PTO/AIA/01 (06-12)
Approved for use through 11/30/2020. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	Detector Controlled Headlight System

As the below named inventor, I hereby declare that:

This declaration is directed to:

- [x] The attached application, or
- [ ] United States application or PCT international application number _____

filed on _____.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Yechezkal Evan Spero Date (Optional): April 24, 2018

Signature: /Yechezkal Evan Spero/

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Mercedes EX1002
U.S. Patent No. 11,208,029

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

PTO/AIA/14 (02-18)
Approved for use through 11/30/2020. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	TRCH0103PUSP3
	Application Number	
Title of Invention	ADAPTIVE HEADLIGHT SYSTEM	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 — Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Yechezkal	Evan	Spero	

Residence Information (Select One) US Residency ● Non US Residency Active US Military Service

City	Tifrach	Country of Residence [i]	IL

Mailing Address of Inventor:

Address 1	20 Rashi St		
Address 2			
City	Tifrach	**State/Province**	IL
Postal Code	85102	**Country** [i]	IL

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	22045		
Email Address		Add Email	Remove Email

Application Information:

Title of the Invention	ADAPTIVE HEADLIGHT SYSTEM		
Attorney Docket Number	TRCH0103PUSP3	**Small Entity Status Claimed**	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	24	**Suggested Figure for Publication (if any)**	15

PTO/AIA/14 (02-18)
Approved for use through 11/30/2020. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	TRCH0103PUSP3
	Application Number	
Title of Invention	ADAPTIVE HEADLIGHT SYSTEM	

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	● Customer Number	US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	22045		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
	Continuation of	15/961861	2018-04-24

PTO/AIA/14 (02-18)
Approved for use through 11/30/2020. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	TRCH0103PUSP3
	Application Number	
Title of Invention	ADAPTIVE HEADLIGHT SYSTEM	

Prior Application Status	Patented				Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	Patent Number	Issue Date (YYYY-MM-DD)
15/961861	Continuation of	13/357549	2012-01-24	9955551	2018-04-24
Prior Application Status	Patented				Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	Patent Number	Issue Date (YYYY-MM-DD)
13/357549	Continuation in part of	10/604360	2003-07-14	8100552	2012-01-24
Prior Application Status	Expired				Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)		
10/604360	Claims benefit of provisional	60/395308	2002-07-12		
Prior Application Status	Expired				Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)		
13/357549	Claims benefit of provisional	61/535981	2011-09-17		
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button.					Add

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)[i] the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

			Remove
Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)
Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.			Add

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

PTO/AIA/14 (02-18)
Approved for use through 11/30/2020. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	TRCH0103PUSP3
	Application Number	
Title of Invention	ADAPTIVE HEADLIGHT SYSTEM	

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

PTO/AIA/14 (02-18)
Approved for use through 11/30/2020. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	TRCH0103PUSP3
	Application Number	
Title of Invention	ADAPTIVE HEADLIGHT SYSTEM	

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

PTO/AIA/14 (02-18)
Approved for use through 11/30/2020. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	TRCH0103PUSP3
	Application Number	
Title of Invention	ADAPTIVE HEADLIGHT SYSTEM	

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1 — Remove

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor
Person to whom the inventor is obligated to assign.	Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here. ☐

Prefix	Given Name	Middle Name	Family Name	Suffix

Mailing Address Information For Applicant:

Address 1			
Address 2			
City		**State/Province**	
Country		Postal Code	
Phone Number		Fax Number	
Email Address			

Additional Applicant Data may be generated within this form by selecting the Add button. Add

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

PTO/AIA/14 (02-18)
Approved for use through 11/30/2020. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	TRCH0103PUSP3
	Application Number	
Title of Invention	ADAPTIVE HEADLIGHT SYSTEM	

Assignee 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

Remove

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		**State/Province**	
Country [i]		Postal Code	
Phone Number		Fax Number	
Email Address			

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button. Add

Signature:

Remove

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Bernard P. Tomsa/			Date (YYYY-MM-DD)	2021-01-19
First Name	Bernard	Last Name	Tomsa	Registration Number	60,121

Additional Signature may be generated within this form by selecting the Add button. Add

PTO/AIA/14 (02-18)
Approved for use through 11/30/2020. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	TRCH0103PUSP3
	Application Number	
Title of Invention	ADAPTIVE HEADLIGHT SYSTEM	

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1 The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3 A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent CooperationTreaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

ABSTRACT

A motor vehicle includes headlamps having a plurality of LED light sources, one or more processors, and a memory storing instructions. One or more processors executing the instructions are enabled to receive first data, including at least map data, indicating a road curvature upcoming along a road on which the motor vehicle is traveling. The processors are also enabled to determine a light change, the change adapting a light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction of the road curvature ahead of the motor vehicle and shaping light based at least in part on the road curvature. The processors are further enabled to control at least a first plurality of the LED light sources to provide light based at least in part on the determined light change and prior to the motor vehicle reaching the road curvature.

WHAT IS CLAIMED IS:

1. A system, for a motor vehicle, comprising:

a plurality of headlamps, each comprising a plurality of LED light sources;

one or more processors; and

a memory storing instructions that, when executed by one or more of the one or more processors, enable the one or more processors to:

receive first data, including at least map data, indicating a road curvature upcoming along a road on which the motor vehicle is traveling;

determine a light change, the change adapting a light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction of the road curvature ahead of the motor vehicle and shaping light based at least in part on the road curvature; and

control at least a first plurality of the LED light sources to provide light based at least in part on the determined light change and prior to the motor vehicle reaching the road curvature.

2. The system of claim 1, wherein the determination of the light change includes selection of the first plurality of the LED light sources.

3. The system of claim 1, wherein the instructions include instructions that, when executed by the one or more processors, enable the one or more processors to reshape light based on the road curvature as the motor vehicle travels at least to or through the road curvature.

4. The system of claim 3, wherein the reshaping of light further includes control to at least one of the first plurality of LED light sources, or a second plurality of LED light sources, including at least one LED light source different from the LED light sources of the first plurality of LED light sources, to provide reshaped light.

5. The system of claim 1, wherein the increase of light in the direction of the road curvature includes at least an increase of light emitted at a level below high-beam light and directed in the direction of the road curvature.

6. The system of claim 1, wherein the instructions include instructions that, when executed by the one or more processors, enable the one or more processors to:

determine a second light change, the second change adapting the light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction of a second road curvature ahead of the motor vehicle, determined based on at least one of the first data or second data including at least second map data, and the second change shaping light based at least in part on the second road curvature; and

control at least a second plurality of the LED light sources, having at least one LED light source different from the first plurality of LED light sources, to provide light based at least in part on the determined second light change and prior to the motor vehicle reaching the second road curvature.

7. The system of claim 1, wherein the increase of light in the direction of the road curvature includes at least one of expansion of the light pattern in the direction of the road curvature or an increase to intensity of light directed in the direction of the road curvature; and

wherein the determination of the light change includes determination of light changes to individual LEDs of the first plurality of LED light sources, at least one of the changes including at least one of:

a variation to at least one of intensity or color of individual LEDs of the first plurality of LED light sources, or

providing light directed in the direction of the road curvature from an LED not providing light directed in the direction of the road curvature prior to the change.

8. The system of claim 1, further comprising one or more cameras positioned to capture data indicating at least one other vehicle ahead of the motor vehicle;

wherein the instructions include instructions that, when executed by the one or more processors, enable the one or more processors to:

determine a position associated with the at least one other vehicle based at least in part on second data captured by at least one of the one or more cameras; and

control, based at least in part on the position, a second plurality of LED light sources providing light directed towards an area including at least a portion of the other vehicle to diminish glare to a driver of the other vehicle by a decrease to intensity of light directed towards and illuminating the area, the light that is directed towards and illuminating the area having lower intensity compared to light directed towards points laterally adjacent the area to either side.

9. The system of claim 8, wherein:

the first plurality and second plurality of LED light sources include at least one common LED light source;

the control of the second plurality of LED light sources is based at least in part on third data received from a non-camera sensor of the motor vehicle;

the position includes at least one of:

a distance associated with the at least one other vehicle,

at least one elevation associated with the at least one other vehicle, or

a position within image data captured by at least one of the cameras;

the first data includes data from a non-camera sensor of the motor vehicle;

either one of the control of the first plurality of LED light sources or control of the second plurality of LED light sources is subsequent to and accommodative of the other;

the control of the second plurality of LED light sources additionally includes termination of light from at least one LED providing light directed to the area prior to the termination; and

the light pattern includes at least one of an illumination pattern or an emission pattern of the headlamps.

10. The system of claim 1, further including one or more optical control elements for controlling light from one or more of the LED light sources.

11. The system of claim 10, wherein the optical control elements include at least one of one or more reflectors, refractors or lenses.

12. A non-transitory computer-readable storage medium, storing instructions that, when executed by one or more processors of a motor vehicle that includes a plurality of headlamps that each comprise a plurality of LED light sources, enable the one or more processors to:

receive first data, including at least map data, indicating a road curvature upcoming along a road on which the motor vehicle is traveling;

determine a light change, the change adapting a light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction of the road curvature ahead of the motor vehicle and shaping light based at least in part on the road curvature; and

control at least a first plurality of the LED light sources to provide light based at least in part on the determined light change and prior to the motor vehicle reaching the road curvature.

13. The storage medium of claim 12, wherein the determination of the light change includes selection of the first plurality of the LED light sources.

14. The storage medium of claim 12, wherein the instructions include instructions that, when executed by the one or more processors, enable the one or more processors to reshape light based on the road curvature as the motor vehicle travels at least to or through the road curvature.

15. The storage medium of claim 14, wherein the reshaping of light further includes control to at least one of the first plurality of LED light sources, or a second plurality of LED light sources, including at least one LED light source different from the LED light sources of the first plurality of LED light sources, to provide reshaped light.

16. The storage medium of claim 12, wherein the increase of light in the direction of the road curvature includes at least an increase of light emitted at a level below high-beam light and directed in the direction of the road curvature.

17. The storage medium of claim 12, wherein the instructions include instructions that, when executed by the one or more processors, enable the one or more processors to:

determine a second light change, the second change adapting the light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction of a second road curvature ahead of the motor vehicle, determined based on at least one of the first data or second data including at least second map data, and the second change shaping light based at least in part on the second road curvature; and

control at least a second plurality of the LED light sources, having at least one LED light source different from the first plurality of LED light sources, to provide light based at least in part on the determined second light change and prior to the motor vehicle reaching the second road curvature.

18. The storage medium of claim 12, wherein the increase of light in the direction of the road curvature includes at least one of expansion of the light pattern in the direction of the road curvature or an increase to intensity of light directed in the direction of the road curvature; and

wherein the determination of the light change includes determination of light changes to individual LEDs of the first plurality of LED light sources, at least one of the changes including at least one of:

a variation to at least one of intensity or color of individual LEDs of the first plurality, or

providing light directed in the direction of the road curvature from an LED not providing light directed in the direction of the road curvature prior to the change.

19. The storage medium of claim 12, wherein the instructions include instructions that, when executed by the one or more processors, enable the one or more processors to:

determine a position associated with at least one other vehicle based at least in part on second data indicating the at least one other vehicle and captured by at least one camera of the motor vehicle; and

control, based at least in part on the position, a second plurality of LED light sources providing light directed towards an area including at least a portion of the other vehicle to diminish glare to a driver of the other vehicle by a decrease to intensity of light directed towards and illuminating

the area, the light that is directed towards and illuminating the area having lower intensity compared to light directed towards points laterally adjacent the area to either side.

20. The storage medium of claim 19, wherein:

the first plurality and second plurality of LED light sources include at least one common LED light source;

the control of the second plurality of LED light source is based at least in part on third data received from a non-camera sensor of the motor vehicle;

the position includes at least one of:

a distance associated with the at least one other vehicle,

at least one elevation associated with the at least one other vehicle, or

a position within image data captured by at least one of the cameras;

the first data includes data from a non-camera sensor of the motor vehicle;

either one of the control of the first plurality of LED light sources or control of the second plurality of LED light sources is subsequent to and accommodative of the other;

the control of the second plurality of LED light sources additionally includes termination of light from at least one LED providing light directed to the area prior to the termination; and

the light pattern includes at least one of an illumination pattern or an emission pattern of the headlamps.

21. The storage medium of claim 19, wherein the instructions include instructions that, when executed by the one or more processors, enable the one or more processors to utilize one or more optical control elements included in the motor vehicle to control light from at least the first plurality or second plurality of the LED light sources.

22. The storage medium of claim 21, wherein the optical control elements include at least one of one or more reflectors, refractors or lenses.

23. A computer-implemented method for adapting light from headlamps of a motor vehicle to accommodate road shape changes, the headlamps including a plurality of LED light sources, comprising:

determining an upcoming shape change of a road, ahead of the motor vehicle, based on first data, including map data, indicating the shape change;

determining a light output, the output adapting a light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction associated with the shape change ahead of the motor vehicle and shaping light based on the shape change; and

prior to reaching the road shape change, causing at least a first plurality of the LED light sources to provide light based at least in part on the determined light output.

24. The method of claim 23, wherein the determining the light includes selecting the first plurality of the LED light sources.

25. The method of claim 23, further comprising reshaping light based on the shape change as the motor vehicle travels at least to or through the shape change.

26. The method of claim 25, wherein the reshaping light further includes controlling at least one of the first plurality of LED light sources, or a second plurality of LED light sources, including at least one LED light source different from the LED light sources of the first plurality of LED light sources, to provide reshaped light.

27. The method of claim 23, wherein the increase of light in the direction associated with the shape change includes at least light output that increases light emitted at a level below high-beam light and directed in the direction associated with shape change.

28. The method of claim 23, further comprising:

determining a second light output, the second output adapting the light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction associated with a second shape change ahead of the motor vehicle, determined based on at least one

of the first data or second data including at least second map data, and the second output shaping light based at least in part on the second shape change; and

controlling at least a second plurality of the LED light sources, having at least one LED light source different from the first plurality of LED light sources, to provide light based at least in part on the determined second output and prior to the motor vehicle reaching the second shape change.

29. The method of claim 23, wherein the increase of light in the direction associated with the shape change includes at least one of expansion of the light pattern in the direction associated with the shape change or an increase to intensity of light directed in the direction associated with the shape change; and

wherein the determining the light output includes determining output for individual LEDs of the first plurality of LED light sources, the output including providing light directed in the direction associated with the shape change from an LED not providing light directed in the direction associated with the shape change prior to the change.

30. The method of claim 23, further comprising:

determining a position associated with at least one other vehicle based at least in part on second data indicating the at least one other vehicle and captured by at least one camera of the motor vehicle; and

controlling, based at least in part on the position, a second plurality of LED light sources providing light directed towards an area including at least a portion of the other vehicle to diminish glare to a driver of the other vehicle by decreasing intensity of light directed towards and illuminating the area, the light directed towards and illuminating the area having lower intensity compared to light directed towards points laterally adjacent the area to either side.

31. The method of claim 30, wherein:

the first plurality and second plurality of LED light sources include at least one common LED light source;

the controlling the second plurality of LED light sources is based at least in part on third data received from a non-camera sensor of the motor vehicle;

the position includes at least one of:

a distance associated with the at least one other vehicle,

at least one elevation associated with the at least one other vehicle, or

a position within image data captured by at least one of the cameras;

the first data includes data from a non-camera sensor of the motor vehicle;

either one of the determining the light output or controlling the second plurality of LED light sources is subsequent to and accommodative of the other;

the controlling the second plurality of LED light sources additionally includes terminating light from at least one LED providing light directed to the area prior to the terminating; and

the light pattern includes at least one of an illumination pattern or an emission pattern of the headlamps.

32. The method of claim 30, further comprising utilizing one or more optical control elements included in the motor vehicle to control light from at least the first plurality or second plurality of the LED light sources.

33. The method of claim 32, wherein the optical control elements include at least one of one or more reflectors, refractors or lenses.

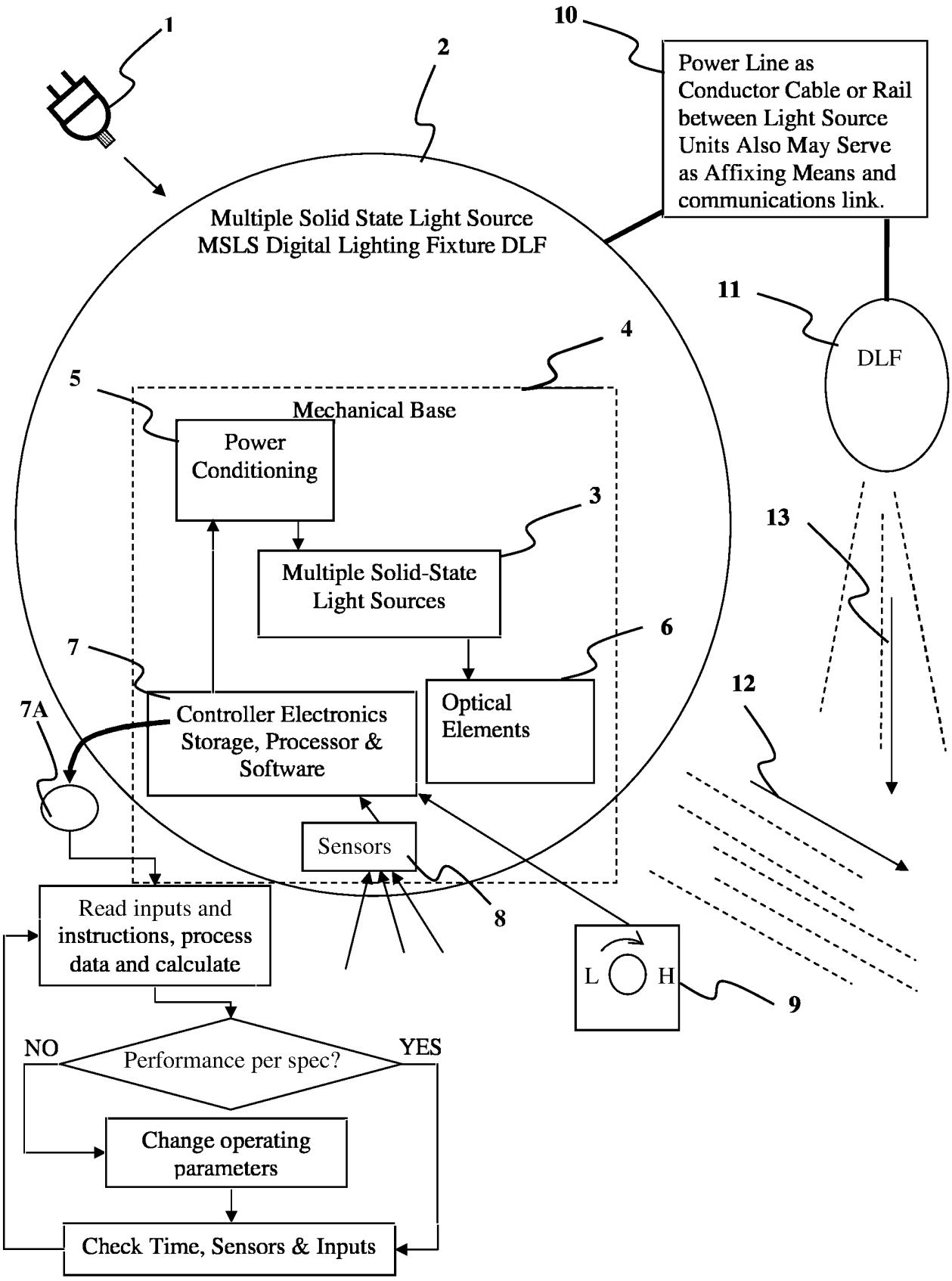

1
2
10
Power Line as Conductor Cable or Rail between Light Source Units Also May Serve as Affixing Means and communications link.
Multiple Solid State Light Source
MSLS Digital Lighting Fixture DLF
11
DLF
4
5
Mechanical Base
Power Conditioning
3
Multiple Solid-State Light Sources
13
6
7
7A
Controller Electronics Storage, Processor & Software
Optical Elements
12
Sensors
8
Read inputs and instructions, process data and calculate
L
H
9
NO
Performance per spec?
YES
Change operating parameters
Check Time, Sensors & Inputs

FIG. 1

PRIOR ART

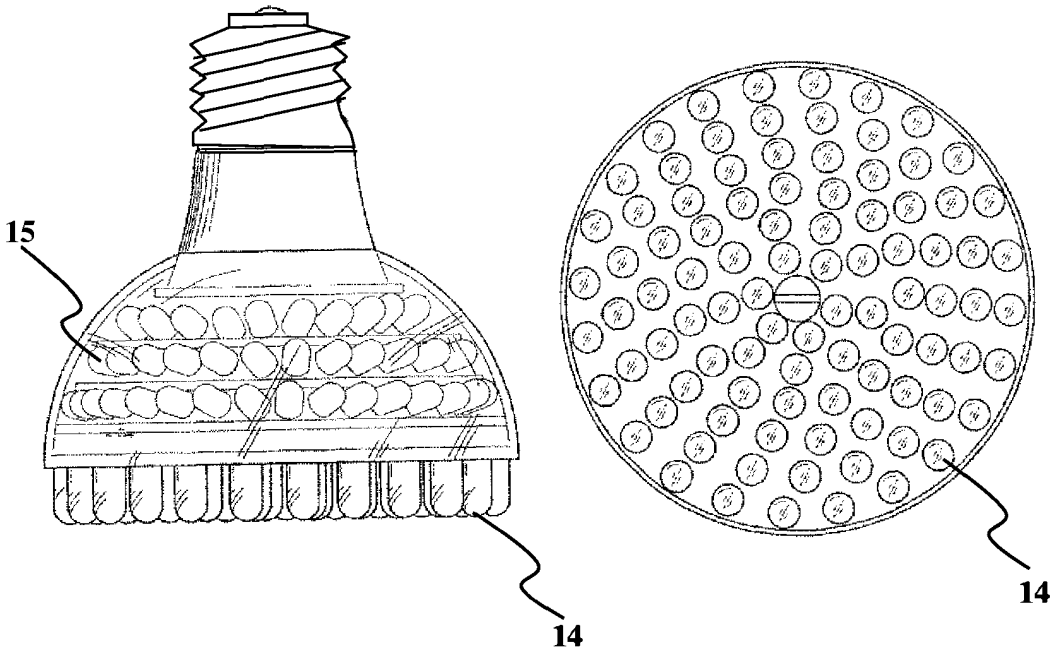


FIG. 2A

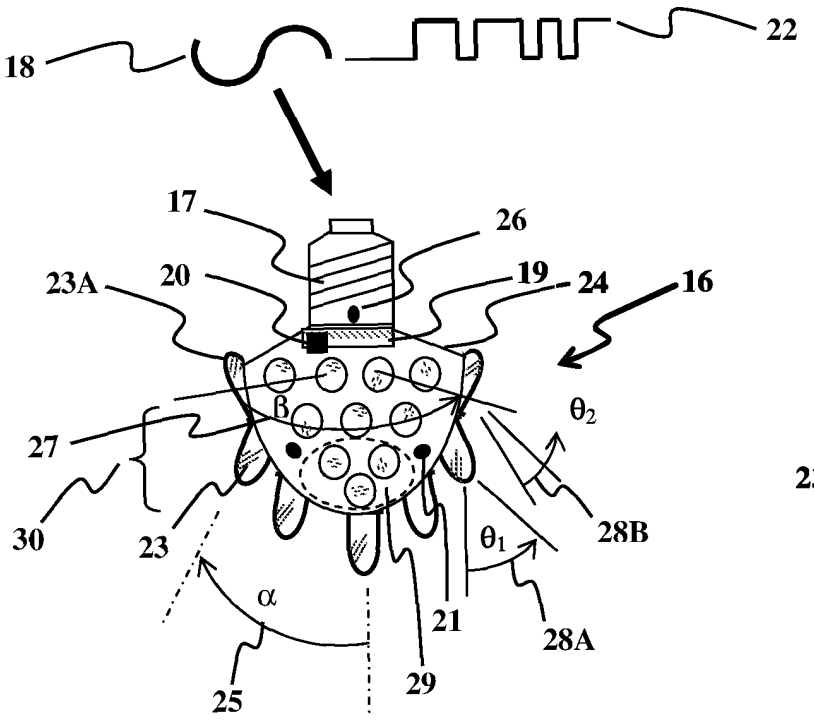


FIG. 2B

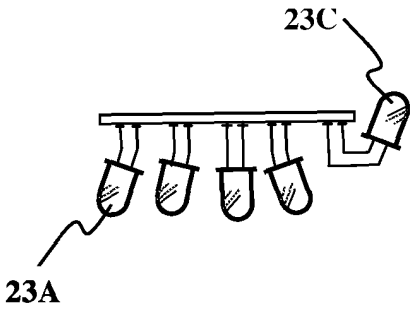


FIG. 2C

PRIOR ART

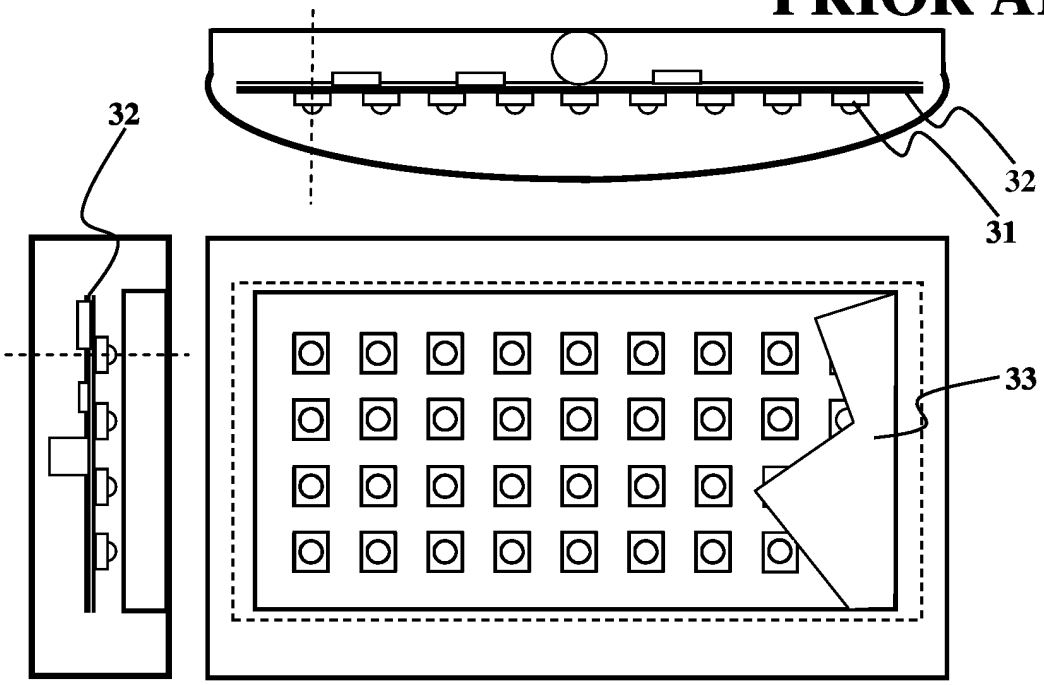


FIG. 3A

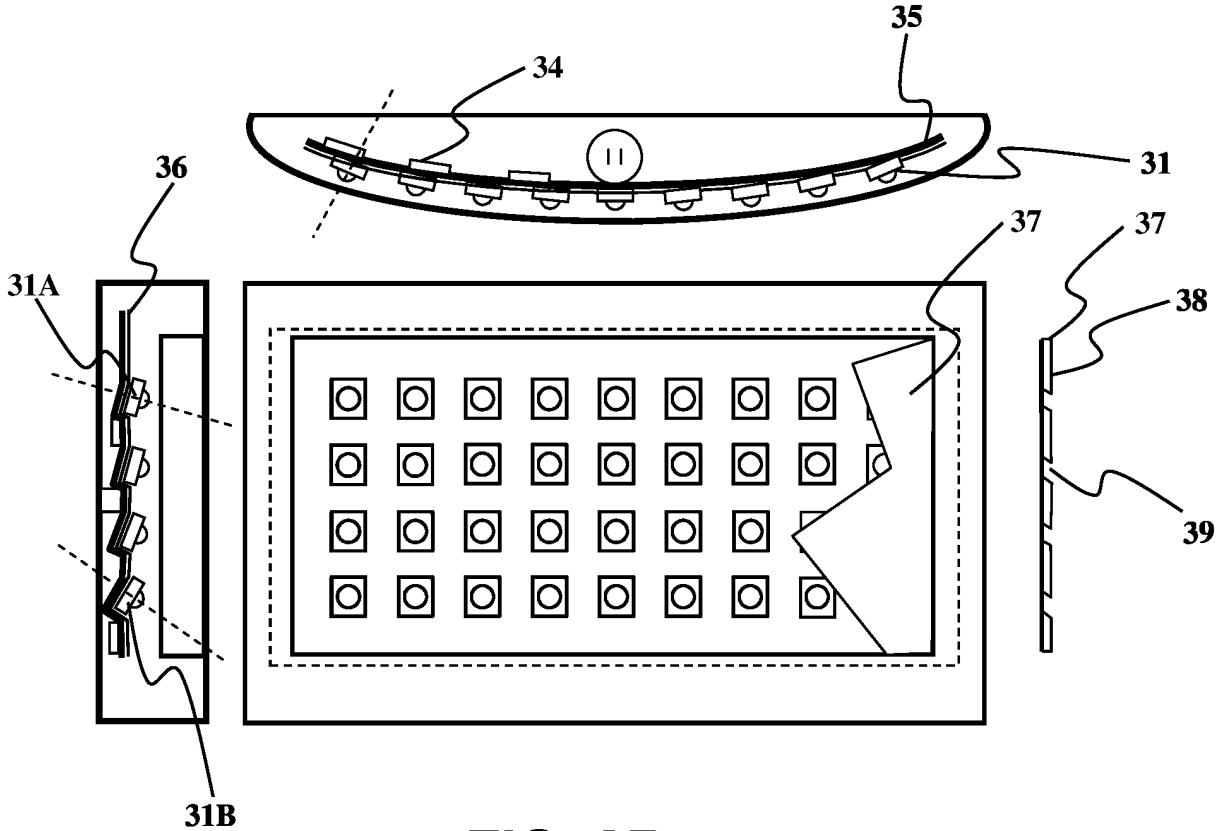


FIG. 3B

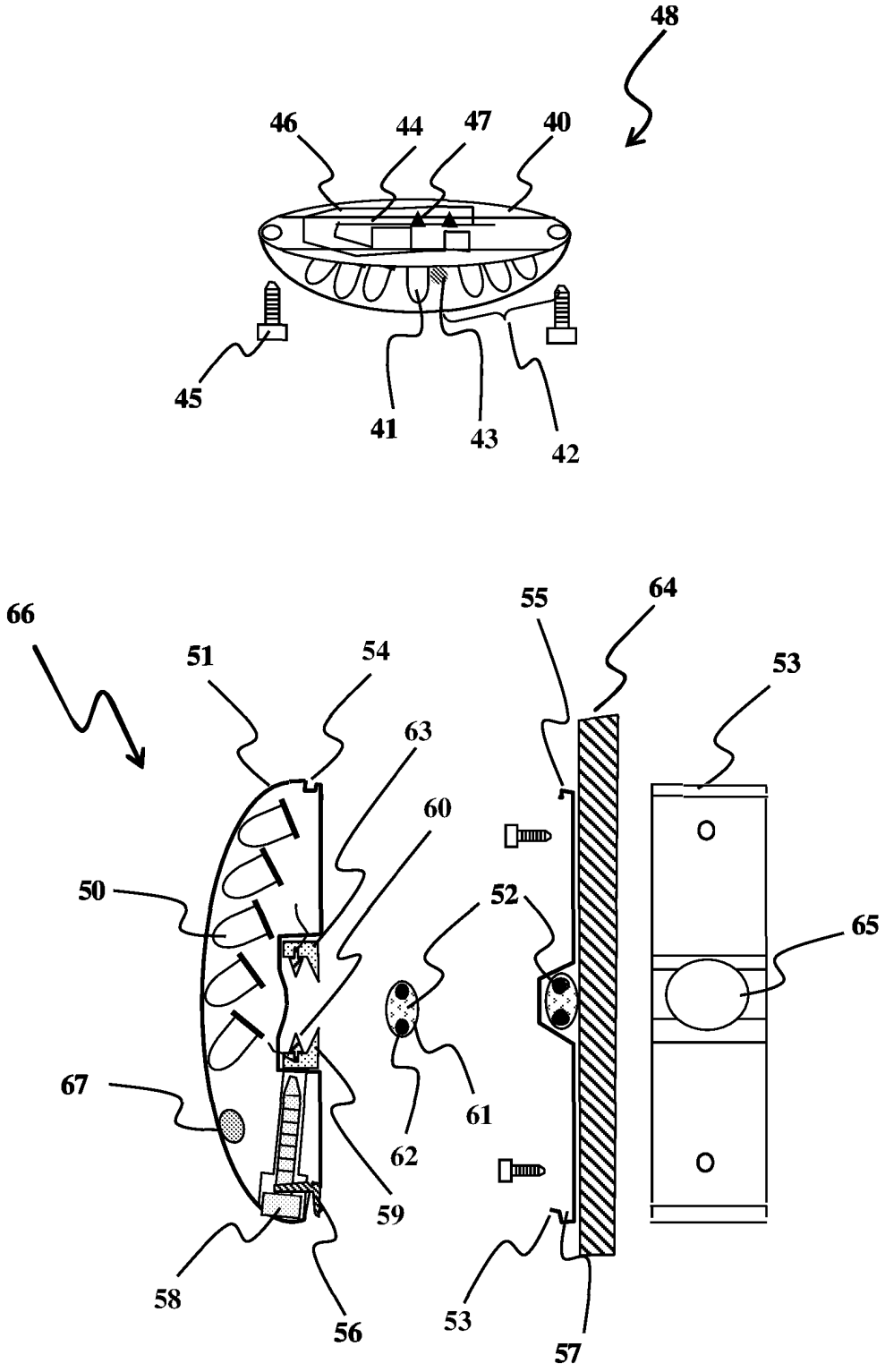

48
46
44
47
40
45
41
43
42
66
51
54
63
60
50
67
59
58
56
55
64
53
52
61
62
53
57
65

FIG. 4

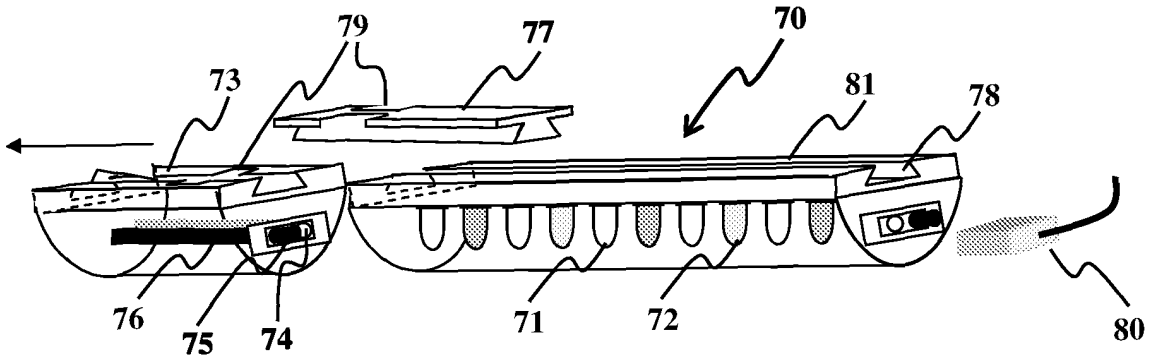

79
77
70
73
81
78
76
75
74
71
72
80

FIG. 5

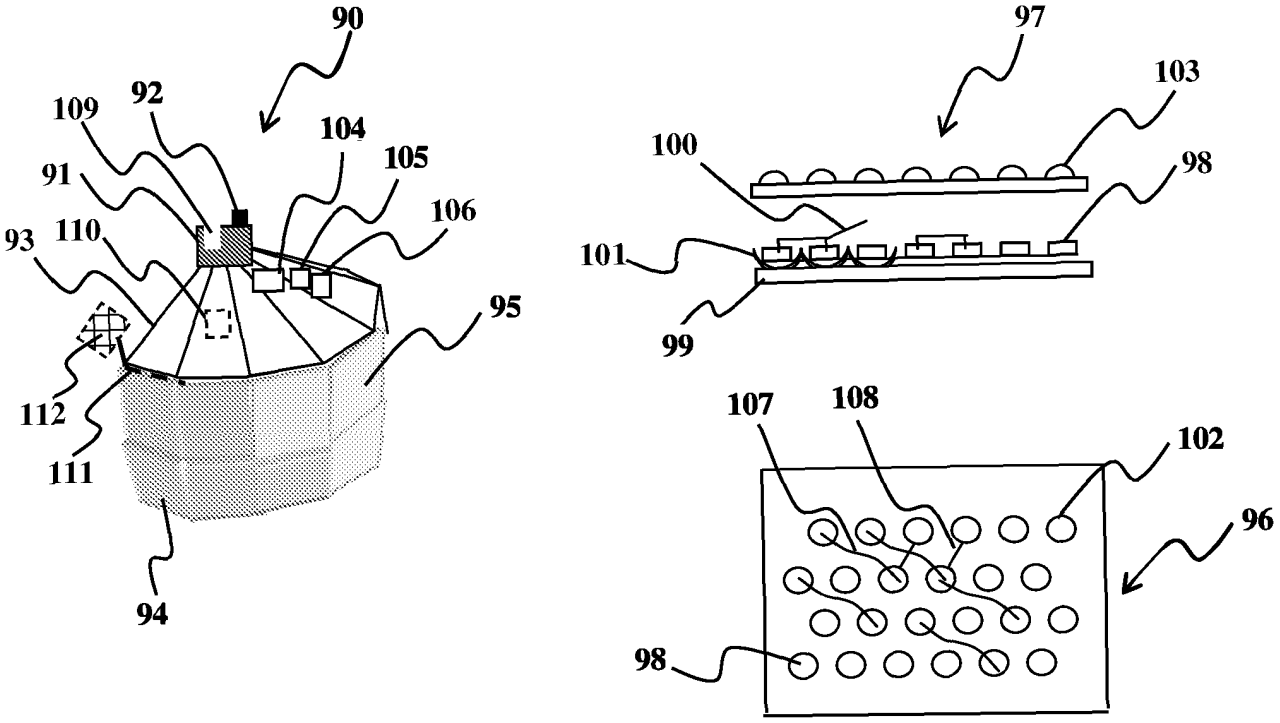

90
109
92
104
105
91
106
93
110
95
112
111
94
97
103
100
98
101
99
107
108
102
96
98

FIG. 6

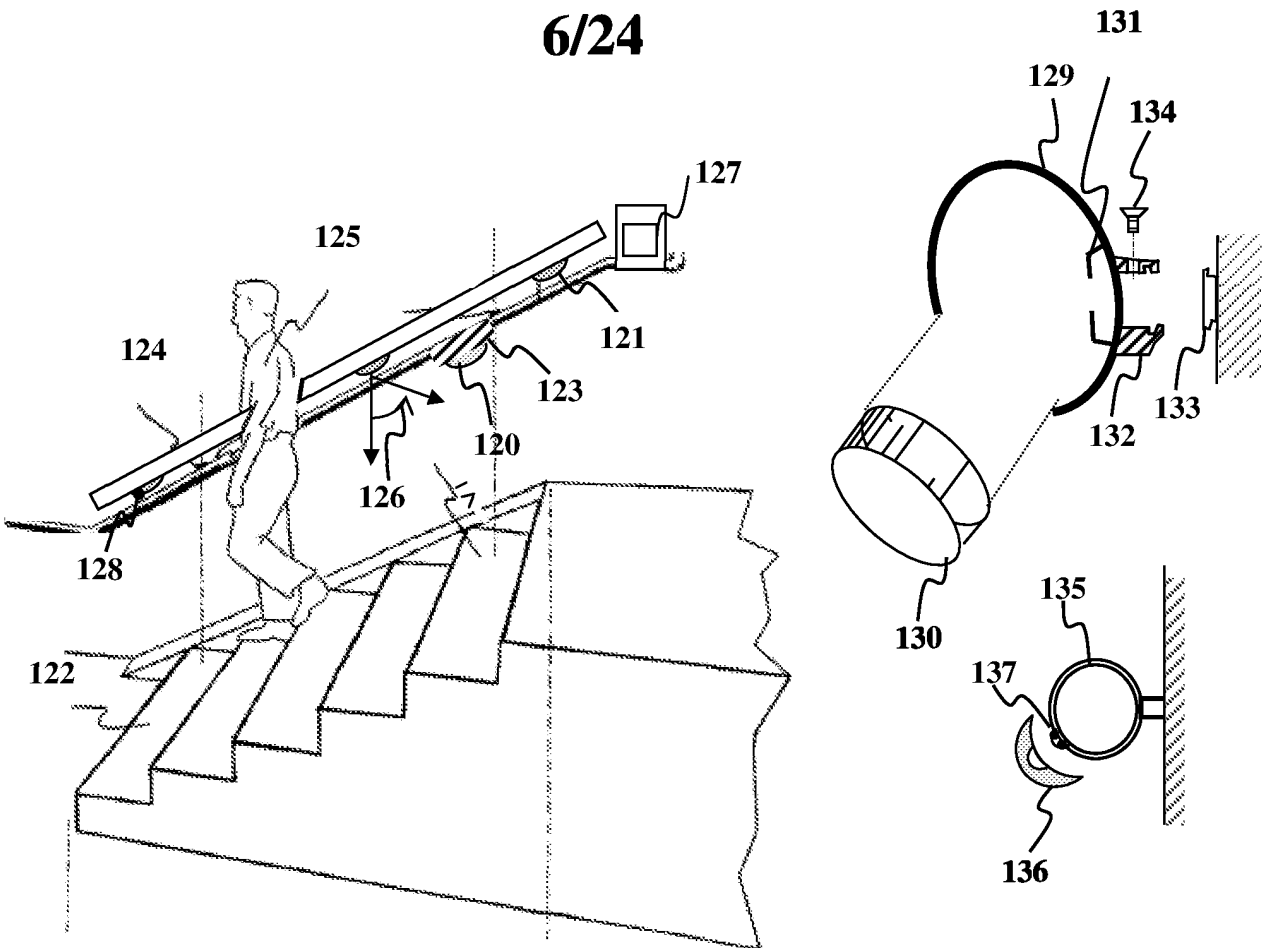

131
129
134
127
125
121
124
123
120
126
133
132
128
130
135
137
122
136

FIG. 7

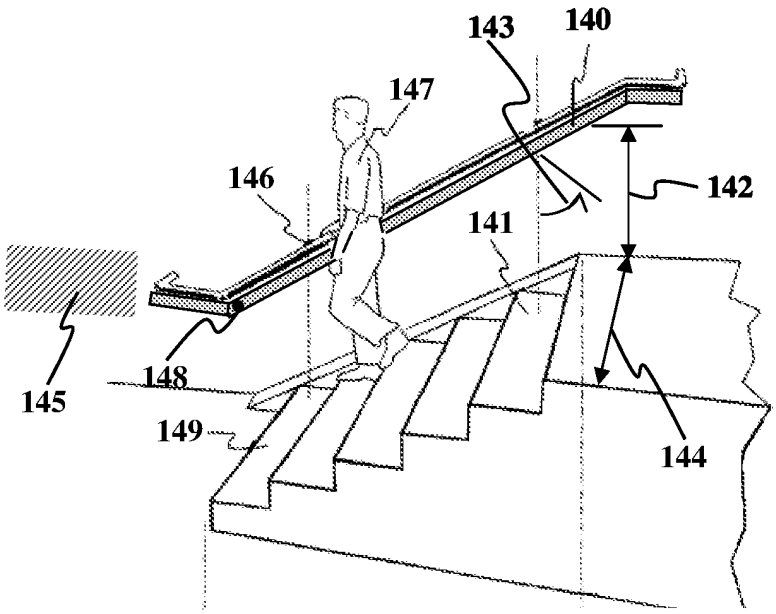

143
140
147
146
142
141
145
148
149
144

FIG. 8

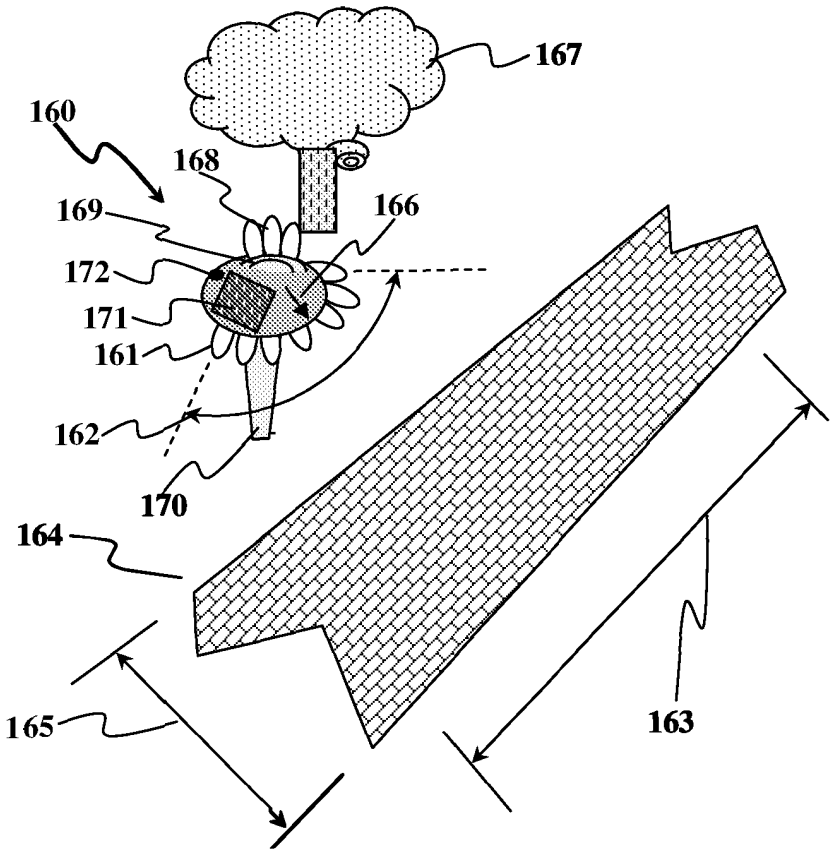

167
160
168
169
166
172
171
161
162
170
164
165
163

FIG. 9

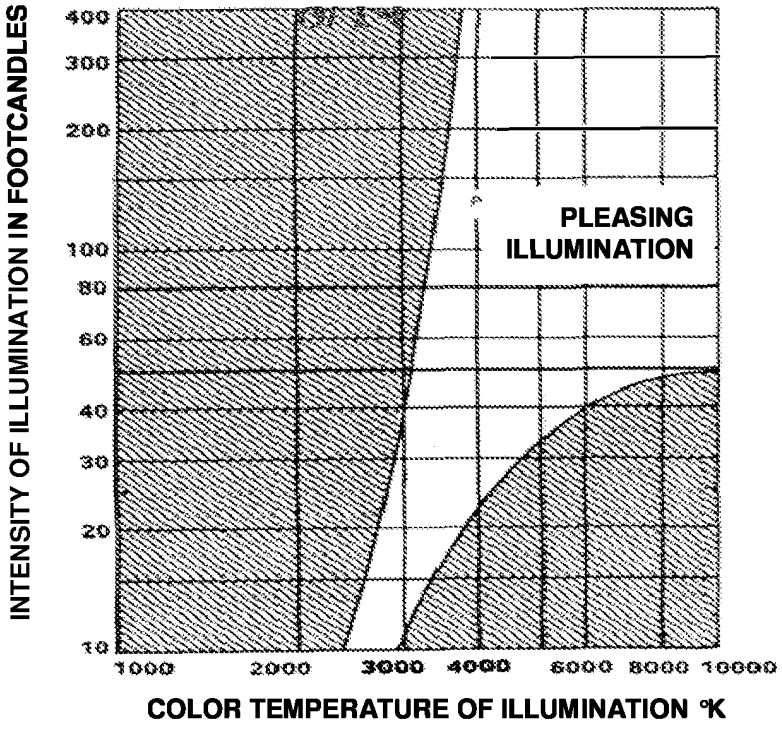

INTENSITY OF ILLUMINATION IN FOOTCANDLES
400
300
200
100
80
60
40
30
20
10
PLEASING ILLUMINATION
1000
2000
3000
4000
6000
8000
10000
COLOR TEMPERATURE OF ILLUMINATION °K

FIG. 10

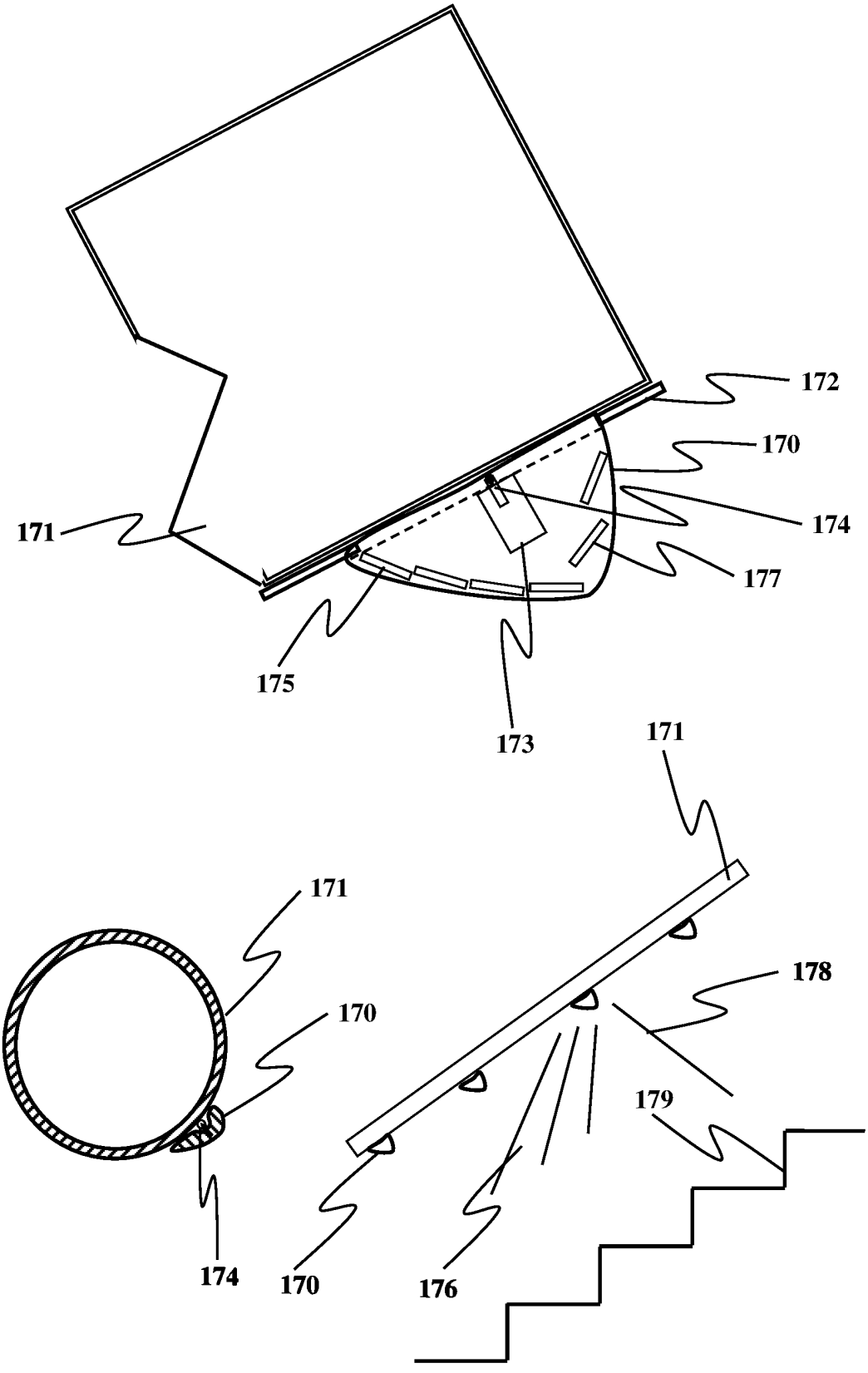


FIG. 11

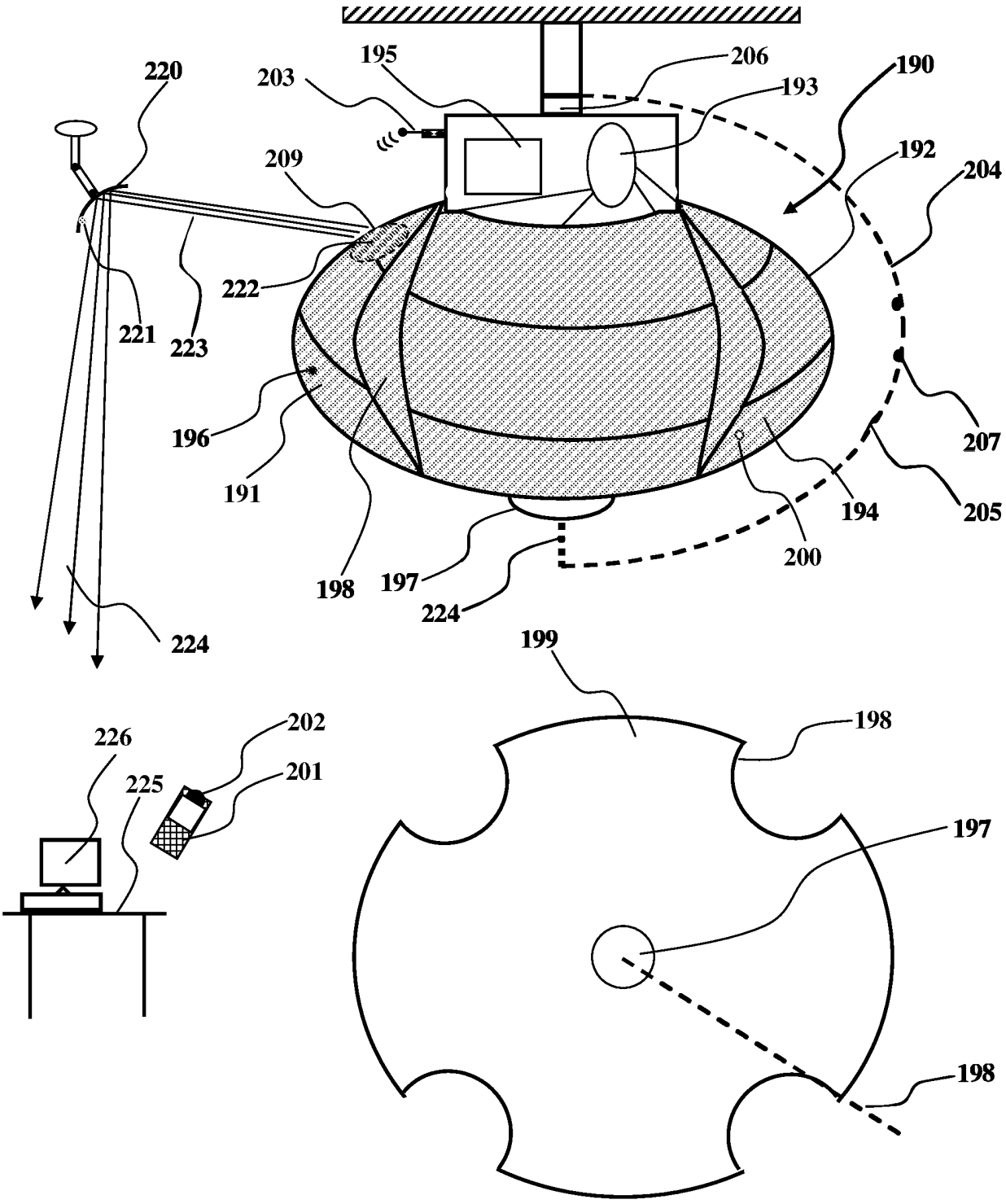

220
203
195
206
193
190
192
204
209
222
221
223
196
191
198
197
224
200
194
207
205
224
199
198
226
202
225
201
197
198

FIG. 12

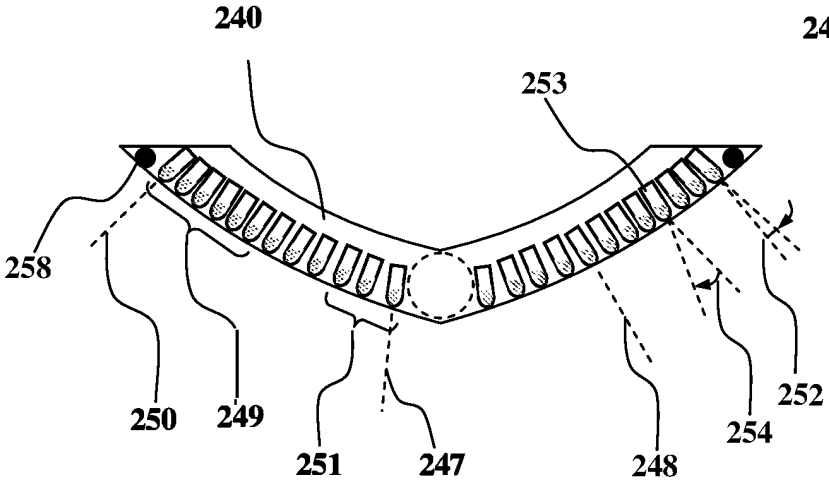


FIG. 13A

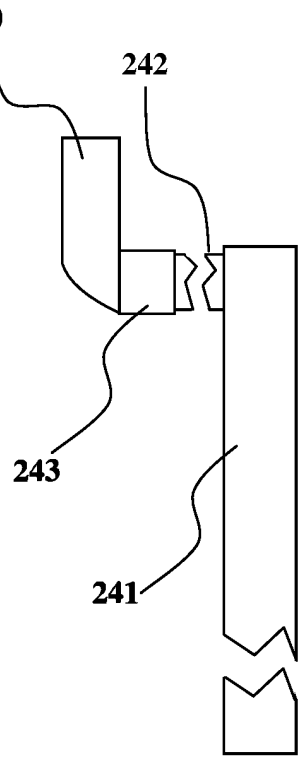


FIG. 13B

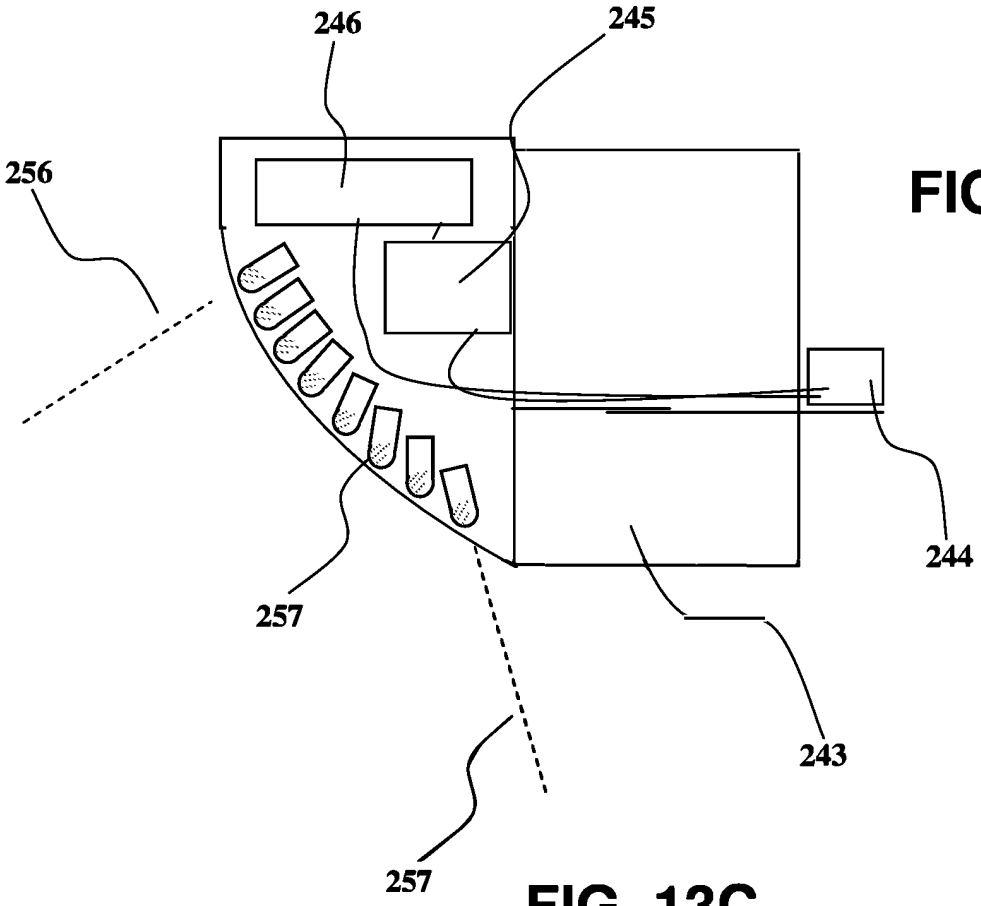


FIG. 13C

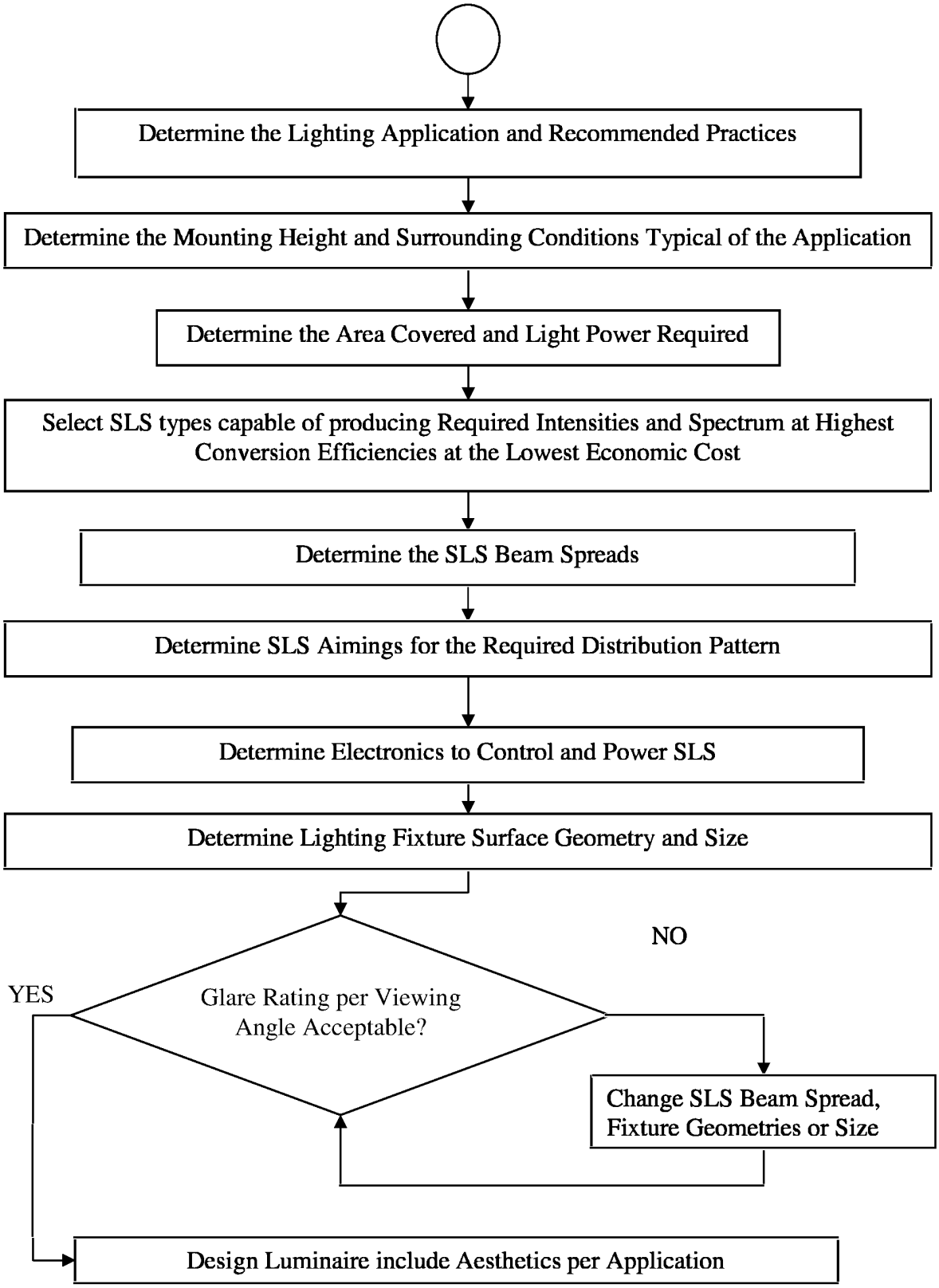

Determine the Lighting Application and Recommended Practices
Determine the Mounting Height and Surrounding Conditions Typical of the Application
Determine the Area Covered and Light Power Required
Select SLS types capable of producing Required Intensities and Spectrum at Highest Conversion Efficiencies at the Lowest Economic Cost
Determine the SLS Beam Spreads
Determine SLS Aimings for the Required Distribution Pattern
Determine Electronics to Control and Power SLS
Determine Lighting Fixture Surface Geometry and Size
Glare Rating per Viewing Angle Acceptable?
NO
YES
Change SLS Beam Spread, Fixture Geometries or Size
Design Luminaire include Aesthetics per Application

FIG. 14

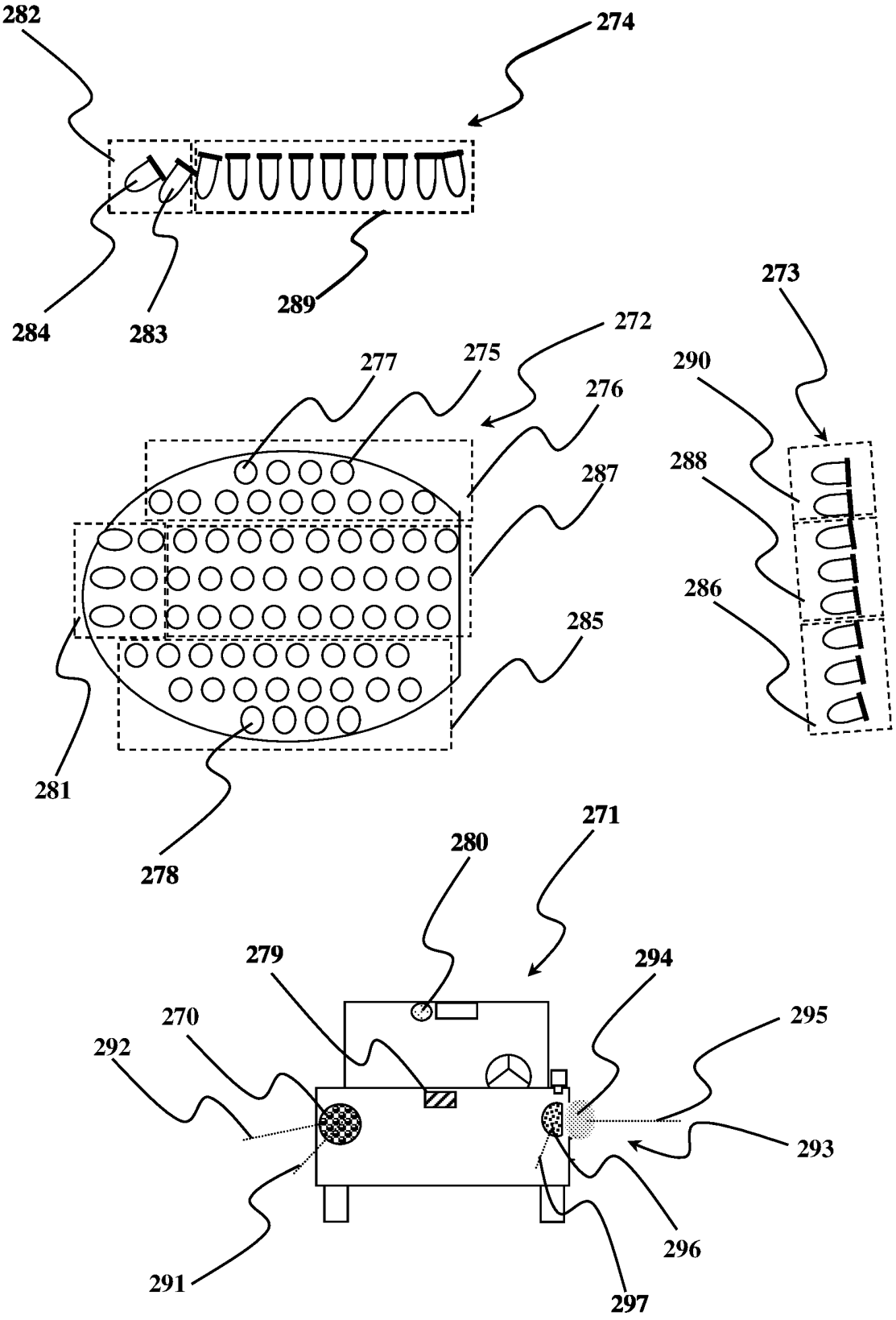

282
274
284
283
289
273
272
277
275
276
290
288
287
286
285
281
278
271
280
279
294
270
295
292
293
296
291
297

FIG. 15

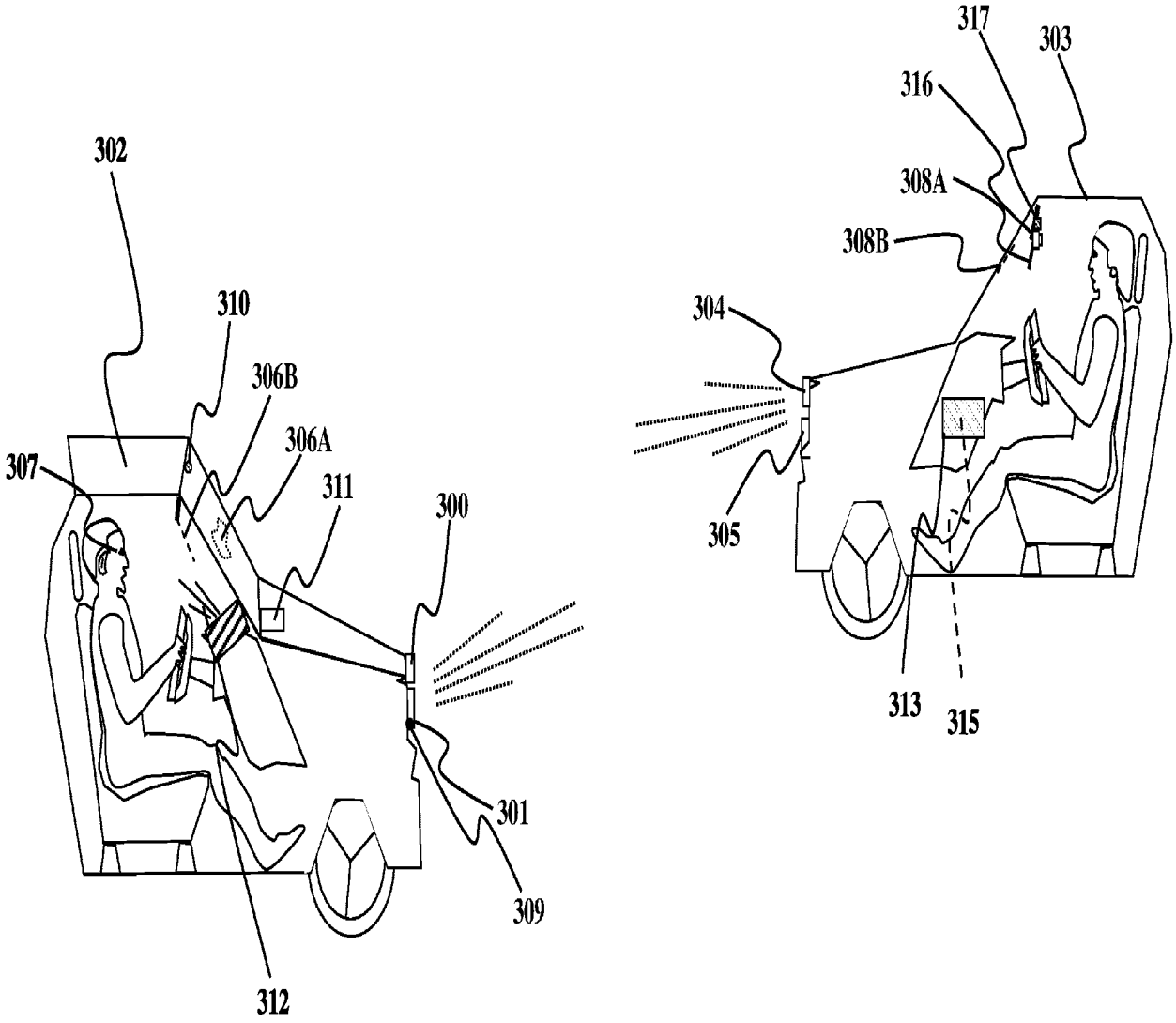

317
303
316
308A
308B
304
305
313
315
302
310
306B
306A
307
311
300
301
309
312

FIG. 16

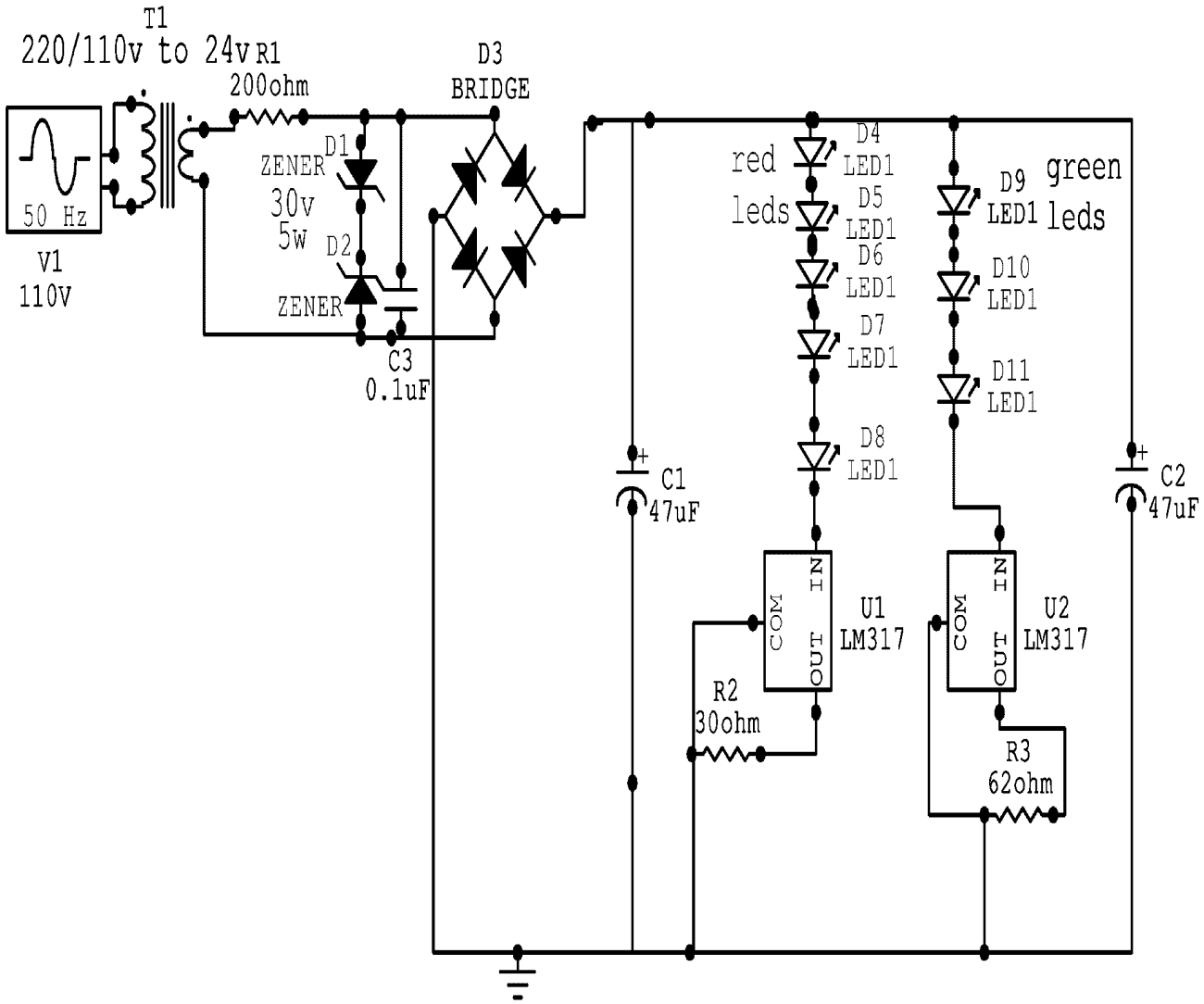

T1
220/110v to 24v
R1
200ohm
D3
BRIDGE
50 Hz
V1
110V
ZENER
D1
30v
5w
D2
ZENER
C3
0.1uF
red
leds
D4
LED1
D5
LED1
D6
LED1
D7
LED1
D8
LED1
green
leds
D9
LED1
D10
LED1
D11
LED1
C1
47uF
C2
47uF
COM
IN
OUT
U1
LM317
U2
LM317
R2
30ohm
R3
62ohm

FIG. 17

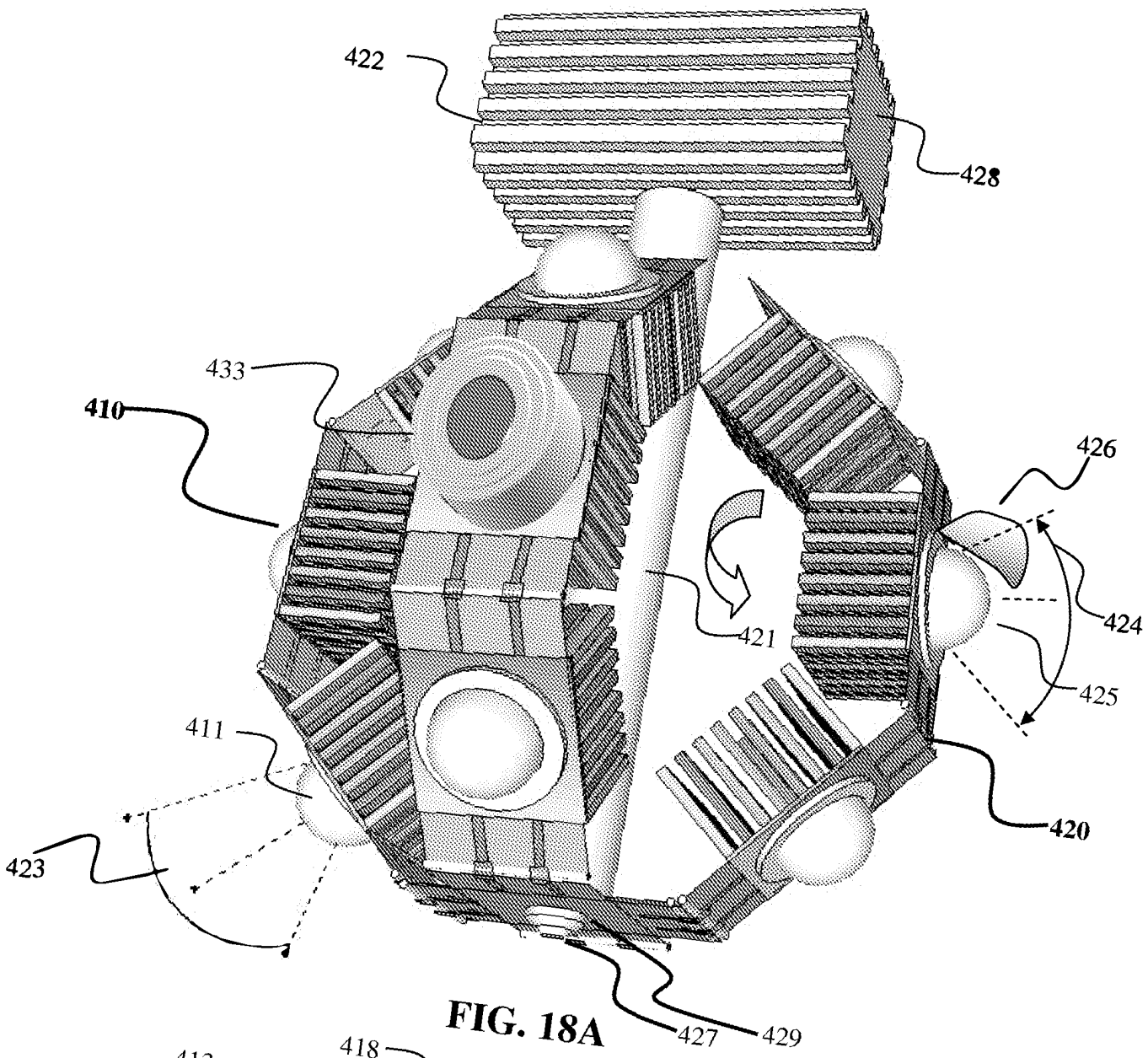


FIG. 18A

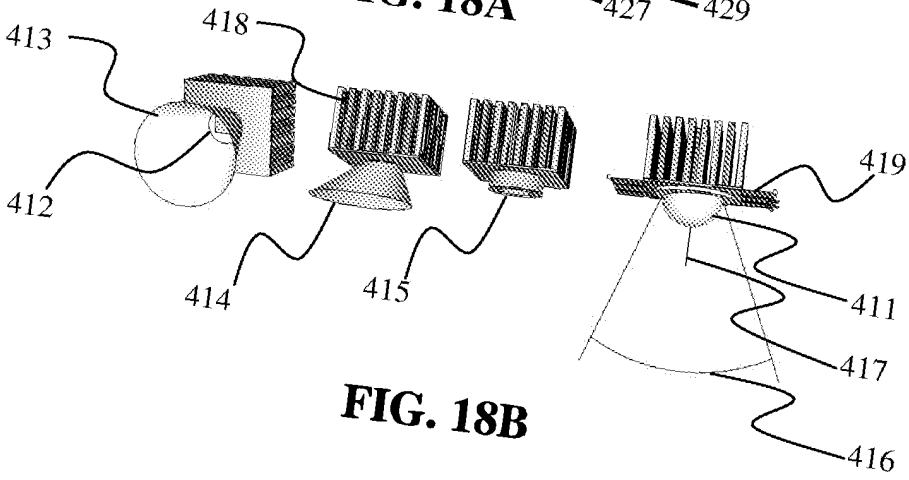


FIG. 18B

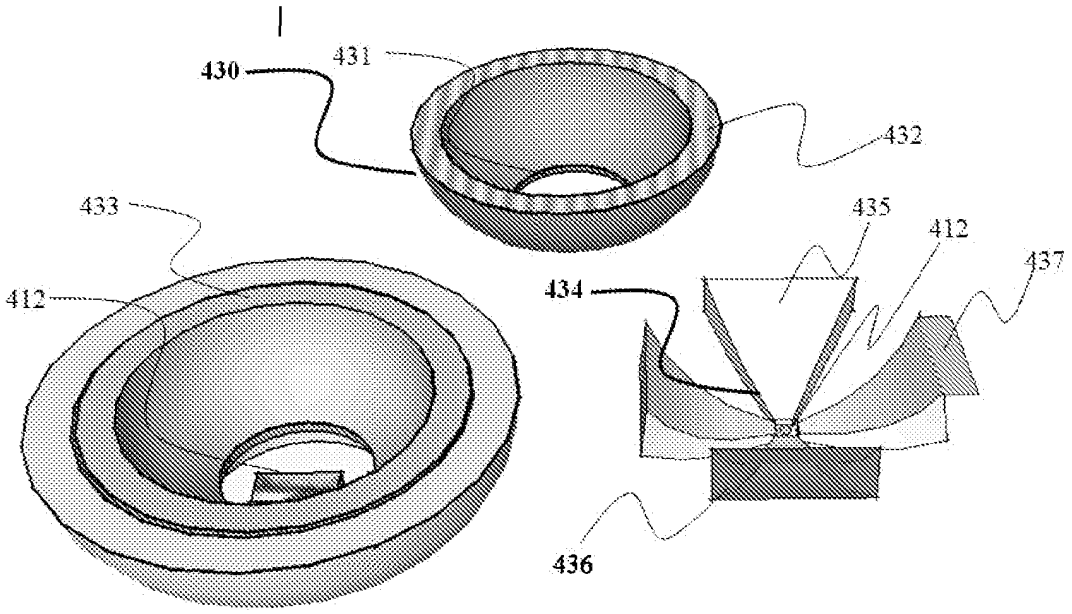


FIG. 19

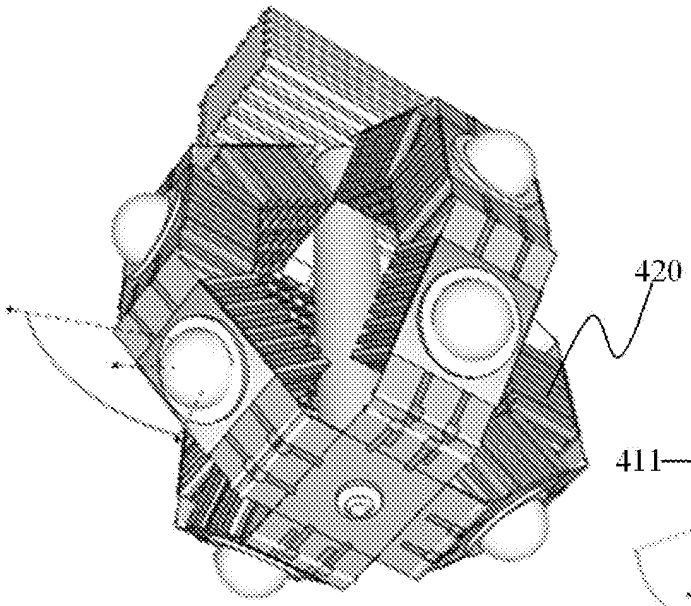


FIG. 20A

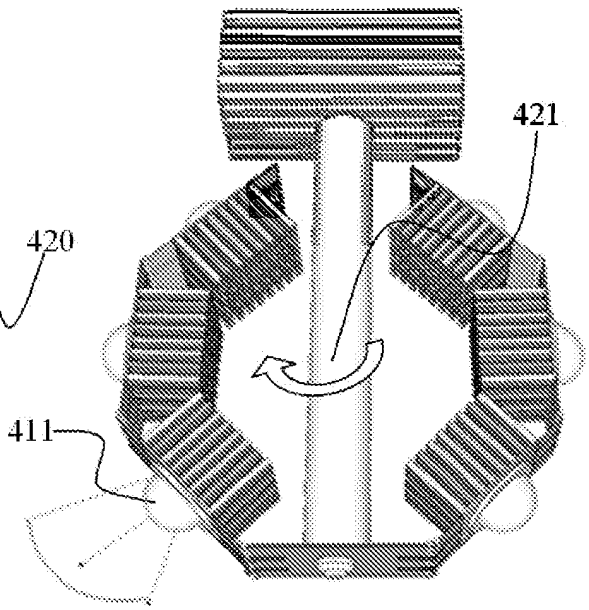


FIG. 20B

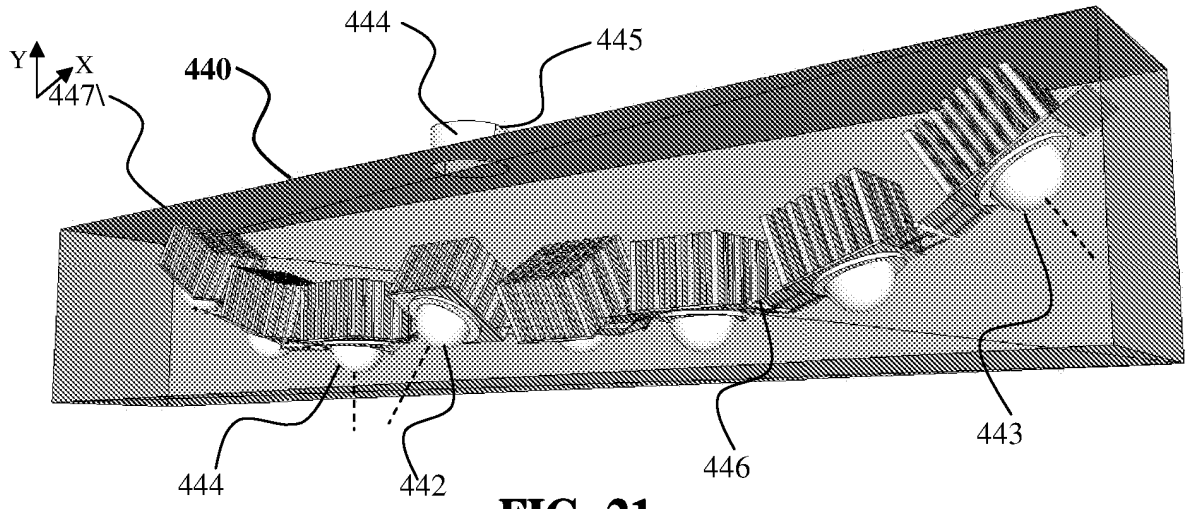

Y
X
447
440
444
445
444
442
446
443

FIG. 21

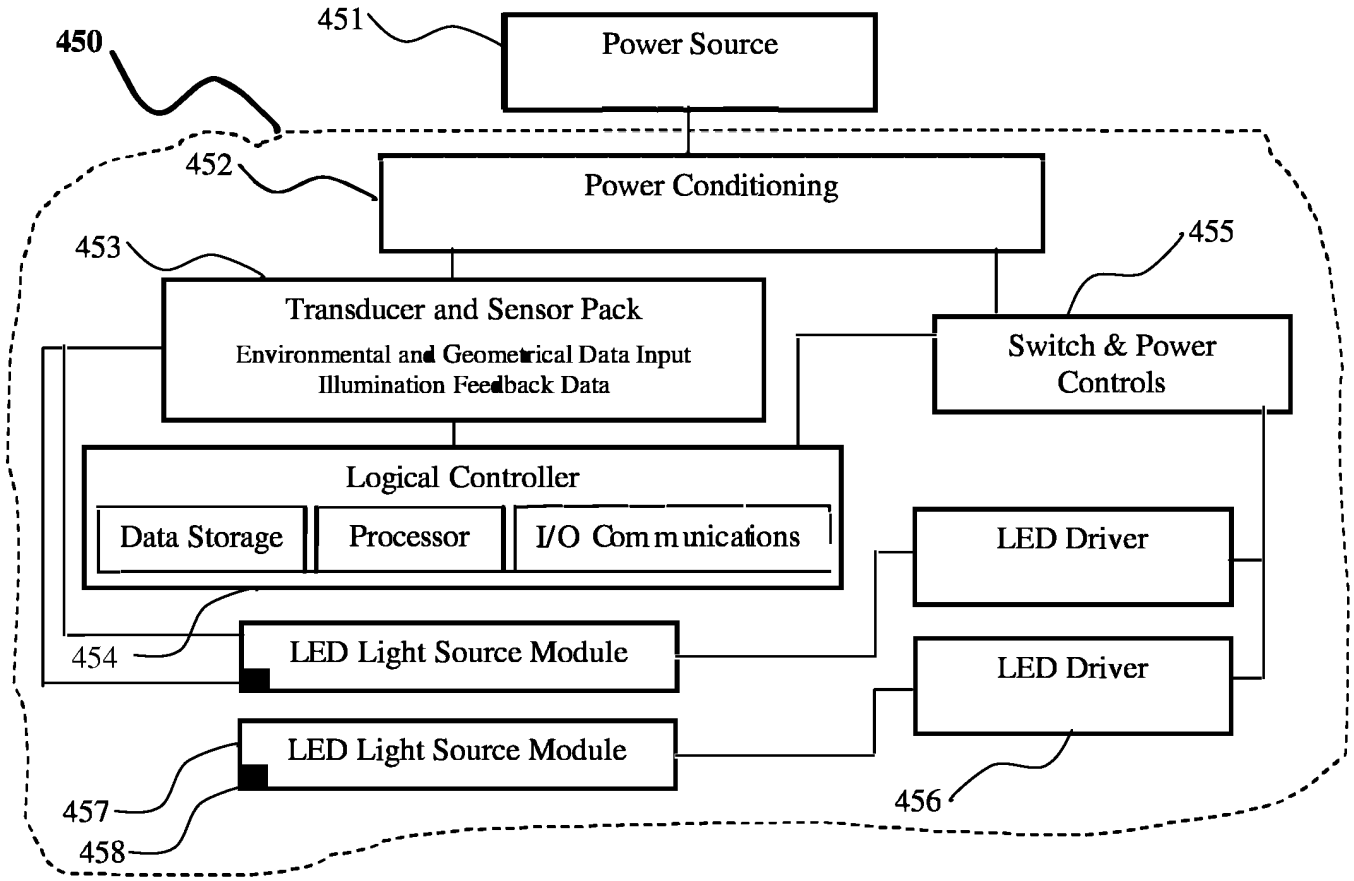

450
451
Power Source
452
Power Conditioning
453
Transducer and Sensor Pack
Environmental and Geometrical Data Input
Illumination Feedback Data
455
Switch & Power Controls
Logical Controller
Data Storage
Processor
I/O Communications
LED Driver
454
LED Light Source Module
LED Driver
LED Light Source Module
457
458
456

FIG. 22

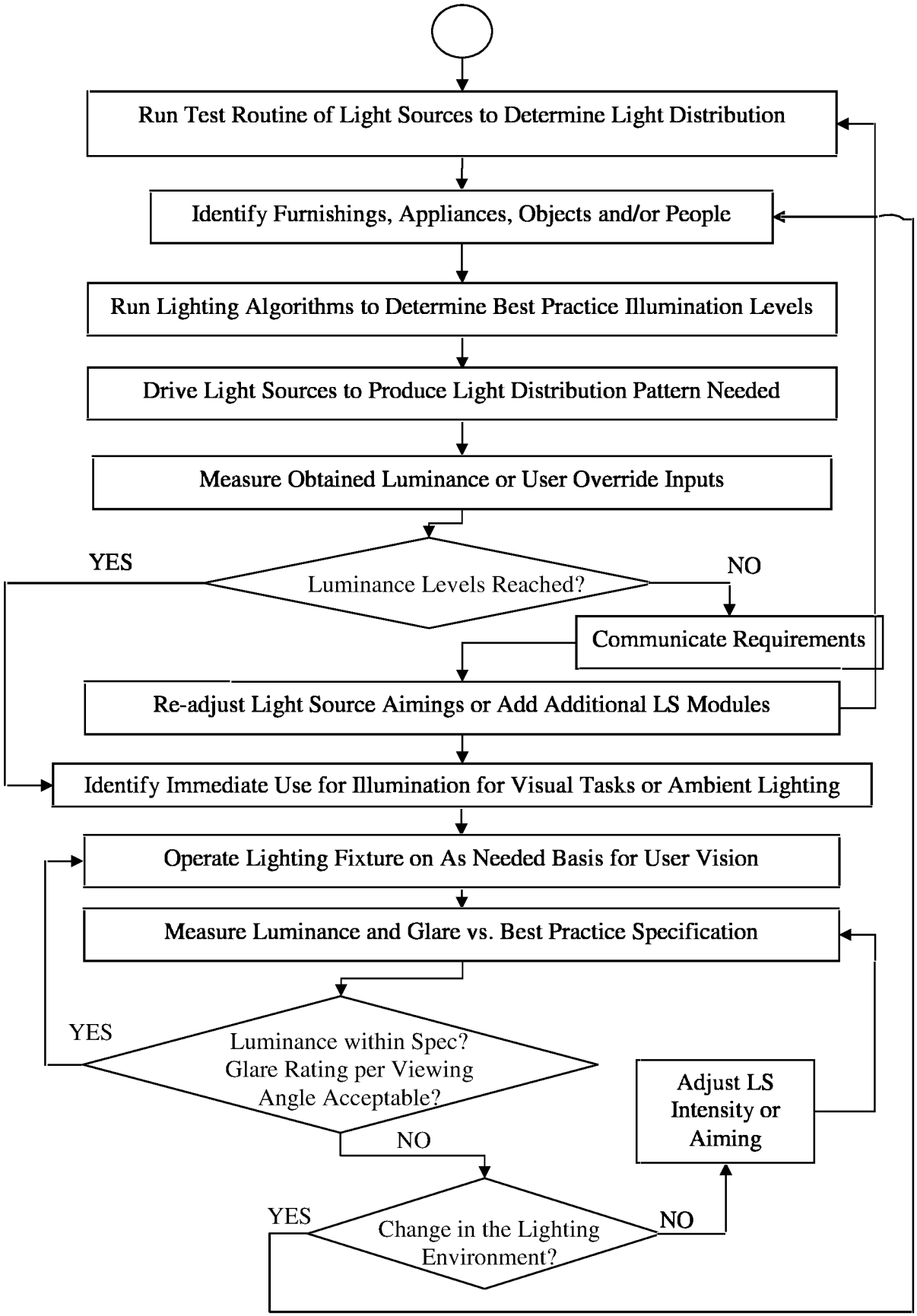

Run Test Routine of Light Sources to Determine Light Distribution
Identify Furnishings, Appliances, Objects and/or People
Run Lighting Algorithms to Determine Best Practice Illumination Levels
Drive Light Sources to Produce Light Distribution Pattern Needed
Measure Obtained Luminance or User Override Inputs
YES
Luminance Levels Reached?
NO
Communicate Requirements
Re-adjust Light Source Aimings or Add Additional LS Modules
Identify Immediate Use for Illumination for Visual Tasks or Ambient Lighting
Operate Lighting Fixture on As Needed Basis for User Vision
Measure Luminance and Glare vs. Best Practice Specification
YES
Luminance within Spec?
Glare Rating per Viewing
Angle Acceptable?
Adjust LS
Intensity or
Aiming
NO
YES
Change in the Lighting
Environment?
NO

Fig. 23

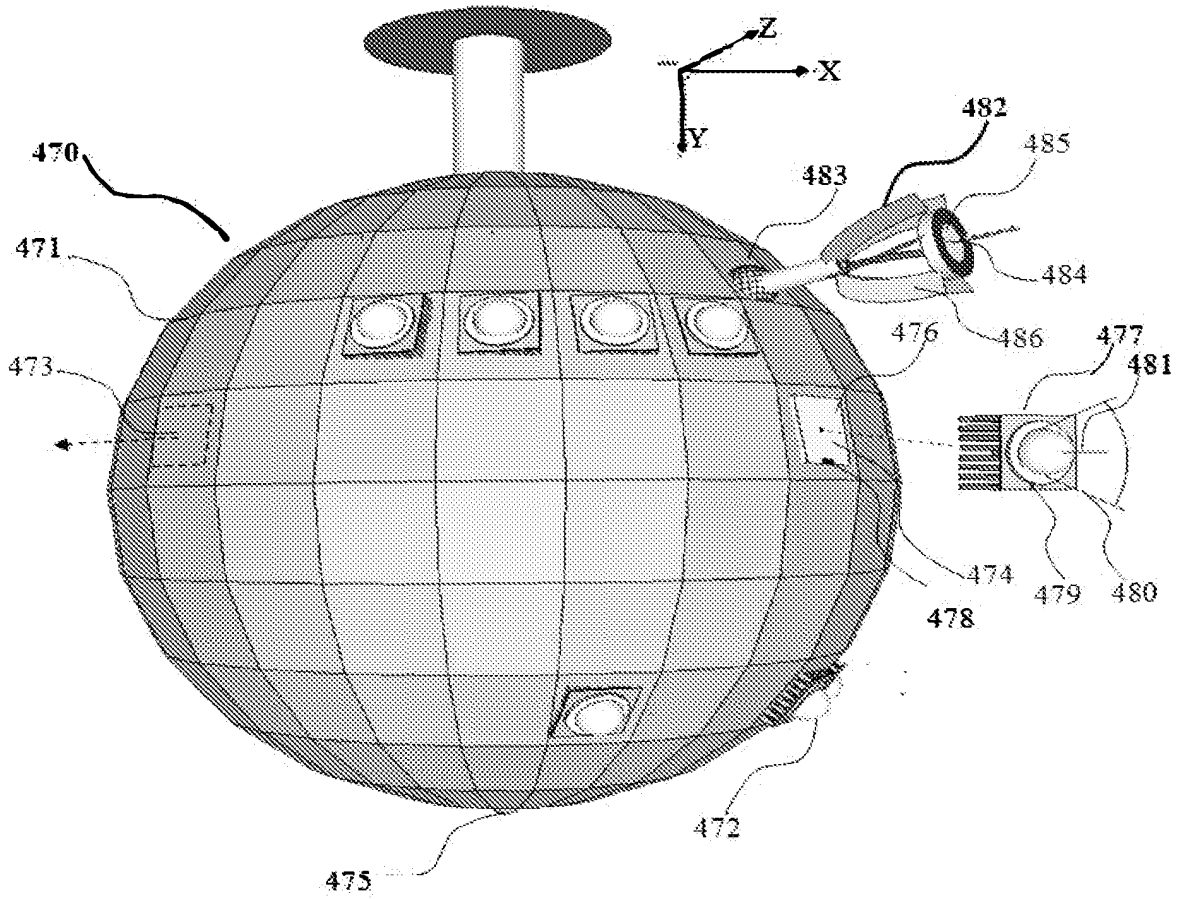


FIG. 24

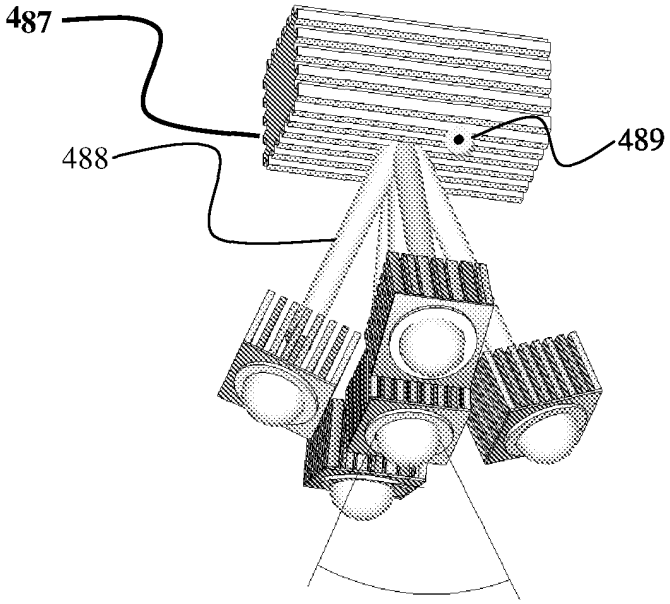


FIG. 25A

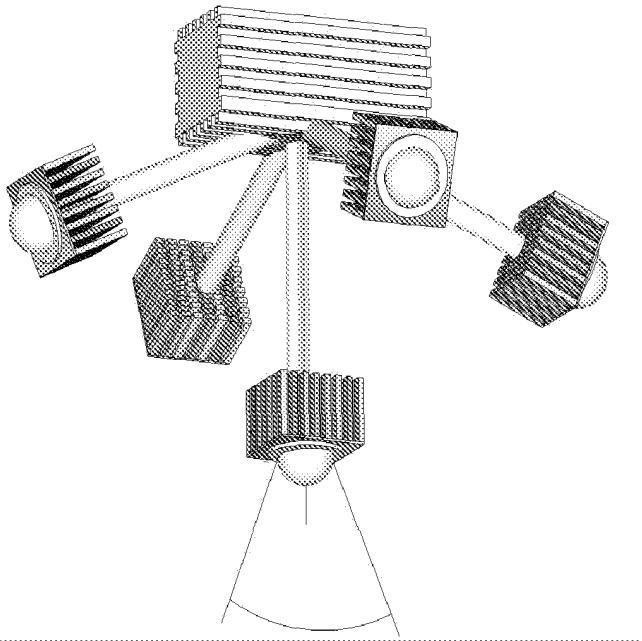


FIG. 25B

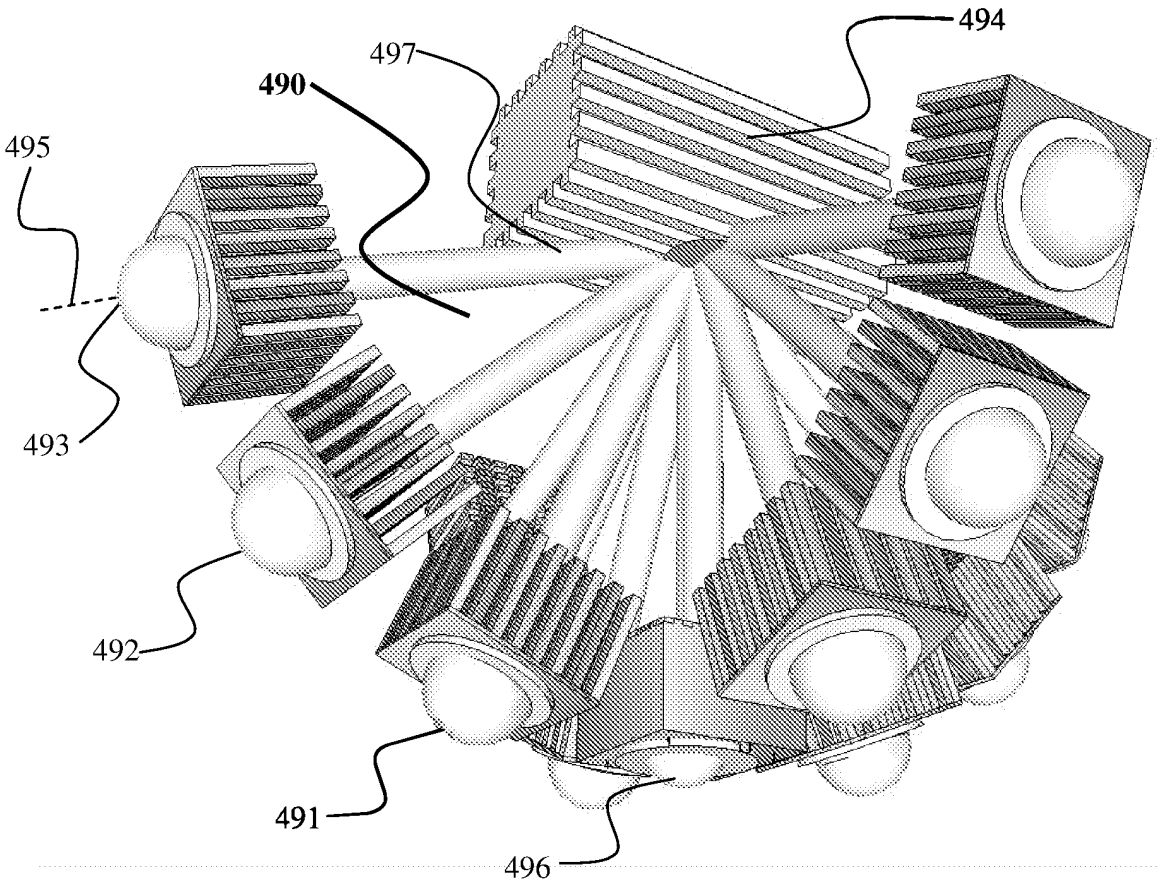


FIG. 26

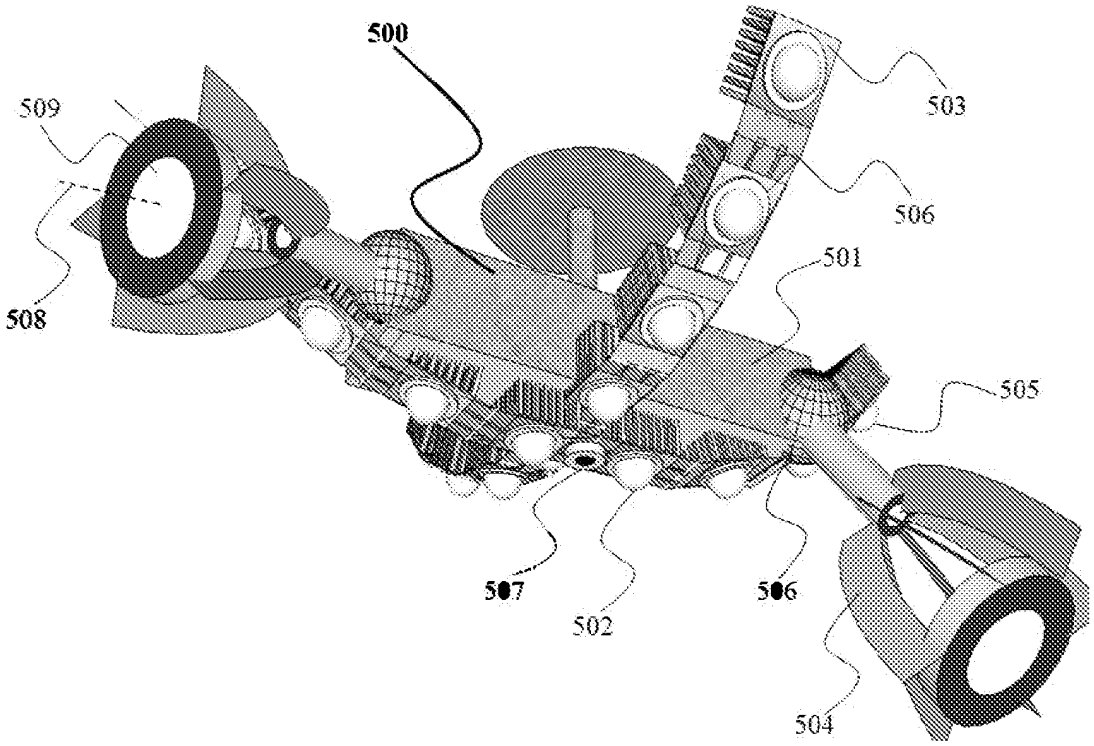


FIG. 27

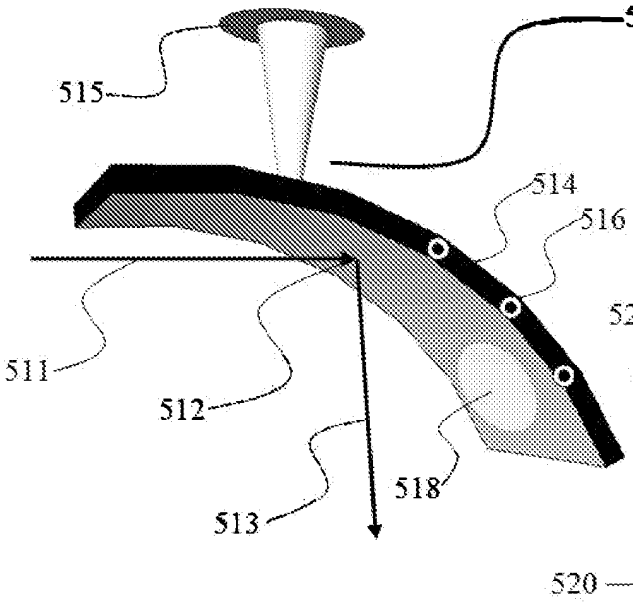


FIG. 28A

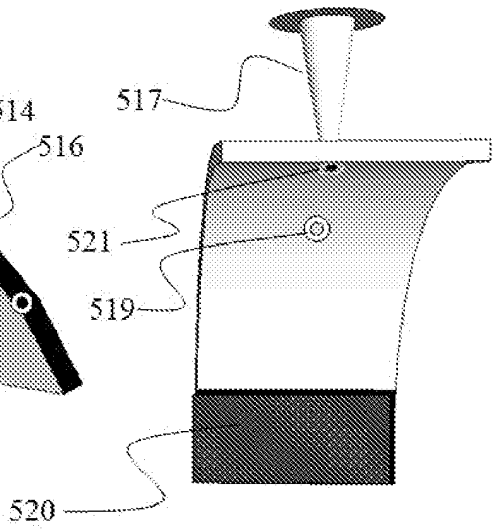


FIG. 28B

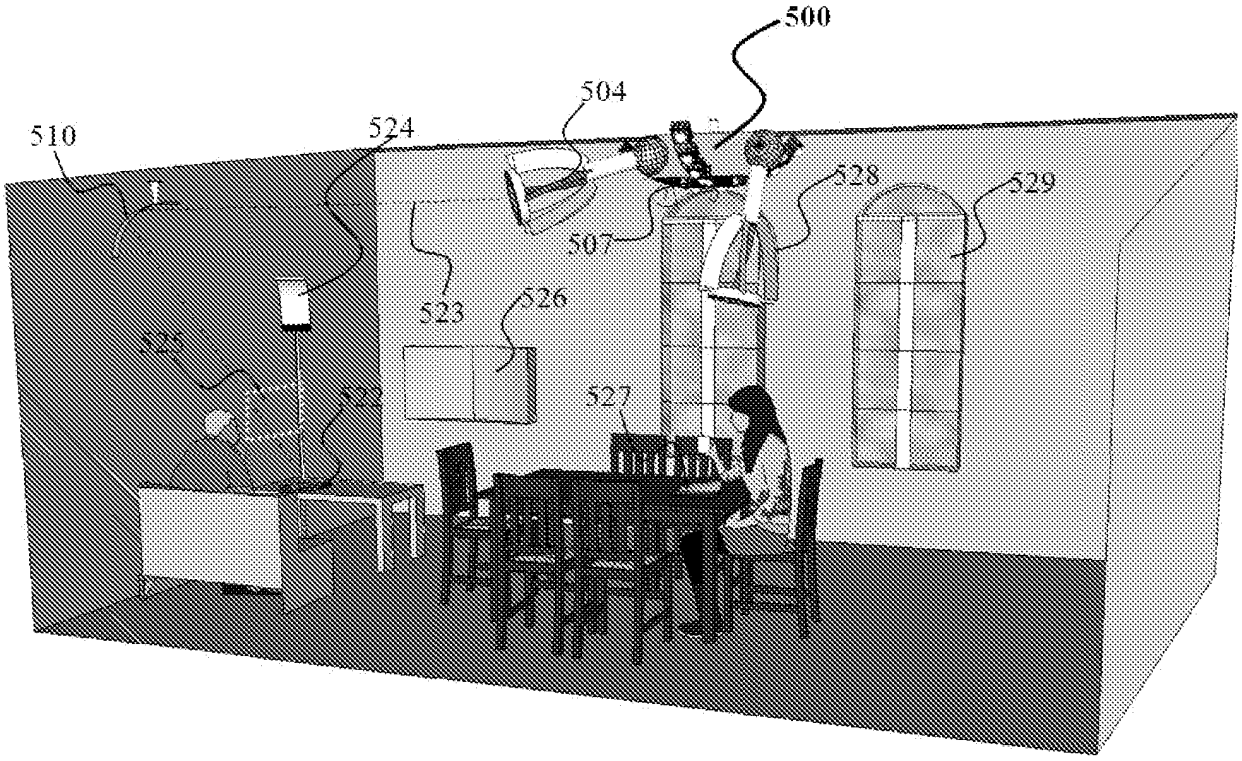

500
504
510
524
528
529
507
523
526
527

FIG. 29

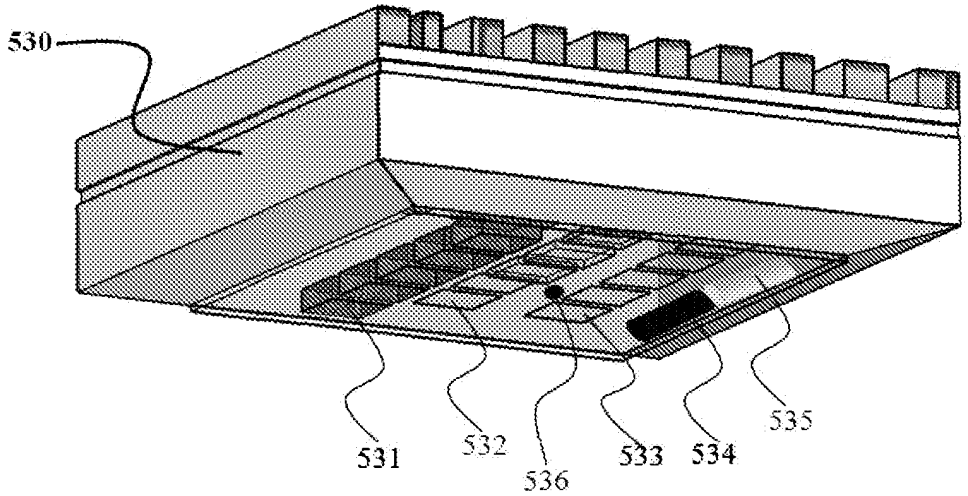

530
531
532
533
534
535
536

FIG. 30

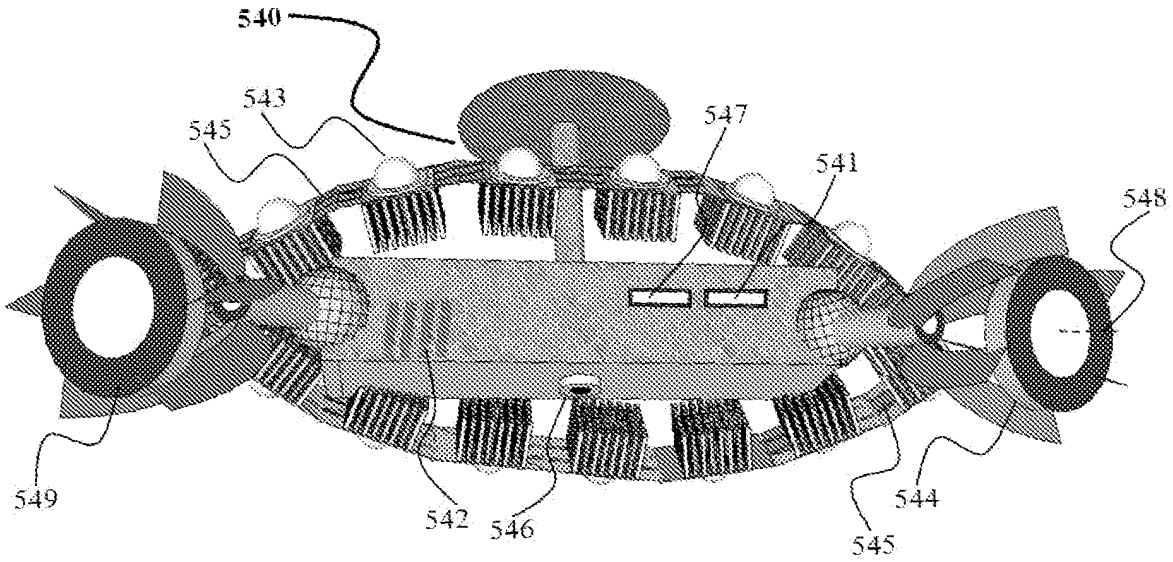

540
543
545
547
541
548
549
542
546
544
545

FIG. 31

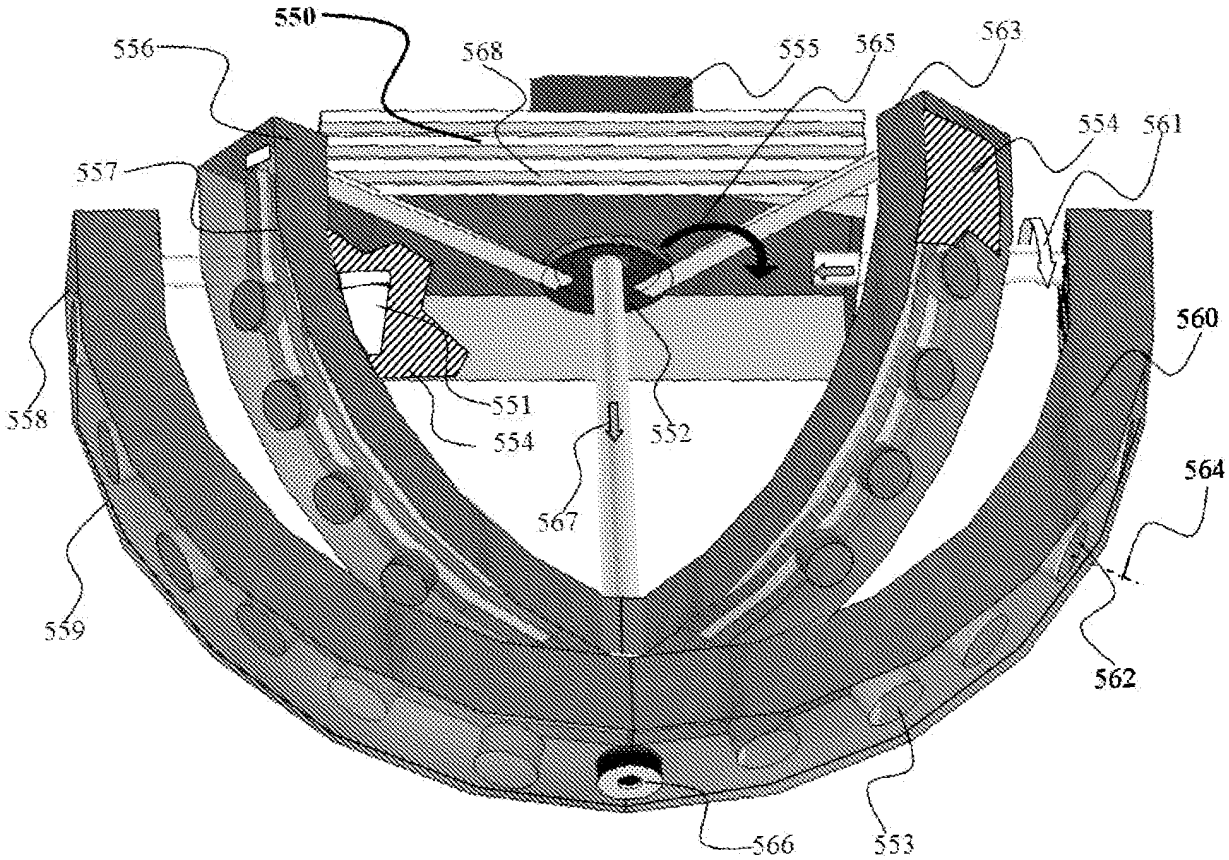

550
556
568
555
565
563
554
561
557
560
558
551
554
552
564
567
559
562
566
553

FIG. 32

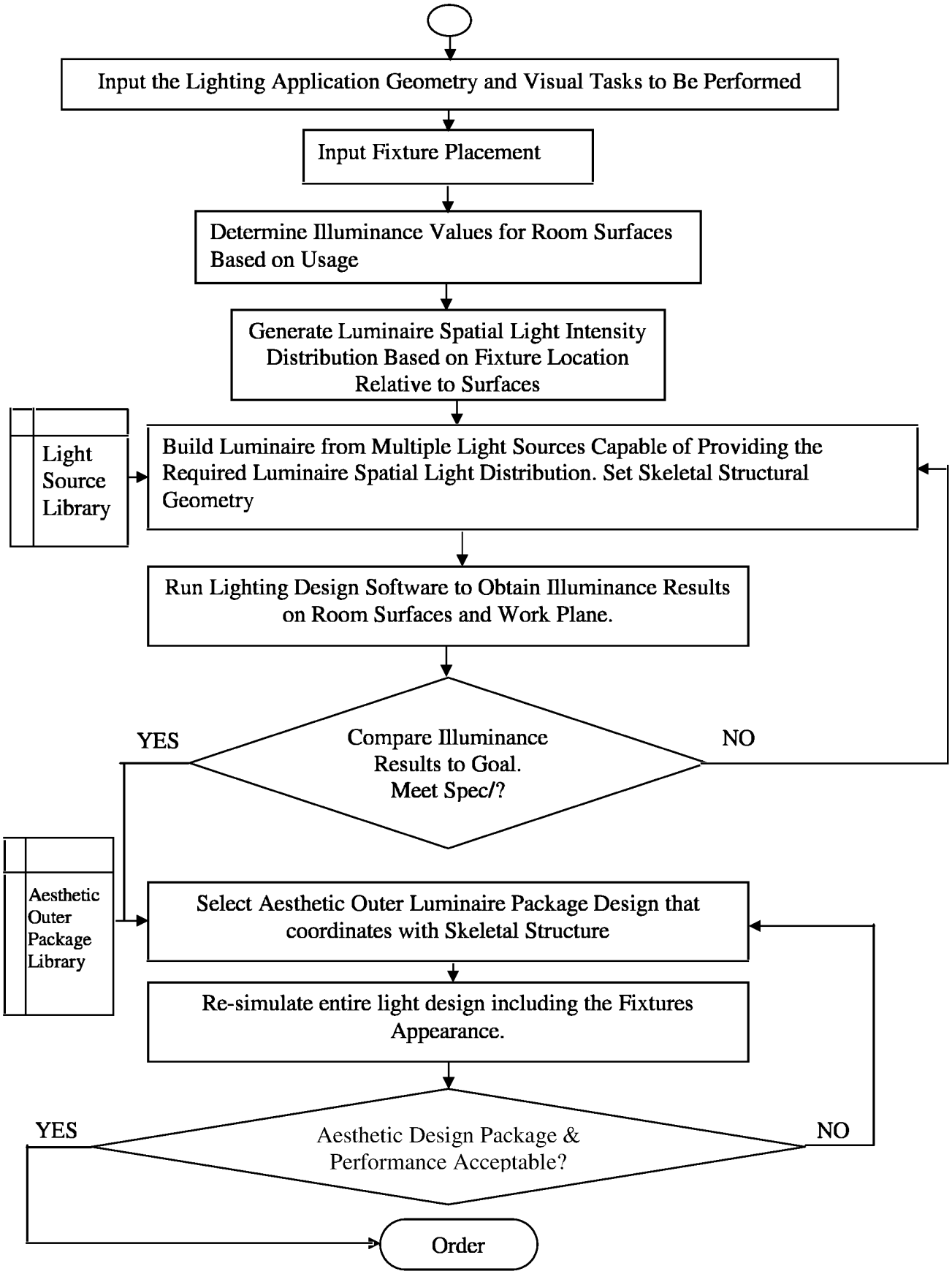

Input the Lighting Application Geometry and Visual Tasks to Be Performed
Input Fixture Placement
Determine Illuminance Values for Room Surfaces Based on Usage
Generate Luminaire Spatial Light Intensity Distribution Based on Fixture Location Relative to Surfaces
Light Source Library
Build Luminaire from Multiple Light Sources Capable of Providing the Required Luminaire Spatial Light Distribution. Set Skeletal Structural Geometry
Run Lighting Design Software to Obtain Illuminance Results on Room Surfaces and Work Plane.
Compare Illuminance Results to Goal. Meet Spec/?
YES
NO
Aesthetic Outer Package Library
Select Aesthetic Outer Luminaire Package Design that coordinates with Skeletal Structure
Re-simulate entire light design including the Fixtures Appearance.
Aesthetic Design Package & Performance Acceptable?
YES
NO
Order

FIG. 33

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	ADAPTIVE CONTROLLED HEADLIGHT SYSTEM
First Named Inventor/Applicant Name:	Yechezkal Evan Spero
Filer:	Bernard Patrick Tomsa/Julie Oumedian
Attorney Docket Number:	TRCH0103PUSP3

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
UTILITY APPLICATION FILING	1011	1	320	320
UTILITY SEARCH FEE	1111	1	700	700
UTILITY EXAMINATION FEE	1311	1	800	800
Pages:				
UTILITY APPL SIZE FEE PER 50 SHEETS >100	1081	1	420	420
Claims:				
CLAIMS IN EXCESS OF 20	1202	13	100	1300
Miscellaneous-Filing:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**3540**

Electronic Acknowledgement Receipt

EFS ID:	41684259
Application Number:	17152399
International Application Number:	
Confirmation Number:	6274
Title of Invention:	ADAPTIVE CONTROLLED HEADLIGHT SYSTEM
First Named Inventor/Applicant Name:	Yechezkal Evan Spero
Customer Number:	22045
Filer:	Bernard Patrick Tomsa/Julie Oumedian
Filer Authorized By:	Bernard Patrick Tomsa
Attorney Docket Number:	TRCH0103PUSP3
Receipt Date:	19-JAN-2021
Filing Date:	
Time Stamp:	17:19:55
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$3540
RAM confirmation Number	E20211IH20180909
Deposit Account	023978
Authorized User	Julie Oumedian
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.21 (Miscellaneous fees and charges) 37 CFR 1.20 (Post Issuance fees)	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Oath or Declaration filed	TRCH0103PUSP3_Declaration.PDF	128542 08f42bcbf5de72522753e8de37b40af0da5a95ae	no	2
Warnings:					
Information:					
2	Application Data Sheet	TRCH013PUSP3_ADS.PDF	1256244 e67e0ba314fee50b39fa80efda7bf6abd5a8cc1b	no	9
Warnings:					
Information:					
3	Specification	TRCH0103PUSP3_Specification_Part_1.PDF	21295919 71c44d0184af58e5fac0942edff8df9124367e29	no	73
Warnings:					
Information:					
4		TRCH0103PUSP3_Specification_Part_2.PDF	18643491 bb417b618e7ec163671fc1118064bf4810414c3c	yes	68

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Abstract	68	68
	Claims	59	67
	Specification	1	58

Warnings:					
Information:					
5	Drawings-only black and white line drawings	TRCH0103PUSP3_Formal_Drawings.PDF	1976180 96a7d5e4b0f280962ba70c48edc50f16e0d20348	no	24

Warnings:					
The page size in the PDF is too large. The pages should be 8.5 x 11 or A4. If this PDF is submitted, the pages will be resized upon entry into the Image File Wrapper and may affect subsequent processing					
Information:					
6	Fee Worksheet (SB06)	fee-info.pdf	38391 590f3803b42376821880b6d277ded33beed89770	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	43338767	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

ADAPTIVE HEADLIGHT SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a Continuation of pending U.S. patent application Ser. No. 15/961,861 filed Apr. 24, 2018, now U.S. Patent No. 10,894,503 which issued January 19, 2021 which is a Continuation of U.S. patent application Ser. No. 13/357,549 filed Jan. 24, 2012, now U.S. Patent No. 9,955,551 which issued Apr. 24, 2018, which is a Continuation-in-Part of U.S. patent application Ser. No. 10/604,360, entitled "Multiple Light-Source Illuminating System" filed on Jul. 14, 2003, now U.S. Patent No. 8,100,552 which issued on Jan. 24, 2012, which claims benefit under 35 U.S.C., § 119(e) of U.S. Provisional Application No. 60/395,308 filed Jul. 12, 2002, entitled "Multiple Light Source Illumination System". U.S. patent application Ser. No. 13,357,549 filed Jan. 24, 2012, also claims benefit of U.S. Provisional Application No. 61/535,981 filed Sept. 17, 2011 entitled "Adjustable Light Fixture" The entire content of the disclosures are all expressly incorporated herein by reference.

TECHNICAL FIELD

[0002] The present invention is in the field of radiation producing devices. More particularly, the present invention is in the technical field of lighting fixtures. However, radiation used for headlamps, heating, night vision, UV or visible light curing, medical X-rays and other radiation uses are covered as well. General lighting fixtures otherwise known as luminaires will be used as the primary example while other irradiating devices such as infrared heaters are covered as well. The invention relates to multiple light source illuminating devices intended to replace incandescent, fluorescent and HID luminaries in general and specialty lighting applications.

BACKGROUND

Definitions, Terms, Elements

[0003] In order to clarify the intent of the present invention and its dissimilar aspects from prior art, a nomenclature system is established.

[0004] Used herein illumination refers to the deliberate application of light to achieve some practical or aesthetic effect. Correct illumination or recommend lighting practice refers to lighting industry standards and recommendations for the illumination of living, recreation, architectural and work areas as described in standards and handbooks published by industry professional organizations such as the Illuminating Engineering Society, the International Association of Lighting Designers, IALD or International Commission on Illumination CIE.

[0005] Lamp: A lamp, other than a reflector lamp, is generally a device that generates light radially from the source. Due to the physics involved in the light generation process, it is difficult at the source to gain control of the spatial light propagation. A reflector lamp will partially control the emitted light which hits the reflector but will not control the remaining light emanating from the filament or discharge tube. A lamp other than a solid-state lamp will generally produce light over a wide range of spectrum. The overall color is a function of the physics involved in the generation of the different photon energies. While some lamps spectra are closer to sunlight and have a good color rendering in relation thereto, other lamps such as low-pressure sodium are highly monochromatic with a yellow-orange appearance. A color temperature in degrees Kelvin based on the color of an incandescent filament is used to describe a lamp. An incandescent lamp color will be termed "warm" at 2000 Kelvin and a Metal Halide "cool" at 4000K. In general, there is no ability to affect the color over the intensity level even where dimming is afforded. A lamp is also intended to be a replaceable element. Lamps are constructed according to universal standards which allow for the substitution of lamps by other manufacturers. Prior-art lamps are thus provided with bulky bases which fit into bulky sockets and do not lend themselves to being permanently wired into printed circuit boards or bonded onto electronic chips.

[0006] Luminaire: A Lighting Fixture or luminaire (the terms are used interchangeably) is a device which is constructed around the lamp to provide lighting specific to the application including non-lighting considerations such as aesthetics, safety etc. Some LF designs are primarily based on aesthetics while others are based on tailoring the lumen output such that the lighting fixture output meets the visual task at hand. Between these two extremes there are many possible designs, with maintenance, fixture cost, hazardous and rough service location considerations also playing a role. This is essentially why the industry produces so many different types of luminaires. One type for high industrial building ceilings known as high-bay lighting, another for office lighting and a third for

roadway lighting and a fourth for illuminating corridors. Each fixture has its photometric distribution characteristics, that is, how many candela at what angle are exiting from the luminaire. Other luminaire considerations include keeping the lighting from causing discomfort glare or from being a source of veiling reflections. The purely technical goal is to get the required amount of light at the work surfaces where visual tasks are carried out by man, animals, plants and machines. A LF has a longer life than the lamp, and the lamp is meant to be replaceable within the fixture. A luminaire is wired directly to the electrical mains while a lamp due to its need to be replaced has a base which fits into a socket by way of which the lamp receives its power. Prior art solid-state lamp assemblies are considered lamps, as they have no provision for being connected to the mains. A luminaire has apparatus whereby it is attached to the building structure while a lamp is mechanically affixed to the lamp holder or socket. Another aspect of distinction is, that in general, correct lighting practice principles are used to guide in the design of a LF while a lamp is "bare" and is expected to have reflectors, refractors, shades and louvers to prevent glare and redirect its rays to increase light utilization.

[0007] Digital: The term digital used herein in refers to the luminaire concept as espoused by teachings of this invention and is loosely defined in parallel to the fine control associated with digital equipment. The multiple light sources of specific characteristics provide quanta of power and spectrum which are smoothly added or detracted to generate a changed lighting effect. The digital aspect arises from the sufficient progression of values, varying by minute degrees to produce a continuum so as be non-discernable or irrelevant to the user. The added controllability is realized by breaking up the light-production, into discrete, specifically aimable, and dimmable elements which can be addressed by control electronics for the purpose of affecting the intensity, spectrum and spatial distribution of spectrum and of intensity of the illumination provided by the luminaire of the present invention.

[0008] The overall combination of control capability and discrete light sources yields a digital lighting fixture. The terminology "digital" as used herein also refers to the discrete nature of the multiple LED lamps provided in the luminaire, whereby, "digital" control results from the individual control of the discrete, i.e., "digital" lighting elements, the LEDs, in the luminaire.

[0009] Correct lighting practice: A bare incandescent lamp illuminating a room is arbitrarily termed poor lighting practice. The bare light bulb hooked up to the electric power via a light switch, causes glare, wastes light, delivering the light to useless areas, has no provision for dimming and is

energy inefficient. The Illuminating Engineering Society of North America (IESNA) as well as other professional groups such as the International Association of Lighting Designers (IALD) have developed recommended lighting practices for specific applications in indoor and outdoor lighting. These recommendations and equations for implementing the recommendations can be found in the IESNA Lighting Handbook, 8th and/or 9th Editions (available from the Illuminating Engineering Society of North America 120 Wall St. Floor 17 New York, N.Y. 10005 included herein by reference. Factors in good lighting include lighting intensity levels which may be based on the age of the users of the light, the color rendering capacity of the light source, its color temperature, the non-production of glare, veiling reflections and energy efficiency amongst others. Recommendations for all aspects of lighting in terms of intensity, distribution, color temperature, color temperature as a function of light intensity and correct color rendering exist in the literature in terms of lighting applications that is the environment to be illuminated, in parameters such as lux for intensity, CRI for color rendering index and Visual Comfort Parameter (VCP) for glare. In recent years, the Unified Glare Rating (UGR) as recommended by the CIE has become widely accepted as a general formula for assessing glare. While the US may still use VCP ratings, all the lighting-practice engineering organizations worldwide have standards and recommended ratings for different activities. For example, lighting levels of 500 lux and a UGR of 19 is recommended in offices while industrial areas intended for coarse work a UGR of 28 can tolerated. In good lighting practice, attention is given by lighting designers to the correct amount of uplight, that is, light exiting from the luminaire towards the ceiling, which prevents a gloomy "dark cave" effect. Attention is also given to the cut-off angle of the luminaire, usually provided by shielding elements, such that high intensity rays are not emitted at an angle where they enter the occupant's eye during normal activity. A correctly designed luminaire for indoor lighting may provide 30% uplight and 70% downlight in the angles from the nadir 0 to 60 degrees and then again 135 to 170 degrees. A governing equation in lighting and used in "reverse luminaire design" of the present invention is the cosine law or Lambert's law, Equation 1:

[0010] $$E=\frac{I\cos\theta}{D^2}$$

[0011] Where: E=Illuminance in lux or footcandles, I=Luminous intensity in candles, D=Distance between the source and the point of calculation in meters or feet, θ=Angle of light incidence with illuminated surface

[0012] Another useful equation used in fixture analysis to avoid glare producing designs yields the level of discomfort on the DeBoer scale. The DeBoer rating scale (1-9) describes the level of discomfort where: 1=Unbearable, 3=Disturbing, 5=Just acceptable, 7=Satisfactory, and 9=Just noticeable. The allowable level is dependent on the application. A surgeon performing an operation may be very sensitive to glare while a chlorophyll producing plant is not. The equation to determine the rating is Equation 2:

[0013] W=5.0−2.0 LOG [E_i/(0.003)(1+SQRT(La/0.04))(φ_i)^0.46]

[0014] where: W=glare sensation on a scale of 1 to 9, La=adaptation luminance (cd/m 2), E_i=illumination directed at observer's eyes from the i-th source (lux), φ_i=glare angle of the i-th source (minutes of arc) from the observer's line of sight.

[0015] Using these equations and correct lighting practice covering preferred angles of lighting for visual tasks, it is possible to design from the specific application's illumination requirements the spatial light intensity distribution and yet avoid manufacturing a glare producing luminaire.

[0016] The present invention generally relates to an improved illuminator for use both in general and specialty lighting. The term general lighting includes use in living spaces such as lighting in industrial, commercial, residential and transportation vehicle applications. By specialty lighting we mean emergency lighting activated during power failures, fires or smoke accumulations in buildings, microscope, stage illuminators, billboard front-lighting, hazardous and difficult access location lighting, backlighting for signs, agricultural lighting etc.

[0017] Energy Efficiency and Costs. In an example to illustrate the advantages of an energy efficient lighting solution, the total cost of lighting a typical 300 foot by 300-foot retail facility at 1000 lux over a 10 year period using state of the art (2002) HID luminaires is assessed. Including equipment, installation and maintenance cost the total bill is over one million dollars. Approximately 80% of this is in energy costs. The commodity being purchased is lighting, the major lifecycle cost is electricity. To cut down on costs and also conserve energy it desirable to maximize the use of light generated. A Japanese survey of office luminaires (Japan Lighting Information Services-Seminar-Save Energy of Office Lighting-Loss of light in luminaire-.htm) shows LF efficiencies (light that exits the fixture vs. the light produced by the lamp) in an open office fluorescent luminaire without anti-glare louvers to

be 84% while one equipped with louvers is only 52% efficient. The "utilization factor" (which equals the light flux which arrives at a work site (e.g. upper surface of a desk) divided by the sum of all light flux of the lamp) is 74% for an open fixture and only 50% for louvered version. This however, is still not what the customer is paying for. The customer is after the best lighting solution at minimal energy cost. Chances are, as experienced lighting designers know, that the light intensity, even in a good lighting design, is still not evenly distributed over the work surfaces. While care is taken in the lighting design computer runs not to fall below the minimum illumination intensity at any point in the room, there are non-trivial excesses at some points in the lighting layout design. This excess light, wasted energy as far as the customer is concerned, probably accounts for another 10% loss. While a fluorescent may appear to be a superior and very efficient light source at 80 lumen per watt vs. 30 lumen per watt for LEDs this is not actually the case, in actuality 60% of the fluorescent LF's light is wasted. Thus, in terms of energy use, a properly designed LED luminaire can be, with the proper luminaire design of the present invention, as effective lumen per lumen as any discharge light source in illuminating living areas.

[0018] Expressed in terms of the above background and nomenclature, it is the goal of this disclosure to teach how to construct a luminaire which will radiate photons where needed, exactly in the correct amounts to accomplish visual tasks and/or create an atmosphere. The controlled radiation of light into a living space with a specific spatial intensity distribution also having optimal spectral characteristics for the seeing tasks at hand is provided by the present invention. Each visual task application has its own correct lighting solution with optimal light intensities, light color emanating at angles which will not cause glare that interferes with vision or causes discomfort. Tasks in living spaces vary with time so it is another objective of the present invention is to provide the optimal lighting solution in "real time" (at that specific moment in time).

[0019] As a light source of ever increasing choice, LEDs have been packaged in numerous forms and used in lighting applications. Special control circuits have been developed to take advantage of the variability offered by the new light source and are today being offered as a solution to specific applications. In general, however the design process has not zeroed in on providing the correct lighting solution. A number of LED illumination devices create "white" light by combining two or more LEDs of various wavelengths. White LEDs are also made using phosphors. The goal has not been to vary this color spectrum in real time to coordinate with the usage of the living space. The term "white" light

is loosely interpreted to cover a range of illuminating light having spectral light distributions acceptable to the user for that application. HPS's yellow light has even been called white by some and the term is exclusive only of almost monochromatic sources such as LEDs and LPS lamps. The terms light spectrum, spectra, spectrum, spectral and color are used to refer to the relative spectral power distribution of the light source.

Description of the Prior Art

[0020] In prior art illuminating devices, a universal light source such as an incandescent or fluorescent lamp emits light in many directions up to a 360 degree light distribution where in practice only a limited angular light distribution is needed in order for people to carry out visual tasks. So as to control the light distribution to certain angles, reflectors and refractors are used to redirect the light where it is needed. A great deal of light is wasted in the inherent inefficiencies in redirecting the light and shielding the glare causing light sources. In addition, the actual placement of the light rays where needed, but not beyond, is often inexact and wasteful.

[0021] In addition, it necessary to have a wide variety of lighting fixtures each with dedicated optics and even then, there is much wasted light or insufficient lighting in the area covered by the luminaire. In addition, the light intensity and color spectrum of the luminaire is fixed while the visual tasks going on in the space are changing all the time. Usually, there is no provision for either detecting the changes going on in the living space nor is the lighting fixture equipped with apparatus to effect the necessary changes in the lighting. In addition, individuals often have their personal lighting preferences as to the color and intensity of the lighting. Prior art lighting fixtures have no provision for the localized provision of preferred lighting to individuals.

[0022] A prior art LED light strip consists of circuitry including a plurality of LEDs mounted on a substrate and connected to electrical conductors. The circuitry is sometimes encased within a tube like, partially transparent protective sheathing and connected to a power source for selective LED illumination. Two examples of LED strip types are described in U.S. Pat. No. 5,130,909 to Gross, entitled Emergency Lighting Strip and U.S. Pat. No. 4,597,033 to Meggs et al., entitled Flexible Elongated Lighting System. Such strips are utilized in a variety of indoor and outdoor configurations such as emergency pathway markers, exit door indicators and ornamental lighting arrangements. The

LEDs are being used as outline markers where the lighting strips are the object to be seen. It is not the purpose of the lighting strips to project light on other objects to make them visible. In other applications, where lighting distributed evenly along an area is required, these strips are placed at an edge. No attempt is made at obtaining an even illumination outward from the edge to the area perpendicular to the long dimension.

[0023] LED lamps and ballast systems can reduce maintenance costs due to an average rated life of 100,000 hours. This is five to eight times the typical service life of conventional fluorescent and metal halide lamps. The present system is especially well suited for applications where relamping is difficult or expensive.

[0024] U.S. Pat. No. 6,346,777 issued Feb. 12, 2002 to Kim teaches an illuminating lamp assembly. An LED lamp apparatus comprises a plurality of LED lamps including at least one LED chip mounted on a Printed Circuit Board (PCB), on which a driver circuit and/or a control circuit are provided in a printed circuit pattern to drive and/or control the LED chip. The device is independent of the lighting application and is simply a lamp not a lamp and fixture combination.

[0025] U.S. Pat. No. 5,018,290 issued May 28, 1991 to Kozek et al. Teaches an exit sign with a plurality of low voltage incandescent lamps mounted on a PCB to provide illumination from within a housing. There is no combination of different light source characteristics to build a new combined light source characteristic and this is a lamp replacement not a LF fit for general illumination.

[0026] U.S. Pat. No. 5,577,832 to Lodhie one of the originators of the use of LEDs for illumination, describes a multilayer LED assembly which is used as a replacement light for equipment used in manufacturing environments. On each layer of the multi-layer assembly, there are multiple LEDs which are mounted perpendicular to a base. The base is used to provide electrical and mechanical connection to a socket. The LED assembly may utilize multiple layers of LEDs, with each layer itself having multiple LEDs. The LEDs in each layer are mounted in a direction perpendicular to the base which results in light emanating in a direction perpendicular to the base. The LED assembly is used as a replacement lamp for equipment used in manufacturing environments. There is no attempt to match the light distribution to the task at hand.

[0027] U.S. Pat. No. 6,379,022 issued Apr. 30, 2002 to Amerson, et al. titled Auxiliary illuminating device having adjustable color temperature, describes an auxiliary illuminating device that has a least two preset ratios of light adjustable color temperature. The color temperature is adjusted by varying the light output at least two independently adjustable light sources. The light source is an array of at least 2 colors. The light source typically uses at least one set of LED's. The application specifically relates to use in producing correct lighting for photography but does not relate to general illumination so that its control equipment does not correlate the overall illuminance level to the color temperature over the range of illumination nor does its control equipment integrate the aiming function for correct light distribution. Essentially the auxiliary illuminating device is a lamp replacement for a photographic flash lamp.

[0028] U.S. Pat. No. 6,340,868, Illumination components, discloses a current control for an LED lighting assembly, where each current-controlled unit is uniquely addressable and capable of receiving illumination color information on a computer lighting network. The teachings of the above patent are incorporated herein by reference. Although this patent discloses how to construct controllable illumination light systems this patent does not relate to the concept of control within the parameters of accurate light distribution and correct lighting practice.

[0029] In U.S. Pat. No. 6,498,440 Stam, et al. incorporated herein by reference, describes a lamp assembly incorporating optical feedback to produce an illuminator assembly that is capable of utilizing a plurality of light sources to produce a desired resultant hue. The assembly includes a processor, a memory, a plurality of light sources and a detector. The memory is coupled to the processor and stores data and information. Each of the plurality of light sources are coupled to the processor and produce a different color. The processor is capable of independently controlling the intensity of each light source so as to produce a desired resultant hue. The detector is also coupled to the processor. The detector provides the processor with information which the processor utilizes in determining how to adjust the intensity of each of the light sources to provide the desired resultant hue.

[0030] In an earlier patent U.S. Pat. No. 5,803,579 titled: Illuminator assembly incorporating LEDs, by Turnbull, incorporated herein by reference, the different color LEDs light output is coincident in such a manner that this overlapped and mixed illumination forms a metameric white

color and has sufficient intensity and color rendering qualities to be an effective illuminator. Electronic circuits for control of the independent light sources consist of microprocessor controlled adjustable current sources.

[0031] United States Patent Application 20020130326 issued to Tamura et al., incorporated herein by reference, describes a lighting device that includes a plurality of LEDs arranged in an at least two-dimensionally dispersed manner; a transparent resin layer that covers the plurality of LEDs in an integrated form; a photo-detecting unit that detects an intensity of light emitted from the plurality of LEDs using a photodetector and a power supply circuit unit that controls driving of the plurality of LEDs based on a detection output from the photo-detecting unit. The purpose is to have a predetermined balance of light intensities of the colors according to an output detected as to each color by the photo-detecting unit. This device does not integrally cover the light distribution function within and does not correlate the lighting spectrum with the light intensity. It also does not provide a method to handle color shift over the lifetime of the illuminating device.

[0032] In U.S. Pat. No. 6,528,954 a light bulb is provided which may include a housing, an illumination source, disposed in the housing, and a processor, disposed in the housing, for controlling the illumination source. The housing may be configured to fit a conventional light fixture. The processor may control the intensity or the color of the illumination source. The housing may also house a transmitter and/or receiver. Although this device includes the desirable communications control aspect, this device does not relate to a multi-light source capability which allows for the smooth variation lighting and its even distribution.

[0033] In the prior-art approach, the LED manufacture and the power supply manufacture are separate units. Typically, one power supply is good for a certain number of LEDs. This is similar to the historical lamp and ballast segregation that came about probably because one manufacturer was working with glass and the other with copper. Electronic light sources are semiconductor components as are the power supply components. A unique opportunity for integration exists in solid-state luminaire design which has not being taken advantage of.

[0034] In many energy conserving multi resident stairwell lighting systems the lights are typically activated by pressing a button in the hallway or in each apartment. This requires special

wiring between the switches and the central controller. In many other stairwells and hallways, the lighting is always left on wasting energy. With long life LED lamps, a low energy distributed lighting solution could always be on for orientation purposes and would only turn on to full output when activity levels require the lights turning on, using integral optoelectronic motion detectors.

[0035] A home lighting fixture is often left on at full power when really only lighting for orientation purposes is required. A light switch on the wall is provided and sometimes this has a dimmer option. An electronic power supply with programmable electronic controller with communication over a dedicated data line or alternately over the power line or alternately wireless is also possible in present art such as with the DALI (Digital Addressable Lighting Interface) protocol. With digital signals, power supplies become individually addressable compared to analog systems where only circuits are addressable. Additionally, DALI allows for bi-directional communication between the power supply and control. DALI also brings the capability of broadcast messaging to ballasts. With DALI or any other protocol much more than dimming can be effected. Control of spectrum, occupancy sensor controls and specific spatial intensity distributions can be modified. However, the present-day lamp or fixture is not designed to fully and efficiently take advantage of these new control capabilities.

[0036] In United States Patent Application 20100302779 by Chemel titled Fixture with Replaceable Light Bars he describes an intelligent LED-based lighting system. The LED based lighting systems may include fixtures with one or more of rotatable LED light bars, integrated sensors, onboard intelligence to receive signals from the LED light bars and control the LED light bars. In this system while an adjustable system of moving bars is illustrated so that the LED luminaire can retrofit a variety of older discharge lamp-based luminaires, advantage has not been taken of the multiplicity of light sources to obtain a superior light distribution lighting solution that is now obtainable with multiple sources.

[0037] Spero in United States Patent Application 20040105264 describes the design of a multiple light source system using unique placements of the LEDs on the structure of a lighting fixture to generate an application specific light distribution pattern capable of providing recommended illuminance levels. The lighting fixture has means for being affixed within a living space to be illuminated in a unique orientation in relation to the surfaces therein. Subsequently, the lighting fixture

is designed by positioning LED light sources thereon that emanate light in direction and intensity as required by the lighting application. The geometric layout is determined by using knowledge of the distances and angles from the light sources to the living-space surfaces as dictated by the inverse square law and Lambert's Cosine Law of Incidence. The combination of the unique placement of the LEDs on the lighting fixture and the unique orientation of the fixture in the living space results in the predetermined illuminance being obtained on the room surfaces. A problem with this technique can arise in non-standard illumination instances which may be the majority of lighting applications. For example, in industrial plant lighting, such as in open chemical processing facilities or where there are desks, shelves, machinery or other elements requiring an unpredictable light distribution. Much energy is wasted in these facilities with the wasted light often contributing to light pollution.

[0038] In another embodiment Spero describes a solution to this problem where an overabundance of LEDs are deployed on the fixture structure giving it the ability to illuminate in all directions at required intensities. The controller of the LEDs is coupled to a camera which analyzes surfaces and usage within the living space and adjusts the lighting accordingly. While the design is highly flexible it requires an over capacity of LEDs and the cost of driver and light sources would be high.

[0039] People need light for the performance of visual tasks, its aesthetic value or security. Light generated but not used by people is wasted energy, money and causes air and light pollution. Standard lighting fixtures, even those that are somewhat area based, such as a low bay or bedroom luminaire, because of the different object and usages within the area, either provide too much light and are wasteful or provide insufficient lighting inhibiting visual performance. Therefore, it would be beneficial to have a lighting fixture that is further configurable to meet the demands of the actual lighting application where it has been installed. In addition, it would be beneficial if the lighting fixture was responsive in real time to the lighting needs at that moment. It is no longer necessary to have fixtures providing illumination where there is nothing to be seen.

[0040] Thus, there is a need for a lighting fixture having provision for the differentiation over space and time of the light's intensity and color that could be set-up in the field and/or adjusted in real-time to the changing lighting requirements. Such an exigency-based fixture would provide correct

illuminance in terms of chromaticity, homogeneous or aesthetic lighting generally and task lighting locally for the visual tasks at hand.

[0041] Prior art lighting practice utilizes an apparatus termed a luminaire or Lighting Fixture to provide illumination to indoor and outdoor living spaces, vehicles machinery etc. for the performance of various visual tasks. A luminaire provides features other than just light which may include light distribution, shielding, man-machine-interfaces such as on/off switches, connection to power mains, apparatus for affixation to construction elements and aesthetics. A typical prior art luminaire is comprised of: a replaceable lamp, a lamp holder, wiring, optical control elements such as a reflectors and refractors, fasteners and brackets. In addition, if the lamp has a negative resistance characteristic, then the luminaire includes power control elements such as a ballast. If a light control system is employed also included are elements including relays, logic controllers and communication devices which may be part of an electronic ballast design. All of these elements packaged together constitute a luminaire. In typical present-day luminaire (lighting fixture) practice, a lamp with a mostly radially uniform spatial light distribution is placed within an optical assembly consisting of a reflector and or refractor for the purpose of having the light exit the luminaire in the desired direction and preferred distribution pattern. This is a process that involves cost and inefficiencies in redirecting the light.

[0042] Recently solid-state light sources have evolved from indicator lamps into illumination sources. The present art approach is to package these new lamp types into luminaires of the old lamp type with some minor adjustments. This was the case when fluorescents replaced incandescents and when HID replaced fluorescents. The question arises, is this really the best solution as far as functionality and construction are concerned. The question is especially cogent when the fact that solid state light sources are electronic devices with high reliability, long lifetimes and are capable of rapid change over a very wide operating range.

[0043] Examples of the inflexible prior-art approach based on today's designs include: lighting is often provided in rooms where daylight contributes significantly to the overall lighting level or in areas near the window but the lighting system is not flexible enough spatially to take advantage of the daylight contribution and reduce power; or the lighting is always on at maximum power irrespective of whether or not there is activity in the room to justify the lighting level.

[0044] Even when external dimming controls are provided to the lighting fixture, the color quality of the lighting is deleteriously affected. At a lower lighting level, a warmer color temperature is generally required, and the luminaire lamp color is not adjustable.

[0045] Lighting systems are generally based around a lamp source and lighting application. When a new lamp source arrives generally they are placed into present-day lighting luminaire designs which are not optimal for the new light source. LEDs are a light source which have a number of advantages due to relatively long-life expectancy. In the future it is also expected that LEDs will have conversion efficiencies equivalent to those of discharge lamps. Presently however, the high cost of lumen per watt appears to make LEDs uneconomical for most lighting applications. A few applications of which step, stairwell, pathway and emergency lighting are examples require low lighting levels to begin with and thus present at this time a feasible application. An LED light source is well adapted to a number of additional applications. Very often in these additional applications the areas over which the lighting is to be provided are large and bringing electric power to the luminaire is a significant safety and cost consideration. An inherently low voltage light source such as an LED is suitable for use with safe 12 or 24 volt of a distributed power system with low current demands. The control of the light distribution, especially the beam cut-off necessary at low light levels to prevent discomfort, is well suited to the high directionality of the small LED light source. Maintenance of prior-art luminaires in outdoor applications and the requirement for watertight resealing increases fixture cost and complexity. Robustness of luminaires is another requirement as they located on ground level endangered by passersby contact or vandalism.

[0046] In prior art lighting fixture construction, the lamp, reflector, socket and ballast are separate units. Foremost, the lamp must be replaceable and thus access provided, because the lamp lifetime is less than other components in the fixture. The reflector is large, to envelope the light source and provide ray control, and is manufactured of special, highly reflective, material. The power-conditioning device such as a core and coil ballast or more recently electronic power transistor components differs again from the glass lamp, reflector and fixture material. The dissimilarity of the manufacturing technologies, operating lifetimes and materials results in a multi-component fixture assembly held together by fasteners which don't lend themselves to mass production and the luminaires are not factory sealed for life.

Objectives of the Invention

[0047] The present invention provides a unique approach to solid-state illuminating devices that is a departure from conventional prior art LED lighting practice. Prior-Art LED lighting technology manufacturers have been taking LED junctions and packaging them in ever more-powerful configurations to carry out the function of lamps. These LED lamps are teamed with reflectors and/or refractors similar to the techniques practiced with standard lamps or put on strips which is just another way of distributing the light over the area to be illuminated. This invention comprises a different approach which is to provide the end user with the most correct lighting solution not a new technology lamp to replace the old one. The present invention comprises a novel multi-light source approach to the design and construction of solid-state lighting fixtures (vs. solid-state lamps), which is termed a "Digital Lighting Fixture", due to the control of individual lighting element "digits" to provide the "correct" lighting solution for the situation at hand.

[0048] The invention embraces LED-illuminating devices covering a wide scope of applications including a room light and step light design as well as the general method for designing solid state luminaires from ground up from indoor to outdoor use in residences, factories, stores stadiums and streets. The general concept allows anyone to build a lighting fixture from the ground up, tailor made to the final application rather than building a fixture around a common lamp. This is because it difficult to control the high temperature processes of incandescent and discharge lamps. In addition, it takes a tremendous amount of investment in tooling to manufacture an incandescent, fluorescent or HID lamp. Electronic components on the other hand are made of large quantities of discrete components which are masked or robotically placed on to substrates. These smaller building blocks can then be easily configured per specific applications.

[0049] This disclosure also teaches that when it comes to solid-state lighting big is not necessarily better. The approach of LED manufacturers trying to get into the lighting business by attempting to replicate the effect of present day lamps has been to make large, high current capacity, high lumen output electroluminescent junctions having marginally acceptable lighting characteristics. Lumileds Luxeon® DS25 Emitter running at 350 mA is an example of such an approach. In a few years manufacturers have raised currents from 50 mA to above 500 mA, at the time of this writing. These advances are certainly favorable at reducing costs and making LEDs a practical light source but

attempting to get 1000 lumen (equivalent to a 60 W incandescent lamp) is not necessarily the best path to take, especially if it comes at the price of light conversion or distribution efficiency. In contrast to a prior art, single large, lamp replacement like light source, the present invention provides multiple, small sized sources of differing characteristics such that the effect of the whole is greater than the sum of the individual parts. The determining size factor then becomes when is there a sufficient progression of values varying by minute degrees or continuum so as be non-discernable or irrelevant to the user. That is, LEDs are generally of a single wavelength (color, frequency), have small optics close in to the individual light sources since they operate coolly, and have stable conversion efficiency over a wide range of currents and light output. The added controllability offered by breaking the total light output up into discrete ("digital") specifically aimable and dimmable elements which can be addressed by control electronics to effect intensity, spectrum and spatial distribution of intensity and spectrum, yields a lighting fixture (vs. lamp) of unparalleled performance. Unique to this patent is the approach. It is the approach of a lighting manufacturer who provides lighting solutions versus that of a lamp manufacturer who produces a generic lamp.

[0050] The advance over prior art is a solid-state light source with increased: 1. Efficiency—more effective lumen per watt electricity. 2. Durability—physical strength, life expectancy, lumen maintenance and spectral stability. 3. Lighting quality—as related to visual comfort and "atmosphere". 4. Functionality—ability to control the light placement, intensity and color temperature and do so as needed. 5. Energy savings 6. Lower overall lifecycle cost

[0051] Integrating the light source with power conditioning electronics, control circuitry and sensors gives additional cost benefits and functionality including: 1. Mass production capability 2. Sealed-for-life fixture 3. Exact optical performance less spill light 4. Compact design 5. Feedback control and recalibrated color consistency over the device lifetime 6. Real-time lighting needs adaptability.

[0052] Therefore, it would be advantageous to have a luminaire that require no maintenance, has smoothly controllable light output in terms of intensity, spectra, spatial distribution, is robust, mass-producible as a single unit, factory sealed against the elements, is self-calibrating over its lifetime, is adaptable to changing requirements, works on high or low voltage, has an affixation apparatus and is aesthetic.

Further Objectives of the Invention

[0053] The objectives of the present invention are (among others) to overcome the deficiencies in the prior art and effect the following: Light is generated only when, where and in the proper amount and color that can best be used by people or is their personal preference. This will save wasted energy, money and air and light pollution while increasing visual performance and comfort. An exigency-based lighting fixture is presented that provides correct illuminance in terms of chromaticity, homogeneous or aesthetic lighting generally and task lighting locally for the visual tasks at hand while preserving high visual comfort.

[0054] A number of unique illuminating device embodiments are achievable using the basic elements presented above. A few examples presented in the disclosure include: (1) an industrial lighting fixture for use in chemical and process plants where lighting that normally spills out of the existing structure as wasted light, is not produced to begin with; (2) a bedroom luminaire where normal activity and night-light lighting levels are provided as well as the ability to provide individualized lighting to each person; (3) Living room lighting with provision of modes for typical uses such as television viewing, reading with the provision of radiant spot heating based on the users unique location and usage at that instant in time; (4) A therapeutic luminaire designed to use illumination and irradiation on persons to alter biological disorders or schedule sleep or awakening; (5) a luminaire for emergency and security forces having a non-readiness situation intensity and chromacity and second high-readiness situation setting of a unique intensity and/or chromacity, where the unique chromacity does not damage the biological visual purple pigment of the retina that is responsible for enabling night vision. It thus eliminates the time these security forces would need to adjust from normal lighting to low-light night vision conditions; (6) a restaurant luminaire which illuminates foods and/or people in their best light while providing for the correct level and chromacity of ambient lighting for generating the optimal dining atmosphere; (7) A general luminaire which the end user configures themselves in situ to best suit their desired lighting preferences. The field adjusted luminaire comes with the lighting elements and their power supplies but the user re-arranges in particular directions and sets their light output levels and/or chromacity to obtain the preferred output; (8) A do it yourself modular lighting fixture which is a structure capable of receiving light sources over its surface where the user chooses the light source with its chromacity and intensity level. The user builds up the light distribution pattern on their own and connects the sources to the integral modular power supply; (9) A

single light engine device for a room or outdoor location with concentrated light output capable of being beamed distances to reflectors or refractors which redirect the light to be more optimally used in a localized area.

[0055] The overall objective of these exemplary embodiments is the disclosure of an exigency-based lighting fixture that provides correct or user preferred illuminance in terms of chromaticity, homogeneity, aesthetic considerations over a general area and/or task lighting provided in a small area for the visual tasks at hand. Providing illumination only where, how and when it is needed to efficiently carry out visual tasks minimizes wasted light thus minimizing energy use for lighting. To achieve this efficiency goal there is a need for a lighting fixture having provision for 1) the differentiation over space and time of its light intensity and color 2) that can be set-up in the field and/or 3) adjusted in real-time to changing lighting requirements.

[0056] While these objectives should not be understood to limit the teachings of the present invention, in general these objectives are achieved in part or in whole by the disclosed invention that is presented in the following sections. One skilled in the art will no doubt be able to select aspects of the present invention as disclosed to affect any combination of the objectives described above.

SUMMARY

[0057] A lighting device incorporates one or more discrete light sources and their ancillary optical and electrical control equipment in an integrated illuminating element. The overall lighting effect is the result of the combination of these multiple sources, detector and control components operating together. Preferably, the power conditioning circuitry, light sources, logic control circuitry, sensors and optical elements are packaged together in one integral device. The system contrives a lighting device which replaces the present day multi-component lighting fixtures or luminaires including: the lamp; optical light control element/s such as reflector, refractor and shade; power conditioning devices such as a ballast; control equipment such as switch, dimmer, and timer. Detectors, emitters and sensors for light intensity, spectrum, temperature etc. such as photodiodes, photocells thermocouples etc. are provided. These provide data input to the controller, allow feedback and enable recalibration. An additional apparatus that conducts electric power along length, as electrical wiring, may be added to the system to provide further unitization. The integral lighting

element is packaged in the shape of a globe, hemisphere, disc or strip and is designed to quick connect to the electric power carrying conductors. Provision is made for mechanical affixation to a structural surface. In the present concept over the life time of the fixture there is no lamp replacement only fixture replacement. It's assumed that after 100,000 hours it is time to change the fixture.

[0058] The method of creating a luminaire adapted to the usage and surroundings in which the luminaire will be integrated is disclosed. The process includes determining: the correct lighting practice for the application; the surroundings; the selection and placement of light sources and their integration with the mechanical support and; electronic control elements to realize the objective.

[0059] The present invention also relates to lighting fixtures comprised of many directional light sources that are mounted with different aimings so as to correctly illuminate an area. The LED light sources are moveable so that they can be adjusted to best illuminate the area where the luminaire has actually been installed. In addition, they may be controllable by a microprocessor as to the light intensity and color so as to best assist people to see what they are doing at that moment, be it reading a book, watching TV or assembling an automobile. The lighting fixture is equipped with a "smart" camera (similar to a cell phone's processor controlled digital camera) which inputs data on the lighting, occupants and current conditions within the room. The result of this added sophistication is that electricity is spent on generating only useful light. The energy savings greatly reduces electricity costs and environmental impact.

[0060] The present invention more specifically relates to lighting fixtures whose spatial light distribution and/or spectral power distribution is capable of being adapted, either manually or automatically, to provide the illumination needed in that specific surrounding and at that specific time. The Field Adjustable Multiple-Light-Source Luminaire, FAML, is thus a universal product that can be tailored onsite so as to provide design illuminance and color spectrum to the relevant surfaces in the specific lighting installation. Thus, a preferred embodiment of the invention is a lighting fixture comprised of many light sources which can be separately aimed and powered so as to illuminate areas or objects in a room or outdoors in a most correct, efficient and comfortable manner.

[0061] To affect this directional lighting versatility, in a preferred embodiment the luminaire is comprised of many directional light sources that can be re-positioned so as to illuminate in different

directions. The light sources at a particular aiming may all be one color, say white or may be of different colors which when combined together yield a different colored light beam. Altering the radiated power of one color light source versus the other allows for the creation of light in a myriad of colors. The luminaire has some light sources at the same aiming and others at different aimings and may come in a standard configuration for the general type of lighting application from the factory. Upon installation, if the factory preset lighting distribution does not fit the actual surroundings, the installer will customize the configuration by adjusting the light source aimings and light intensity output such that the correct amount of light is supplied to where it is needed while not at all or minimally illuminating areas where it is not needed. The installer will also make provision for the existence of other lighting fixture in the same or adjacent areas. When light is provided at higher angles and glare would result from the LED light source being visible, the light is not wasted by covering it with a shade or passing the light through a diffuser thereby losing the directionality and light flux due to absorption. Instead taking advantage of the small étendue of the light source, an optical spreader is used to increase the area from where the light is exiting thus lowering the luminous exitance while maintaining directionality.

[0062] To effect the provision of lighting that is in concert with the actual illumination needs at a given time, in an embodiment of the FAML, a camera serves as a sensor capable of detecting light, color and contents of the living space. The fixture is equipped with a logical controller. Using computer vision technology to recognize people, objects and surroundings the lighting fixture can provide the lighting requirements needed in the room at that moment in time. The computer vision system has been taught to recognize different visual tasks such as an individual operating a machine, reading a book or watching TV. The logical controller has instruction sets as to what color lighting at what intensity is preferable for that specific visual task. Thus if no one is in the room the lighting is off or a dimmed, aesthetic lighting is provided for the good feeling of those looking in. When people enter the room, immediately general room lighting is turned on and following that, specific task lighting is provided and adjusted to the right level and color based on where they are in the room and what they are doing.

[0063] An automatic embodiment of the FAML would include motion control elements for the light sources. Coupled with the camera and logical controller, the light distribution is altered automatically as required by changes in the physical surroundings, people or environment. In a similar

fashion to how a preprogrammed moving head stage light follows the performer about the stage the FAML logical controller will automatically locate the person in the room and provide locally the lighting needed for the performance of visual tasks. To save energy, the rest of the room will then be illuminated at a lower, yet comfortable lighting level.

BRIEF DESCRIPTION OF THE DRAWINGS

[0064] FIG. 1 represents a block diagram of the elements making up a Digital Lighting Fixture system.

[0065] FIG. 2A is prior-art design and FIG. 2B an illustration of a preferred embodiment of this invention of a retrofit LED lamp illuminator while FIG. 2C is a side view of an embodiment of this invention using a PCB provided with standard 5 mm hole-through LEDs.

[0066] FIG. 3A and FIG. 3B illustrate a preferred embodiment of a decorative LED outdoor wall sconce juxtaposed with a prior-art design.

[0067] FIG. 4 is an illustration of a Surface or Railing Mounted Digital Lighting Fixture.

[0068] FIG. 5 is a Surface or Railing Mounted Distributed Digital Lighting Fixture.

[0069] FIG. 6 is an Asymmetric Light Source made of Directional Chip Facets.

[0070] FIG. 7 illustrates an application employing the Discrete Unit Step Light.

[0071] FIG. 8 illustrates an application using the LED based Distributed Step Light Fixture.

[0072] FIG. 9 is a path lighting application using an LED Stake-Top Path Light.

[0073] FIG. 10 is the Illuminating Engineering Society Preferred Color Temperature vs. Intensity Correlation.

[0074] FIG. 11 depicts an integrated digital lighting fixture using discrete solid-state light source arrays deployed angularly about the geometric volume.

[0075] FIG. 12 is a universal luminaire embodiment using an adaptive digital lighting fixture which is programmed to illuminate the area as is needed.

[0076] FIGS. 13A through 13C depict a streetlight fixture designed according to the teachings of this invention.

[0077] FIG. 14 is a flowchart of a typical design procedure for a multi-source lighting fixture of the present disclosure

[0078] FIG. 15 shows a multiple light-source headlamp capable of optimally carrying out the diverse illumination functions used in driving under various environmental conditions and surroundings.

[0079] FIG. 16 is an illustration of an anti-glare system using the multiple light source headlamp.

[0080] FIG. 17 a representative Electronic Power Supply Unit for Surface or Railing Mounted Luminaire.

[0081] FIG. 18A is a perspective view of a configurable LED luminaire comprised of many light modules;

[0082] FIG. 18B is a view of light module optical accessories;

[0083] FIG. 19 is a perspective view of a light guide;

[0084] FIG. 20A and FIG. 20B are perspective view of basic embodiments of the present invention;

[0085] FIG. 21 is a perspective view of a substantially linear embodiment of the present invention;

[0086] FIG. 22 is a block diagram of the elements comprising the present invention;

[0087] FIG. 23 is an exemplary flow chart for a computer program run to obtain the optimal illumination;

[0088] FIG. 24 is a perspective view of a universal lighting fixture structure with means for attaching light source and sensor elements mechanically and electrically;

[0089] FIG. 25A and FIG. 25B shows an embodiment where the light source arrays are mounted at the end of moveable rods;

[0090] FIG. 26 is a perspective view of a lighting fixture capable of producing both a differentiated spatial light intensity distribution as well as a spatially differentiated light spectrum distribution;

[0091] FIG. 27 is a perspective view of a field adjustable multiple light source lighting fixture;

[0092] FIG. 28A and FIG. 28B is a perspective view of satellite light source from the side and from the front respectively;

[0093] FIG. 29 depicts an adjustable luminaire in a lighting application;

[0094] FIG. 30 is a perspective view of a luminaire with a special night-light functionality;

[0095] FIG. 31 is a perspective view of an adjustable luminaire with added irradiation functionality;

[0096] FIG. 32 is a perspective view of an industrial lighting fixture for use in hazardous locations;

[0097] FIG. 33 is a process flow chart for a computer lighting fixture design program.

DETAILED DESCRIPTION

[0098] As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention that may be embodied in various and alternative forms. The figures are not necessarily to scale; some features may be exaggerated or minimized to show details of particular components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but

merely as a representative basis for teaching one skilled in the art to variously employ the present invention.

[0099] The system is built around a "digital" light source. That is, the emanating lighting effect is the sum of the characteristics of a multiplicity of discretely controllable "digit" sources. The difference between the individual "digit" light sources and their summation manifests itself in the resultant light characteristic, be in its intensity, spatial intensity distribution, spectral energy content and spectral intensity distribution. All of these characteristics are also variable with time. A light source for this purpose may be electroluminescent such as a Light Emitting Diode (LED) junction, Organic Light Emitting Diode (OLED) or carbon-related field emission devices such as a nanotube-phosphor-combination, HID, fluorescent or even an incandescent source. While a one-source lamp will not have the flexibility to effect the most correct illumination characteristics, such as maintaining correct intensity and color temperature for the lighting task at hand over changing environmental conditions, two or more differentiated sources will have an increased operating range. This flexibility is useful as for example in a multi-source luminaire with spatially differentiated dimming capability used in an office lighting application. In a normal day's operation, such as in a windowed room between peak daylight and nighttime hours, the intensity and color temperature of the light varies greatly over different portions of the room. The smooth variation possible with many light sources ("digits") vs. one light source offers superior flexibility in providing the actual lighting needs. Therefore, the illuminating device may be described as a "digital" light source or as a Multiple Solid-state Light Source (MSLS), comprising many "digits", SLSs, and essentially replaces the lamp of present-day luminaires.

[0100] As used herein, the term "light source", LED or "solid state light source" means any system that is capable of receiving an electrical signal and producing light in response to the signal. Thus, the term "light source" should be understood to include light emitting diodes of all types, light emitting polymers, semiconductor dies that produce or emanate light in response to current, organic LEDs, electro-luminescent strips, and other such systems. Incandescent and discharge light sources are also included, and multiples of incandescent and discharge light sources also provide a digital luminaire. In an embodiment, a "light source" may refer to a single light emitting diode package including multiple semiconductor LED dies that are individually controlled.

[0101] The term "illuminate" should be understood to refer to the production of a wavelength of radiation by an illumination source. The term "color" should be understood to refer to any wavelength of radiation within a spectrum; that is, a "color," as used herein, should be understood to encompass wavelengths not only of the visible spectrum, but also wavelengths in the infrared and ultraviolet areas of the spectrum, and in other areas of the electromagnetic spectrum.

[0102] In designing a multi-light source luminaire, the minimum design criterion for intensity and spectrum differs for each application and is related to the end user who is the ultimate measuring instrument and economic consideration of the light provider. The regularity of the changes in effects is derived from the user's perception. It is generally accepted that the eye cannot discern changes in beam intensity that are smaller than a factor of two to ten and color temperature differences of 200 to 300K. Illumination intensity changes are discernable as a logarithmic function and depend on background illumination levels. For example, illuminating practice allows for hallway lighting to be 20% of room lighting due to rapid eye adaptation. However, the eye is very perceptive of intensity changes when comparing images such as in comparison of gray scales and thus lighting for an art lay-up room must be very even.

[0103] A further improvement is where the lamp and lighting fixture function are carried out in one device. In a typical present-day lighting fixture, a lamp with a symmetrical distribution in placed in a reflector to redirect the light, a requirement involving added cost of the reflector and performance inefficiencies. While PAR and other integral reflector lamps exist, they again have a symmetrical distribution in one of the axes and are large due to the high temperature of operation and requirement to distance reflective surfaces due to heat and large light source dimension consideration. Since the solid state or LED lamp is made of cool operating components which have a mechanical base (versus a 1000K gas discharge which is free floating) the LED allows for an integral small sized optical element near the power source. Where the terms optics or optical are mentioned herein, they refer to redirecting light rays through any of the known phenomenon including: reflection, refraction and diffraction. Typically, an LED will come packaged in an optical assembly consisting of a reflector and lens with 8° to 50° spreads being typical. A Surface Mount Device—SMD LED with no optics will still be limited to 180° due to its construction.

[0104] A power-conditioning device such as a ballast is required to operate efficient fluorescent and HID light sources but is separate there from in function and physical construction. In the MSLS the power source is electronic as is the control equipment and thus the electric power conditioning circuitry can be integrated with the light source circuitry and packaged as one on a PC board or integrated circuit manufactured in the same way of the same materials. Chip on board and chip on chip technologies are used as a packaging configuration for LED chips as well as power and logic control transistors and other components. Power transistors come packaged in plastic and so do LED junctions only that the LED package is light transmitting and can be formed into a lens. Transistors, molded in a transparent package together with LEDs, may be shielded from undesirably receiving illumination causing base photocurrent, by providing opaque "junction coat" over the transistor die, as is well known in the semiconductor industry. The packaging also lends itself to the same manufacturing methodology such as soldering elements onto a PC board. Both hole through and SMT configurations are presently available for most of the components. This combined unit of compatible, mass producible, apparatus, including the solid-state lamps, their optical assembly, electronic ballast gear and structural fixture equipment, provides a unique Digital Lighting Fixture (DLF) device.

[0105] In a preferred embodiment the DLF is provided with an onboard controller. The controller may be a computer board, embedded device, a Digital Signal Processor, etc. In general, the term "logical controller, controller or computer" can be broadly defined to encompass any device having control circuitry or a processor which executes instructions from a memory medium.

[0106] A further improvement is the reduction of all electronic and optical components to the chip level. That is, light-emitting junctions may be placed with power electronics in an integrated circuit. For example, combination GaAs LED-JFET technology may be used, the JFETs (junction FETs, acting as control devices for the LEDs. The carrier is made of materials and shaped to carry out optical and or heat transfer functions. Multiple light emitting junctions of similar or differing characteristics, a function of doping and diffusion, are placed with the control circuitry on chips. The VLSI techniques used in digital camera photodiode arrays containing millions of pixels is used to create arrays of light emitting diodes. Actually, reversing the current flow on some photodiodes will cause them to emit light. This is how OLEDs were discovered. OLEDs began in the lab as photovoltaic cells until by error they were driven in reverse. Alternately other die bonding techniques are used to

create chip on chip assemblies as is known in the art. Sets of chips with similar or differing characteristics may be geometrically arranged to provide a specific light distribution and color mixing. The total envelope is then a combined lamp, power supply and lighting fixture "luminaire", and is positioned within the room to be illuminated at the design height and position to give a consistent and sufficient lighting to the area under its control. Cooling is effected using natural convection or for air currents from a cooling fan or fluidic cooling using natural or forced circulation.

[0107] On the chip and die level further magnitudes of manufacturing and packaging efficiency are realized. The integration can avail itself of other more compact packaging technologies such as chip on board and chip on chip. Assemblies with conductive and non-conductive diebonding using epoxies and eutectic solders used for a variety of semiconductor die types including ASIC's, MEM's, LED's and Sensor's. These may be used on a variety of substrate materials including FR4, Alumina, Metalized Ceramic, Carbon Fiber and Chip on Flex as single die or multiple die arrays for Chip scale packaging/CSP's. Conductors are attached to the dies via Aluminum and Gold wirebonding using both wedge bonding and ball bonding. The manufacture of Multi-chip modules/MCM or Chip scale packages/CSP are also possible and can be ceramic, laminate or PCB based. These assemblies can be single or multiple die assemblies with external components making it possible to manufacture all light, sensor, power and control components as a superior integrated device.

[0108] The present invention provides an illuminating device which serves as a replacement for the lamp, socket, reflector, electric power control gear, dimmer and mechanical structure of a present-day lighting fixture or luminaire. A semiconductor junction packaged integrally with light controlling components provides a Solid-State Light Source SLS and many together form an MSLS, which when combined with power conditioning, and optionally logic control, communications and affixing elements, provides a DLF. The basis of the invention is the use of a multitude of discrete light emitting sources ("digits") to generate light. The light control elements can be applied on a per junction basis or on a "white" color generating set grouping such as RGB or on a larger set which may be convenient for manufacturing or other color rendering considerations. The requirement for controllability is however, that the SLS output is definitive in relation to spectrum and spatial distribution.

[0109] The discrete light emitting elements by operating and not operating, at full power or at a fraction of, either partially or in unison, generate light with optimal intensity, spectral distribution, and spatial distribution of intensity and spectral distribution for the viewing task at hand. This is accomplished without recourse to separate (exterior to the DLF) reflectors to redirect the light, filters to alter color, shades to control glare or dimmers to control intensity. An example of light source used in a DLF would be an electroluminescent semi-conducting material an example of which is a LED. Such a source is characterized relative to a standard incandescent lamp by its small dimensions, low voltage, low current, monochromatic spectrum, high resistance to physical shock, high directionality of the light output, and at the present, relatively high cost. In addition, the intensity of the light output over a defined range is a function of the current and within limits may be varied by orders of magnitude without deleteriously affecting the efficiency or lifetime of the LED.

[0110] Although the light production of a typical 5 mm, 50 mA maximum rated, LED of between 1 to 2 lumen is much too low to be of any practical use for illumination, the combined output of a few to hundreds to thousands of LED's is quite significant. Higher current LEDs are now being introduced which operate at 350 mA and provide 20 to 30 lumen. This however, is still is highly impractical for use in lighting a room when compared to a 100 watt incandescent lamp of 1700 lumen. Based on progress to date it is expected that LEDs will reach comparative lumen per Watt efficiencies of 60 to 120 l/W as found in gaseous discharge lamps. This invention relates to technologies which are feasible at the present state of the art 1/W as well as those which will become feasible in the future.

[0111] A “light bulb” of the present invention is comprised of a multitude of LED's where each LED or group of LEDs may be of the same or different wavelength, (color—where said wavelength may be mono or multi-chromatic), light output, spatial distribution and operating frequency (as when an alternating signal is used or it is multiplexed). The light from an LED or group of LEDs of red color operating with an LED of blue and green color impinging on an object would appear to the viewer as “white light”. By varying the number and/or light power output of a specific color LED or group of LEDs relative to the others, a different intensity and color temperature of light with a “warm” or “cool” appearance may be effected. “White” LEDs can also be used in the invention alone or with other monochromatic LEDs. A white LED comprises an emitter in the blue spectrum covered with a phosphor which fluoresces in yellow such that the combined output appears white. White LEDs come in various angular light distribution patterns and color temperature variations.

White LEDs can also be combined to vary intensity and spectrum. In the preferred embodiments, "white" LEDs are not used, as the use of phosphor adds unnecessary conversion inefficiencies and output degradation with time. The ability to correct for color shift over the DLF lifetime with white LEDs is limited. However, the present invention includes the use of white or other multi-spectrum light sources.

[0112] Presently the efficiency of many types of LED's (the chemical make-up of the junction differs between colors) is high relative to incandescent but low relative to discharge lamps. However, the theoretical efficiency is quite high, and the inefficiencies have to do with getting the light out between the junction and heat dissipation considerations. Expressed in lumens per watt LED's may produce up to 30 lumen/W versus 100 l/W for a discharge lamp and 18 l/W for an incandescent lamp. In the preferred embodiment, a highly efficient constant current power source is used to drive the LED's where the electronic circuit is a series connection of the discrete LED light sources. The open failure of an LED or series of LEDs which would interrupt the circuit is circumvented by the use of Zener diodes, placed such that the functionality of the lamp would not be seriously affected. The constant current power source has the advantage that different LEDs, of different forward voltage drops, from different manufacturing runs or chemical composition, may be operated together. Alternately, power circuits available in the literature for driving the LEDs are used as published in technical notes by manufactures such as Agilent®.

[0113] The life expectancy of an LED can be expected to be as high as 240,000 hours between failure. Due to light degradation over time average lifetime is normally rated at 100,000 hours. At best an incandescent's rated life may be 2,000 hours and that of a fluorescent, 20,000 hours. However, the LED operated in a circuit would have only the reliability of the circuit and MTBF divided by the number of series connected LED'S. A printed circuit board with the LED's alternately connected to separate circuits with redundant access to the power sources and with the use of Zener diodes every so many LED's to circumvent any failed sections could operate directly off of the 120/240V line. Any voltage AC or DC from 4V up to 480V is practical. The LED's of the hole —thru or SMT type would be soldered in place or the LED's connected leg to leg without using a PC board.

[0114] The LED's are mounted flat in rectangular patterns or in concentric circles or on or within holes situated on geometrically curved surfaces such as on a sphere or hemisphere of round,

parabolic or elliptical shape according to the desired candle power distribution pattern. The LEDs can be mounted perpendicularly to the geometric fixture surfaces or at any other angle. When mounted perpendicularly the surface, geometry is dictated by the light distribution pattern and the LED photometrics. This is the generally assumed design case in this disclosure. However, any geometry is possible with the non-perpendicular mounting of the light sources. A flexible PC board is manufactured in the flat and then "origami" style cutouts are made allowing the PCB to be bent and shaped into the preferred form. LEDs are insertable into holes made in plastic or metal forms to secure the LEDs in the correct location at the correct aiming.

[0115] For fluorescent lamp retrofit applications, the MSLS "luminaire" would be linear with LED's mounted all around the circumference or predominantly downwards for whichever lighting effect is desired. While a fluorescent's light distribution is usually not controlled in the longitudinal direction (the reflector can't get around the long dimension of the lamp) the LED version would be spatially directed so as to give uniform light. In comparison to a fluorescent lamp, where the light is produced equally in all directions irrespective of the final distribution pattern required in the room, the DLF has the advantage of producing light directed only where it's needed. The number of SLS aimed in a specific direction at the time of manufacture is such that the proportion and angle of the light going to the ceiling and floor are calculated to produce the desired result. Louvers and reflectors are unnecessary to prevent glare or redirect the light. Up to 40% to 60% of the light produced in a fluorescent fixture goes to waste due to these considerations.

[0116] In other embodiments of a linear fluorescent replacement SLS lamp "luminaire", the position regarding the nadir (floor) of the rows of SLS are adjustable. One or more SLS strips are free to move in an arc about a long axis such that they are aimed for uplight or down light. Apparatus is provided to fix the re-positioned SLS in place. Markers along the arc can delineate the angle. Thus, the installer can adjust the amount of up-light, down-light and floor coverage in the field, (markings on the fixture would indicate standard settings) just as an adjustable reflector changes luminaire light distribution. Here again, the difference is that there are no reflector-induced inefficiencies because of operation away from the ideal design point.

[0117] A pear-shaped globe "luminaire" studded with LED's projecting light outward from the surface would give both down-light and up-light with more projection surface towards the down-light

side in a typical 1 to 3 recommended ratio. Most buildings, rooms or areas to be illuminated are of a rectangular shape. The LED's on the DLF are concentrated at the 90-degree intervals. This yields a more square lighting pattern to ensure equivalent lighting in all areas of the room including the corners. This is in contrast to the chronic lack of even coverage obtained from the circular light pattern of present day light bulbs or most luminaires. At best these prior-art lamps give a circular light distribution which requires overlapping to ensure complete coverage of the area with the overlap lighting levels in wasteful excess of the requirements. A position oriented MSLS lamp has a greater concentration of LED's aimed at 90° intervals so that more light energy is directed into the far-off corners of a room to give an even illumination throughout the rectangular or square shaped area. A DLF is made with square, rectangular and even rounded light distribution if the application requires.

[0118] Typically, an incandescent or HID lamp is used in conjunction with a reflector to redirect the light to obtain a desired light pattern where more of the light is directed where it is most useful. A luminaire for area lighting will have a "bat wing" candlepower light distribution pattern, which yields equal horizontal illumination on a surface as it compensates for the "inverse square law" (a function of the cosine of the angle and the distance squared from the source). Generally, such an optical assembly has efficiency less than 80% due to losses on the reflector's surfaces. The MSLS needs no reflector to redistribute the light since each discrete SLS "digit" is aimed such that the candle power intensity varies with angle as is needed to give the optimum illumination on the room work surfaces for a given mounting height. The MSLS lamp distribution is pre-designed according to typical house or office settings. Thus, there is no need for a reflector to redirect the light and its consequent inefficiencies in order to obtain a "bat wing" distribution. The present approach by LED manufacturers is to provide single high output LEDs with optics yielding a "batwing" distribution. These batwings are usually less than optimal and are circular. The "digital" approach of this invention would yield a finer control and thus a more accurate batwing, generating a more even distribution in a rectangular/square vs. circular pattern.

[0119] In a DLF it is possible to combine a task light having a very narrow "spot" beam at the correct aiming with a general area lighting "flood" beam into one fixture. The digital lighting fixture is positioned according to recommended lighting practice near a workstation and correctly oriented such that the DLF gives a wide (though still controlled, so as not to cause glare on a computer display) general illumination distribution as well as a narrow distribution aimed at the desktop for high intensity

task lighting. In a preferred embodiment a positionable task lighting spotlight located on a section of the DLF can be aimed manually or by servomotor to project onto the work area.

[0120] In another example of prior art practice, a table lamp for reading is provided with a shade. The shade is there to partially redirect the light onto the book and also prevent direct, glaring, rays from the lamp used for general lighting from reaching the reader's eyes. According to the present invention, instead of having a glaring lamp producing light which is then made non-glaring by a shade at a loss in excess of 50% the LF is built such the amounts of light directed downward at useful angles and the amount of light directed upward are in the correct ratio. The surface area, from which discomfort-glare causing rays exit, is designed such that the luminous exitance is within recommended UGR levels for home use. The fixture has no need for a shade to protect from glare; the glare was never produced at those angles to begin with due to proper geometric design. To get the desired luminous exitance expressed in terms of lumen per sq. meter or luminance in terms of candela per sq. meter, the light exiting the source of specific intensity at angles which normally reach the room occupant's eyes, is spread over an area such that the exiting light is non-glaring. These lighting design parameters serve as the product specification and are incorporated into the initial design. There is no need to add on components to achieve correct lighting.

[0121] In MSLS technology an antique style table lamp uses a MSLS "bulb" specifically designed for the application, there is no need for an additional shade other than for aesthetics. The shade is a decorative element which diffuses a small amount of light for the rustic effect. The small amount of light which would be directed between 70° to 150° (the glare zone) would cause as little discomfort glare as that which is obtained from a shaded incandescent lamp but without the waste. This is done by sizing the area and intensity of the light source responsible for providing light at those angles such that the luminous exitance from the surface is within acceptable non-glaring luminance values. If desired, uplight to the ceiling above the glare zone is provided with light sources projecting between 150° to 180°. To maintain the aesthetics that people are used to or for the good feeling, a shade may be placed over the "digital" table lamp. A few LEDs can be dedicated for the purpose of illuminating the shade, either by projecting thru the shade and diffusing the light or projecting the LEDs into the shade as in a light guide. Colored LEDs could make the shade look yellow, pink or blue as preferred and programmed by the user.

[0122] The dimming capability of the MSLS is quite dramatic. A typical LED of today such as an Agilent® HLMP25-ED-xxxx will produce light at a tenth of a milli-Ampere and may be operated up to 50 mA. At 0.1 mA it may produce 5 milli-lumen while at 50 mA over 1000 ml. This is a hundredfold range. Another radiation output control technique is to provide pulsed power in place of constant current. LEDS are operated on DC as well as pulse power and current as well as timing in terms of duty cycle, pulse width and other signal modulations are useable by the controller to effect intensity changes.

[0123] Correct lighting doesn't only include an even light distribution and a lack of glare but a list of other factors including intensity, warmth and color rendering. Experiments have shown (IES Lighting Handbook 8th edition p. 99) a graph of preferred color temperature of light sources at various illumination levels. The graph specifies a warmer color temperature say 2,500 Kelvin for lighting levels in the 100-lux range and a cooler temperature say 3,500 for 1,000 lux. However, a typical dimming system used in a fluorescent luminaire will lower the lighting level but will not change the color temperature. A DLF of the present invention will change the balance of the different spectrum light sources in order to achieve the correct color temperature for the new lighting level. As far as dimming goes, it possible to get an instantaneous "instant on" from the SLS light source. Thus, with a built in or exterior motion detector, the DLF can be operated at emergency lighting levels, sufficient for orientation, and then immediately power up to full level when someone enters the room. Whereas a fluorescent dimmed to 50% power will give a negative return of only 10% light an LED will generally give a linear if not positive decrease in power with light reduction. Auto-dimming circuits taking sunlight into account have been touted as an energy saving technique.

[0124] In another embodiment, the electronic luminaire has a light level detector and automatically adjusts the output to the required level. If the lighting level on only one side of the room is enhanced by the sunlight, directional luminance meters, external or integral to the DLF, detect the imbalance and the controller dims only those SLS oriented to illuminate in the sunlight illuminated direction. This detailed spatial distribution intensity control is not possible with other lamp types.

[0125] The MSLS lifetime is long such that there is essentially no need for "lamp" replacement over the life of the DLF luminaire. However, power supply circuit and light source characteristics may vary over time and correct lamp color will deviate from the standard. A feedback control loop using

sensors would recalibrate color based on daylight readings over the twenty-year lifetime of the fixture. Thus, a photodiode with an RGB filter is calibrated under natural light conditions. Alternately, discrete wavelength or alternately stable "white", or color, LEDs which are used only for calibration or only operated in a regime where their color is known not to shift are used as the recalibration color standard. This basis serves the dimming system in its color temperature control over its lifetime. The controller is programmed over the lifetime to seek possible recalibration opportunities. These may include using daylight or other artificial light sources available when the LSLS is not producing light. The systems can determine the accuracy of this source partially by comparing it to its previous factory or onsite calibration. Time of day analysis and initial small deviations would allow the system to evaluate whether the source was a reliable standard to use over its lifetime to correct for component color shift.

[0126] To ensure higher reliability the MSLS in the preferred embodiment will make use of large-scale integrated circuit technology where the LED junctions, Zeners and other elements are interconnected on, a chip. The chips then mounted into plane surfaces which are flat, rounded or X-hedrons.

[0127] The MSLS lifetime is long such that there is essentially no need for "lamp" replacement over the life of the DLF. This requires that the designs of the other electronic components are similarly reliable. The fixture mechanical design is again a significant departure from prior art. The fixture is sealed for life. There are no openings, gaskets, and sockets and there is no need for a mechanism to open the luminaire. All the components can be encapsulated for life to prevent water and dust ingress and thus provide a reliable, maintenance free, weatherproof and hazardous location ready lighting fixture.

[0128] The small dimensions of the light sources makes them ideal for use in conjunction with fiber optic light transmission systems. One of the primary requirements of such systems is the ability to collect the generated light into the narrow fibers. The excellent controllability of the light beam and the small source size allows for the generation of high-power narrow non-dispersing beams as would be used in flashlight, searchlight and beacons.

[0129] Multiplexing of the lamps is possible for power and lighting effect considerations. Slower duty cycles will reduce energy consumption, increase lifetime and would be used in a number

of applications. Aircraft warning beacons which flash is an application, as the on-off cycling of an LED is not harmful to lamp life as it is to an incandescent lamp. Disco lighting-effect lamps are another flashing application. Dimming as well as illumination color can be carried out with both the duty cycle and current being altered.

[0130] In summary, as opposed to LED industry trends of going with a single large source, the present invention provides multiple smaller sized sources of differing characteristics such that their combined effect is greater than that which could have been offered by sum of the individual parts operating separately. The added controllability offered by breaking the total light output up into discrete specifically aimable and dimmable elements, "digits", which can be addressed by control electronics to effect intensity, spectrum and distribution, yields a lighting fixture (vs. lamp) of unparalleled performance.

[0131] In order to better understand the embodiments and methods of this invention reference is now made to the following figures.

[0132] FIG. 1 is a block diagram of the elements which in combination provide a digital lighting fixture (DLF). The DLF serves as a complete luminaire solution including: power conditioning circuitry, control electronics, sensors, mechanical fixture and light source. The DLF replaces the lighting fixture, ballast, socket, lamp, dimmers, reflector, gaskets and fasteners with a sealed for life electronic assembly. An electric power source **1**, supplies power at line Voltage 110 to 480V or at low Voltage 12-24 Volt to the DLF **2**. The DLF includes more than one light source **3**, which is preferably an electroluminescent solid-state light source but may be any other light source, such as incandescent, high intensity discharge, fluorescent, etc. such that the individual characteristics of each lamp's light are combined in operation to achieve a sum of the characteristics presenting a benefit not achievable from a single source alone. The light sources are affixed or contained within a mechanical device **4**, which may serve as containment to all of the components and facilitates affixation to building surfaces. The electric power is received in the correct waveform, voltage and current from the power source **1**, or is conditioned within the DLF **2**, by power conditioning elements and circuitry **5**. The direction of light exiting from the DLF as a whole or from each SLS individually is controllable by optical elements **6**, such as reflective surfaces and or refractors, and may be electronically variable optical elements.

[0133] The separate light sources may be of the same color and intensity characteristic or may have different color and intensity characteristics. Thus, for a 3-stage light bulb equivalent, each of three sources can have the same lumen rating or two sources are used where one is twice the output of the other. In a finely variable, digital embodiment the effect of continuous dimming effect is achieved when the differences in the lighting level is imperceptible to the people in the room. Typically, a 5% change will not be perceived. Thus, with twenty equivalent intensity LEDs as a base (one additional would add less than 5%), additional quanta could be smoothly added, or on the other hand, to in reality perform perceptible dimming (which is the objective) a greater than 5% change should be effected. The same is true for the final spectral color of the light emanating from the DLF to illuminate objects. The eye adds the radiation reaching the eye and cannot perceive the separate components, contrary to the ear's recognition of sounds where each frequency is individually resolved. Therefore, quanta of specific spectral color energy may be added to the mix without perception. For example, changes up to 200 degrees Kelvin in HID lamps are not perceived. Thus, to effect a noticeable color change, a quanta of spectral color power would need to be added or detracted from the sum.

[0134] In a preferred embodiment the DLF contains logic control electronics unit **7**. Logic control electronics unit, **7**, receives input and/or feedback from motion, intensity and/or spectral sensors **8**, or from manual control button **9** and increases or decreases or turns on or shuts off the power to one or more of the SLS to effect the desired change. That is, the control logic unit **7** has stored parameters for intensity and spectral distribution and operates the MSLS lamp within the predefined range. The control unit may include a DSP or computer with storage media, computer algorithms, signal input and output electronics, analog to digital converters, and communications elements to carry out intensity, distribution, dimming and color balance control. Computer algorithms and instruction sets **7**A are induced by the logical controller to manipulate data, calculate results generate output signals and maintain the operating parameters within the specifications. Measured parameters are checked against the stored parameters and the control circuitry adjusts the power to SLS.

[0135] Sensors **8** include any of the following: light, temperature and motion detection devices. Two types of optical detection sensors may be used: A photo detector with specific spectral sensitivity to detect a specific color. For example, a standard red, blue and green set which would then indicate how "white" the light is. Alternately, a wide spectrum photo detector that irrespective of color measures the intensity of each excited die as it is test fired, based on the eye visual sensitivity curve.

The optical sensor may be lensed and capable of forming an image, that is a camera and the detector may be a detector array of photodiode pixels. The detector array may be a CMOS or CCD VSLI array and may be monochromatic or color as in a monochromatic or digital camera. Such arrays are readily available in mega-pixel resolution.

[0136] With changes in ambient lighting the light sensors detecting conditions at a specific location receive input. The detector instantaneously reads the ambient during a momentary shut off the artificial light source. The momentary shutoff is of short duration, e.g., less than one millisecond duration, at rates undetectable to the users as the eye does not discern flicker rates above 1/100th of a second. The controller then readjusts the driving circuitry to the correct power level. The sampling of multiple sensors around the DLF can be simultaneous using buffers in the controller to facilitate analysis by methods known in the art. Alternately, the light sources and coordinated detectors at specific locations are turned off, sampled, turned on again and sampled, to verify that the illumination is within recommended specifications. Interaction between DLFs, located in close proximity to each other, is avoided, by the use of the short-duration momentary shutoff controller readjusting time interval. The probability of simultaneous controller readjustment of two adjacent DLFs is very small. Further, the timer which controls the time between the controller readjusting time intervals, is preferably analog, such that there is very low probability of two DLFs having the same time between controller readjusting intervals.

[0137] In a system with feedback, changes in the light source output reflected back to the lamp such as color shift and diminishing flux over time can be compensated for. A typical fluorescent or HID source will experience serious color shift over its 10,000 to 20,000 hour lifetime. It would be a significant advantage to have a 100,000 hour life lamp with color accuracy over the complete lifetime of the lamp.

[0138] In a preferred embodiment a re-calibration system will operate as follows. The DLF is provided with a reflective rod or strip the surface of which has a wide spectrum, non-angle of incidence dependency and stable reflection characteristics over time. The reflective rod or strip is positionable so that the rod or strip can reflect light back to the outward facing photodetector based on the DLF body. In another embodiment the DLF is provided with a calibration wand on which inward facing photodetectors are placed. The calibration wand is capable being positioned such that the detectors

can detect SLS performance. Both the reflective rod/strip and calibration wand can be narrow such that they can be permanently deployed about the DLF and not block light. In another embodiment the rod, strip or wand is stored and is only deployed when calibration is required. When called upon, the rod, strip or wand is rotated around the DLF to read SLS intensities. Alternately, the DLF body rotates and the rod, strip or wand remains fixed. The DLF is originally calibrated in the factory using external detectors. The spectral output of each SLS is calibrated with the power supply controller over the range of power outputs and the characteristics are stored in a memory device for recall during operation. The calibration wand or reflective rod or strip is then used by the DLF in an internal calibration where the DLF detector's readings at the initial SLS power settings are recorded. These readings become the standard for future calibrations, where the controller will affect the power to individual junctions such that proper intensity and color is produced.

[0139] The DLF has a clock unit and/or a communication unit capable of receiving signals from the US government operated "atomic clock" which is located in Colorado. The DLF automatically searches for the signal or once a day it automatically recalibrates its time. On a periodic basis after degradation is assumed to be significant, the controller **7** invokes the calibration routine.

[0140] In another preferred embodiment the DLF surroundings are used for calibration in place of the calibration strip. A short time following installation, (after the furniture and decor has settled down), an onsite calibration is scheduled and run at the first opportunity. The purpose of this on-site calibration is to have the controller check the spectral characteristics of the illuminated area. A specific die on an SLS is fired on a timed basis and the controller reads the photo detector value. The new site-specific reading is then taken and compared to the original calibration and stored. The site-specific reading will serve as the base for the next calibration, as it is assumed to render the surroundings correctly based on still calibrated light sources. The next calibration may be scheduled for night and holidays to ensure a date when dark conditions prevail. If darkness cannot be ensured, the incremental shift in intensity above the ambient can be measured. Photo diode detectors of known field of view are placed on the DLF such that SLS output is detected. In lights-out conditions of darkness, the controller takes a base reading sample of a detector. The base reading allows the subtraction of "noise" from further readings. During the calibration the base reading may be repeated to ensure accuracy. Periodically, possibly every half a year, more or less depending on manufacturer data of how much the LEDs drift from their initial performance, a calibration routine is run. If a change in decor has been

made, then the drastic change will signal the logic controller to ignore the latest reading and use the present "white" setting to recalibrate the new decor. Although photodetectors are stable devices, over a 30 year DLF lifetime it may be necessary to calibrate the photodetectors as well. Absolute intensity readings can only be recalibrated against a laboratory standard. However, daylight may be used to recalibrate color sensitive photodetectors over the 20-year lifetime. At the post installation calibration session, a day reading of photodetectors is performed and the readings analyzed for daylight sources. This is done using the clock where daylight will show a predicable spectral shift over the hours of the day. The controller will then compare the readouts of detectors over the day to identify those exposed to daylight. First during the day readings of the photodetectors are taken.

[0141] The detectors facing the daylight are assumed calibrated to read "white light. In darkness SLS units, SLS **1** in view of one calibrated daylight facing detector, detector **1** and one uncalibrated detector, detector **2**, are powered to produce white light as determined by the calibrated detector. Now detector **2** is calibrated. Moving stepwise around the DLF the process is repeated with now calibrated detector **2** used to adjust SLS **2** located between detector **2** and not yet calibrated detector **3** to produce "white" light. SLS **2**'s output is then used to calibrate detector **3**. The process continues around the DLF till other daylight-calibrated detectors are reached. For greater accuracy the process can then be performed in the other direction, moving stepwise until detector **1** is reached again. By using this nodal analysis method discrepancies propagated in the calibration process are reduced.

[0142] A power guide **10** can serve as both a power distribution and mechanical affixation device to the placement of additional DLF units **11** within an expanse. Light output **12** from one DLF may differ in distribution from another 13, if say one MSLS is in the center of a room and the other is at the edge or one light illuminates steps between the landings and another is the last step before the landing, the last step would be illuminated in a different color.

[0143] Since an LED device is operable over a wide range of currents, when an LED serves as the light source, dimming and color balance are smoothly and infinitesimally variable.

[0144] For the purpose of illustration, a preferred embodiment of the present invention is presented in FIG. 2B juxtaposed with a prior art solution using LEDs shown in FIG. 2A. A typical "bulb" shape with a screw in base is provided for retrofit locations where a socket is available. The

prior art design depicts LEDs spread out on the surface of what looks like a reflector lamp. It is evident from the downward facing 5 mm hole-thru type LEDs—**14** that no attempt has been made to extract a "batwing" or any other effective type of light distribution pattern. Upward facing LEDs—**15** seem intended for uplighting and again it is clear from the symmetry that no attempt has been made to provide a rectangular pattern which will give a better use of light for indirect lighting.

[0145] FIG. 2B illustrates the teachings of the present invention. In this case, although packaged to appear as a typical "A" shaped light bulb, the device is actually a DLF and provides a complete lighting solution. Although shaped like a lamp with a screw base to facilitate replacement when the "lamp" burns out, this is not necessarily the intent. Rather, in the present concept, after 100,000 hours (over 30 years in typical use) it's time to refurbish the room and change the fixture. The outward design is thus generated by what people expect to purchase and not what a DLF, that is not a lamp should look like. A true DLF design would not include the ceiling mounted socket and would be provided with a wiring connector and accoutrements and fasteners for attachment directly to the ceiling.

[0146] A retrofit MSLS lamp or digital lighting fixture/luminaire **16** intended to replace the lamp, fixture, reflector or shade and control-gear combination of a typical lighting fixture, includes a screw base **17**, which receives line power **18** into the electronic power conditioning circuitry **19**. In a preferred embodiment, control circuitry **20** is provided in the lamp. The input to the control is from an external source or internal logic circuit or both and in a preferred embodiment a sensor pack **21** with one or more radiation and communication sensors capable of detecting motion, day/night, spectrum, luminance etc. is provided. In external control, a control signal **22** rides on the power signal **18** and enters via the screw base **17** or an infrared or other radiation detector provided in **21** picks up the control signal. Discrete packaged light sources, e.g. Solid-state Light Source SLS **23** containing one or more junctions are mounted on the DLF lighting fixture body **24** and connected to the controlled power circuitry that determines which of the SLS **23** will operate and at what power. Each SLS with it spectral and distribution characteristic is mounted in a specific location on the surface of the DLF with an angle α, **25** from the nadir. Any angle from the nadir is possible including 180 degrees and the light flux can serve to provide uplight or illuminate a picture on a wall.

[0147] In a position oriented lamp arrangement, that is where the socket has a distinct stop point, detent or pin and is mounted substantially oriented to the room or its contents such as a work desk or wall painting, and also the DLF has a specific mounting orientation relative to the socket, then the light distribution can be nonsymmetrical and tailored to the needs of the room. The screw base **17** has a detent or pin **26** that coincides with the stop point on the socket, which is mounted in a specific location radially around the lamp at an angle β, **27** in reference to pin **26** and a design start point on the circumference of body **24**. The SLS are placed at an angle f horizontally and vertically angled a to illuminate specific areas and also have their own spatial light distribution angle θ **1 28**A. An SLS aimed to illuminate an interior area may have a wide distribution or a distribution without a sharp cutoff **28**A while those SLS located at the edge of the area to be illuminated may be of narrow distribution θ **2 28**B and have a sharp cutoff. This technique is similar to how a sport playing field is illuminated with multiple floodlights. Floodlights of narrow beam spreads such as a NEMA 2 are used to illuminate at the edge of the illuminated area while wider NEMA 4 beam spreads are used near the center of the playing area. The MSLS lamp will have concentrations of SLS at specific aimings to provide a wide "flood" type distribution to one part of the room and a "spot" type distribution to another such as to a painting on the wall. Each illumination target is at a different light intensity and color temperature or color rendering.

[0148] In another embodiment SLS, which perform an equivalent to a task light function with a very narrow beam, are combined with SLS performing a general background lighting function in one fixture. While general lighting recommendations in an office call for the provision of 300 to 500 lux over the working plane, specific task lighting, for example where copy work is to be illuminated by auxiliary lighting, 1,000 lux is required. To this end a section **29**, containing SLS on the DLF, provides a narrow beam of higher intensity, to provide added light flux to the working surface. In an alternate embodiment section **29** on the DLF is on a swivel and can be manually adjusted to be aimed at the worktable. In an alternate embodiment the swivel is positioned by a servomotor and controlled by a remote-control unit. In an alternate embodiment to the fixed task light section **29**, in an attempt to cut down on separate fixture types with left or right handed spot or other asymmetric orientations, the MSLS portion of the DLF body **24** is rotatable in relation to the affixing base **17**. Such an embodiment also obviates the need for a position-oriented socket and base pin **26**.

[0149] In another embodiment, modulating the output of wide distribution and narrow distribution LEDs by the controller varies the net resultant beam spread characteristics. The fixture is placed near a workstation and gives a wide distribution general lighting as well as a narrow high intensity beam for increased illumination level task lighting on demand.

[0150] In order to assure an even distribution of light from a point source over an area, it is necessary to take the effects of the angle and distance to the illuminated surfaces into account as stated in the inverse square law. Often a "batwing" type of candlepower light distribution is used. In a prior art luminaires, the reflector, which concentrates reflected rays in the higher angles, accomplishes this. In a preferred embodiment of the MSLS there are more, or more powerful, SLS over a range **1** aimed at higher angles to increase light flux at those angles in order to maintain an even light distribution. If the lamp is specifically oriented in relation to the room concentrating more light into the distant corners effects a squared distribution pattern, which would fill in the corners of a square room with equivalent illumination. An added amount of SLS are added on the DLF body **24** at 90 degree angles on β, **27** where SLS aimings will push added light into areas corresponding to the "corners". To effect uplight towards the ceiling or for indirect lighting SLS **23**A are aimed towards the ceiling such that an optimal utilization of the light is achieved.

[0151] In the preferred embodiment color of light emanating from an SLS **23** is "white" light. This is accomplished by using a "white" light producing arrangement of LEDs that is comprised of two or more spectrally differentiated junctions, which then combine their light output such that the illuminating light appears white. Other white LED technologies use phosphor or other coatings over the junction which causes a shift to longer wavelengths. The separate junctions in an SLS or separate SLS may be independently controlled. In a multi-junction SLS the total color of the illumination may be shifted to "warm" or "cool" light in correct accordance with the illumination level (see FIG. 10) or other considerations. In another preferred embodiment, a motion detector is used to conserve energy. The room lamp is dimmable to a lighting level sufficient for safe orientation. A motion sensor **21** picks up activity and increases the illumination level to meet the activity level. This integral placement significantly reduces the wiring from sensor to power supply and again back to lamp in prior-art dimmer—motion sensor applications.

[0152] In alternate embodiment each SLS **23** may have a non-white color. The operation of many SLS in unison of different or similar wavelength may be used to create any color desired from white to monochrome in any specific region to be illuminated. A spectrum sensor **21**, inputs data to controller **20**, which maintains color at predefined level. Such a feedback mode allows for the MSLS to maintain constant color over the full lifetime of the lamp even if specific wavelength SLS shift output characteristics such as light flux and spectrum with age within bounds of the sensors calibration over age. Constant color is maintained in a room with an influx of a less desirable color temperature light on one side. Spectrum sensor **21** with a specific orientation would detect a "cool" light reflection emanating from a specific side of the lamp and will increase "warm" e.g. 2000K light to compensate. Over the long lifetime the DLF could recalibrate its spectral sensors **21** to white light based on readings of daylight where such daylight is available, and the controller has determined that the room at the time of calibration is being illuminated with white light "daylight" of a specific color temperature per orientation and time of day.

[0153] The same light distribution effect based on light source aimings could have been accomplished as in the prior-art, easy to manufacture flat pc-board configuration by simply angling the LEDs **23**B from the perpendicular as shown in FIG. 2C. Shown is a side view of a PCB provided with standard 5 mm hole-through LEDs. The LEDs are produced with standoffs on the legs such that after soldering automatic machinery can bend the legs so that the LEDs project at the required angle from the nadir to achieve the required photometric pattern. Lead bending as is known in the art also allows for uplight as with LED **23**C. Though not as elegant as DLF **16**, this easy to manufacture configuration will accomplish much of the sought-after light distribution.

[0154] FIG. 3A is an illustration of a prior art wall sconce for outdoor use displayed by a leading LED manufacture in at a lighting trade show in 2003. It is juxtaposed with FIG. 3B to highlight the difference in the design methodology as taught buy this invention. The very aesthetic prior-art wall sconce fixture encased in a curved decorative frame is portrayed in top, front and side views. It uses a multiplicity LED light sources to shine through a diffuser to produce an even glow. "White" LEDs **31** were placed on a flat printed circuit board **32** and the light was dispersed via a white diffuser **33** with the light exiting lambertianally in all directions. The good optical control initially present on the LED **31** is now squandered on the prior-art diffuser in an attempt to prevent glare from the pinpoint LED source and produce a pleasant glow on the diffuser. Light is projected evenly in all directions including

uselessly upward, where it will help drown out starlight. The prior art flat PCB and optional metal heat sink **32**B facilitates manufacture and heat transfer and that is probably why the design is the way it is, with production feasibility considerations driving the design, rather than correct energy saving lighting principles.

[0155] FIG. 3B illustrates how the same improved lighting design process can be accomplished for an outdoor wall sconce DLF intended to illuminate a walkway at night. According to the teachings of this invention, the LEDs **31**, power supply and other electrical components **34** are assembled on strips of semi-flexible printed circuit boards **35**. The LEDs can be multi-colored or monochromatic LEDs with overlapping coverage or white LEDs. As illustrated in the top view of FIG. 3B, the LEDs **31** are mounted on a convex surface **35** such that some face to the left, some right and a smaller quantity towards the middle. The middle aimings require fewer light sources due to the inverse square and cosine law for a point source as is this DLF, where light at the angle of illumination of 0 degrees is more intense than for light at an angle greater than zero and a point closer to the DLF is more intense by the square of the distance in the denominator. The exact solution for the aimings is such that for a desired coverage and illumination level the illuminance equation 1 is used to calculate the necessary light intensity in candela at each aiming angle. The side view shows the LEDs **31**A and **31**B with varied downward angles, such that even illumination is produced on the walkway out to the prescribed distance from the wall. The PCB strips are optionally affixed onto a curved and angled aluminum heat sink **36** with electrically insulative but thermally conductive adhesive such as Dow Corning® SE 4400 Thermally Conductive Adhesive.

[0156] The diffuser **37**, is shown in the side section view to have white diffusing sections **38** and clear, fully transmissive slots **39**. The controlled angular distribution light emanating from the LEDs **31** passes through the clear slots **39** and illuminated the walkway. The diffuser **37** is illuminated by stray light emanating beyond the controlled angle of the LED **31** or one or more LEDs can be dedicated to the task and aimed into the diffuser material, using it as a light guide to spread the light within the diffuser as is practiced in the art.

[0157] FIG. 3B illustrates how the same end result as the prior art fixture FIG. 3A, of having a pleasantly illuminated diffuser can be accomplished while not compromising on the energy efficiency and correct lighting output of the luminaire. The fixture aesthetics can be maintained while

a more physically compact design can be carried out. The components depicted in FIG. 3B are possibly more complex and thus initially more costly. However, in a comparison of the life cycle cost per effective lux, which includes the electricity charges over the life of the fixture, the DLF is certainly superior to the prior-art.

[0158] The above design depicted in FIG. 3B is easily adapted to a hallway application where some light to the ceiling is beneficial. To provide up light a row of LEDs **31**A is aimed towards the ceiling instead of downwards.

[0159] FIG. 4 illustrate additional embodiments of a DLF which may take on any shape be it disc shaped or linear depending on the aesthetic choice of the designer and the lighting application at hand. Thus, a preferred luminaire configuration for lighting an area from within, (using a number of lighting fixtures to prevent shadows) would be a concentrated point source design. To illuminate from the perimeter of the room or along a walkway, a linear configuration luminaire or many distributed point source luminaires are optimal. In FIG. 4 a disc shaped containment **40** would contain SLS **41** where again, the radial position of each SLS and the aiming is such as to yield a specified lighting pattern on the surfaces to be illuminated therefrom. A smooth light distribution is achieved by aiming relatively more SLS **42** in the direction of the more distant (or less perpendicular) surfaces or objects to be illuminated. One or more sensors such as motion, day/night, spectrum, luminance, are provided for in **43** or any other location as is required. A printed circuit board with power and control circuitry is provided for **44**, as are screws **45** and or adhesive on the rear **46** for affixing to a surface. Electrical connection is made via a connector or sharp prongs to a conductor **47** which are pressed against the conductors to make electrical contact. The total assembly **48** with its light sources at specific positions and aimings, its power conditioning and control equipment and connection to power source, be it integral such as with on board batteries, or external from a power line constitutes a complete lighting fixture replacement element.

[0160] Based on the disc or puck shaped integrated luminaire above an application featuring a snap on Step Light **66** used outdoors is illustrated. One or more SLS **50** are contained in housing **51** which is substantially transparent in the area in front of the SLS. The SLS light source is very long lived therefore the unit is sealed watertight for life in the injection molding process or via glue. The SLS **50** are aimed so that the distribution pattern, at standard mounting height, effectively illuminates

the steps. In one embodiment the luminaire is provided in two models each specific to a right side and left side installation with opposite aimings in order to yield an even distribution along either the receding or proceeding stairs.

[0161] A two-conductor cable, which conducts power **52**, is installed along a building surface or railing along the area to be illuminated. A bracket **53** is attached to the wall **64** on which the light puck is to be placed. The slot **54** atop the puck is inserted under the top clip **55** of bracket **53**. The puck is hinged down and the bottom pivoted, catch lever **56** enters within the void of bottom clip **57**. The screw **58**, which can be a tamperproof screw to prevent removal by vandals, is tightened forcing the protruding leg of top-heavy catch lever **56** to fill the void in the bottom clip **57** of bracket **53** and lock the light puck in place. At the time of tightening screw **58** pushes contact block **59** with conductive piercing prong **60** against power cable **52**. Conductive prong **60** pieces outer insulation layer **61** of power cable **52** and makes contact with electrical conductor **62**. Further tightening of the screw **58** forces the prong on the opposite contact block **63** to pierce through the insulating layer and make electrical contact. A power cable **52** conducting current at low voltage, say 24 Volt, may be directly affixed to the wall **64** without enclosure in a conduit, and the light puck attached at points along the power cable. A bracket or clip **53** is used to affix the lighting puck fixture to the wall and has an opening **65** for the contact blocks **59** and **63** to fit through. The fixture **66** may be sealed for life during manufacture since there are no serviceable parts inside for the lifetime of the electronic components.

[0162] Other applications include stairwell lighting that is activated by motion detector or is always on due to the low power consumption or a combination of constant low level on state, with the increase to full power based on activity. Distributed along a power strip running along the stairwell are disc shaped DLF units such as luminaire **66**. A motion detector **67** in the first and last units between the floor landings is used to turn on the lamps ahead of the person using the stairs. An outdoor solar energy step light application will use a photocell or any other arrangement to turn the system on at night and a motion detector to turn the lights on for a short duration after motion is detected thus reducing the amount of energy needed to be collected in solar cells. Instead of being in a totally off state, the lighting can be partially on, such that it is visible in order to give definition to the landscape and help in orientation. This power usage is very low since even at very low current LEDs are visible at night. Upon being initiated by the motion detector it can go to full power to illuminate obstacles in the path.

[0163] Last Step or first step could be indicated by a different color of light. A motion detector could accordingly change the MSLS output color if the individual is approaching the steps say to green and to amber or red when reaching the last step.

[0164] FIG. 5 illustrates another DLF embodiment, a linear lighting fixture **70** where the similar or different SLS **71** and **72** are distributed along the area to be illuminated such as is typical with fluorescent lighting fixtures used in soffit lighting. The system may have a power conducting strip of a similar shape **73** which connects to lighting strip **70** via receptacle **74** and pin **75** set and which are attached to conductor set **76**. The two strip types, the lighting fixture strip and the power conducting strip may be adjoined together or affixed directly to the wall or attached to bracket **77** which may slide into a slot **78** in **70** and **73** and where there may also be provided matching cutouts in the lighting fixture and bracket. The matching cutouts **79** allow for a quicker, straight on insertion before sliding horizontally in the slot **78**. The bracket is thus first attached to the wall and the strips are brought up to the bracket and moved sideways to latch.

[0165] Many lengths of strips **70** or **73** up to the power capacity of the conductors can be joined together and connected to a power source with a connector **80**. Interchangeable sections of the power strip can contain LEDs of different colors for effects or alternate between power strips and lighting strips for a similar aesthetic architectural design.

[0166] The lighting/power strip may be thin and linear substantially in one or two planes or for aesthetic considerations have curves or be constructed of a flexible material and have the ability to be manipulated into curves and bends in three planes, to make such designs as an arc, wave or circle. The electrical conductors may provide the malleability to shape the strip and then hold the configuration after it is bent up, for example if they are made of copper or aluminum or alternately an additional bendable, yet shape-retaining material may be inserted in the casing **81** or the casing material itself may have such properties.

[0167] The Lighting strip **70** and Power strip **73** may also conduct light and radiate light to give a lighting effect all along its length. Alternately, the strips may be a light conductor with little light exitance from the surface and the total internal reflection is selectively frustrated to let light out along the length in a specific direction or at desired intervals. The strip lighting may come from SLS

specifically aimed to project light into the strip or from light leakage from regularly placed optimally (per the main lighting application) aimed LEDs.

[0168] Another embodiment of a solid-state lighting fixture, DLF or luminaire is shown in FIG. 6. Whereas previously described luminaires were described as incorporating LEDs in standard hole-through or SMD packages, here, a luminaire using the unpackaged solid-state light source junction is described. A multifaceted luminaire **90** is comprised of any of the following list including a mechanical affixing method to a surface **91**, an electrical connection to an outside power source **92**, a mechanical frame **93** to hold the one or more light sources **98** or lighting facets **94**. Power conditioning, heat rejection and control elements are contained on or within the interior of the structure **93**. A number of light sources, facet or many facets are placed in position radially around the lamp and angled vertically to effect the desired light distribution. Thus, while facet **94** is positioned in the frame **93** radially and angled so as to be aimed substantially downward to the left of the fixture position, facet **95** is positioned and angled to illuminate an area further out and to the right.

[0169] A detail of a lighting chip or facet is shown in front view **96** and side view **97**. In the first embodiment P/N junctions **98** of light emitting semiconductor material are placed on a thermal conducting and or light-reflecting surface **99**. Electrical connection **100** is made between the junctions often referred to in the industry as dies, such that different color junctions may be located in close proximity to each other and their combined light spectrum yielding the desired color. The power and control circuitry have access to each individual die, a cluster of dies or to a total facet. This allows for the dimming and color temperature adjustment of the illumination. To more tightly control the light intensity distribution the surface **101** beneath the light-emitting junction is formed concave to reflect and concentrate the radiation into a narrow beam. Alternately, or if additional optical control is needed, the top layer of the junction **102**, if it is light transmitting, is formed to act as a lens such as a Fresnel lens or a surface **103** above the die serves as a lens.

[0170] The level of miniaturization is irrelevant. The principal is the method of powering and controlling the light source intensity directionality and color spectrum in one integral unit by varying power signal to specifically positioned light sources of specific spectral power distribution. Device **90** contains for this purpose any or all of the following: unit **104** for effecting the power conditioning of electric current supplied to the light emitting elements, a control unit **105** to vary power to specific

junctions or chips and sensor units **106** to provide input and feedback to the control elements as described earlier in devices **2** and **14**. The earlier described DLFs of FIGS. 1 through 5 are also designable using the facet light source building blocks.

[0171] In an LED, light is produced at the p-n junction of the diode. It is known that one of the major losses of light output from solid-state lamps is the absorption of light within the epitaxial layer of the chip. On a submicron level, other inefficiencies derive from defects caused by the lattice mismatch. Often LEDs are producing light at a quantum efficiency of approximately 5 percent. Depending on the chemistry and the junction molecular geometry a specific thickness of light emitting layer is required. Also, the width of the junction is important as light is absorbed in the interior.

[0172] Light extraction from AlGaInN-based LEDs is limited by the various parasitic optical loss mechanisms present within or surrounding the AlGaInN epitaxial layers. These mechanisms include absorption at the semi-transparent metallic layer as well as absorption within many layers comprising the epitaxial portion of the LED, such as the buffer layer the active region and the heavily Mg-doped GaN contact layer. Because of the refractive index step between the multi-layered epitaxial structure (n=2.4) and the sapphire substrate (n=1.77) or the encapsulation epoxy layer (n=1.5), only approximately 25% of the light generated within the active region escapes into the epoxy or the substrate upon first encountering these interfaces. The rest of the light is trapped in a waveguide formed by the encapsulation epoxy layer above the chip and the substrate. The trapped light must travel distances on the order of the length of the chip to escape from the sides of the LED. Such distances require many passes through the various loss mechanisms within the LED structure, increasing the probability of absorption. Thus, much of this trapped light is eventually lost, decreasing the overall light output of the LED.

[0173] The LED is designed to allow the light produced to escape through an end face. However not all of the light is able to escape a diode in air because a portion is totally internally reflected at the interface between the diode and surrounding air. Due to the very high refractive index of most semiconductor materials, the portion of the light totally internally reflected is very large.

[0174] Therefore, contrary to the present trend in high flux LED design of building very large, high current diodes, it would be advantageous to build a multitude of very small diodes with relatively large surface areas relative to volume and lessen these losses.

[0175] The layout of the facet in FIG. 6 is applicable to a submicron-sized dice **102** with nano wires **107** and other subminiature connectors **108** bringing power to the junction. To prevent absorption of light by the neighboring junction the cusped reflective structure **101** of the lower surface surrounds the lower hemisphere of the junction.

[0176] The reflector as mentioned earlier for the dice on the micron level may be similar to the one described in "Semiconductor light emitter" U.S. Pat. No. 5,537,433 by Watanabe, where a semiconductor light emitter, such as the light-emitting diode or the semiconductor laser, having a structure in which a light emitting area or an active layer; a transparent layer which is pervious to light radiated from the light emitting area or the active layer; and an opaque layer or an opaque substrate which is impervious to the radiated light are arranged in order or in the inverse order. The semiconductor light emitter includes (a) total reflection layer(s) arranged between the transparent layer(s) and the opaque layer(s) so as to come into contact with the transparent layer. The refractive index of the total reflection layer is smaller than that of the transparent layer. Therefore, at least one part of the light, which has been radiated from the light emitting area or the active layer and which has been reflected by the total reflection layer thereafter, is either radiated outward from side surfaces of the transparent layer or returned to the active layer.

[0177] To carry away heat from the electronic components, a hollow center **109** will act as a thermal chimney and components are mounted on heat sinks. In compact applications, a fan or pump **110** is used in forced circulation cooling. In alternate preferred embodiment, a highly optically transmissive cooling fluid, **111** surround the chips, junctions or facets **94**. The fluid absorbs waste heat and circulates to a radiator area **112** on the body **93** where the heat can be transferred to the surroundings. The circulation can be natural thermo-siphon circulation, based on the density differences or forced, utilizing a pump **110**. An added benefit can be derived from the optical coupling of the fluid between the junctions **98** or facets **94** and the cover **103**. At an air plastic or glass interface typically 4% of the light is reflected back. With two such interfaces the loss will be 8%. The cooling

fluid is selected such as to have a refractive index that it is close to the plastic, ceramic or glass used in the cover **103** and this loss mechanism is eliminated boosting efficiency.

[0178] FIG. 7 is an illustration of a typical application using the digital lamps as proposed in the present invention. A digital lighting fixture such as the puck shaped illuminating unit **66** of FIG. 4 described above shown here as **120** and **121** would be used to illuminate steps **122** by being affixed to the wall **123** or onto or within a railing **124**. A pedestrian **125** using the stairs would not be blinded by stray light reaching his or her eye's since the highly controlled light beams of the SLS **50** in FIG. 4 are aimed downward and have a sharp cut off of light distribution at an angle such that even a pedestrian coming from below and looking up the steps would not see the light source (except from a great distance on long stairways where the light intensity is weakened by the distance and does not glare). A right handed and left handed fixture design would further prevent any blinding light by always illuminating the stairs with SLS aimed toward the nadir or at angles from the nadir in the upward direction of the stairs up to 70 degree angle **126** and by having the fixtures mounted below the eye height of short adults **125** or children who walk stairs at night. A low voltage transformer **127** located within or by the outlet box or at any other power supply juncture can supply power, free from the danger of causing electric shock. A motion detector **128** could be a separate device or as propounded in this invention, be an integral part of the fixture and could cause the fixture to change color and illuminate in amber, red or green to signal the approach of the last or first step.

[0179] In a solar energy powered application, the motion detector would turn the DLFs on or alternately increase power. To conserve energy, when there is no foot traffic, it would operate in a low power mode where it is visible and gives a general outline of the terrain to warn of approaching steps. When motion is detected it would switch to a mode where it actually illuminates the steps for correct foot placement to prevent mishaps.

[0180] In another embodiment the railing **124** is an aluminum or steel extrusion **129** specially constructed to accept the lighting fixture **130** and formed with brackets **131** to carry the conductors which supply electric power. The railing is actually a combined railing lighting fixture and carries out the both functions including providing elements for the power distribution. Grooves along the extrusion accept mounting brackets **132** that facilitate attachment to the wall or upright post **133** and also have a locking mechanism such as fastener **134**. It is to be understood that any other shape or

material of railing, fixture and combinations of bracket and extrusions can carry out the similar function of a combined railing —lighting fixture device.

[0181] In another embodiment the railing is a standard railing profile **135** available in the industry and the digital lighting fixture is shaped in an arced or banana shape **136** or has a bracket shaped to facilitate its merging with the railing. An insulated electrical conducting element, **137** runs along the railing to provide power to the fixtures at intervals along its length.

[0182] FIG. 8 illustrates the use of the linear packaged digital lighting fixture **70** as described earlier in FIG. 5, here shown as **140** in a step **141** or stairwell lighting application. The power and lighting need to be distributed substantially linear at constant distance **142** of the light source from the stairs to be illuminated and the correct light distribution for the task is designed into the SLS and or digital lighting fixture from ground up. The angle **143** of light distribution from the SLS is such that it takes the mounting height **142**, step **141** width **144** and required illumination level into account. The lighting fixture may attach to the wall **145** or onto the handrail **146**. The person's **147** presence is detectable by a motion detector **148** as he nears the last step **149** and indication by a change in color or frequency can be signaled by a segment of the lighting fixture. Alternately or in addition to, in order to save power as with a solar energy installation, the detector may cause a change in the power supplied to the DLFs.

[0183] FIG. 9 depicts a DLF **160** which can be used in pathway lighting where upon being installed at the correct orientation the SLS **161** are aimed in a controlled wide distribution **162** (but yet not in the wasteful, present-day practice of 360 degrees), such that they illuminate a section **163** along a walkway **164** of standard width **165** with equal light distribution and there is no stray light upward or to the rear. A marker, **166** situated on the fixture **160**, aids in orienting the fixture perpendicular to the path. Alternately, shrubbery **167** can be illuminated with another grouping of upward aimed SLS **168** with a more spotlight like distribution alternately of another color spectrum which may illuminate the green growth in a more aesthetic light. The group **167** may be mounted on a swivel base **169** so that it can be aimed independently of the path lighting SLS aimings. A dedicated shrubbery illuminating DLF configuration is another alternative. A stake **170** is used to install the DLF in the ground at the correct orientation and may be provided with an electrical connection box to hook up to power through piecing quick connectors as is known in the art. Alternately the DLF can be self-

sufficient with an onboard power source consisting of solar cell **171** and batteries. As described in previous devices, in more embellished embodiments, onboard control logic circuitry and sensors are employed to control intensity, color spectrum and on/off switching. A motion detector **172** can control the transition from a standby mode to full operation.

[0184] FIG. 10 is a graph of the preferred parameters for lighting color temperature at different illuminance levels. It is adapted from the IES Lighting Handbook 8th edition 1993 and illustrates the Kruithof effect. It is used here as a sample of one of the recommended lighting procedure templates used by controlling logic circuitry on a DLF to keep lighting parameters such as color temperature, color rendering properties, illuminance levels and distribution in optimal bounds. Other control parameters such as switching on and off and color change used to signal critical circumstances are examples of look up, truth tables and media storage data that can be provided to a controller.

[0185] Shown in FIG. 11 is a revisited step light which incorporates the chip technology introduced in FIG. 6 into the step light application which has been used to demonstrate the general method of digital luminaire design as espoused by the present patent. The intent is to illustrate the advantages of the placement of the junctions on a facet configuration over the discrete component approach in the previously described step light design of FIG. 4. The significant feature that stands out is the size reduction. Many junctions are packed in a facet and the facets are cast in epoxy at the correct position and angle to properly illuminate the steps. Again, the entire lighting fixture function is carried out in this properly shaped button-like device which yields the correct light distribution. A button shaped step light **170** is shown on the bottom side of the railing section **171**. A power cable **172** single wire (it can be a single conductor with the railing serving as the other conductor) supplies AC or DC power, which for safety considerations can be low voltage. The power, sensor and control circuitry package **173** makes contact **174** with the power cable **172** and distributes power to the light generating discrete LED or multiple-packaged facet elements **175**. The light facets **175** are strategically located on the relevant geometric surface of **170** such that their aimings contribute to the illumination **176** of the steps from the preferred direction and at even intensities. While facet **175** is contributing light at higher angles on the receding step surfaces facet **177** is illuminating **178**, the close face of the upward step **179**. In manufacturing such a luminaire the components must all be wired together and then positioned in their proper locations at the exact angles. This can be done with automatic machinery while the components are in the flat. Each component is placed by automated

pick-and-place machinery in a hollow where it is temporarily set and where the wiring is attached as well. The hollow is actually a computer positionable setting and all the hollows are moved with the components in situ into the molding positions. An epoxy like spray is used to temporarily lay up the components until the final encapsulation into the final "button" shaped lighting fixture. This is a general lay-up method and applies to subassemblies as well, which can later be brought together before final encapsulation. Conductors that require subsequent electrical connection are mechanically or chemically covered during the spraying process.

[0186] In another preferred embodiment shown in FIG. 12 the DLF is an Adaptive Digital Lighting Fixture. As opposed to a DLF described earlier, is not pre-designed with light source aimings based on a pre-known application. Instead the DLF is equipped with a plethora of light sources ready for most of the conceivable lighting tasks in the illuminated area. The light sources are then controlled such as to adapt the lighting to the room construction and the lighting tasks at hand. The same technique applies to outdoor area lighting applications. This universal DLF is the preferred design when the cost of having an overabundance of light sources is low enough such that other economic considerations such as minimizing stocking units in inventory, repeated changing of the room tenants etc. will be more expensive. It is similar to purchasing a 100-Watt lamp where a 40 W lamp would suffice and always operating it on 60% dimming. The capacity is there but it is unwise to use it since electricity is costly.

[0187] The adaptive or intelligent DLF **190** shown in FIG. 12 has multiple light sources **191** placed about the body **192** having a geometric shape. The shape, which influences the spatial light distribution, may be of a fixed or flexible design. In a flexible design, solenoids, servo motors, actuators, pumps, controlled fluid or air pressure devices **193** are used to realign surfaces, moveable plates or expandable tubes or cylinders **194** to morph the topology of the fixture. The ADLF is equipped with an electronic power supply, computer control and communications unit **195**. One or more light sensors **196** are placed strategically to detect necessary inputs. Alternately one or more digital cameras **197** with a photodetector array which is equipped with a lens which can be a 360-degree lens, or a fisheye lens is placed with a field of view of the area to be illuminated. The geometric shape of the body **192** is such that an asymmetric lighting pattern is produced for the provision of a non-circular lighting pattern in a typically rectangular room. Because more light needs to be directed to the far corners of the room, more surface area for projecting SLSs at that position is required. If

multiple fixtures are used in a large room then squared lighting patterns will obviate the need for overlapping coverage as with circular distribution luminaires or the prior art. Concave section **198** increases the ADLF surface area available for light source mounting at the room corner orientations. In bottom view **199**, a section of the body **192** is shown with asymmetric surface cut out **198** which increases the available surface area on the ADLF.

[0188] Spatially differentiated motion detectors **200** are provided on the Adaptive Digital Lighting Fixture along with the light sources **191** and light sensors **196**. Typically motion detectors have been associated with lighting in motel rooms to shut off the lighting if there is no activity. There is another level of control that can include matching the lighting to type and amount of activity. On sport fields for example, 200 lux may be used general sport activities, 1,000 lux for night practice sessions while 3,000 lux is used in a televised game. Taken to the extreme, one or more limited field-of-view motion detectors **200**, or camera **197**, can be used to follow the whereabouts of room occupants. The DLF controller acts to provide heightened lightning to the occupants" present locations. The controller has stored look-up-tables, instruction sets and algorithms which it uses to processes the information communicated from the sensors or a camera and in response control the light provided to the illuminated area.

[0189] A special or standard remote-control unit **201** can be used to operate and program the ADLF. In one embodiment the control **201** is equipped with a laser pointer and/or light sensor **202** that is used to assist in providing positional an angular data on the location of work surfaces, room structures and dimensions. The control **201** can then pass on information concerning the visual task performed at that specific location. This data now enables the controller **195** to use stored algorithms, look-up-table templates to calculate and program the correct lighting intensities and spectrum for that room location as explained earlier in the block diagram as functionality **7** and computer processes **7A**. The photometer on the remote control **201** held at the specific location will then corroborate the illumination and spectral performance of the ADLF with the specific light source aiming being programmed at the particular instant. The communication can be optical in the visual or infrared wavelength or wireless. An antenna **203** is provided for wireless communication. The adaptive DLF is thus manually capable of being programmed with all the input parameters necessary for a computer program **7A** as is practiced in the art of lighting design, to determine the correct intensities and spectrum to carry out the visual tasks at a specific room location. This is a unique property for a single

luminaire. Lighting designers are usually forced to compromise and provide the entire room or area with the highest common denominator of lighting in the room. With the ADLF non-glaring, spectrally correct lighting at minimum intensities is provided and this affords significant energy savings. The added daylight and activity related dimming functions are another significant energy savings factor with its ensuing economic and environmental benefits.

[0190] A calibration system is provided in the form of calibration element **204** constructed such that it has coverage of the light source radiation on the ADLF body **192**. The calibration element **204** is a reflective rod or strip the surface of which **205** has a wide spectrum, non-angle of incidence dependency and stable reflection characteristics over time. The reflectance of **205** is known at each wavelength and it serves as the standard reflector for the calibration routine. The reflective rod or strip is moveable so that it can reflect light back to the outward facing photodetector **196** based on the ADLF body **192**. To test SLS performance the calibration element **204** is rotated about the body **192** by actuator or motor **206**. When the reflecting surface **205** is opposite a column of SLSs **191**, the controller times the firing of each independently addressable SLS **191** location and acquires detector **196** intensity readings uniquely for each SLS. The results of the test firing are analyzed in controller **195** which has the functionality described in FIG. 1 of components **7** and software **7**A. Correction is made to the junction power supply parameters in order to maintain metametrically balanced outputs for white light and overall lumen production. The controller **195** re-powers the SLS **191** again using the updated power supply instruction set and retests for accuracy. The process continues until the SLS performance is repeatable at different power levels. In another embodiment the ADLF is provided with a calibration wand **204** on which inward facing photodetectors **207** are placed. The calibration wand is capable being positioned such that the detectors **207** can detect SLS **191** performance as the wand **204** is rotated about the body **192** and SLS **191** are independently tested as describe in the previous embodiment. Both the reflective rod/strip and calibration wand **204** are narrow such that when not in use, rod/strip/wand **204** is parked at a specific position where it does not block light sources **191**. In another embodiment the rod, strip or wand is stored and is only deployed when calibration is required. When called upon, the deployed rod, strip or wand **204** is rotated around the DLF body **192** to read SLS **191** intensities. Alternately, the DLF body **192** rotates and the rod, strip or wand **204** remains fixed.

[0191] An ADLF **190** outfitted with computer calculation, communication, calibration and other feature may be costly, such that using a number of units to illuminate a room is impractical. Correct lighting practice encourages the use of multiple point light sources to illuminate an area using a number of criteria. A single fixture cannot cover an area larger than glare and mounting height considerations allow. There is a limit on the maximum angle of light provision. Another consideration has to do with the production of shadows. Finally, due to the cosine law there is a practical maximum angle at which the lighting can be delivered. At large angles the lighting effect becomes negligible. Therefore, due to all the above considerations it is advantageous to have multiple lighting fixtures in a room. A single ADLF **190** is used in a large room. The ADLF is designed to be used with one or more satellite reflectors **220** which are strategically positioned about the room. The satellite has provision for being attached to a supporting structure such as a ceiling or light pole and being fixed with a certain orientation in relation to the ADLF **190** and the working surfaces below. The satellite's inward facing surface is a highly efficient specular, semi-specular or diffuse reflector or combinations thereof. A part of the surface **221** is provided with a full spectrum, white reflector which may be a spot or a band across the top bottom or middle or all combinations thereof used in calibrating the intensity and or spectrum photodetectors and/or light sources over the lifetime of the DLF. A part of the surface may be a special reflector **221** such as a retroreflector which will serve as a ray targeting aid useful in the installation process of the satellites. The targeting can be manual using a red laser pointer or automatic using the detectors **196** on the ADLF **190** and the retroreflector **221** on the satellite **220**. A section **222** of light sources, which may be high power light sources, is dedicated to provide sufficient light to the other areas of the room or for specific task lighting applications such as to computer terminals which require lighting at small angles from the nadir. The section **222** may be on a swivel so as to be aimable at the satellite **220**. Section **222** projects light **223** at the satellite reflector **220**. In use, the satellite is installed substantially over the work area to intercept rays **223** from **222** so as to provide task-lighting **224**. The specular reflector **220** is positioned and angled such that it concentrates and re-directs the light rays **224** downward onto an area or worktable. The downward directed light coming at very small angles will illuminate the worktable **225** but will not cause veiling glare reflections on the computer screen **226**. To provide general lighting to room extremities, the satellite reflector is specular, semispecular or diffuse and has a surface geometry for reflecting the incident light **223** so that it spreads the light evenly over the area to be illuminated.

[0192] In place of the manual programming technique for ADLF **190**, a semi-automatic self-programming process using luminance measurement via detectors **196** is provided. The camera **197** has a view of the room its contents and occupants. Pattern recognition techniques known in the art are used to identify room occupants, furniture, office equipment such as computers etc., room structures such as walls and windows.

[0193] The intelligent lighting fixture system **190** is adaptive to the room structure, usage and occupants on a dynamic basis. In one embodiment a hand-held laser pointer and sensor on the remote control **201** is used to assist in providing positional an angular data on the work surfaces and room structure enabling the controller to corroborate program lighting for the location with the specific light source aiming being programmed at the particular instant. The room occupants also use the remote control **201** at any instant to input lighting preferences or call up stored lighting scenarios to the DLF **190**. Thus, the controller **195** or a controller **195** which communicates with a PC computer is provided with an interactive program which based on application look up tables will determine recommended light intensity and spectrum for the application at hand. Procedures useful in the lighting design process, lookup tables and specific application guidelines can be found in the IES Lighting Handbook 8th edition pages 447-903. A number of commercially available programs are available which prescribe lighting based on the application and calculate the illuminance based on the fixture. In this invention the procedure is reversed in that the recommendations are first used to generate the illuminance on or luminance from the room surfaces. The computer program **7**A is used to calculate the light intensities required at each angle in order to produce the desired illuminance or luminance results. Luminance in cd/m 2 is the reflection of the light flux lumen/m 2 from a surface having a reflectance property and is more similar to what the eye sees. The algorithms are processed onboard the ADLF **190** or run on a PC which communicates with the ADLF. Computer programming for lighting calculations and correct lighting practice recommendations is known in the prior art. Commercial programs using procedures based on IES, ILDA and other standards and professional lighting engineering and design organizations are available. Lumen Micro® and Simply Lighting® from Lighting Technologies Inc are examples of such programs which provide tools to create and simulate lighting layouts for both indoor and outdoor applications. Simply Lighting® is a suite of Windows®-based lighting analysis tools that are designed to answer the questions you need answered using a step-driven application targeted at a specific lighting application. Lighting Analysts, Inc

AGI32 ® is a program used to predict lighting system performance for any application from one to hundreds of luminaires, interior or exterior. Users can build environments for most any electric lighting application with unlimited luminaires, calculation points, and reflective or transmissive surfaces including day lighting effects. The program used in this invention is an adaptation of a state of the art lighting programs. It is capable of receiving data inputs automatically or manually interpreting them according to correct lighting practice and calculating the candlepower distribution from the illuminance back to the luminaire. A post processor and outputs the operational instructions to the controller **195** for the application at hand.

[0194] The operation of the system is demonstrated in home use, but the method is the same for office, store and industrial applications. The input program **7**A is user friendly including the use of icons representing pieces of furniture, e.g. table, lounge chair, equipment such as TV, computer etc., and visual tasks being performed such as reading, and watching TV. The homeowner moves about the room with the remote control **201**. At a specific location the homeowner enters the furniture type, possible occupant postures, sitting reclining, standing etc, and visual tasks to be performed. The room and its surfaces is defined the by being positioned at a wall, entering into **201** that it is a wall at that position and at another position entering that it is a window. The control unit **201** is optionally outfitted with a photometer **202** which can be used to read the surface reflectance of the wall and transmit the data to the lighting program **7**A. This is the same process a lighting designer uses to enter data to the lighting analysis programs. The lighting program as known in the art then specifies the correct lighting levels, aimings and spectrum for the different locations and uses throughout the room. This is reversing the typical design process as described earlier where the lighting fixtures performance is simulated on a computer and the results calculated. Here, the required illuminance results are known first and the fixture is then programmed to make them happen. The controller **195** uses its stored performance characteristics to determine the power supply to the SLS so that it provides the required intensities and obtain the required illuminance. The lighting calculations and programming of the power supply **195** of the light sources **191** is preferably performed in real time such that the sensor **202** detects the illuminance to corroborate the performance while the homeowner is still at the location. If the lighting is not to specification, then the controller **195** readjusts the parameters so as to bring them in line. This trial and error process continues until the readings are within tolerance. The process is best carried out in the dark or when there is non-varying daylight. Alternately, the photometric reading sensors are on

the luminaire and they are used to corroborate performance. Alternately, the process is automatic using feedback from the surroundings and pattern recognition to determine surroundings and applications.

[0195] Providing correct lighting for the various activities a homeowner in a room involves the use of numerous lighting regimes. Typically, he or she would move about the room performing various activities with diverse lighting requirements. First, moving from the table where work was performed on the computer to a lounge chair to read the paper and finally moving to the sofa for a little relaxation watching TV. In prior-art practice, several lighting fixtures of different design are used to carry out the different tasks. In order to conserve energy each one would have to be turned on and off or dimmed as the resident moves about the room. A glare-shielded luminaire would be used for correct illumination in the computer task, while a floor lamp may provide lighting for reading on the lounge chair. General lighting from an overhead luminaire is sufficient for TV viewing. According to the present invention, as the room occupant moves about the room performing varied tasks, the motion detector **200** or camera **197** picks up the new location and from its stored templates which correlate location to lighting application, controller **195** provides the correct lighting regime.

[0196] According to the teachings of the present disclosure, the room lighting needs are provided by one or more DLFs or ADLFs including satellites or combinations thereof placed such that they are capable of providing lighting at the correct non-glaring angles for the lighting tasks at hand. The ADLFs are programmed as to the whereabouts of furniture, computer monitors, TVs etc. as described above. The ADLFs and DLF can communicate with each other and an ADLF can control a DLF and vise versa so that level lighting is accomplished in the room. Two or more DLFs can share in the illumination requirements of a location located between them. The DLF turns off its illumination towards a specific location, reads the ambient luminance and then correctly powers the SLS to provide the additional illumination. An oscillating "singing" feedback network incapable of settling is prevented by the provision of inexact timing. The DLF lighting assessment process occurs on a periodic basis as the controller surveys its numerous detectors and SLS, the complete cycle taking a number of seconds. The same process is occurring in the neighboring DLFs. A clock on the DSP controls the process. The DSP is programmed to randomly nudge the clock timing by a number of a multiple of milliseconds typical of the survey process from cycle to cycle. The similar timed assessment process with an independently random shift in timing occurs on the adjacent DLFs. Thus,

the chance of seesaw interaction between DLFs is insignificant. Alternately, communication between neighboring DLFs can also be used to synchronize the process and prevent feedback oscillations.

[0197] The novel lighting-application oriented approach to light-source construction, as taught by this invention impacts on the method involved with marketing the DLFs. Rather than speaking of a wattage for a lamp or lighting fixture, now with DLF technology, the area covered is the determining factor, somewhat like the coverage area of a can of paint printed on the container. The customer needs only to specify the room area and what the lighting is used for in order to select the correct luminaire. In today's prior-art process of selecting by lumen or wattage, there is an additional step, that of taking the effective lumen output and dividing it by the area of the room. Instead, a DLF is packaged and marked according to the area it will cover (when mounted at the designed for), mounting height (usually standard for most residential ceilings) and the lux it will provide or the visual tasks for which it is suited. Thus, a homeowner in a store will be queried by the sales staff or be presented with instructional promotional media which allows for the determination of the room dimensions, type of room and typical activities carried out therein. The lists printed on the cartons for the various DLFs will include location types and task types. Location possibilities for consumer lighting include corridors, kitchens, bathrooms, bedrooms, play areas, garages, driveways, backyard, playing fields, steps, workrooms etc. Task possibilities which would generally be a subdivision in a location type will include reading, dining, TV viewing, exercise, sport etc. A single DLF may be suitable for more than one location and task type and be so marked. Thus, typical DLFs would come in bathroom, kitchen, garage, bedroom, hallway, and etc. models. The bedroom model comes in a 12 ft. by 12 ft. Coverage and is also the TV room model etc. An ADLF is suitable for many more locations and applications and is so marked.

[0198] Industrial and commercial lighting DLFs are similarly marked and marketed. Mounting height determines the maximum area covered according to correct lighting practice principles and adds another variant less prevalent in the consumer market. The many DLF models will not exceed the plethora of prior art luminaire designs, as they are also based on mounting height and lighting application. While prior art luminaires rely on large reflector and every variant requires new investment in tooling, in a DLF a basic carcass will support many MSLS configurations with their particular amount of SLSs and their aimings.

[0199] In non-color critical applications for example in low lighting used for orientation a further energy saving can be obtained. LED junctions are made of different materials. The blue, green, and white illuminators utilize InGaN LEDs and the amber and red utilize AlInGaP for the junction material. Some materials are more efficient at converting electrical energy to visible light than others. As an example, (in terms only relevant at the time of this writing since the efficiencies are increasing daily), while a green LED which has the advantage of high photopic eye sensitivity to its wavelength, is producing only 30 lumen per watt, a super flux red LED can produce over 50 lumen per watt. Thus, when color rendering is not important in the lighting application at hand it is possible to shift the workload onto the more efficient LEDs. This of course must also take the eye sensitivity at the specific lighting intensity into account. While a purely scotopic rod eye response at extremely low light levels, less than 0.01 lux gives added sensitivity to the 510 nano-meter green blue, photopic vision at levels above 100 lux is most sensitive to the greenish yellow 555 nm wavelength. In most illuminated cases low lighting would not be below 5 to 10 lux where the sensitivity peak is around the 550 nm yellowish green. Thus, two factors are used by **7** in **7**A to calculate the most efficient light color of the DLF; the LED radiation power per watt multiplied by the eye sensitivity curve for the present illuminance value. In a less rigorous embodiment, if the par between the LED efficiencies is large such as in the example above, then the red LED is used combined in ratios with other wavelengths, such that the color still found acceptable by the users.

[0200] In a preferred embodiment, using pattern recognition techniques the ADLF **190** is semi or fully automatic in programming itself to correctly function where installed. The DLFs or ADLFs will adapt to the seating arrangement of room occupants in real time. In the preferred embodiment, the addition of a machine vision system with pattern recognition capabilities as is known in the art, easily deduces room occupancy and usage. The camera **197** including a wide angle or fisheye lens camera is mounted on the DLF or ADLF. In an alternate embodiment, one or more cameras in communication with the lighting system controller, has coverage of all, or part of the area to be illuminated. The camera may also serve as an illuminance and spectral measuring device as the individual detectors in the array, for example as on a CCD or CMOS array, may be read for their individual stimulus. The detector array pixels are calibrated to the room coordinates. The calibration routine can be manual or automatic. A manual method includes walking a controller around the room and programming in the coordinate to the camera system or alternately using a PC CAD program to input room coordinates

overlaid on the image obtained from the camera such that the lighting system coordinates and the camera coordinates are the same. An automatic routine as in **7**A uses timed firing of a coordinate-specific light source, or array of light sources and the following reading of the camera detector of light reflected to that specific coordinates pixel, or set of pixels to corroborate action between light sources and the detectors. The detector pixels **197** can then be used to obtain images of the room which the controller **195** can assess as furniture, equipment or occupants. Pattern recognition methods known in the art, including neural networks, can provide a generalized stored application library of usages to the controller or the controller is an artificial intelligence controller and can learn the actual room usage with time. Outputs from the CCD arrays are analyzed by appropriate computational means employing trained pattern recognition technologies, to classify, identify or locate the contents. These techniques known in the art are covered in texts such as: Schalkhoff, Pattern Recognition, statistical, structural and neural approaches, John Wiley and Sons, New York, 1992 and Neural Networks for Pattern Recognition by Christopher M. Bishop, Chris Bishop, Oxford University Press; (January 1996) included herein by reference. Thus, the controller with or without human intervention will program the ADLF lighting system to carry out lighting within the realm of correct lighting practice. This includes providing the correct illumination in real-time based on occupant whereabouts, activity being performed and outside factors such as sunlight contribution, time of day factors etc. Advanced robotic vision techniques including object segmentation and selective-attention modeling (Itti, Visual attention and target detection in cluttered natural scenes in Optical Engineering, Vol. 40 No. 9, September 2001 included herein by reference) will aid in identifying various room objects and the lighting program **7**A will associate with their location the visual tasks and recommended lighting characteristics. In case if the machine settings are not acceptable to the users, provision is made for human intervention. Through the data input device **201** a user, the ultimate "sensor" corrects or customizes the lighting arrangement and reprograms the controller.

[0201] In a further ADLF intelligent lighting system improvement over prior-art practice, machine vision is used to control surrounding luminance. A prime example is an office application where a computer Visual Display Terminal is in use. This is an application where the quality of the localized task lighting is important. Contrast plays a major role in seeing and glare plays a role in producing veiling reflections as causing fatigue. The correct illuminating solution involves the control of surrounding luminances. A prior art workstation design will include partition, carpet, ceiling and

desk surface reflectance which reduce the luminance in the workers field of view. Using the ADLFs ability to recognize the computer screen chair, desk and surrounding floor and ceiling, the illuminance in lux on each element is varied to obtain the optimal luminance. That now allows any color scheme to be used by the interior designer on the work cell decor. The ADLF will control the luminance by varying the spatial light intensity distribution over the different surfaces.

[0202] In another embodiment using the camera **197**, the controller **195** is instructed to identify and track a roving speaker during a video presentation. A signaling device is used by the speaker to allow the pattern recognition program to initially lock-on and recognize a target attribute as is known in the art of object tracking. The signaling device can be a laser light pointer **202** aimed at the camera or a hand held remote control **201** in communication with the camera vision system. The controller **195**, based on the camera input runs the pattern recognition routines, derives the coordinates and generates instructions to drive the specific light sources with aimings which will project light at the speaker as the speaker move about the room. It is to be understood that in a theater lighting application there is no need for a preprogrammed moving light using motors to change position. Instead a fixed DLF or ADLF with multiple light sources powers the necessary light sources to illuminate the performer as he or she moves about the stage. This actually is similar to the banks of shuttered lights used in present day stage lighting. Only now the digital aspect of discrete multiple light sources allowing for a smooth transition of aimings with instantaneous control of almost infinite variation of spectrum and intensity is accomplished. The controller, once locked-on to the performer using images from the camera **197**, will now follow the performer around the stage illuminating instantaneously in the intensities and spectrum as preprogrammed in the choreographic setup or in correspondence to the music or some other characteristic as in known in stage lighting practice.

[0203] An emerging problem with LED light sources is that with the increase in light conversion efficiency the LEDs are becoming ever brighter and for their small size present uncomfortable sources of glare. These high intensity light sources would have to be used with diffusers which would impair the light control characteristic. One solution is to construct the DLF large enough such that the area over which the light flux emanates is sufficiently large that the luminance in candela per square meter will not exceed allowed luminous exitance values or glare limits. In this solution of increasing the luminaire area over which the light emanates, the number of light sources at specific location may not be sufficient to provide the continuum of light distributions and spectral

combinations necessary to carry out correct lighting practice as per the teachings of this invention. Another way of looking at the problem is, that with added lumen output, a few high-performance LEDs could provide the illumination for a room but due to even distribution and spectrum consideration many discrete SLS are required. That is, the SLS needed for the smooth continuum, digital aspect of the invention exceeds the number required for the maximum light flux.

[0204] In a preferred embodiment the DLF or ADLF is rotated about an axis such that the time any source in the glare causing zone is exposed to an observer's eye is such that it is not observed as glaring and the time the source is out of view is below the flicker rate for that intensity level. HID and fluorescent lamps operated on 50 Hz have a 100 Hz flicker rate and are not considered to flicker. For aesthetic, aerodynamic and dynamic balance reasons the DLF can appear as the globe shape **190** of FIG. 12. However, the now reduced dimension DLF is spun rapidly on its axis **227** by motor **206**. The LEDs can be concentrated in an arc from top to bottom along the surface **192** or be located in the concave arc section **198**. The concentration of SLS in this section is sufficient to offer a large number of spectral combinations at any aiming. Two arcs of SLS **191** opposite each other for balance or one arc with counterweight can be used. With one arc a 6,000 RPM rotation rate is used to prevent flicker and with two a 3000-rpm rate. In an alternate embodiment instead of a complete globe just an arc section such as **198** runs from top to bottom. The arc is on an axis and is motorized so it rotates rapidly on its axis. The speed of rotation is such that the light source does not appear to flicker. This way a compact unit can be made since the apparent brightness is reduced. This process is possible because the eye is an integrator of light over time and persistence of vision minimizes flicker. The LEDs **191** disposed along the surface are timed to fire in the correct intensity according to the instantaneous position. The timed operation is coordinated with room location. Thus, when the spinning light sources **191** are facing a corner more intense light at higher angles is projected so the far corner is illuminated equally to the areas near the DLF. The positionally correlated timed firings of the rotating DLF will illuminate as need per location per usage requirements in real time. The side of the room near the window receiving ambient daylight will receive less illumination than the opposing darker side. This is also possible because the controller electronic **195** operates much more rapidly than the mechanical motion and that the rise time of the SLS is extremely fast measured in single digit microseconds. In a preferred embodiment, the globe or arc can be placed in an outer jacket which is partially evacuated of gas. The globe or arc is then rotated in a partial vacuum envelope to reduce air friction losses.

[0205] In FIGS. 13A through 13C a streetlight fixture designed according to the teachings of this invention is shown. The design and functionality distinction as compared to prior-art streetlights is derived from the multi-light source, digital design. In FIG. 13A the aesthetically designed DLF streetlight **240** is shown in a front view. The geometric shape is a derivation of the surface geometry for mounting the SLS perpendicularly thereon to obtain photometric light distribution compatible with the requirements of the street lighting application. These photometric distributions are expressed in terms of luminaire cutoff angle which refers to the angle beyond which rays capable of producing glare are prevented from exiting the fixture. Another type of classification used by the IES, refers to the elongation of the light pattern along the road in terms of Long, Medium and Short and another categorization, perpendicular to the roadway called "Type", describing the distance in units of mounting height (where the fixture is mounted), that is illuminated. The novel design includes SLS with over 100,000-hour lifetime allowing for the fixture to be factory sealed for life. This obviates the need for cleaning reflectors, as all the exterior surfaces are cleanable by rain and there are no light sources at the sharp bottom drip point where dirt normally accumulates. The compact design **240** shown mounted on a pole **241** in side view FIG. 13B has a small exposure area, reducing wind induced drag force loads on the pole. This low wind factor and low weight of the electronic components allows for the use of a less expensive pole. The pole arm **242** fits into slipfitter **243** which is provided to perform the mechanical fixing means of the DLF **240**. FIG. 13C is a side section view through the center of the fixture. The electrical power and communications connection is made to a connector block **244** mounted such that it accessible for the external wiring of the fixture during installation. The grid power is connected to power supply **245** and the data to the controller DSP **246**. A dedicated communications line is used, or the data is sent over the power line using communications protocols as known in the industry and the DLF communicate with each other or with a central control. The SLS aimings are shown in front view FIG. 13A where the SLS aimings to the right **247** and left **248** along the roadway show how an even distribution pattern out to the maximum design distance from the pole center is obtained. This distance is a function of the fixture mounting height and cutoff angle. Hole-through SLS units have been drawn to illustrate the point but the principle the design is valid for SMD, SMT, the chip **94** design of FIG. 6 as well as other package arrangements known in the art. Many more SLS **249** are concentrated at the larger angles **250** to illuminate out to the extremes of the area covered by the DLF. Fewer SLS **251** are needed at the small angles near the pole to maintain with equal illumination. The SLS at the cutoff angle **250** have a tightly controlled beam spread **252** to

maintain a sharp cutoff, minimize glare and eliminate spill light. The SLS **253** in the interior have a wider beam spread **254**. The DLF **240** projects light in a highly controlled pattern perpendicular to the roadway as well SLS **255** as seen in the side sectional view FIG. 13C are aimed such that the cutoff angle **256** is out to the road width with or without the shoulders as designed. In applications where illumination for a sidewalk is required, "house side" illumination is provided by inward SLS aimings **257**. On a dual carriageway road where the illumination provided is limited to a single carriageway, the lighting from the roadway fixture need not be symmetric about the nadir along the roadway. While approaching the streetlight, glare is to be avoided and the cut-off angles must be small for light aimed at the advancing vehicles. However, after passing the streetlight, the lighting in the direction of travel may be provided at increased beam angle from nadir and still not cause glare. This would significantly increase pole spacing saving cost and eliminating hazardous poles.

[0206] In all stages of the SLS positioning and aiming design process which works in reverse of the normal process by engineering from the illumination required on the working surface back to the light source. Glare ratings for the design are checked to make sure they are within the acceptable limits. If the light source concentration is such that drivers or pedestrians in normal eye viewing conditions would experience glare, then the luminous exitance is lowered by design changes in the geometry or light source attributes. The ramifications of a dynamic and exact light control are numerous in a street light luminaire. First there is no spill light and no light trespass. If the position of a luminaire is such that light is shining into a house the individual SLS at that aiming is not powered by the control **246**. All the light power is placed where needed in the designed for illumination intensity, neither in deficit nor excess. While prior art luminaire show 80% of the light falling in the area designed to be illuminated, the DLF will have a near 100% utilization factor.

[0207] When artificial intelligence methods known in the art is combined with the fine control and functional flexibility of the DLF additional advantages are realized. A detector or camera **258** in concert with a logic controller **246** is capable of providing the road lighting needs to a driver or group of drivers in according to the time of day, needs of the roadway layout and usage at any moment. The detector **258** will provide signal to the controller **246** of the ambient lighting conditions. When daylight is no longer sufficient for viewing such as at dusk the DLF will add lighting. At dawn the process is reversed. In an alternate embodiment the roadway lighting can be dimmed if there are no approaching vehicles. The detector or camera **258** is capable of detecting oncoming and retreating traffic. The

headlights and backlights are used, or more sophisticated pattern recognition is used to determine traffic on the roadway. When there is no traffic the luminaire will illuminate at a fraction of the power used to generate the 5 or 10 lux used in street lighting. Taken to the extreme the controllability of the DLFs or series of communicating DLF street lights allows for the lighting to precede the vehicle by the stopping distance, say 300 ft. at 65 MPH (91 meters), and dim the unused lighting behind the driver if it is not necessary for other drivers. In the late hours of the night when traffic is low this function can save significant amount of energy. A typical 250 W HPS streetlight will consume over 25,000 Kwh in its 20 yr. lifetime. On moonlit nights the dimming of the DLF can be greater as moonlight provides up 0.10 lux. The dimming of SLS actually improves their lighting efficiency and prolongs lifetime. Dimming of HID sources has a negative return, typically 10% light at 50% power. The color spectrum of the light is also varied in the DLF to match the intensity levels. Here an additional efficiency boost is achieved when the added scotopic eye sensitivity to 510 nm bluish white similar to the pale moonlight is taken into account.

[0208] It has been shown that certain colors of light i.e. of different spectral power distribution (SPD) are perceived to be more glaring than others in night driving. Studies of drivers (Flannagan, M. J., (1999). Subjective and objective aspects of headlamp glare: Effects of size and spectral power distribution, Report No. UMTRI-99-36). Ann Arbor: The University of Michigan Transportation Research Institute.) indicate that blue-white color has been found to cause more glare discomfort than yellow light. On the other hand, studies have shown that driver night vision is better under the blue-white spectral power distribution. Recent laboratory studies have also shown, for example, off-axis detection peripheral detection can be better for bluish, metal halide lamps than for yellowish, high pressure sodium lamps at the same photopically specified light level (Bullough, J. and Rea, M. S. 2000. Simulated driving performance and peripheral detection at mesopic light levels, Lighting Research and Technology, 32 (4), 194-198). In the DLF streetlight luminaire it is possible to use the blue-white SPD to illuminate most of the roadway yet increase the cutoff angle, which is determined by glare considerations, by using yellow-white SPD light at the large angles which throw the light further along the road. The higher angle lighting provides more vertical lumens and is actually more effective at illuminating objects along the roadway. The increased visibility afforded by the added vertical lumens at high angles offsets the decrease in visibility due to the yellow-white SPD. This means that the overall visibility over the roadway sections is constant. Thus, SLS near the angle **250**

would have a yellow-white non-glaring SPD while interior SLS such as **253** would have the superior blue-white SPD. The higher the cutoff angle, the fewer luminaires that are required to illuminate a roadway. The same differentiation would be possible with SLSs **255** in the side view of which some illuminate the sidewalk **257**, some the right lane and others the left lane. The SPD of the SLSs at the high glare causing angles **250** facing the oncoming driver aimed to cover the near lane would be yellowish while those SLS covering the same lane but now to the rear of the receding driver, will still be of bluish-white SPD. The opposite is true for the far lane. The SPD of the SLS aimed **257** at covering the sidewalk would again be in the blue-white to aid in peripheral vision detection of pedestrians or objects approaching the roadway from the side.

[0209] As with all correct lighting practice the visual surroundings at any instant in time determine the amount of illumination required to carry out visual tasks including the luminance of background surfaces. Roadway luminance as detailed in the IES Handbook pages 751-779, is the preferred factor used in specifying required illumination levels. Freshly paved blacktop with its diffuse reflection will change over time to a mostly specular reflection. The higher luminance value pavement requires less illumination to see objects. This characteristic changes over time with wear and periodic road maintenance and illumination levels need to vary accordingly. A detection by **258** of this road luminance will provide the controller will the data necessary to set the required illumination. Roadway activity is another factor in determining illumination levels. This factor often changes over days of the week or seasons of the year. An adaptive DLF with detectors **258** and computer devices **246** capable of recording this traffic activity will provide the correct illumination for the traffic situation at hand.

[0210] Though the design of a streetlight has been detailed the same design process is valid for floodlights and other outdoor lighting applications. The use of the SLS of specific spatial candlepower distributions at particular aimings, the use of tighter beams at the edges of coverage, the non-glare design and the optional use of logical control are as applicable to DLF floodlight design as to the street light design.

[0211] FIG. 14 is a flow chart which illustrates the general design concept which allows anyone to build a multi-light source lighting fixture from the ground up, tailor made to the final application. This process differs fundamentally from prior art lighting fixture design. Rather than building a fixture around a common lamp and then coercing the usually isotropically radiating lamp

to perform in a certain application, the lighting application is used to describe the light source construction. The light source construction is unique in that its flux density is spatially differentiated over its volume in concert with its final orientation when in use. The light source design then defines the supportive power, control and mechanical elements. These elements are then integrated into a single unit with shared components and packaging. The method for designing an application oriented luminaire designed according to correct lighting practice, providing the correct light intensity, spectrum, and spatial distribution of intensity and spectrum, suited to the specific lighting application, would comprise a number of steps some of which can be left out of the process while others may be added including a) determining the lighting application, and the recommended lighting practices for the application b) determining the luminaire mounting height, illumination area covered and surrounding conditions typical of the application c) determining candlepower required to effect the required illumination over the area d) selecting SLS types capable of producing required intensities and spectrum at highest conversion efficiencies at lowest economic cost e) determining SLS beam spreads f) determining SLS aimings for the required distribution pattern g) determining electronics to control and power SLS h) determining lighting fixture surface geometry and size i) testing whether the glare rating for the viewing angle is acceptable j) if the glare rating is not acceptable, then changing SLS beam spread, fixture geometries, or size, resulting in an acceptable glare rating; and, h) when the glare rating is acceptable, then designing the luminaire aesthetics for the application.

[0212] The digital lighting concept is extended to transportation vehicle applications. A headlamp for an automobile uses multiple light sources based on electro luminescence of semiconductor junctions. The proposed unique approach is to combine the lighting engineering function i.e. the correct light distribution, color spectrum and level necessary for the visual task at hand into the lamp, such that the digital lamp obviates the need for additional light controls and fixtures. The digital electronic lamp utilizes ⅓ the energy and has over 100,000 hours lifetime versus 2000 for an automotive incandescent lamp and can be rapidly switched on and off without deleteriously affecting lifetime (Quite the opposite, off time is not part of the lifetime). The multiple light-source, digital device, is an electronic headlight which provides the driver with the correct aiming, illumination level and distribution (e.g. parking lights, low beam, high beam, lighting around curves and corners) based on input from the vehicle's speed, steering wheel position, turn signal

indicator and detection of approaching headlights. These functions are carried out automatically however; the standard manual override controls are still maintained.

[0213] Headlamp glare is addressed in two alternate ways. European regulators recognize the danger presented by excessive headlamp glare, and so European cars with HID lamps must have dynamic headlamp leveling. On-the-fly headlamp vertical aim adjustment has been required by European directives for quite some time now, but dashboard dial control of the vertical aim is no longer acceptable. Recent European regulations require that the headlamp leveling of HID-equipped cars be linked to the suspension system of the car so the lamps don't glare as much to oncoming traffic when the rear of the car is loaded-down or the car is heading up a small hill. The digital headlamp solves this problem by automatically sensing the angle of the headlamp assembly and will employ in real time only the properly aimed light sources to illuminate so as not to glare oncoming traffic.

[0214] An alternate method of glare control is accomplished by rapidly switching on and off the headlamp light output or only the high beam portion thereof at such a rate that flicker is not observed by the driver. This persistence of vision is the same effect on which motion picture viewing operates using shutters to intermittently block the light while the frame changes. On the oncoming vehicle, a variable light transmitting element, an electronic shutter, located in the driver's field of view is rapidly switched to a blocking state synchronized in time with the on state of the oncoming car's headlamp. The situation is vise versa for the driver in the other vehicle such that in the instant one driver is seeing the other is not.

[0215] The Spectral Power Distribution, SPD, of the headlamp is also variable as a function of the area being illuminated. Studies by Flannagan cited earlier, have shown a preference by drivers for yellow tinted headlights on oncoming vehicles. The drivers find the yellowish colored light of an incandescent less glaring vs. the bluish "white" light of an HID Metal Halide lamp. On the other hand, recent studies by Bullough, cited earlier, on driver's peripheral night vision show the clear benefits of HID MH headlamps in detecting pedestrians and objects along the side of the road. Thus, an ideal solution is to have the SPD in that part of the beam visible to oncoming drivers be of the less glaring yellowish type while the beams headed everywhere else would be of the blue-white SPD for increased driver visibility. In fog or snow the color spectrum would also be adjusted so as to maximize visibility. Yellow colored lights are used in fog and snow conditions to prevent flashback. Thus, according to

the teachings of this invention the DLF headlamps serve as the fog-lamps. The digital headlamp will automatically or manually be adjusted to the optimal intensity and SPD lighting parameters for the environmental conditions at hand.

[0216] Present advances in automobile lighting include Adaptive Frontal-lighting Systems which aid in seeing around curves and other features in the road. In these systems the light distribution pattern and color spectrum will be changed according to the instantaneous road conditions at hand. Thus, the headlamp now has much more flexibility than the high beam/low beam variation of today. At any instant in time the intensity, spectrum and beam pattern of the headlamp may be varied as a function of the driver's intent, lay of the road and environmental factors. A GPS system on the car may also let the headlamps system know of curves up ahead, one-way traffic and others factors such the headlamp may be operated in the optimal mode at that instantaneous location. With sensors sensitive to environmental surroundings such as ambient light, fog or snow conditions etc. lighting can be adapted to the optimal operating regime.

[0217] Additional features include an optional concentrated flashlight type of beam to illuminate distant overhead and roadside signs, which due to the narrow, directed beam will not blind oncoming traffic. Image recognition via a camera will allow the beam to follow the retroreflective sign as the vehicle moves or the signs will be provided with a special marker for this purpose. In this way the headlamp cutoff above horizontal except for the concentrated sign beam can be total.

[0218] FIG. 15 illustrates a preferred embodiment of a digital automotive headlamp. A headlamp is a specialty lighting application unrivaled in terms of the need for controllability and is especially suitable to the methods and devices described in this disclosure. The headlamp fixture is unique in the continuum of beam patterns, intensities and color spectrum. The number of possible control modes are: 1. Parking Lights. 2. Low Beam lights; 3. High Beam; 4. Cornering Lights; 5. Load leveling adjustment; 6. Integral turn signal indicator, 7. Programmable alternate beam spread selection so that one headlamp fulfills the different sets of legal regulations for the high and low beam in different regions of the world such as the U.S.A., Japan and Europe; 8. Driver preferential color; 9. Oncoming vehicle or vehicle-ahead driver's preferred color 10. Color of ambulances extra headlamp provides red flashes to be more easily picked up in rear view mirror; and 11. Non-Glaring pulsed headlamps.

[0219] Input data to the controller would first and foremost be in the control of the driver and would consist of an overriding manual selector switch. Otherwise headlamp control is automatic, from turning on automatically when ambient lighting levels fall to such a level where it is advantageous to have headlamps on, either to aid in illuminating the way ahead or facilitate being seen by others, to automatic dimming of high beam due to detection of oncoming vehicles and shut off when ambient lighting levels are sufficient. A possible control system for such purposes is described in U.S. Pat. No. 6,281,632 by Stam, et-al from Aug. 28, 2001 titled: A Continuously variable headlamp control incorporated herein by reference. The patent describes how continuously variable headlamps offer greater flexibility for roadway illumination but offer challenges in automatic control design. Each continuously variable headlamp has an effective illumination range varied by changing at least one parameter from a set including horizontal direction aimed, vertical direction aimed, and intensity emitted. Stam discloses a system for automatically controlling continuously variable headlamps on a controlled vehicle includes an imaging system capable of determining lateral and elevational locations of headlamps from oncoming vehicles and tail lamps from leading vehicles.

[0220] Using a control system such as that above, many driver functions are automated. With the digital headlamp, automatic control of headlight beam is a function of speed of travel, that is: when vehicle is in Park the parking lights are on, when speed is low the lamp beam is aimed sufficiently forward to give ample reaction to brake for objects in the vehicle's path per the speed it is traveling up to the intensity, angle and thus distance which is the upper legal limit for the beam. If there is no oncoming traffic, then it operates as the high beam. If there is oncoming traffic, then it acts as the regular low beam.

[0221] Additional features can include an optional very narrow flashlight type of beam. Present day LEDs come in very narrow aimings such as two half angle 8 degrees which may not be narrow enough (a 10 meter spread for 150 meters down the road which may be sufficiently aimed to the right) but with need, smaller angles are also feasible. Such a beam at the correct narrow aiming can continue to illuminate far ahead (in high beam) without blinding oncoming traffic. Analysis by a detector or an imaging system of the oncoming vehicles position (using its headlights for example) can be used to determine which exact aiming is the maximum allowable for any given traffic situation and road layout.

[0222] Using color and pattern recognition techniques it is possible to determine what is a sign. It is then possible to provide the equivalent of "task lighting" and use the controller and properly aimed SLS to follow and illuminate distant overhead and roadside signs for a longer time, yet not blind oncoming traffic due to the narrow beam.

[0223] Wavelength specific SLSs in the infrared or near Ultra Violet spectrum, not visible to the driver by the unaided eye are used for communication between vehicles and roadway controllers or toll booths. Infrared SLS will provide radiation to be reflected from objects for night vision cameras. UV SLS are used for or illuminating UV fluorescent dyes in clothing bicycles and baby carriages to increase pedestrian visibility as is known in the art.

[0224] In FIG. 15 a headlamp **270** of a land, sea or air vehicle **271** is shown in front view **272**, side view of a section **273** and top view of a section **274**. A discrete SLS light source such as an LED **275** with specific location within the cluster **276** has a specific spatial light distribution, color wavelength and aiming relative to the vehicle, such as straight ahead, and or downwards and or off towards the right or left. The SLS may have one junction and be monochromatic or have many junctions and provide a wide spectral power distribution and the power to the SLS may be varied. An SLS can also be a "white" LED. For example, a typical "white" LED such as a Luxeon® white LED such as LXHL-XXXX will have a colder "bluish" 4,500K color temperature. LED **277** at a second location within the same cluster may have a similar or dissimilar aiming, wavelength and spatial light distribution. The concept cluster shown by the dashed lines, is used to describe a control function and is not necessarily related to contiguous placement. In general, a cluster may be deemed a separate grouping due to a function it performs, either exclusively or in conjunction with other clusters or sub-clusters, such as high beam function versus a second cluster **278** which may provide a parking light function. The same SLS may be used, albeit at different intensities, for both the above functions and thus clusters may overlap and be discontinuous. As two LEDs may be of different wavelengths, operating in unison at different power levels will yield a variable light "color". A possible combination of two or more LEDs such as a blue, 470 nanometer and an amber **590**, nanometer wavelength LED would yield a "white" light similar to the yellow tint of sunrise at the correct power intensity setting for each lamp. Coincidently aimed LEDs **275** and **277**, at the correct output intensity of each LED, with more power in the amber will accomplish this. Thus, when following another vehicle, assuming, as drivers have reported, that they find yellow incandescent colored headlamps less offending than the

HID blue-white color, the external controller **279** which receives traffic data from sensors **280** would shift wavelength specific radiant power contributions of SLSs such that the resultant on the CIE chromacity diagram would be yellowish. If, however, there is no car immediately ahead or oncoming traffic, then assuming as drivers reported they see further with bluish light, then the energy of the 490 nanometer LED is increased, and the resultant color will shift to bluish white, allowing the driver to better ascertain road conditions further up ahead. The LEDs, their packages, wavelength and light source type are mentioned by way of example and it is clear that any other types of discrete light sources, such as the chip **95** of FIG. 6, with differing aimings wavelengths and distributions could be used to accomplish the same functions.

[0225] To further illustrate the innovative DLF headlamp device, a cluster **281** would be used to illuminate around a corner. Thus, when the turn indicator has been selected or the steering wheel has been rotated by the driver, the DLF headlamp is powered by the controller to illuminate sideways at angles which according to the speed of travel is correct. (A driver can't make a 90-degree turn traveling 90 km/h but from a stop, the turn may be around a corner.) In a preferred embodiment a multitude of LEDs in **281** are differently aimed in top view **274** showing the top view of the cluster **282** with SLS **283** angled less outwards and SLS **284** angled more outward with the forward aiming (distance ahead of the vehicle) of the more angled SLS **284**, closer in for illuminating sharp turn, than that of the less angled SLS **283** for a shallow curve. Side sectional view **273** shows a general downward aiming with SLSs of front view **272** cluster **285** corresponding to cluster **286** shown from the side. The cluster **286** is the most angled downward such as for a slow driving as in a parking light type of application where the idea is not to cause glare yet to be seen. The parking light function can also be done with higher angled LEDs by just lowering the intensity to very low non-glaring intensities. Cluster **287** of the front view would be the main illuminating workhorse and is shown in side view **273** as angled SLSs in cluster **288** and top view **274** as cluster **289**. The top cluster **276** shown in side view **273**, as **290** would perform alone or in tandem with part of **287** the high beam lighting function.

[0226] Many more degrees of flexibility are possible with the digital headlamp by varying the timing of the LED operation. For example, more intense illumination of red LEDs for a fraction of time would give the effect of flashing ambulance lights if required by the type of vehicle and could be effected by programming alone without the need for a different type of headlamp greatly reducing the different types of headlights that need to be installed on a vehicle or maintained in inventory. That is

the same MSLS light engine device could be placed in different aesthetic packages by different manufacturers and could provide different functions. In one embodiment the digital headlamp carries out all the functions in a single unit **270**. SLSs have different locations and aimings **291** and **292** to carry out the functions. In another embodiment **293** the spotlight sign illuminating function or corner lighting function is in a separate package **294** with its aiming **295**. The low and high beam lighting is accomplished with fixture **296** and its general aiming **297**. The separate units may be dictated by design or sales considerations and yield more flexibility but are within the scope of the overall integral digital lamp headlight device. The controller **279** will addresses the power supply of each DLF headlamp **270**, **296** and **294** independently such that each lamp performs its functions separately.

[0227] In another embodiment FIG. 16 the digital headlights **300** and **301** on vehicle **302** are also part of an anti-glare system operating between two or more vehicles **303**. The system is designed to prevent discomfort and disability glare from oncoming headlights or glaring headlights viewed in the rear view or side mirrors. The anti-headlight-glare system works based on the "persistence of vision" of the human eye-brain system and is accomplished by the synchronization of the illuminating and light attenuating or blocking devices which intermittently enable the driver to see the night scene ahead but not the counter-timed glare of oncoming vehicles. The elimination of blinding glare will increase traffic safety, as a driver may lose vision may for a number of seconds following a glare event. It will also prevent driver fatigue caused by glaring headlights. Another of the advantages of the anti-glare system is that it increases the distance that a driver can see at night by allowing the use of more powerful headlamps aimed at higher angles, thus illuminating more of the road ahead while not blinding oncoming traffic. The anti-glare system consists of pulsed headlamps **304** and **305** on the oncoming vehicle **303** and a synchronized on/off switched light filtering or blocking element **306**A in between the driver's eyes **307** and the glare sources **304** and **305**. The light attenuating element is normally highly transmissive of light i.e., see-through. When energized, the light-attenuating element turns non-transmissive and attenuates or totally blocks the glare intensity. The attenuating element is similar in operation to the fast-acting automatic darkening welding helmets commercially available, only here the off switching is also very rapid. The glare, or light-attenuating element may be the windshield, a part of the windshield be a specific element located on or within the windshield **306**A and **308**A or on a visor located in front of the driver shown in **306**B and **308**B. The light attenuating device **306**A or **306**B is synchronized with the oncoming headlight such that when low-beam or even

high beam, glare causing headlamps **300** and **301** of vehicle "one" **302** is "on" the light attenuating device **308**A or **308**B on vehicle "two" **303** is toggled into a mode which reduces or totally blocks the light beams. Conversely, in the next instant, when the headlamps **304** and **305** of vehicle "two" **303** is "on", that is, in the glare causing mode, the light attenuating device **306** on vehicle "one" **302** is switched into a mode, which reduces or totally blocks the light beams. The light-attenuating device **306**A or **306**B consists of an LCD, ferroelectric, SPD, electrochromic or any other medium that can be switched between substantially light transmitting to substantially light blocking in the form of a screen, visor or film. It may be placed on the windshield from without or within, in between the glass layers of the windshield safety glass **306**A or positioned anywhere in between the driver's eyes and windshield **306**B including being worn as eye glasses. A motorcyclist would have it installed in the visor of the helmet or on a windscreen. The speed of vision is slow relative to electronic pulsation and depending on the illumination level persistence of vision will fuse on/off levels into a constant flicker free level. Motion pictures operate at 24 frames per second. For scotopic nighttime levels 10 HZ is sufficiently flicker free while at high levels of illumination 60 Hz is required. Totally flicker-free operation is assured at 120 Hz operation even for peripheral vision which is more sensitive to movement.

[0228] LEDs are excellent light sources for a pulsed lamp since they are not damaged by on/off cycling (actually off-time adds to the overall lifetime) as are the prior-art incandescent and other cathode-based lamps. Rise time to full output is on the order of microseconds, much faster than necessary. The pulsed SLS is operated at a higher power during the on-time of the duty cycle to offset for the off-time in order to produce the required illumination. This is typical of normal LED operation which may be run in DC mode or pulsed, AC operation. Actually, HID lamps cycle on/off at twice the line frequency and the eye integrates the light intensity over time. However, it should be understood that incandescent or any other lamp switchable within the constraints of the flicker free visual requirement are acceptable for use according to the teachings of this invention. In an alternative embodiment, the lamp may be a state of the art incandescent, halogen or HID lamp and the switching is accomplished by an additional light-attenuating element placed in front of the light source. Alternately, electronic signal control circuitry can rapidly switch an HID or incandescent headlamp used in the anti-glare system. The lamp need not totally turn off, the requirement is that during the seeing portion of time when the driver's light attenuating element is letting light through un-attenuated,

the light intensity reaching the eye is non-glaring. Therefore, it shall be considered that present state of the art incandescent and HID headlamps operated in a pulsed mode fall under the realm of the present invention. That is, any headlamp system where the high beam is toggled such that it is synchronized with a light-blocking element before the driver's eyes in the approaching vehicle is included within this disclosure. It is also to be understood that the headlamps when not in high beam mode may not be totally off rather they can be in a non-glaring low beam mode. This leaves the vehicle visible to oncoming traffic.

[0229] It is to be understood that for the system to work, all oncoming vehicles using high beam synchronized blocking must be working according to the same timing among them versus all the traffic headed in the opposite direction. A timing protocol based on major heading determines the synchronization. Thus, on a substantially north south route, a train of traffic headed north will all be similarly timed, and counter synchronized with all southbound traffic. The blocking screen's timing is synchronized with the oncoming high beam headlight's timing either universally, through a global clock system such as that of the global positioning system GPS or the National Institute of Standards and Technology atomic clock broadcast over radio station WWVB located in Fort Collins, Colo. or locally through communication among vehicles in proximity to being within the line of sight. A combination of directional data together with a timing protocol based on direction will determine the synchronization among proximate north/south and east/westbound vehicles. The vehicles direction data is derived from an onboard compass or gyro or GPS to eliminate the influence of roadway curves in cases of borderline directionality, the vehicle's direction for synchronization is not the instantaneous reading but rather is based on distance traveled over time and previous headings history. A stop and turn for example will change the synchronization while a smooth curve will wait for an oncoming cars synchronization to indicate that the road ahead is actually in a new heading unless sufficient elapsed time makes it clear the car is on a new course. The protocol will give benefit to the north on a 45 degree North/East heading and to the south on a 135-degree heading. GPS location and route recognition can also be used to set synchronization protocols for opposing vehicles. In one embodiment, the communication between vehicles for synchronization is effected through the headlamps themselves either through modulations in visible light LEDs of the digital headlight itself or with LEDs, radio or infrared emitters dedicated for the purpose **173**. Detectors **174** on the vehicle,

pick up the signal and signal-processing equipment passes the information on to the controlling unit **175**.

[0230] Glare attenuating elements can be placed over the mirror surfaces or the side windows where the glare from the side mirrors passes. Thus, not only the glare from oncoming headlights through the windshield is blocked but also glaring beams emanating from following vehicles, reflected off the rear and side view mirrors is controlled. To eliminate glare off the mirror **176** from reaching the driver's eyes from the side mirrors **177**, a pulsed blocking screen or film **178** is placed on the driver facing side of the mirror's the reflecting surface. Similarly, a rearview mirror **179** is embodied with a pulsed blocking screen or film. The timing of the modes in this instance is such that the light-attenuating mode occurs at the same time as the glaring or high beam headlamp mode since all cars in the same direction are in glaring mode at the same instant. All mirrors are synchronized to block the headlight glare coming from the rear which are on at the same synchronization time as that of the first lead vehicle in the traffic train.

[0231] In another embodiment additional information used to control the headlight aiming can come from analysis of the driver's eye movement and gaze. The headlight aiming system obtains information from a driver eye tracking system concerning the driver's gaze (i.e. what the driver is looking at). Analysis of saccade can be used to instantaneously predict where the driver will end up looking and the headlight intensity in that aiming changed to illuminate the area where the driver wishes to see in advance of the driver's re-accommodation. A machine vision system using pattern recognition and other object identification techniques to discern eye gaze direction, is contrived of the camera **316** with a view of the driver's eyes, infrared emitters **317** and the computer logic system **311**. The data obtained is analyzed according to eye tracking methods and algorithms known in the art of in a computer routine **7**A to adjust the light aimings of the headlamps according to the drivers gaze at required intensities. The allowed intensities at any aiming take glare considerations into account so as not to cause offending glare. In another embodiment an outward and inward facing camera **316** is used to acquire both images of the scene ahead and the driver's gaze and using both sets of data adjust the headlamp illumination.

[0232] Accordingly, it has been illustrated in the streetlight and headlamp application the benefit of a multiple-light source illuminating device. The flexible characteristics of the DLF allow

for spatial variations of the intensity and spectral power distribution of the light over the area covered. When the element of variation of intensity and SPD with time over the area covered is introduced another dimension of flexibility is introduced. These properties are unique to the DLF and allow them to deal with dynamic lighting situations in a way not afforded by prior-art lighting devices. When combined with devices capable of detection changes in the surrounding environment the flexible DLF is capable of changing the illumination so as to provide the optimal lighting solution in real-time.

[0233] FIG. 17 illustrates a power supply circuit used on a DLF such as the Surface or Railing Mount Discrete **66** or Distributed **70** Digital Lighting Fixture of FIGS. 4 and 5. The circuit controls current and illustrates the use of two disparate LED sets one red colored with specific voltage and current characteristics and the other green colored with its own voltage characteristics. When operated in this quanta and regime of voltage and current the combined output light is whitish in color according to the earlier teachings of this disclosure.

New Preferred and Additional Embodiments

[0234] Referring now to the invention in more detail, in FIG. 18A there is shown an illuminating or irradiating device which is capable of being adjusted in situ to match the radiation output with the actual illuminating requirements of the surround where the lighting fixture has been installed. As an example, the device is a lighting fixture and the installation is in a chemical processing plant which is an open facility with piping and vessels placed in the structure with walkways, floors and stairs made of metal grating. The walkways, vessels, machinery and piping need to be illuminated at night by lighting fixtures placed on the structural support uprights along the walkways. In this lighting application example, the walkways are at the exterior edge of the structure with the piping and machinery towards the interior. Beyond the walkway safety fence there is no structure and no need for illumination. The spatial light distribution pattern of the lighting fixture shown in FIG. 18A can be arranged so as to illuminate inwards towards the vessels, machinery and piping as well as downward along the walkways and stairs but not outward into free space.

[0235] The lighting fixture **410** is comprised of light sources **411**. The multiple light sources are referred to as LEDs, Light Emitting Diodes which is but one type of exemplary light sources used herein. Light sources referred to in this disclosure include any of a wide range of visible and non-

visible electromagnetic radiation emitting or generating devices formed from organic or inorganic semiconductor materials such as LEDs, organic light emitting diodes, OLEDs and all gaseous high and low intensity discharge lamps, incandescent filament and other solid-state light sources. The light sources **411** shown in FIGS. 18A and 18B have means to be coupled with apparatus for modifying the light output of LED chips or arrays of chips **412** such as a reflector **413** which yields a symmetric light distribution or an asymmetric reflector **414** which yields a substantially asymmetric light distribution. An optical lens or light guide **415**, or other refractive or diffractive device may be used to modify the light output as well as phosphors or filters within the light guide **415** which may be used to add or filter out certain wavelengths. The spatial light distribution of the light source refers to the luminous flux emanating from the light source **411** at various candle power intensities as a function of the angle. The light source **411** has a characteristic angular light distribution **416** also called herein beam spread and when installed on a lighting fixture attached to the building, object therein or lighting pole with a specific orientation in the surrounding living space, the beam axis **417** will have a particular aiming towards surfaces within the living space and therefore the light source will illuminate only the specific surfaces it is intended to fall upon. In an embodiment of the invention a light source module **411** is comprised of the one or more LED chip **412**, optical modifying device **413**, **414**, or **415**, a heat dissipative element **418** such as a heat sink and a physical and/or electrical connecting element for the LED chip **412** such as a printed circuit board **419**. In one embodiment a very narrow beam laser LED is mounted in the array of chips **412** such that it shines along the optical axis of the light module **411**. In an embodiment of the LED the beam spread has been determined on the die level without the need for additional optical modifying devices as part of the light module **411**.

[0236] A preferred embodiment of the invention is a lighting fixture comprised of many light sources of which some or all can be separately aimed and powered so as to illuminate areas, surfaces or objects in a room in a most correct, efficient and comfortable manner or for a desired lighting effect. The overall luminaire **410** spatial light distribution at various angles is comprised of that of the individual light sources. Thus, when the multiplicity of light sources having their respective light distribution patterns, which are substantially directional and subtend lesser angles than those of the overall light distribution pattern are mounted and arranged on the lighting fixture structure their respective directional light distributions combine to form a wider overall light fixture distribution pattern. The overall distribution pattern is efficiently formed directly by the multiplicity of light

sources without recourse to inefficient reflectors or refractors. Using a goniophotometer to measure over space the emanating light intensity in the various directions one obtains the overall spatial light distribution pattern of the luminaire **410**.

[0237] Using commercially available LEDs such as the Artavi 10° product from Illumitex which offers 90% of the light output in 10 degrees of the beam, it is possible to generate well controlled light distribution patterns with minimal spill light. Thus, the Coefficient of Utilization (CU) or the utilization factor of the luminaire is high. That is, the ratio of the luminous flux (lumens) from a luminaire received on the work-plane to the lumens emitted by all the luminaire's light sources alone. The Illumitex LED package emits light in a uniform, highly-precise beam directly from the source. The result is that with die-level optical integration, the need for cumbersome and inefficient secondary optics to control light is obviated. Using well defined light beams to illuminate the area allows for the floor surface in the distant corners of a square room to have the same illuminance as the floor at the nadir, directly beneath the luminaire. This results in high uniformity which is a measure of variation of illuminance over a given plane, expressed as either the ratio of the minimum to the maximum illuminance or the ratio of the minimum to the average illuminance and a measure of the energy efficiency of the luminaire system.

[0238] In order to alter the spatial light distribution, the lighting fixture **410** has apparatus such as joints and flexible electrical connections giving it the ability to morph or change shape. That is, by the alteration of fixture geometry, moving structures or arms on which the light sources are mounted or by changing the LEDs' refractor or reflector geometry, the direction of the light emanating from groups or even individual light sources is modified so as to generate an overall site specific light distribution pattern. For example, LEDs are mounted on moveable luminaire structural elements such as the end of posts, on bars or curved arms which can be adjusted to provide various symmetrical and asymmetrical illumination patterns as the installation requires. In the lighting fixture **410** the arms, such as arm **420** has apparatus to swivel around the central support post **421**. In an embodiment of the invention control electronics **422** have electronic means and circuitry configured to provide different power levels to LEDs or groups of LEDs such that the light intensity in any given direction and angular aiming may be varied as needed. In an embodiment of the invention the power supply and control electronics **422** are further defined to provide power only in the amount needed using a logical controller **428**. Controller **428** performance can be further enabled with sensor **429** providing

information about the surroundings. The resulting light fixture embodiment described is thus a Field Adjustable Multiple-light-source Luminaire or FAML.

[0239] Thus in FIG. 18A the beam spread **423** of LED **411** differs from the beam spread **424** of a LED light source **425** which may have a wider area from which the light exits so that its higher angled light output will not be as bright so as not to cause glare. An accessory reflector **426** may be used to shield from glaring rays. The method disclosed for reducing the glare from concentrated high luminance light sources is the use of light guides to reduce the luminous emittance or luminance of a very bright LED. Light guides using the principle of total internal reflection redirect the light. They may in addition be used to increase the area from which the light flux is exiting and thus reduce the luminance or luminosity of the light source.

[0240] FIG. 19 shows a light guide which can be used to redirect the light from a light source and/or increase the area from which the light is exiting in order to reduce the apparent brightness. The light guide is constructed of a transparent material with an index of refraction greater than that of air. The light guide **430** will accept light rays emanating at large angles away from the beam axis and bend the rays to smaller angles from the axis thus producing a narrow beam. Light produced by the LED **412** at various angles enters the aperture **431**. The light then bends as total internal reflection contains it within the walls of the curved light guide and exits from the light guide at surface **432** with a different aiming. More than one light guide can be used and when stacked light exiting the light source at different angle can be directed outwards at different angles or the same angle. Light guide assembly **433** is shown with two light guides stacked but many similar or different beam modifying characteristic light guides can be stacked for a unique total light distribution resulting from the source. Thus in FIG. 18B the optical device **415** can be a light guide assembly **433** as shown in FIG. 19 which has been added over a light source in FIG. 18A aimed at a potentially glaring angle as shown covered by the light guide assembly **433**. The exit surface **432** may be a lens, a Fresnel lens or microlens whose optical features enable precise control of uniformity, exit angle and beam spread. In addition, any of the surfaces may be covered with optical substrate or films to reduce light loss on entry or exit, frustrate the total internal reflection or filter or control the light. Light guides may also be asymmetrical.

[0241] In an alternate embodiment when using a single light source in a FAML yet an asymmetric spatial light distribution is desired, light guide assembly **434** made of light guide segments

435 is designed take light from the single light source and spatially differentiate its delivery to different parts of a room. For example, if the light fixture light source is located on the ceiling in the center of a square room and the assembly **434** is turned over so the light exits downward; then when the light exits the surface **436** with a Lambertian distribution and the segments are aimed in the direction of the corners of the room, a substantially homogeneous illumination can be obtained on a work plane near the floor in the square room. More than one segment of assembly **434** can be stacked and light guides with different light exiting directions can take the light of one light source and symmetrically or asymmetrically distribute over an area. Combined with reflective control elements **437** added within, upon the surface or external to the light guide further light control can be achieved.

[0242] While light guides are known for their ability to carry and redirect light, in this disclosure another novel embodiment of a light guide used as a light control device is its use to increase the area from which the light from the LED is exiting from thus reducing the light source luminance or glare. In an embodiment where the inlet aperture **431** cross section is small and the cross section of the light guide exit surface **432** is large there will be a significant reduction in the light source luminance and it will appear less bright and cause less glare to persons viewing it. Thus, while persons in a room would find high brightness LEDs disturbing it is possible to add optical devices that while maintaining the directionality of the illuminating beams spreads them over a larger area thus reducing the luminous emittance.

[0243] The Spectral Power Distribution of the luminaire refers to the distribution of light energy emitted by the light source arranged in order of wavelengths. In an embodiment of the invention the LED chip **412** is made of many separated LED chips or LED array. The array of semiconductor LED chips or dies **412** are of the same material and have a similar wavelength or are of different composition and produce a variety of wavelengths. In an embodiment the controlling power circuitry **428** is connected independently to each chip. The result of using differentiated composition chips **412** or phosphors with them is that the light output is a mix a various wavelengths of light and therefore of variable chromacity. Thus, a warm color temperature of lighting can be produced as well as a cool daylight color temperature. Thus, when the light sources that make up a light module **411** are not all producing the same color spectrum or wavelength, the luminaire's chromaticity, spectral power distribution or spectral light distribution is alterable by the controller **428** via driver **422** energizing to a greater or lesser degree the individual light sources. These light sources may be substantially

monochromatic or wide spectrum with different wide SPDs and monochromatics complementing each other. Using the principles of additive color mixing of light sources to control the change in chromacity via the differentiated powering of coincidently aimed light sources, the luminaire produces a unique spectral light distribution having a certain color temperature and/or color rendering index of light at all or any particular aiming.

[0244] For example, the curvilinear light guide **430** can be used to combine different colored LED chips **412**. Thus if 3 different colored LEDs were stacked and their light entered into one or more light guides the light guides will re-orient the light and aim them in the same direction whereupon they will mix. The mixed light when falling upon a surface and reflected to a person's eye will generate a uniquely observed color lighting effect. When phosphors are added to the light guide material other chromaticity may be generated. Thus, a blue LED could generate one color temperature with one light guide and another color temperature in another light guide. If the guides are co-directional the colors will be mixed. Physical movement of the inlet aperture from one light guide of particular phosphors to another would then serve as a way of changing the correlated color temperature, CCT and/or color rendering index, CRI of a light source. Thus, an active way of controlling the spatial and spectral output of the LED light source **411** is to reposition the light guide apparatus **433** or **434** thus changing the angular or spectral characteristic of the light modification.

[0245] Individual bars or arms **420** by their structural geometry determine the aimings of the light sources mounted on them. Thus, using Lambert's cosine law and the inverse square law the arm geometry is designed such that more luminous flux can be directed to surfaces further away or surfaces at greater angles to the incident light to achieve a more homogenous light distribution. In addition, when mounted in a living space the arm **420** can be rotated into a better aiming in order to optimally illuminate the area. Thus, as a principle teaching of this invention the light sources attached to the arms have already been given the capability of generating a unique spatial distribution pattern in the factory set format. Most importantly, this preset distribution carries though to the homogeneous illuminance of room surfaces even after specific installation adjustment requirements have been made.

[0246] After adjustment the position of the arm can be input into the controller **428** or the camera **429** can be used to determine the lighting effects produced by the new arm arrangement. This calibration is accomplished by energizing a light source or array of light sources and reading the with

the camera sensor array the luminance values off the surface. Comparing the new results with prior control luminance values at known power settings the present luminaire configuration is determined. A reference sheet of known reflectance is placed on surfaces to aid in the re-calibration. Alternately, the prior stored reference luminance values are for a number of surfaces of different reflectivities allowing the controller to guess from the surface at hand which reflectance model is a best fit. The data stored in the controller **422** can now be used for applying recommended lighting practice to specific lighting application or lighting tasks that luminaire is called on to perform. Herein this disclosure, a logical controller executes instruction sets based best lighting practices as recommended by lighting engineers and published in handbooks such as the Illuminating Engineering Society of North America IESNA and standards such as ANSI or CIE. The latest by the IESNA is the 10th edition ISBN-13: 9780879952419, Publisher: Illuminating Engineering Society of North America that has numerous recommendations and best practice standards specifically related to LED lighting. The specific location lighting task information or programming may be manually input to the luminaire controller via an input device such as a keypad or be remote input controller using infra-red communications or other wireless device using a communications system such as, Wi-Fi, Bluetooth™ etc. communicated via a computer or smart-phone or via a speaker microphone system. To determine lighting requirements in an area based on usage and characteristics of the users, the controller uses a speaker to communicate queries from a lighting specification questionnaire and receives audio response processed by a voice recognition software application as input for the purpose running the lighting design algorithms.

[0247] FIG. 20A is a perspective view of an embodiment of a modular industrial lighting fixture with the addition of another adjustable arm **420** where the same LED driver electronics **422** are capable of powering additional arms when added or not powering them when they are subtracted such as in FIG. 20B. The arms **420** are rotatable so that they may be concentrated at a specific aiming so as to produce higher illumination intensity in a specific area. In an alternative embodiment the driver electronics are modular in concert with the light source arms **420** such that when an additional arm is added an additional plug and play driver module is added as well with full communications and hookup capability to the logical controller **428**.

[0248] An example using a FAML in an industrial, commercial or house lighting application may be a hallway lighting function. An embodiment of an asymmetrical lighting fixture shown in FIG.

20B with two arms **420** at 180 degrees with light source modules **411** laid out on the arms at higher angles to illuminate along the hallway will do a more economical job of illuminating then would the four armed symmetrical luminaire of FIG. 20A. The light sources illuminating the hallway at higher angles from the nadir may have large areas to reduce the luminous emittance to comfortable, non-glaring levels using optical light guides such as **430** to increase area while maintaining directionality. When the camera sensor element **429** detects people entering the hallway, the logical controller **428** increases the power driving the LEDs and the lighting intensity is increased from zero power or some low level of lighting sufficient for orientation purposes to full level. After the person has passed under the luminaire the LEDs on the approach side can already be dimmed again saving power. It is to be understood that the luminaire embodiment of FIG. 20B is only showing the practical operational elements. Obviously, when used as a home hallway lighting fixture, additional aesthetic elements can be added to improve the fixtures artistic appeal.

[0249] In an embodiment of this invention the adjustments to the light output distribution, intensity and chromacity are made automatically by the logical controller **428** operating per programmed instruction sets based on data supplied by sensors regarding living space geometry, environment and contents including living beings. Such sensors **429** use sound or electromagnetic radiation to measure distances to surfaces within the intended design illumination range of the lighting fixture. An embodiment of the invention uses as a sensor an electronic camera with a lens **427** allowing it to view the surroundings. Natural light sources or light sources on the luminaire firing at known timings and chromacity can be used with the sensors **429** and logical controller **428** to determine distances, movement, reflectance, surface colors and other information about the surroundings during set up and in real time. The camera chip transfers the image information to the logical controller. Using real time image processing methodologies with image and scene recognition technology known in the art, room or outdoor area elements, objects and people are identified. Using face recognition techniques an individual may be identified and personal lighting preferences or functions can be provided by the luminaire. The controller being programmed to illuminate people, objects and surfaces according to best lighting practice or user preferences then manipulates fixture elements to adjust the lighting to meet the standards or personal preferences. In addition, the computer vision can recognize the visual task being performed. The logical controller **428** then uses control of the power signal to the LED to provide recommended practice light intensities.

[0250] Light entering the digital camera **429** through its lens **427** is converted into electric signals by a CCD or CMOS image sensor. The lens can be an optical lens or a wide-angle lens or a Fresnel lens giving the sensor array a view of the area illuminated by the lighting fixture or a wider area covered by a group of lighting fixtures under control of the logical controller. More than one camera sensor **429** with different areas of coverage can be used if more accuracy is required for image processing. The processor based control system for illumination has stored data and programs for driving the LEDs at the correct levels in order illuminate according to recommended lighting practice and stored algorithms which it uses to process pattern recognition, image recognition and other computer vision methodologies known in the art to recognize a particular object, surface or individual as well as distances to surfaces, their color, reflectance and the geometry of the environmental surround. The same image recognition camera may be used as the luminance meter or a separate light sensor may be employed. A further capability of the digital lighting fixture using image recognition methodology known in the art that it can recognize the individuals and provide personal preference lighting conditions or determine the optimal lighting parameters as required by their age. A processor-based control system for illumination having stored data and algorithms which uses image recognition algorithms to recognize a particular individual. Using image recognition algorithms and artificial intelligence techniques known in the art, based on the appearance and movements of the occupants, the camera vision system will automatically guess their age and sex. The processor runs the computer vision routines to determine an occupants age or sex and sends instruction to a building's utility devices to provide individualized services such as heating and lighting on basis of age or sex.

[0251] The personalized control of the illuminating device or other appliances in communication with the controller can be effected by using a brain-computer interface, (BCI, often called a mind-machine interface (MMI), or sometimes called a direct neural interface or a brain-machine interface (BMI). Using apparatus to read brain activity, a direct communication pathway between the brain and the external device can be effected. The BCI can be combined with the computer vision system having knowledge of the surround to help the controller relate the brain activity to the visual aid required to carry out the desired function. For example, in an automotive application the brain activity related to eye saccade can replace eye gaze tracking in knowing where the eye desires to see next and illumination can be provided on time, in advance of the visual task to be performed next.

[0252] The sensor **429** can be an LSI chip enabling high-speed processing of the generated image data by a digital image processor function within the logical controller **428** using algorithms known in the art for motion, scene and/or face detection. From these signals the logical control affects lighting changes as needed to perform visual tasks or create ambiance. The sensor and transducer pack **429** is sensitive to a wide range of electromagnetic or sonic pressure variations and has means for determining luminance, temperature and humidity. The logical controller **428** having communications capability can transfer information gained from the sensor pack **429** to other home automation networks or it can supply information to other home heating, cooling, security, lighting and host of other appliances. With a view of the front door the luminaire sensor can serve data to the home automation network on whether someone has entered of left the house.

[0253] In a preferred embodiment of this invention the lighting fixture is equipped with a camera vision system comprised of the digital camera **429** and logical controller **428** having computer algorithms for performing computer vision and has the capability of identifying the eyes of occupants in a room (this is similar to present day face detect mode used in digital camera technology such as a Canon PowerShot SD900, where the processor face recognition identifies the triangle of two eyes and a nose and focuses automatically). The camera vision system is capable of detecting glare causing visual discomfort on the eyes of room occupants caused by the lighting fixture and the logical controller will accordingly reduce the intensity of the illumination reaching the eyes from the responsible light source. The camera vision system can detect the glare by assessing the amount of light reflected back to the camera from the eyes of room occupants and determining on the basis of a scale, such as the de Boer rating scale for discomfort glare, whether or not glare is occurring. Alternatively, the logical controller **428** upon detecting eyes will set the light source intensity shining in the direction of the eyes to a level that will not cause glare.

[0254] In addition, the camera vision system **428** will prevent the lighting fixture **410** from producing veiling reflections on objects such as glossy magazines or computer screens. Using machine vision technology known in the art such as neural networks training and other pattern recognition techniques the vision system has sensor, algorithmic and computational means for identifying devices or objects. Using lookup tables to identify a possible veiling glare situation in the user's field of view the logical controller **428** adjusts the lighting by providing illumination from a different angle such as

beaming light off the ceiling in place of direct lighting and/or altering the intensity of the direct lighting.

[0255] Actual vision and perception is not only a function of the illuminance falling on the object being observed but also of the luminance of surfaces in the surround, spectral distributions of the object and background and the general illuminance level to which the eye has adapted. Veiling luminance and veiling reflections may even be as interfering so as to disturb the ability to see. Described is a method of using an embodiment of multiple light source lighting fixture of the present invention with finely controlled light delivery to assist people to better see objects or carry out visual tasks such as reading. The method comprises altering the intensity and/or color of the illumination delivered to the task versus other surfaces in the visual surround (that is they are in the viewer's field of view) such that the luminance of the object, the luminance of the background, the contrast and the veiling reflections are controlled so as to produce optimal vision conditions. To accomplish the spatially differentiated light delivery to the object of the visual task such as a book or computer screen the light sources to produce task lighting have multiple, narrow beams with minimal spill light. The limited coverage area of each beam and sharp cutoff is such that the lighting fixture controller can target a book while not substantially illuminating the desk. Other light sources illuminate the desk and other surfaces in the visual surround at an optimal background level luminance. The background level is determined by factors such as whether it is an office environment where others are present, and a dark office is unpleasant or if the reading is at home and a lower background can be tolerated.

[0256] With the eye recognition capability, the lighting fixture can, irrespective of the glare consideration, lower the illumination in areas where eyes are not looking thus saving power. Thus, as in the FIG. 20B hallway lighting application the logical controller upon identifying the occupant's eyes can illuminate at higher intensity the areas forward of the occupant in their field of view but limit light rays to below the eye level and dim the areas not in the visual path of the occupant. The same capability for dimming is available in many other lighting applications such as in other rooms in a house, warehouses, stores, factories as well as outdoors. In sports lighting glare can be eliminated by the controller **428** following the ball and calculating which light sources **411** are adding to vision and those which are detracting and reducing the intensity of those detracting. Thus, the lighting fixture **410** provides illumination in real time only where people need it to carry out visual tasks while the illumination in other areas is off or dimmed to comfortable or aesthetic lighting levels.

[0257] An alternate embodiment of the FIG. 20B fixture used in a highway lighting fixture application having a camera vision system has controllable light distribution and logical means for providing illumination based on the vehicle's position in relation to the lighting fixture **410**. In low traffic conditions in order to save energy used for lighting, the controller **428** using stored algorithms increases illumination with the approach of a vehicle and changes the beam cut-off levels as the automobile advances towards the lighting fixture to eliminate glare from the driver's eyes. It then dims the lighting after the vehicle has passed and is no longer useful. When multiple vehicles are presents the operating regime changes to illumination from the adjacent luminaire located behind the vehicles. By using communication between the luminaires **410** the optimal lighting regime is coordinated between them.

[0258] In a preferred embodiment the illumination device **410** of FIG. 18 with computer vision capability, also having means for communications with other devices and human factors engineering algorithms that allows it to predict in certain situations what a room occupant is interested in doing, has wired or wireless electronic communications apparatus for communicating the information it obtained via the camera for actuating or closing other devices. For example, a person sitting down in front of the TV can have the TV turned on automatically and have heating concentrated on that area of the house. The camera-based lighting system via a central logical control unit or the home computer inputs data on the house occupants' whereabouts and aids in the control of house lighting and heating and cooling. Thus, the lighting fixture **410** communicates data and integrates with intelligent home automation systems as 1) it provides an ideal location for the sensors which includes any of sensors **429** for: temperature, humidity, motion and artificial vision and 2) the smart illuminating device **410**, itself which has a logical controller **428** capable of communicating with and being controlled by the automated home network.

[0259] The lighting fixture being the world's most ubiquitous device serves as the ideal platform for simple and intelligent camera vision systems for use in home, commercial, outdoor and industrial facilities control systems to the end of surveillance, control of the use of energy and supplying people with sound, lighting, heating, cooling and fragrance. A lighting fixture is almost always installed in any living space, from work spaces to entertainment spaces and an infrastructure of power lines and often data lines are already installed to them. Thus, a lighting fixture is ideal as a platform for sensors, transducers and detectors. It is also ideal as a platform for delivering lighting,

sound, radiated heating and the dispersion of fragrance. For example, a multiply placed speaker sound system for providing a listening experience upon receiving from the camera's information on the users' whereabouts can better tailor the sound delivery based on their location as in known in the art thus enhancing the sound experience. Computer recognition of the person/s in the room can call up from memory the users individuals listening and sound setting preferences. A fragrance system will provide aroma based on room occupancy and location if there is apparatus in the fragrance system for delivering fragrance to separate areas of the room. Again, here a computer recognition of the individual can tailor the type of fragrance.

[0260] In an automated embodiment of the invention the light sources **411** and **425** are mounted on moveable elements **420** having actuators or motors that are controlled by the logical controller. The automatic mechanization of light source supporting fixture parts allows for the direction of the light output to be altered by the logical controller thus enabling the luminaire to perform better in the specific lighting application where the fixture **410** has been installed. This may be a onetime rearrangement of the light source aimings or may be performed in real time as the lighting requirements in the living space change. Similarly, based on changed parameters in the surrounding, the logical controller **428** adjusts as required the light intensity in any direction and/or the chromacity. Thus, hereby we have demonstrated the systems unique lighting agility and energy saving capacity where the controller **428** can affect a dimming function based on factors in the surrounding such as the real-time sunlight contribution within parts of its coverage area, the amount of people in the room or the density and positions of cars on a highway.

[0261] FIG. 21 is an alternative embodiment of a field adjustable multiple light source lighting fixture **440** with light source modules arranged in a substantially linear form. Thus, light source module **441** may be aimed towards the nadir while light source module **442** is aimed sideways to illuminate a different area off to the left. Light source module **443** is aimed at a higher angle from the nadir and illuminates a third area. The modules are connected mechanically and electrically to each other and to the power supply **444** and logical controller **445**. A different configuration is affected by changing the angle between modules on joint **446** which is capable of bending in the x and/or y direction. Detents and/or markings are provided on the joints **446** indicating different angular settings. Thus, instructions for each joint's **446** setting can be given to the homeowner or lighting fixture installer by a lighting design computer program known in the art. The light sources are specified and

the room dimensions are entered into the program and the light source aiming angles are specified for the FAML **440**. Whereas, in a special aiming configuration with light sources directed at different aimings, an even or homogeneous light distribution will be affected over the area under the fixture, the light fixture can be rearranged so that all the light sources are aimed in the same direction and thus a distribution similar to that of a single light module's own spatial light distribution will be obtained. Thus, if the light module light distribution is narrow, and they are all aimed in the same direction a spot light distribution will be obtained from the fixture **440**.

[0262] Alternatively, the LEDs can all be aimed at the ceiling or objects on the wall for an indirect lighting effect or soffit lighting effect. Alternately, some LEDs can be aimed in the same direction and others at differentiated aimings obtaining both a spot and flood light distribution from fixture **440**. Light source modules can be added to the chain or detracted depending on the lighting application. In addition, the light source modules can be enclosed in an aesthetic enclosure **447** hiding the actual light source modules. As shown in FIGS. 18 and 20, the embodiments are depicted in their practical light engine form with the skeletal light source support structure. It is clarified that the skeletal support structures in the luminaire embodiments presented may be embellished with outer enclosures of a more aesthetic nature. The only requirement is that the outer structure does not interfere substantially with the light and heat transfer from the light engine outwards. Thus, the disclosure has shown a FAML that can be agile in meeting differing illumination requirements, aesthetic and energy efficient in providing illumination in a specific lighting application.

[0263] The unique approach of this multiple light source luminaire invention over previous art luminaires is that in prior art, even when many LED sources are used the spatial light intensity distribution output of the luminaire is determined by the primary or secondary optics on the light source. Whatever light distribution there is emanating from the light source that is the light distribution of the luminaire. In this invention the overall light distribution of a single luminaire is comprised of many smaller light distribution patterns. It could be argued that a track lighting luminaire with its multiple light sources is such a fixture. As opposed to a dispersed track lighting luminaire used to spot light specific areas spread in a room the FALM is a centralized, integral lighting unit with both general area lighting and spot lighting functionality under the uniting structural, logical control and electronic circuitry of the luminaire.

[0264] FIG. 22 is a block diagram of the functional elements comprising adjustable LED luminaires **450** disclosed in this invention. The block diagram illustrates the power and communication connections between the elements. The power source **451** can be electrical utility power or battery power which is altered in a power conditioning element **452** such that it may operate the transducer and sensors pack **453** and other electricity users such as the logical controller **454** and LED drivers **456**. The logical controller **454** receives information from the input communications and sensors **453** and provides instructions to the power controls **455** and LED drivers **456** so as to drive the LEDs **457** as required by the lighting application. To alter intensity or chromacity of the light output by LED chip arrays **457** the logical controller uses techniques such as multiplexing of the power signal going to the light sources or pulse width modulation thereof. In another embodiment, the light module **411** includes control electronics which divides power up between the LED chips **412** according to instruction signals received from the central controller **428**. Thus, the light module **411** receives from the central control electronics both a power and control signal. The control signal may be modulations on the power signal. The light module controller then re-divides the power to the individual LED chips **412** as required to obtain light intensity and chromacity. To lengthen the times between the power signals to the light module, the light module **411** may be equipped with an energy storage means such as a capacitor or battery.

[0265] A unique feature of the adjustable lighting fixture is that extra lighting element modules **457**, i.e. those not needed in a specific application can be deactivated. Thus, if an arm **420** is removed, the corresponding LED driver circuit **456** can be deactivated. In a modularly built system the customer can purchase light source modules for the application such as four light source modules **457** for symmetric illumination as in fixture **410** or just 2 modules for a two arm **420** hallway light as in FIG. 20B. The electronic circuitry allows for LED drivers **456** to be added as needed and thus the customer would purchase the matching LED driver circuitry **456** for the hallway light configuration.

[0266] In a preferred embodiment the LED light fixture system is provided with mechanical means **458** for changing the structural shape which affects the direction of the illumination produced by the LED module **457**. By re-aiming the light sources, a new fixture **450** light distribution pattern is obtained. The feedback of the new position of joint **446** is accomplished by input from a position sensor at joint **446** which is part of the sensor pack. In a manually adjusted system joint **446** is provided with markings and/or detents for vertical and horizontal angular positions such that instructions given

to the user for aiming the light sources are in understandable terms. The logical controller **454** uses the new geometric data to recalculate the light distribution. Alternately, or in addition to, the camera acting as a light a sensor coupled with the logical controller's firing of the newly adjusted LED sources **457** at a known timing, obtains the new light distribution pattern. In addition, results are corroborated with the position sensor data. The logical controller **454** with new knowledge of the light distribution calculates, using computer programs such as FIG. 23, how to best provide required illumination based on algorithms run on the processor **454** pulling stored lookup-data from the data storage of **454** or received information via the communications device of **454**. The transducer sensor pack **453** is comprised of any of the following devices: an ultrasonic transducer and receiver, an electromagnetic radiation source and detector, including IR, UV, Light and Laser sources/detectors, a speaker and a microphone for audible output and reception among others. Thus, the intelligent light system **454** can receive voice input from the user which the logical controller equipped with voice recognition programs will interpret into commands and give feedback. The input to the fixture can be via a wired input device, voice recognition of commands similar to those used in computers and mobile phones, other noises such as clapping, a remote-control device or wireless communication from a computer. Thus, a user of the lighting can override lighting choices made by the logical controller and input their personal lighting preferences which if desired, are stored for the future. The logical controller is programmed to interpret the input signals into functions to be carried out by the FALM **450** in terms of spatial, spectral and intensity distributions of the light in space and in time.

[0267] FIG. 23 is an exemplary flow chart for a computer program run by the logical controller of the lighting fixtures disclosed in this invention to provide correct illumination. Based on information obtained by the sensors or manually input the logical controller **428** of light fixture **410** again shown in FIG. 22 as logical controller **454**, calculates and sends control signals to power controller **455** and LED drivers **456** to produce the optimal illumination for the visual tasks being performed by people within or adjacent to the area being illuminated. The computer routine first acquires information regarding the light distribution pattern of the luminaire in its present configuration. Using data from the initial calibration stored in data storage **454** and powering a LED **457** at a specific aiming, the digital camera light sensor array reads the luminance value returned by surfaces. The processor using the inverse square cosine law obtains the reflectance of those surfaces which are then registered in the data storage **454** for further use in determining spatial distribution of light flux from the luminaire after

adjustment. Thus, a feedback control routine is effected by the controller and sensor devices using the stored computer routines.

[0268] The logical controller **454** next determines the lighting environment in which the luminaire has been installed and area for which the luminaire is to provide illumination. If other intelligent luminaires are present, the communications program coordinates between them. If the neighboring luminaire is unintelligent, then the installer powers it on and off and the controller **454** records the differences in illumination due to its influence for future use. Using pattern recognition technology known in the art of machine and computer vision, the controller **454** identifies architectural features of the room such as windows and walls as well as furniture and appliances. Powering the LED light sources **457** or transducers **453** and reading the reflected signal captured by the sensors **453**, the logical controller **454** obtains a first guess result for the iterative process of customizing the luminaire for the installed location. Running algorithms, the processor **454** determines the luminance values obtained from the sensors **453** and compares with best practice lighting recommendations. If necessary, the logical controller corrects on its own the light source **457** aimings via control of joint **458** which is equipped with automatic means for movement. Alternately, via communication with other devices or people it relays the necessary angular setting information for them to carry out the adjustment. The controller next measures the obtained luminance and checks if the recommended or best practice luminance level has been reached. The customer may also receive a report of the measured luminances from the lighting fixture system **450** and input to the logical control the desired changes. Alternately, the customer based on their own or other users' visual experiences can input desired corrections to the logical controller **454** which then re-adjusts the light source aimings. If re-aiming the light sources **457** alone cannot solve the required illumination requirements the controller **454** determines and communicates the need for the installation of additional light sources or communicates which light sources are superfluous.

[0269] In a preferred embodiment of the invention the logical controller **454** receiving image input from the camera **453** and running pattern recognition software will identify what is the visual task a person is trying to perform. The computer routine receives images from the camera and by determining the proximity of persons to objects such as books, newspapers, computer screens, telephones, televisions, cereal bowls, a writing pad, etc. that are recognized by the computer vision techniques predicts what visual task the user is trying to perform. The logical controller **454** then drives

the light sources **457** according to recommended lighting practice levels stored in its data storage. In another preferred embodiment of the invention the user can command the logical controller as to the visual task being performed and the type of lighting desired such as "warm white" or "more light" and their preferred intensity level. The user input to the logical controller **454** may be thru a keyboard on the light fixture or via an electronic device in communication with the light fixture via the communications apparatus of **454** therein or audible or visual commands detected by the microphone or image sensor apparatus of the sensor pack **453**. Alternately, a smart mobile phone application with a Bluetooth or Wi-Fi communications capability serves as the remote controller and will handle the voice recognition, present a touchpad menu for control input or provide keyboard for command entry. If the logical controller makes an incorrect decision in the eyes of the user, the user can override the last change by a signal such as snapping one's fingers or voice command etc. Unique to this invention people are able to choose the lighting that suits them best and the fixture, having differentiated light delivery, can provide a first user with one type of chromacity and/or intensity and a second type for a different user in a different area.

[0270] The logical controller **454** provides its own feedback by checking in real time via the sensors **453** if the illumination provided by driving the light sources at the current setting is in accordance with recommended lighting levels and chromacity. In addition, by using pattern recognition and knowing the location of the user's eyes the logical controller can determine if the illumination is causing glare discomfort or veiling reflections. The logical controller by comparing new images with previous images detects if there is a change in the lighting requirements. If changes have occurred, the illumination determining process of FIG. 23 is repeated and a new configuration of driver settings and/or light source aimings is obtained.

[0271] Yet another feature of the present invention logical controller and software is that the lighting fixture **450** has apparatus to check the illumination level of the lighting set-up upon installation and provide feedback so that manually made aimings are directed to obtain a desired illumination or luminance. The camera **453** serving as a light meter obtains luminance readings on surfaces in the living space. It inputs data to the controller **454** which provides readout either on a display on the FAML **450** or communicated to another device having a display. The installer using a calibrated reference reflective sheet of known color and reflectance values placed on surfaces at particular aimings will check if the desired illumination and chromacity is being provided. The reference sheets

can also be used to calibrate the room surfaces for future camera sensor **453** readings by storing in **454** the actual surface readings vs. those of the reference sheet. Once the camera **453** is calibrated as to the reflectance and color of room surfaces the FAML **450**, in a servomechanism enabled embodiment, with automatically movable light sources **457**, will perform its own re-configuration to reach optimal light provision. The calibration is affected by using the camera array **453** to detect luminance as a measure of the lighting fixture instantaneous illuminance in that direction vs. the power level at which the light source is being driven. To calibrate the illumination system, the logical controller **454** can use a given LED installed on the fixture which serves as a light source standard when driven at known voltage and current. Alternately, an additional light sensor of superior accuracy stability is provided for in the sensor pack **453** and can be used to calibrate the camera sensor array.

[0272] In a preferred embodiment the control unit **454** is optionally outfitted with a photometer **453** which can be used to read the luminance of the room surfaces and transmit the data for use in the lighting program FIG. 23. Using the same process, a lighting designer uses to enter data to the lighting analysis programs the installer inputs to the controller as to the illuminance goals for each surface. The lighting program as known in the art then specifies the correct lighting levels, aimings and spectrum for the different locations and uses throughout the room. This is reversing the typical design process where the lighting fixtures performance is simulated on a computer and the results calculated. Here, the required illuminance results are known first, and the fixture is then programmed to make them happen. The controller **454** uses its stored performance characteristics to determine the power supply to the light sources so that it provides the required intensities to obtain the required illuminance. The lighting calculations and programming of the power supply **456** of the light sources **457** is preferably performed in real time such that the sensor **453** detects the illuminance to corroborate the performance while the installer is still at the location. If the lighting is not to specification, then the controller **454** readjusts the parameters so as to bring them in line. This trial and error process continues until the readings are within tolerance. The process is best carried out in the dark or when there is non-varying daylight. Alternately, the photometric reading sensors are on the luminaire and they are used to corroborate performance. Alternately, the process is automatic using feedback from the surroundings and pattern recognition to determine surroundings and applications.

[0273] A number of circuits in devices **452**, **455** and **456** are utilized to power equipment in the fixture **450** and carry out control. The power supply may be a constant voltage supply or current

source. The control circuitry comprises feedback sensors **453** coupled to the logical controller **454** to detect light intensity and color spectrum of the radiation. Associated logic circuitry, responsive to the detected light intensity and color spectrum over the spatial distribution, controls the power delivered to the individual LED diodes, so as to provide a desired intensity distribution over space. In an example using a combination of different colored LEDs, the logic circuitry **454** is responsive to the detected color spectrum of the outputted light. It controls the driver **456** to selectively increase or decrease power to individual coincidently directed light emitting diodes as is needed to obtain the desired color spectrum of the illumination as well as it luminous intensity.

[0274] FIG. 24 is a universal lighting fixture **470** comprised of a structure **471** with means for attaching mechanically and electrically to any of the elements selected from the group consisting of electric power conditioning apparatus, a logical controller with processing and storage capacity, light sources, radiation sources, transducers and sensors. The structure can be factory manufactured or come in a do-it-yourself DIY version. The lighting fixture has a geometrical shape calculated by the inverse square cosine law for set types of light pattern distributions. In one embodiment the structural shape of fixture **470** is such that an even, homogenous light distribution will be obtained on a work plane below when the Plug and Play light source modules **472** are connected. In a do-it-yourself lay-up-able embodiment of the luminaire **470**, the luminaire light source elements **472** are configured by the user in situ according to the illumination needs where the fixture **470** is hung. They may be reconfigured when the lighting needs changes such as when furniture is rearranged in the room. The lighting fixture structure **471** covered with removable facet covers **473**. Facet **474** has been opened exposing the receptacle **476** to accept additional light source module **477**. The receptacle **476** is provided with a connective affixing means **478** for having light source module **477** attached to it both mechanically and electrically. Light source module **477** is also provided with a complementary connector element **479** which mates with connector **477**. Connector **478** is wired to a power conditioning and control elements provided with luminaire **470** as needed by the configuration. The additional light source module **477** with its characteristic beam spread **480** mounted on an opened facet **474** on the structure **471** is at a different aiming via the position on the luminaire **471** where it is being mounted. The light sources **477** have a characteristic beam spread **480** and optical axis **481**. The receptacle **476** allows for some rotation of the installed light source **477** on the X Y or Z axes. Thus, when a number of light sources are laid up and aimed in the same direction they will add intensity to the light distribution in

that direction and when added on the curved fixture **471** surface at different angles they will increase the coverage area of the lighting fixtures illumination. Markings are provided on the structure with the angle of the position thus the user following instructions can attach the light sources at angles which will yields an even light distribution up to the cutoff angle.

[0275] A lighting design computer program known in the art will simulate to the user what the light output will be from the luminaire as it is configured. A logical controller on the luminaire can determine from the plugged in light source units which have an identifying data chip **479** in the connector relaying what its light distribution is and communicates to a simulation program the present configuration aimings and light source characteristics. In addition, a sensor **482** is provided on the luminaire. The camera like sensor **482** measures the resultant light output and relays those results to the simulation program. Thus, the user can build a customized lighting fixture that ensures proper lighting intensity where needed and does not waste light where not needed. The plug and play light source characteristics are known to the controller and their operating characteristics may then be programmed via the lighting simulation program. Using the lighting simulation program, the employed element characteristics, now a part of the controller's feedback loop, are used to direct the user to rearrange the lighting modules to further refine the fixture's **470** light output.

[0276] The do-it-yourself lighting fixture **470** has special lighting fixture accessories that are attachable to the structure. Spot light module **482** with a narrow beam spread is an example of a special accessory. It can be a light source or a radiation source such as an Infra-Red heating source or a combined heat and light source. It is mounted on the fixture via swivel joint **483** which is manually positioned at an angle required for the illumination task. A special laser pointer LED **484** is provided in the center of the light source LED array **485** to facilitate exact aiming of the spot light. The lighting module **482** is provided with connection means to the power and control signals via the joint **483**. The module is also provided with cooling fins **486** to maintain optimal temperature for the LED sources. The swivel joint **483** can be a motorized joint with motion in two axes controlled by the logical controller. Thus, the logical controller **454** in conjunction with the camera vision system **475** when identifying a person in need of spot lighting as per the computer program of FIG. 23 will pivot the spot light **482** so that it is aimed in the direction where the task lighting is required. At the same time the lighting fixture **470** will maintain general lighting at recommended levels over the rest of the room thus significantly saving energy.

[0277] In another embodiment one or more light sources, acting as a spot light **482** of limited beam angle, is on an automated swivel joint. The controller **454** receiving input from the camera and using computational image recognition algorithms in a program as in FIG. 23 follows the person around the room providing them with higher intensity lighting for their visual tasks. Further image recognition capability which may also be complemented by video analytics technology where computer vision is used to filter and manage real time video for security and intelligent traffic monitoring, helping to recognize activities as they happen in real-time which enables the controller to determine any of the following: a change in the persons activity, in what direction the eyes may be directed, what objects the person is viewing and what visual task the person needs to perform. Based on that information the controller **454** powers the spot light sources **482** and general lighting sources **472** to provide the correct lighting for the specific visual task undertaken, be it reading a book or watching TV.

[0278] An irradiation device embodiment of this FAML invention can use the computer vision and aim-ability function to provide infrared heating to individuals in indoor and outdoor settings. The heat radiation sources can be infrared filament lamps or infrared LEDs in addition to other wavelengths. The irradiating devices **472** mounted on the irradiation fixture can provide general area heating or spot heating **482** to people or objects. Computer recognition of individuals is used to irradiate them as they move about the living space. Using face recognition algorithms and stored personal preferences from the data storage, the logical controller **454** will aim the heating rays specifically where on their body they prefer to be heated as well as in what amount and at what times. The camera **475** has sensors sensitive to infra-red wavelengths around 12 μm (micrometers) radiated from people. The controller obtaining the information from the body temperature sensor will run algorithms to calculate radiation parameters and will control the irradiation in time and intensity on the individual to maintain comfortable heating per best practice standards, drawing on stored data of heating practices, or personally input preferences. People may be sensitive to radiation heating on certain parts of the body. For example, heating on the head area causes some people discomfort, the camera and controller processor system can use image recognition to identify parts of the body and the controller can provide a different radiation level to the head vs. the rest of the body. Other people feel the cold in the legs etc. In addition, the controller can obtain information on other environmental parameters such as the temperature, humidity etc. which affect the heating regimen. Thus, the camera

sensor **475** is an energy saving sensor replacing the room heating thermostat used to maintain the entire room at a high ambient temperature with a more accurate and localized actual measure of the individual's temperature. The radiating fixture **470** will them provide localized heating on an as needed basis to maintain comport. The FAML logical controller **454** runs the algorithms and provides spot heating only when necessary and in the right amount. Just as moveable head stage lighting follows the performer about the stage the camera/controller vision system follows the person around the room or outdoors and keeps them warm with an infra-red lamp **482**. It is to be understood that the irradiating source can be supplying UV radiation, visible light, or any other radiation for therapeutic, pleasure or manufacturing purposes such as UV, EB or heat curing adhesives etc.

[0279] In an embodiment of the FAML the infrared radiation sources are added to the light source and can work together when necessary to provide heat and light. Thus, in a living room fixture where the house heating has been turned down to energy saving levels an individual can receive concentrated light for reading as well as concentrated beam of infrared heating.

[0280] FIG. 25A and FIG. 25B shows an embodiment of this invention for use indoors or outdoors the light source arrays are mounted at the end of rods extending from the light fixture housing containing the control equipment. In an example lighting application, the fixture **487** is located over a table in a living room. The rods **488** supporting the light source modules have means for re-positioning either manually or automatically. In a manual system, the user based on the future use of the luminaire, sets up the spatial light distribution to best meet the visual requirements of people within the living space by re-positioning the rods. In one embodiment, for set up purposes, a red laser pointer is built into each array as was laser **484** in FIG. 24. Alternately, a laser pointer accessory is clipped onto the individual light module to assist in aiming. The user by trial and error using their own eyes as detectors or sensors **489** eventually reaches a functional light distribution with the lighting fixture for that specific installation. In an automatic system when the camera sensor **489** detects a person sitting at the table the automatic servos move the rods **488** so that the light output of many sources is aimed towards the table below producing high intensity task lighting as shown in FIG. 25A. When a room occupant is seated on the couch in the living room and watching TV the lighting fixture structure is changed to the configuration of FIG. 25B which offers general lighting at a lower intensity. The camera vision system will recognize a TV screen and the controller using the program of FIG. 23 will not illuminate

light sources shining in the screen's direction that are aimed towards it at angles which would cause glare.

[0281] An outdoor FAML **487** equipped with camera vision capabilities for the detection and/or tracking of people, is another embodiment of this invention which has a number of improvements over present area illumination technology. The outdoor lighting fixture **487** is first configured to the geometrical peculiarities of the specific yard where it has been installed and is calibrated with the sensors **489** readings. If the area to be illuminated is rectangular with a narrow distance ahead of the fixture and a wide area of to the sides, the light sources mounted on the moveable arms are moved closer together in y axis while on the x axis the light source are distanced from each other and are at aimings angled higher to cover the extended width on the x axis. To compensate for the larger are the LEDs on the x axis are driven at higher power to cover for the larger area. Conversely for a square area the light sources are distributed evenly so as to illuminate on the intensity level set at the factory as in FIG. 25B. If there is an area where high intensity task lighting is needed the luminaire is configured with multiple light sources coincidentally directed to intensely illuminate that area as in FIG. 25A. The lighting level for security and orientation is usually low and when people arrive on the scene the light level increases. When people are present in the specific area where high intensity is needed for tasks the spot light function is engaged. If infrared lighting is need for the security camera then provision is made to have IR sources aimed at the specific areas of concern.

[0282] FIG. 26 is a perspective view of a lighting fixture embodiment **490** capable of producing both a differentiated spatial light intensity distribution as well as a spatially differentiated light spectrum distribution. The luminaire **490** has multiple light source modules **491**, **492** and **493** with each module comprised of more than one LED chips which can be powered by the logical controller and control electronics **494** at differentiated power levels. LEDs are arranged in arrays of RGB (substantially red, green and blue color LEDs) or arrays with of any of ROYGBIV LEDs completing white LEDs to produce varieties of white light. The logical controller **494**, using algorithms based on the principles of additive color mixing of light sources to control the change in chromacity affects, via the differentiated powering of coincidently aimed light sources, the production of a unique spectral light distribution having a certain color temperature and/or color rendering index of light. This may be accomplished at once for all light output from the luminaire **490** or any particular

aiming **495**. The logical controller operates with data storage and program similar to the system shown in FIG. 22 and FIG. 23.

[0283] Alternately, to vary the CCT or CRI, in place of an RGB or MCY (substantially magenta, cyan and yellow LED's) or some alternative LED colorimetry system, the luminaire is equipped with different types of phosphor based white light LEDs **491** of different color temperature, where one or the other is used for a specific lighting task. In another embodiment, a monochrome LED can be added to the white LED to adjust its color temperature or rendering shifting its CCT and/or CRI. In addition, the use of shorter wavelength LEDs with nano-dots or quantum dot optics such as those from QD Vision, whose Quantum Light™ optics and films improve the color gamut of LEDs as they absorb some of the cool, blue LED light and efficiently re-emit it as warm, red light. This balances the lighting color spectrum, creating a pleasing incandescent quality light yet at significantly higher efficiency. Thus, the fixture **490**, in addition to having a controllable non-symmetric light intensity distribution in different directions also has a controlled spectral light distribution in different directions enabling a unique color rendering of one surface and a different color rendering of a second surface.

[0284] As an example of the luminaire's benefits and agility to provide correct lighting where it is needed at minimal energy consumption, an embodiment of the invention, a spatially and spectrally adjustable restaurant lighting fixture is presented in FIG. 26. In a restaurant lighting application, it would be beneficial for the customer experience if those dining, the food and ambience would all appear at their best. The problem is that even at high CRI, some color temperatures are better than others at making food appear more appetizing to customers than another. As the portions served under a single prior-art lighting fixture vary, some of them will not be shown in their best light. For example, light at 3500K-4100K helps accentuate the textures and colors of fish and white meat while the rosy hue of a 2250K light source will accentuate the color and juices of red meat. Thus, it would be beneficial if the light which is illuminating the specific table setting can be varied in accordance with the food being served. The FAML with its capability of delivering spatially differentiated illumination will render each portion in its best light. Using programmed scene recognition algorithms, the luminaire's computer vision system comprised of the camera sensor **496** and logical controller **494** identifies the food on the plate, looks-up in storage the recommended CCT and powers each of the different colored LED chips aimed thereon at the correct power level in order to provide the optimal color illumination.

[0285] In addition, the logical controller can determine on its own the preferential color of the illumination based on the reflections off of the food. The controller runs a computer routine where it rapidly varies the light spectrum to preset CCTs and/or CRIs shining on the food on the plate. The camera records the image at each preset and the logical controller **494** compares the image coloring with stored rules of recommended practice for color rendering and determines the best illumination color setting. The controller **494** resets the illumination characteristics until the next change on the table occurs. The recommended practice programmed into the controller is based on IESNA illuminance information or restaurant illumination as described in industry literature such as Successful Restaurant Design by Regina S. Baraban, Joseph F. Durocher John Wiley and Sons, 2001.

[0286] The lighting fixture **490** has means to illuminate separate portions at a table comprised of directable or aim-able lighting modules **491** etc which are on moveable structural parts **497**. The lighting fixture **490** also has computational means of providing the optimal color and intensity of light so as to render people, food, objects in their best light as well as to build a dining room ambience through lighting according to recommended practice or user preferences. The moveable structural bars **497** are manually positionable so as to aim the light sources towards the people, table and surrounding. In a preferred embodiment, the moveable structural parts **497** connected to the light modules are automatically moveable via actuator or servo motors controlled by the logical controller **494**.

[0287] We have described a system for improving the appearance of the food, but the same system applies to making the customer appear at their best. In another fixture embodiment the intensity and chromacity of the lighting illuminating the customer is adjusted manually via input means or automatically via stored algorithms to suit the customer's preferences. The fixture **490** has separately amiable light sources such as LED module **492** to illuminate the food and light source **493** to illuminate the customer. The specific group of light sources for each task may be manually positioned or a camera vision system has algorithmic means to identify and track the position of people and objects and the logical controller has motion control means for re-aiming the light sources towards targeted elements and changing the power level to the LED chips.

[0288] In an automated embodiment, controller **494**, based on image recognition of images provided by camera sensor **496**, moves the powered structural parts **497** to re-aim the light sources on the food, table or those dining as needed. Thus as an example of the unique, differentiated lighting

capability of the novel luminaire **490**, multiple light sources are used as follows; a number of wide angle light distribution light sources **491** are used to illuminate the table at a low 100 lux illuminance with a warm 3000K color temperature to build dining ambiance; while narrow beam, spot LED **492** illuminates the fish on the plate at 300 lux and 4000K CCT (in conjunction with ambient lighting LED **491**) to help accentuate the textures and colors of the fish; while the light module **493** is aimed at a diner with low enough luminous exitance so as not to cause glare but with a color spectrum that is complementary to that of general lighting module **491** such that it enhances the makeup and skin color of the customer showing them at their best. When the visual task of the customer reading the menu is recognized by the computer vision system, the logical controller **494** can increase the light module **491** output to 300 lux making the reading easier. The controller re-dims the light module **491** when the menu is recognized by the vision system **496** as being put away.

[0289] In an integrated restaurant illumination system embodiment, the customer will first try out the lighting in the rest room where they may apply makeup under a FAML luminaire having capability of producing light in a variety of chromacities, which the customer can experiment while viewing themselves in a mirror. The rest-room lighting fixture has a readout or is equipped with communications means, as is the lighting fixture controller **494** with which it is in contact. Having discovered their CCT and/or CRI lighting preference, the customer uses an input means and communications means to set the lighting fixture **490** at the table to the same successful chromacity obtained in the restroom.

[0290] In another embodiment a lighting fixture on the wall or floor such as a torchiere or a ceiling mounted fixture serves as a light engine for the entire room replacing a number of lighting fixtures while increasing the efficiency and quality of the lighting. FIG. 27 is a perspective view of a FAML lighting fixture **500** capable of providing both general and task lighting. The fixture body **501** has power conditioning electronics and logical control electronics and has light sources mounted on curvilinear light bars **503** that are configurable. This geometry and configurability enables light source aimings that will provide a substantially homogeneous illumination on a work plane through the room in which it is installed. It will also offer customization of the illumination to the actual geometric and usage peculiarities of the living space where the fixture **500** has been installed. In addition, the lighting fixture **500** is equipped with one or more spot lights **504** having a narrow light beam spread which are able to provide high intensity illumination over a small area. As opposed to general area lighting, the

spot may provide task lighting. It is a principle of this invention that the fixture **500** provides as much light as is needed in the living space, no less and no more. Thus, the LED powering circuitry as shown in FIG. 22 is configured such that each light source covering a different area is capable of being driven at a different power level. The differentiated electronic power supply is configured such that if a homogenous illuminance is required by recommend lighting practice within a living space, the illuminance in the area covered by higher angled light source **505** is at recommended level even if that area is at a greater distance and angle from the luminaire than an area illuminated by a second light source **502** as dictated by the inverse square cosine law. The adjustable lighting fixture structure is provided with moveable joints **506** which have means for being positioned at specific angles which are relatable to a lighting design software program such as those commercially available to lighting designers. The software can be run on the logical controller **501** or on a remote computer. When the light source module **502** etc. light distributions and aimings are input into the lighting design software program along with the room dimensions and surface reflectance's, the illuminance within the room is calculated. The powering of the LED modules is then adjusted via controller electronics **501** to obtain the recommended practice illuminance.

[0291] Normally, a light fixture must be placed substantially above the area to be illuminated so as not to produce glare and veiling reflections. For example, computer screens are to be protected from light rays at large angles from the nadir to prevent veiling reflections. In addition, the illuminance of light rays at large angles from the nadir striking horizontal surfaces decreases as described by the cosine law. In addition, the quality of the lighting is a function of the balance of vertical as well as horizontal lumens illuminating an object. A tennis ball illuminated on top but not on the sides flying at 80 mph will be difficult to see. It is also important to provide illumination from multiple angles to prevent shadows that can be created by single lights. Thus, many lighting fixtures would be needed to illuminate a large room to insure the visual performance and comfort of its inhabitants. In an embodiment of the invention, a single light engine device for a room our outdoor location allows for the light to be generated in one place and then beamed from the concentrated light sources **504** at small angles of divergence to reflectors or refractors which redirect the light to the users in a localized area or to other reflectors so as to go around corners and illuminate areas not in the luminaire's direct line of sight. A single location for the light source simplifies the provision of power to the fixture. A builder doesn't need to run wiring all over the ceiling and not having an outlet box in the right place in a room

or lot is no longer a problem. In addition, a single location allows for greater investment in an efficient cooling system as well as for the removal of waste heat from an air-conditioned environment and reduces installation and fixture costs. It also allows for greater investment in computer vision and logical controller apparatus enabling higher quality lighting at lower energy expenditures.

[0292] A necessary prerequisite for this remote lighting technology to be effective is the ability to generate concentrated beams of light with low divergence angles at high beam utilization. That is, 1) that most of the initial light generated gets out of the optical apparatus used to generate the tight beam and 2) most of the light flux is within the narrow beam with minimum spill outside the beam. A commercially available LED product such as the Artavi 10° product from Illumitex offers 90% of the light output in 10 degrees of the beam. The beam efficacy is above 80 lumen per watt proving that it is possible to generate well controlled light distribution patterns with minimal spill light. However, to reduce the size of the remote reflectors at the mounting heights and distances typically found in rooms, a 5 degree beam spread is even more attractive. Typically, 3 meter distances are beyond the coverage of a comfortable cutoff home and office luminaires mounted at 2.7 meter ceiling height. Thus, large room lighting needs would not be best met with a single light source due to the visual discomfort due to glare at higher angles of light emission. Therefore, it is highly beneficial to have an efficient manner of moving light in narrow beams of limited divergence over large distances to reduce the cost of lighting installations. LED optics as shown in FIG. 20 including a collimating lens for narrow beam generation are available with a light collection efficiency of >85%. Its function is based on the optical principle of total internal reflection, which contributes to the high efficiency of the optical system. Further measures can be taken to collect the 15% escaping light such as an encompassing reflector system.

[0293] FIG. 28 is a perspective view of satellite secondary light source which is a light modifying element capable of redirecting light from primary light sources such as lamps or the sun while not producing light on its own. In this embodiment the light engine **500** is equipped with light sources **504** capable of projecting at an exact aiming **508** high intensity, narrow light beams with minimal beam spread to the distant light modifying elements **510** in the room such that the light rays **511** from the light source **504** that are reflected off of theses surfaces **512** become local light source rays **513** at smaller angles from the nadir (directly down at zero degrees angle) substantially above or behind the user's eyes thus providing comfortable non-glaring lighting. These light direction

modifying devices **514**, referred to herein as Satellite Light Source, STLS, are reflective surfaces or refractors or combinations thereof or other optical light modifying apparatus. The satellite light sources may be ubiquitous insofar as a reflective decal on the wall or a painted wall or ceiling with sufficient reflectivity will function well as a secondary source. Thus, specially installed STLS can work together with room elements of sufficient reflectivity using direct lighting and indirect lighting to achieve lighting goals. The secondary light source may be attached via an extended rod to the luminaire itself or may be a highly reflective large diameter ceiling medallion. The illumination advantages of having secondary light sources are many and include: lighting exits the light source at angles which do not cause glare, the lighting comes from additional directions to that of the luminaire avoiding shadows and adds light from angles that contribute to the proper mix of vertical and horizontal lumens. In addition, there are a number of practical, economic and efficiency advantages.

[0294] In a manual system, the fixture's **500** concentrated light sources **504** can be aimed using a laser pointer to aim the light beam **508** to target **519** on the re-directive optical device. This manual method may also be used to initially calibrate an automatic aiming system with preset scenario positions for the concentrated light sources stored into the logical controller **501**. In an automated embodiment, the light engine uses a computer vision capability to identify the whereabouts of persons performing visual tasks in the room. The controller then aims one or more concentrated light sources at the optical device which re-distributes the light locally. The light engine can be equipped with more than one aim-able concentrated light source and can provide more than one user with task lighting. Thus, a ceiling fixture **500** may have light sources providing a general lighting function with light aimed at the ceiling edges to perform an indirect, soffit lighting type of lighting effect, with task lighting performed by the concentrated light source aimed on the task directly from the fixture itself or via a re-directive STLS optical device. In a preferred embodiment an infra-red or visible laser on the concentrated light source assists the automated computer vision system in aiming all the light producing and modifying elements such that maximum light is directed on the visual task in real time. Undetectable infra-red sources may also be included in the light source array make-up so as to assist in computer vision recognition. These non-visible sources may be pulsed to aid in tracking of people, their eyes and objects while not disturbing normal vision.

[0295] The light engine **500** of FIG. 27 together with the re-directive optical devices of FIG. 28 can be used to integrate light energy obtained from the sun with the artificial lighting system. That

is, where a building has apparatus for the collection of sunlight and its transport via light guides or fibers into the building's interior, the light fixture **500** will serve to distribute the sunlight within the living space. Whereby the light engine **500** has any of: a) optical device for accepting the solar light, b) optical guide paths for conducting the light; c) optical devices for redirecting the path of the light and d) filters for adjusting the amount and spectrum of the light to be used so as to be able to distribute it within to the room to where it is needed. These optical devices and filters include light valves, prisms, controllable piezoelectric light guides, MEMS devices, optical switches and mirrors to redirect or modulate light beams. In addition, the light engine has optical devices which when necessary, can direct the sunlight to the satellite re-directive optical devices deployed around the living space. When light from the sun is no longer sufficient the artificial lighting system powers the light sources to make up for the shortfall. The light engine may be placed on a wall and integrally include the sunlight collection system outdoors with the artificial light generation and distribution system indoors. It would be similar in concept to how a wall air-conditioner system works. The sunlight collection system via the controller would take the need for the lighting into account based on occupancy and environmental conditions. In the summer the system using dichroic or other filter method would remove the infra-red spectrum from the light while in the winter when heating is needed would pass the radiation indoors. The sunlight collection system using controlled re-directive optical devices to capture the sunlight will redirect the light through windows or optical paths to aid in light is required within the room.

[0296] FIG. 29 depicts an adjustable luminaire **500** in a lighting application where the user needs for illumination vary with time. The STLS **510** is a specially mounted remote reflective surface, strategically placed in the room so as to illuminate work, living or entertainment stations or alternatively is a wall or ceiling surface with sufficient or modified reflectivity. The re-directive optical devices have an optical design capable of efficiently redirecting the light symmetrically or asymmetrically for the performance of visual tasks such as looking at a computer screen or reading. They have means of attachment **515** to the ceiling, wall or placed on a piece of furniture. The STLS may be of fixed light modification characteristics or have means **516** for moving the reflecting surfaces **512** and selecting between various light distribution patterns. That is, the satellite light source **510** has manual or automatic means **516** for changing its optical performance, say from a spot light to a flood light distribution and/or it has automatic or manual means **517** for changing the direction of the

satellite's illumination. In addition, the outgoing beam **508** from the FAML **500** to the STLS **511** can be modified by the controller **501** via the light source **504** in a way that changes the output luminous flux to the visual task. The outgoing beam spread is varied or its aiming changed to a different area **518** on the STLS with a different light modification characteristic. To change the beam spread of light **508** exiting from light source **504** the logical controller **501** has means to vary the LED chips being powered or the configuration of beam modifying optical device **509**. The optical device may be a lens using refraction or a reflector, a combination of both or any other light ray modifying device.

[0297] In order to aid in aiming the concentrated light source **504** such as with the laser pointer device described earlier, there is a target area **519** on satellite **510** for use with manual or automated computer vision aiming. In an automated satellite embodiment there is need for electric power to control apparatus used for light beam aiming, sensors and communications. A hook up of control mechanism **517** to electricity from a battery or the mains power supply is provided for in attachment means **515**. In an advanced embodiment, satellite light source **510** is powered by photovoltaic cells **520** receiving light energy and converting it to electric energy which may be stored in the movement control apparatus **517**. The movement control apparatus **517** also has communications capability with the lighting control system and light engine **500**. To obtain better images for scene recognition software or for eye tracking, a camera or sensor **521** is positioned on the satellite light source **510**. Thus, the STLS can provide high definition images of people and objects within a living space for use with the lighting control system as well as with other home automation or security systems.

[0298] In an automated embodiment of this invention the logical controller **501** can communicate with and modify the secondary satellite light source **510** optical performance, say from a spot light to a flood light distribution, via controlled joints **516** or alter the STLS aiming via rotation apparatus **517** to illuminate a different area or object in real time as picked up by the camera **507** and analyzed in controller **501**. As the illumination need in the room changes, the controller **501** sends a light beam with tailored spread, intensity and chromacity to the re-directive STLS optical device or room surface best positioned in the room to provide the optimal lighting. The controller **501** determines the visual task needed to be performed at that moment and chooses the optimal STLS device in the room to send light towards. The controller re-directs light source **504** which is mounted on moveable joint **506** to beam correct intensity and chromacity light flux to that STLS. In instances where an installed STLS device is not correctly positioned to provide lighting at optimal incident angles, the

wall or ceiling (if their reflectance and color values are reasonable) can be used. In order to power sensors and actuators on a STLS satellite not connected to the mains power supply, a battery can be used. In a preferred embodiment in place of a cumbersome power mains supply hookup, a photocell or power transducer is mounted on a portion of the STLS. It is used to translate light energy or radiation from the FAML or other energy source to electric power for use by power consuming elements such as sensors, automated motion equipment or communications devices on the STLS.

[0299] To further illustrate the capabilities of a multiple light source lighting fixture with differentiated control of the spatial light distribution coupled with a camera sensor system, an example of usage in a home environment is described. As shown in FIG. 29 a man seated on a chair reading a book **122** is detected by camera sensor **507** and the vision recognition software recognizes the scene and the logical controller **501** runs algorithms and looks up the recommended lighting level and set up from the data storage as described earlier. The light engine luminaire controller **501** adjusts concentrated light source **504** via joint **506** so that it is aimed at satellite reflector **510** which has been attached to the ceiling or wall. Reflector **510** is positioned and angled relative to the incoming beam **523** such that that the reflected beam **525** illuminates the book **522**. The reader now receives illumination to read the book from the rear over his shoulder which is superior to receiving light from the luminaire **500** in front. To corroborate if enough light is being provided for the visual task of reading, the controller **501** uses feedback control methodology obtaining an approximation of the luminance on the book **522** from camera **507**. The light intensity of beam **523** can be raised or lowered by logical controller **501** to conform with recommended practice. If the user is unhappy with the lighting system's performance, he signals logical controller **501** audibly or electromagnetically to affect a change and obtain their personally preferred lighting characteristics.

[0300] The table lamp **524** next to the man on the chair is another embodiment of this invention and consists of remotely positioned electricity to light energy conversion device **500** which beams light to a STLS mounted on a table atop a post which captures the beam **511** coming from centralized light engine **500** and redirects it downwards on the book **522**. Thus, the controller **501** has the capability to use an alternative path to illuminating the book **522**. Instead of from behind and above the reader, it controls adjusting means **506** to redirect light source **504** such that it is aimed at table satellite lamp **524** which illuminate the book from the side. Another alternative illumination method to illuminating the book **522** is controller **501** directing light source **504** to illuminate the reflective

wall section **525** proximate to the book **522**. The logical controller **501** uses the camera sensor **507** and vision system **501** to check if there are obstacles in the beam path and choose the best illumination scheme at the lowest energy use for getting the visual task done. Most importantly, the user themselves have control access to the wide variety of optional lighting schemes from which to choose the one they prefer. Their preferences are then stored for future instances of the same application in controller **501**. The logical controller **501** sensing that the TV **526** is being observed, such as when the TV screen is turned on and the book closed, adjusts luminaire **500** light output in that section of the room to the recommend lighting level and chromacity for TV viewing.

[0301] Another room occupant is sitting at the dining room table. She is sipping a cup at the same time as he is watching TV. At the same time logical controller **501** discerns, using scene recognition algorithms, that based on her head position, she is reading a book **527** and not watching the television screen **526**. The concentrated light source **528** is aimed by controller **501** to provide direct illumination to perform the visual task of reading the book that she is assumed to be undertaking. If not happy with the lighting level she may command the lighting controller, either audibly or by a gesture picked up by the camera vision system or electromagnetically through a control device, to affect a change.

[0302] To further save energy the logical controller **501** receives input from the light sensor **507** that natural lighting from the window **529** is contributing to the illuminance on the book **527**. To get an accurate reading of illuminance on the book from the natural lighting source, the logical controller will, for an instantaneous fraction of a second, indiscernible to the human eye, turn off the artificial lighting of luminaire **500**. If the natural lighting is not at the required level per correct lighting practice, the controller drives area lighting LED light source **528** as needed to compensate. When the sun changes position, the altered contribution is picked up by the sensor **507** and the intensity of illuminator **504** is adjusted by the controller. Further power saving is obtained due to the differentiated light delivery capacity of the luminaire as well as its differentiated area sensor system. Light sources **502** on the light bar **503** whose aimings are towards surfaces illuminated by the sunlight are reduced in power while those directed at areas in the room far from the window not receiving a significant solar illumination are powered at the usual level.

[0303] In another embodiment of this invention, the centralized light engine **500** is adapted for use in an open plan office lighting system. The large office space is divided into cubicles and workstations beneath an acoustic ceiling. The light engine **500** is mounted within the plenum space above the acoustic ceiling in a location central to a number of workstations. It is equipped with a number of high intensity narrow beam light sources **504** which project light to STLS satellite light sources **510** which is a light guide or reflector which redirects the beam through a transparent aperture in the acoustic ceiling to the workstation below. The STLS sensor **507** detects whether an office worker is at the workstation and communicates with controller **501** to power the light source **504** so as to provide lighting at the workstation. The camera sensor **507** relays images to the controller which analyzes the data to determine the visual task being performed and drives the LEDs so as to obtain the correct illumination. When the workstation is vacated, even temporarily, the lighting returns to the low ambient lighting level. More than one STLS can be used per workstation to provide illumination to individual objects, surfaces or other STLS or light guides beneath the acoustic ceiling which can provide illumination under overhanging shelves on work surfaces.

[0304] The artificial vision scene recognition system algorithms programmed into the controller **501** are obtained by methodologies known in the art such as using neural network architectures and learning algorithms for pattern recognition, image processing, and computer vision. The remote lighting system that has been disclosed herein, the home example of which has been illustrated in FIG. 29 and an office example in the preceding paragraph is a generalized illumination technique for providing distinctive area illumination from a single light engine is a unique teaching of the present invention; whereby a centralized area lighting system is comprised of 1) one or more primary light sources which generate light from electricity capable of directly and indirectly illuminating a living space, 2) differentiated secondary light sources, dispersed over the area that receive light energy from the primary light source and 3) sensors that are in communication with the controller which provide feedback on the illumination, help in aiming the light output from the sources and collect images for identifying visual tasks to aid the controller in directing and regulating the light. The light is sent either directly to the areas to be lit or to the secondary STLS, wall, ceiling, or satellite light sources. The result being that the lighting system provides correct and comfortable lighting for a variety of visual tasks being carried out in different, distinct sections of the area.

[0305] FIG. 30 is a perspective view of a luminaire with a special night light functionality. In locations such as a bedroom or tent used for security forces, besides the luminaire's standard white-light illumination function, there is need for an additional nightlight function for providing light of different chromacity or wavelength. Thus, in an embodiment of the adjustable luminaire of this invention, a number of modes of lighting, varying in light intensity alone or both in intensity and chromacity are provided for by night light luminaire **530**. The luminaire is comprised of multiple light sources **531**, **532**, and **533** of different color spectrum and/or wavelength. The LEDs are powered by electronic power condition gear **534** and logical controller **535** which implements these modes based on programmed times via the light fixture's internal clock as well as by an input device. An optional sensor pack **536** is provided which has a camera array or a light and/or occupancy sensor.

[0306] Using light at wavelengths that have different effects in the stimulation of the rods and cones in the eye, it is possible to provide night vision that does not require adaptation time normally required to best see in darkness. In addition, it is possible to provide night light vision with light at wavelengths that do not interfere with the production of melatonin, the sleep hormone, by the pineal gland which is sensitive to light. In addition, it is possible to provide bright light to increase serotonin levels and aid in waking. There are also instances where one occupant of a room needs to arise while another desires to remain sleeping and not be awakened by the turning on of a disturbing light. Thus, it would be preferable for the lighting fixture used in sleeping areas to possess a lower illumination mode which allows for limited visual tasks to be carried out by some, while not intense enough to awaken others. It would also be preferable that the lighting intensity and/or spectrum be unique such that it does not disturb the sleep cycle of others who may be sleeping in the room by avoiding the suppression of melatonin production by the pineal gland.

[0307] An application for the use of the luminaire **530** is in permanent or temporary sleeping quarters for military or security personnel. The power conditioning equipment **534** is able to receive power at different voltages from 10 volts to 480 Volts from DC to any frequency any source of power. In a military setting it is important that soldiers exiting the sleeping quarters are able to immediately perform visual tasks in the darkness without waiting for their eye to adapt to the dark. This is because rhodopsin, also known as visual purple, a biological pigment of the retina that is responsible for enabling vision in low-light conditions, immediately photo-bleaches when exposed to light and it takes about 30 minutes to fully regenerate. Thus, it would be beneficial for security force personnel who

need to move around the living quarters to ready themselves for duty could use light at low levels that would not interfere with the rhodopsin. Thus, when the quarters are occupied only by non-sleeping individuals, the logical controller **535** powers the white light sources **531** at the power level set for high-activity general lighting. When the quarters are occupied by sleeping individuals, the logical controller **535** dims the white light sources **531** and powers the special wavelength light sources **532** and **533** at low intensity.

[0308] The special wavelength light sources are chosen as a function of the eye's photoreceptor's sensitivity. The rods (responsible for night vision) are most sensitive at a particular color blue-green (507 nm). Thus, low lighting by light source **532** at that wavelength would provide the greatest visual response while minimizing energy causing the rhodopsin breakdown. A problem however with scotopic rod vision is that nothing can be seen directly in front of the eyes (no rods in the center of the retina). To see in the extreme dark one must learn to look about 15-20° off center. Not doing so results in the night blind spot which can cause mishaps and physical injury. On the other hand, the center 1.5% of the retina (the fovea) which provides the most detailed vision is packed almost exclusively with red sensitive cones. Thus, to correct for the night blind spot light source **533** producing low levels of red light at a greater than a 650 nm wavelength are powered to illuminate. Experimentation shows that red LEDs with a peak around 697 nm seem to work best to supplement the low intensity blue-green 505 nm wavelength LED **532**. Other wavelengths to accomplish the night vision functionality are possible and the two described here are by way of example.

[0309] Thus, in an embodiment of the luminaire **530** for use where there is immediacy in the performance of low light visual tasks, there is provided an illumination capability with light sources of wavelength which interfere minimally with seeing in the dark. FAML **530** for use in airplane cockpits or living quarters used by security forces in a state of high readiness has a controller **535** and control gear **534** which drives special wavelength light sources **532** and **533** at the above mentioned wavelengths at low intensity. Either of light sources can be present and used independently or most beneficially in unison in the luminaire **530** to facilitate night vision. When maximum dark adaptation is required the red light intensity is set by the controller **535** and monitored by optional light sensor **536** to provide a low luminance of 0.07-0.35 cd/m2 (0.02-0.10 ft-L). In normal states of readiness, the controller employs light sources **531** producing white light general lighting at an illumination level recommend by the IES for normal activities which is dimmed to a night light setting during non-alert

low readiness situations. The nighttime low setting is such that the light flux will yield an illuminance of 0.15 lux on the floor with the chromacity of 4000K similar to moonlight.

[0310] In an embodiment of the multiple wavelength producing lighting fixture **530** light sources are provided that can be used to aid in the onset of sleep and/or in the onset of awakening. The multiple light source fixture is equipped with control and light source apparatus to illuminate persons or animals with light at wavelengths that are conducive to sleep or awakening. Kayumov et al. showed that light containing only wavelengths greater than 530 nm does not suppress melatonin production even in relatively bright-light conditions. Also, Brainard et al in "Evidence for a Novel Circadian Photoreceptor" The Journal of Neuroscience, 15 Aug. 2001 shows that in normal healthy humans, equal photon density exposures of 1.9×10^{18} photons/cm^2 at 460, 630, and 700 nm monochromatic light elicited a significant melatonin suppression at 460 nm while only small reductions of plasma melatonin levels at 630 and 700 nm. Thus, the lighting fixture **530** has a general lighting light sources **531** which has radiation at wavelengths that suppress melatonin production and other light sources **532** and/or **533** which are at wavelengths above 570 nm and do not suppress melatonin production. Individuals with difficulty in going to sleep who are aided by increasing the melatonin level can then instruct logical controller **535** to provide only melatonin friendly illumination at the necessary time of day so as not to interfere with their or the children's sleep time. To aid in awakening the controller would illuminate the living space with light sources **531** which have melatonin suppressing wavelengths helping the individual to awaken. Research shows that if the light is in a particular spectrum (around 460 nanometers, which is in the blue range) greater benefits can be derives even from much dimmer light.

[0311] In places where individuals with sleep disorders reside in the hours before going to sleep, it would preferable to have illuminating devices capable of influencing sleep patterns. Thus, it may be preferable to use lighting house wide to control sleep times. In a preferred embodiment the lighting fixture in the living room, bedroom or office would aid in the onset of sleep or aid in the onset of awakening with the lighting fixture making use of intensity variation and chromacity. The lighting intensity in the patient's surround is controlled with reference to the planned sleep hours to adjust the circadian cycle and/or induce hormones so as to assist sleepers to arise by the use of light that is stimulating.

[0312] FIG. 31 is a perspective view of a multiple light source adjustable luminaire with added irradiation functionality. Returning to the geometrically adjustable FAML design with light sources for general lighting on moveable light bars and aim-able spot lighting sources we present an innovative added functionality illumination device. In this embodiment the luminaire **540** has means for limiting at certain times the spectrum of the illumination visible to an individual with difficulty in falling asleep. A fully featured FAML embodiment would be comprised of: a logical controller **541** having means for processing algorithms, data storage, communications and control capability for the task of influencing sleep cycles; power conditioning means **542** for powering controllers, sensors and light sources; standard full spectrum chromacity light sources combined with uniquely driveable light sources **543** that produce light at wavelengths most effective in stimulating or suppressing nocturnal melatonin; and sensors for detecting light and/or images **544**. That is, the logical controller **541** can drive LED chips comprising light module **543** that produce a wide range of wavelengths or selectively drive only chips within a permitted wavelength range for some medical, therapeutic or even aesthetic effect. The narrow beam spread, spot light illuminating source **544** also has light producing semiconductor chips of a variety of wavelengths that can be independently powered from driver electronics **542**. The light sources **543** and **544** are on movable mounting elements such as light bar **545** and there is the provision of sensors for logical control and feedback in sensor pack **546**.

[0313] The use of the luminaire to affect sleep cycles is as follows: prior to going to sleep the individual will command controller **541** of the FAML **540** to illuminate their surroundings exclusively using light sources producing wavelengths greater than 530 nm. Light sources **543** and **544** of one or more wavelengths above 530 nm may be employed. Utilizing algorithms or stored preset power levels the logical control via the metametric mixing of light source chips in **543** and **544** illuminates the area or visual task with a color close to white light. Thus, the individual will be able to carry out routine tasks such as watching television in the living room or reading a book in bed. However, the pineal gland will be "fooled" into producing melatonin as if the individual was sitting in darkness.

[0314] The melatonin friendly white light can be generated for example by using commercially available Osram Golden Dragon Plus LEDs LT, LY and LR W5AM as the light source chips or diodes comprising the light modules **543** and **544** in the FALM bedroom luminaire **540**. When powered by driver **542** at 20 Watts at approximately 350 mA, about 1,200 lumen of very warm white 1200K Color Coordinated Temperature, CCT, light can be produced using the following mix: 156 lumen of 528 nm

higher wavelength green light mixed with 400 lumen of 590 nm yellow and 640 lumen of 625 nm red. This mix yields a good color rendering index, CRI of 80 while still allowing for melatonin production. Alternately a single monochromatic LED above 530 nm could be powered but vision and comfort would be compromised. The same luminaire **540** in a second operating mode, that is not required to stimulate melatonin production, can at the same wattage produce a cooler color temperature light. This is achieved by powering blue light source diodes in addition to the previous mix while having the logical controller **541** adjust the power level of each LED chip. For example, with the addition of two watts or 48 lumen of 470 nm blue LEDs (e.g. Osram LB W5AM) a 4250 Kelvin CCT daylight white light can be produced using 600 lumen of 528 nm green light mixed with 500 lumen of 590 nm yellow and a mere 100 lumen of 625 nm red yielding a good color rendering CRI of 82.

[0315] In another embodiment, the same fixture **540** is used for the standard lighting in the bedroom in a normal high output operating mode. Thus, by powering more light sources still at approximately 350 mA a higher lighting level and whiter chromacity is achieved. For example, doubling the power to 40 Watts with the addition of four watts or 100 lumen of 470 nm Blue LEDs (e.g. Osram LB W5AM) a 3800 Kelvin CCT cool white light can be produced using 500 lumen of 528 nm green light mixed with 400 lumen of 590 nm yellow and 150 lumen of 625 nm red yielding a good color rendering CRI of 82. A similar effect can be achieved without increasing the number of light sources but instead increasing the current to each LED. This usually however results in shortening of the LEDs useful lifespan. Using a controller **541** and power source **542** capable of powering each LED individually a full range of dimming to very low light levels can be achieved. In an alternative methodology of using different wavelength LEDs for generating melatonin friendly light, a white LED or any other wide spectrum light source could be used with the manual or automatic introduction of a light filter to remove wavelengths lower than 530 nm as needed.

[0316] Thus, the same bedroom fixture **540** can serve as a night light obviating the need for an additional night light lighting unit in the same room. Again, the night light mode has special chromacity to allow visual tasks to be performed yet with minimal interference to sleep as described above in FIG. 30. Utilizing the non-symmetric light distribution capability of the FAML when in night light mode, higher intensity lighting for orientation could be provided in areas of movement around the bed or on the way to the bathroom while zero or only very low intensity night lighting would fall near the head of the sleeping person. The fixture **540** is illustrated as having been hung on the ceiling

of a bedroom above the beds for two occupants with the spot lights **544** facing the wall above the head of the beds. In the spirit of the adjustable luminaire of the present invention, the light bars **545** holding the light modules **543** have been swung out of direct view of an individual lying on the bed with their eyes facing upwards to the ceiling. The flexibility of the invention is again demonstrated insofar as this re-configuration ability is unique to the multiple light source lighting fixture making it a truly universal lighting fixture. In this unusual case of the eyes facing upwards, indirect lighting via the ceiling becomes the recommended lighting practice alternative of choice, especially if the TV is mounted high off the floor.

[0317] In another embodiment, the FAML bedroom luminaire **540** is equipped with a camera **546** and the logical controller has means for image recognition and computer vision. Thus, now as opposed to a standard night light which is always on, the innovative night light **540** using computer vision analysis could be highly dimmed or off most of the time making it easier to sleep and saving power. It would be reactivated when there is major movement on the part of the sleeper indicative of the need for illumination or a baby crying is picked up by microphone in sensor pack **546** in anticipation of light being needed by the parent awakening to care for the child. Greater movement such as getting out of bed would further increase light levels for proper orientation and object avoidance.

[0318] As a further customization of the illumination characteristics, when utilizing the light source aim-ability feature of the FALM, one occupant of the room could receive controlled exposure to lighting conducive to melatonin production while other occupants in the room at the same time receive a normal, fuller spectrum illumination. Thus, the right side spot light **544** could be of melatonin friendly light wavelengths for the individual receiving its light while a second individual in the second bed receives a full spectrum of light for reading from the left side spot light **549**.

[0319] In addition to using light of specific wavelength for treatment of sleep disorders and other circadian rhythm disorders such as delayed sleep phase syndrome, light therapy or phototherapy can be used for the treatment of vitamin D deficiency, skin disorders (for example psoriasis, acne vulgaris and eczema, and some psychiatric disorders for example seasonal affective disorder. As described earlier the spot light source **544** can be moved by actuators under the control of the logical controller **541** much as a moving head stage light follows actors on the stage. This is a unique feature

of a computer/machine vision capable FAML irradiating device which can follow and irradiate the patient while they are carrying out their daily activities and is of major benefit. To ensure that the light therapy rays from the FAML strikes the retina from the best angle, a portable STLS may be placed on the floor or furniture in front of the patient's eyes. In instances where the FAML is providing UVB radiation such as in vitamin D therapy and high intensity UVB is hazardous to the eyes, the computer vision system would make sure to stop radiation unless it knew that the eyes were not being irradiated. Other medical applications of light therapy also include pain management, accelerated wound healing, hair growth, improvement in blood properties and blood circulation, and sinus-related diseases and disorders. Many of these use low level laser therapy and red light therapy in the 620-660 nm range.

[0320] In an embodiment of the therapeutic luminaire **540** having radiation sources controlled by a logical controller using computer image recognition algorithms that enable face recognition the device is capable of providing the correct dosage to an individual. For example, curing SAD winter depression caused by serotonin deficiency by treatment with bright light therapy the luminaire's logical controller **541** will measure the individual patient's exposure time ensuring that it complies with the medically prescribed dosage to preserve serotonin levels for that time of year. In an embodiment where the computer vision system **546** has capability for eye recognition and tracking, a more accurate dosage intensity and exposure time is metered. The dosage analysis is based on either computer knowledge that the eye is exposed by actually measuring the radiation reflection off the eye which may include a daylight component in addition to the artificial luminaire component. Thus, a more accurate therapy record may be obtained and reported to a monitoring computer or health practitioner if necessary. If a satellite light re-directive STLS device is positioned fore of the patient, a specular mirror section is provided on the STLS and may be used by the camera imaging system to capture the eye or reflections off of the eye and verify the dosage received. Non-disturbing infra-red radiation may be used by the transducer sensor system **546** to capture and measure the eye reflections for imaging and dosage measurement purposes. Using eye-tracking algorithms the controller logs all the time the eyes have received the therapeutic radiation dosage and adjust the treatment accordingly. Having communications apparatus, the controller conveys the treatment history to medical care supervisory personnel.

[0321] Another embodiment of the luminaire assists people to awaken at any hour by irradiating them with shorter wavelengths of light or safe UV, which suppress melatonin production.

A FAML **540** is provided with: a logical controller **541** having algorithms and data for the task of influencing sleep cycles and with light sources that produce light at wavelengths most effective in suppressing nocturnal melatonin. It then uses a time and intensity controlled exposure to illuminate the person or animal at a prescribed interval time in advance of the wake time. Decreases in melatonin production in human and animals are known to be caused by environmental lighting, especially short-wavelength lighting (between 460 and 525 nm). Test results strengthen earlier findings that the human circadian system is more sensitive to the short wavelengths of light than the longer wavelengths. It is principally blue light, around 460 to 480 nm, that suppresses melatonin, increasingly with increased light intensity and length of exposure (Wirz-Justice, A; Benedetti, F; Terman, M (2009). Chronotherapeutics for Affective Disorders: A Clinician's Manual for Light and Wake Therapy. Basel: Karger. ISBN 978-3-8055-9120-1. It is also possible to use violet colored LED to which the visual response is low such as a 420 nm wavelength. The disturbance to sleeping individuals may be lower, however, though studies demonstrated a clear fluence-response relationship between 420-nm light and melatonin suppression the response is weaker.

[0322] Thus, a person sleeping in their bed could program the lighting fixture controller **541** to begin irradiation with the melatonin suppressing wavelength LEDs in advance of the wake-up time as required. Again, with the light aiming differentiation capability of the FALM **540**, two people in the same room with different wake-up times could receive different dosage at different times as programmed into the controller. One person could be irradiated with melatonin producing radiation or none at all while the other receives melatonin suppressing irradiation. Alarm clock functionality can be added to the logical controller **541** of the bedroom illuminating device and/or an additional device **547** is provided. It will use lighting and/or sound from alarm speakers **547** to awaken the individual when wake time finally arrives. Voice commands can be used to program and turn off the alarm clock. To ensure the user is really awake the alarm clock can ask the user to solve a mathematical equation before stopping the alarm.

[0323] In another embodiment example of a bedroom application (a living room or kitchen lighting application would be much the same), the FAML **540** is located on the ceiling near the room center. It uses distributed light sources **543** or optical means over a single light source to provide for homogeneous ambient lighting and concentrated light sources **544** or optics to create a narrow beam for task lighting. The concentrated sources **544** and **549** may be used to provide illumination for the

visual task of reading a book thus replacing the night-table lamps. It is preferable that the beam not come from above and in front of the reader lying in bed as the rays from above will disturb reader. Also, one occupant of the room may desire to sleep while the other is reading. Thus, a re-directive satellite light source STLS is placed directly behind or off to a side and behind the reader. The STLS has a substantially specular reflectivity rather than a diffuse one so as to maintain a concentrated spot beam with little spill light beyond the book. Of course the book itself is a Lambertian reflector but the maximum has been done to minimize disturbing others. The FAML **540** configuration can be adjusted upon installation to have the narrow beam spot light aimed at the STLS. The STLS itself may be manually adjusted by the user to best direct the light for the visual task at hand such as reading a book in bed. The user will keep the laser pointer on the target disc while swiveling the STLS until the book receives the maximum light. This is similar to adjusting the shade of the table lamp which it replaces. When properly aligned there is very little spill light and the other occupant of the room can sleep undisturbed. In an embodiment having a computer vision enabled luminaire capable of determining the book position, the controller **541** will automatically re-direct the light beam **548** from the movable light source **544** and/or re-aim the movable STLS so as to maximize illumination effectiveness. Alternatively, the wall or surface behind the bed or the headboard has sufficiently good optical characteristic enabling light from the beam to be used or has had a specially reflective decal placed on it. In a computer vision enabled embodiment the logical controller **541** is programmed such that when the reader puts the book away the light goes out or slowly dims into the night light mode.

[0324] It has been demonstrated that a single bedroom luminaire **540** can replace two other typical bedroom lighting fixtures. The night-table lamp and the nightlight. In addition, by using the directional light output capability of the FAML fixture, this spectrally accurate lighting may be further limited in its illumination coverage to bedroom areas where movement is possible, thus not shining towards a sleeping person's eyes. Using machine vision techniques for image recognition, the position of those sleeping and those up and awake is determined. In addition, computer vision allows for automatic tracking spot lighting similar in function to how a moving head stage light for stage performers follows them about the stage. All this can be carried out by the automated lighting fixture **540** where the light sources are moved by the controller so as to illuminate only the person awake in the room. The trajectory of the light beam is checked by the controller such that the light beam does not fall on the head of anyone else sleeping in the room.

[0325] FIG. 32 is a perspective view of an industrial lighting fixture for use in hazardous locations. These are locations that are characterized by the presence of combustible gasses or dust particles. So that the explosion proof lighting fixture **550** can to obtain ExProof certification for use in hazardous locations, it is constructed in a unique manner which prevents ignition of the gases or dusts by electricity or heat produced by the fixture. The intrinsic safety protection techniques used in its construction enable safe operation in explosive atmospheres and ensure that the available electrical and thermal energy in the system is always low enough that ignition of the hazardous atmosphere cannot occur. The intrinsic safety of the illuminating device **550** includes the control of component temperatures even in fault conditions (such as an internal short inside an electronic device). The electrical control gear **551**, logical controller **552** and LED light sources **553** are all thermally protected. The temperature of a failed component will not rise to a level higher than the autoignition temperature of a combustible atmosphere. Current limiting safeguards, such resistors and fuses, are employed in the electronic circuitry throughout to ensure that in no circumstance can a component reach a hazardous temperature.

[0326] To a major extent the fixture is intrinsically safe as it is hermetically sealed for life. This is accomplished because the LEDs **553** are driven at or below design currents as well as having the junction being thermally cooled to well below allowable temperatures due to lifetime and explosion proof certification considerations. Note that in prior art ExProof fixtures the lamp needs to be replaced and therefore allowance was made in fixture design for opening the fixture to replace the lamp. Under these low current cool operation conditions, the LEDS will provide 90% of their initial lumen output even after 100,000 hours or over 20 years of night operation. This in turn allows for a design where the LEDs are encapsulated for life in resin type materials **554**. There is no possible contact with explosive materials between electrical or heat generating components. Thus, in this novel hazardous location fixture design, the LEDs, electronics and electrical components are intrinsically safe in a sealed for life fixture. This is an inherent safety design and allows for the fixture to be located even in the most hazardous locations including underground mines or inside of tanks i.e. division 1 and zone 0 classified hazardous areas. In an embodiment of the fixture there are no screws to open for access to the internal fixture parts other than on the wiring box **555** which connects the Exproof fixture to the power mains. The wiring box itself is approved for zone 0 hazardous locations and has explosion proof sealing apparatus. While prior art fixtures that can be opened for service may not be properly

closed by service personnel thus becoming an explosion hazard this sealed fixture is foolproof in that there is no access for life.

[0327] Referring now to the adjustable lighting fixture embodiment in more detail, in FIG. 32 there is shown an illuminating or irradiating device **550** which is capable of being adjusted to match the radiation spatial distribution with the actual illuminating requirements of the surround where the lighting fixture **550** has been installed. The light sources **553** are mounted on curvilinear support structures **556**. The rear side **557** of the support structure (or light bar) **556** is a heat exchanger structure of increased surface area for the transfer of heat from the LED junctions to the surrounding air. The front surface material **558** of the support structure is highly transmissive to light allowing the light generated by the light sources **553** to exit the luminaire. These curvilinear support structures **556** possess a unique geometry and thermal transfer characteristic and are innovative in a number ways. The luminaire is comprised a multiplicity of light sources having respective spectral distributions and respective light distribution patterns which are directional and subtend lesser angles than those of the overall luminaire light distribution pattern. The light source mounting structure **556** is configured to mount the light sources **553** so arranged on the structure such that the respective directional light distribution patterns and the respective spectral distributions combine to form an efficiently distributed overall light distribution pattern. This overall light distribution has been calculated to efficiently provide the surface areas intended for illumination by the fixture **550** with the design illuminance. In this unique configuration the overall light distribution pattern, subtending greater angles than that of the respective light distribution patterns is produced directly by the multiplicity of light sources without recourse to inefficient non-integral reflectors and/or refractors.

[0328] As the overall spatial light distribution of luminaire **550** is comprised of the sum of the narrower beam light sources **553**, each light source covers a specific area proximate to the luminaire. The aiming angles of the sources of known light flux and beam angle are determined by using the inverse cosine law to determine the amount of light flux required to illuminate the surfaces to be covered by the luminaire. Once the aiming angle with reference to the nadir is known there is yet another design criterion that needs to be met. There is great importance in maintaining the light emitting diode junction at low temperature. To remove the heat from the junction it is important for the LED assembly **553** to have excellent thermal contact with the heat sink **557** at every aiming angle. Thus, the construction of the support structure has been dictated by the individual light source aimings

that are designed to illuminate both near and distant surfaces with the recommended illuminance. In addition, the rear side of the support structure **556** which is exposed to the outside air is integral with the heat sink **557** which is most beneficially in direct contact with the LED junction to maximize thermal transfer away from the diode structure to the environment. Uniquely both of the design requirements have been met by the unique construction of the support arm **556**. The final benefit of the unique curvilinear light bar is the strength it imparts to the structure. In an embodiment the shock proof glass lens **558** is slightly recessed within the light bar channel **556** allowing for the edge **559** to act as a protective bumper protecting the glass from breakage even if impacted by a metal tool. Often explosion proof glass globes are protected by a guard. The curved metal guards protect the glass from mechanical breakage in the harsh industrial setting. The shape of the bars **556** and the recessed glass cover maintains this protective design approach to effect shielding from mechanical breakage.

[0329] An exemplary embodiment of the adjustable explosion proof fixture in a chemical processing plant characterized by an open facility design is presented. In the facility, piping and vessels are supported by the skeletal support structure with walkways, floors and stairs made of metal grating. The walkways, vessels, machinery and piping all need to be illuminated at night by lighting fixtures placed on the structure along the walkways. In this lighting application example, the walkways are at the exterior edge of the structure with the piping and machinery towards the interior. Beyond the walkway fence there is no structure and no need for illumination. The configuration of the lighting fixture as shown in FIG. 32 has been arranged so as to illuminate inwards towards the vessels, machinery and piping as well as along the walkways and stairs but not outward into free space. The luminaire has been mounted on an upright beam at height of 3 meters at the inward edge of the 1.5 meter wide walkway. The LED bar **560** is rotated 15 degrees off the nadir out of the page around the axis **561** to be aimed at the center of the walkway and the LED **553** beam spread is 30 degrees. LED **562**, because it is projecting to the work plane further away at a higher angle from the nadir, will, following the inverse square and cosine law, have a narrower beam spread (at least along the width of the walkway i.e. the beam **564** may be rectangular or elliptical, taller than it is wide) ensuring that most of the light is utilized and not spilled over the edges of the walkway. The light bars **556** and **563** have mechanical means to be rotated 360 degrees about the center **565** and have been aimed to the same side, inwards to the facility. Thus, they illuminate the piping and machinery and do not shine out of the facility wasting the energy or even causing light pollution as would a standard prior art

luminaire. Now in their new configuration, the light intensity output of each LED must be reset in the driving electronics **551** and controller **552** so as take into account overlapping coverage on surfaces to be maintained at the recommended illuminance.

[0330] In a preferred embodiment a sensor apparatus **566** is capable of measuring the illuminance of surfaces in the processing facility and providing the logical controller **552** the necessary feedback information to control the power to the light sources **553** etc. so that the illuminance goals are met. Alternately, if the light bars have been incorrectly configured in aimings that do not allow for coherent illumination of the surfaces, the controller communicates the necessary aiming modification to the installer. An example of the logical controller **552** circuitry, computing apparatus and algorithm processing were described above in FIGS. 22 and 23. In an embodiment where sensor **566** is a digital camera and the logical controller **552** has means for computer vision, an installer can use reference sheets of known reflectivity and luminance to calibrate the illumination level setting of the individual light sources within the logical controller **552** based on the fixtures initial factory calibration data. For example, when setting up the system the installer can customize the illuminance level on each element of interest. The system calibrates light coverage by firing LEDs at synchronized timings with the vision analysis system **552** determining which LED illuminates what surface. Next the installer can input the desired illuminance via the reference sheet by indicating on it the number of lux desired on the surface. For example, attaching a note with 200 lux printed on it on a valve. The image recognition software then provides the logical controller the illuminance goal of 200 lux on that surface and the logical controller **552** powers the light sources **553** etc. aimed towards that surface with the necessary power signal to obtain the needed light flux. Feedback is provided to the installer if additional light sources are needed or their re-aiming is required. Information is provided to the installer through visual display on the logical controller **552** of the luminaire or another display device in communication with the logical controller **552**.

[0331] In another embodiment the cooling of the harsh environment luminaire **550** is effected by using liquid cooling of the LED light sources. The coolant may be anything from deionized water (approximately 18.2 megohm-cm) to heat-conductive oil. The oil may be part of the methodology used to secure intrinsic safety classification from ignition danger of electrical circuits in explosive environments. It may also be an optically transmissive medium which couples optically with the light sources to produce a desired light distribution with other complementary optical devices. The oil may

be pumped mechanically with a pumping apparatus such as a long life diaphragm pump to cool the diode junction. Alternately, in a preferred embodiment shown here, thermos-siphon effect circulation is utilized to convect the thermal transfer fluid from the light bars **560**, **556** and **563** to the central heat exchanger **568**. The thermos-siphon return post **567** serves as the path for the cooled lower density cooling fluid to return to the light bars **560**, **556** and **563** from the heat exchanger **568**. The benefit of the thermos-siphon system is that it is motor less, doesn't require power and is highly reliable. It also adds longevity and efficiency to the LED light sources by offering superior heat transfer rates maintaining the diode junctions at the lowest possible temperature.

[0332] FIG. 33 is the process flow chart for novel web-based computer application that can help the customer design the multiple light source luminaire for their particular lighting application and order it compete correctly configured from the factory. Alternately, in a DIY luminaire version, they can receive all the necessary luminaire parts with their unique set of assembly instructions for their lighting application. The build-the luminaire-to-order program turns the customer into a professional luminaire and lighting designer. In creating the tailor-made luminaire, the customer, aka lighting fixture designer, has control of illumination performance based on the skeletal light engine design as well as a choice of various aesthetic luminaire outer body designs. The program is novel insofar as it builds the lighting fixture from multiple light sources according to the dictates of the living space. Prior art practice used hitherto in other lighting programs take standard lighting fixtures with known photometric data as to the light distribution and calculates the resultant illuminance obtained on the workplace or room surfaces. Here the process begins with specifying a surface illuminance and using goal solving techniques, the application builds the fixture's light distribution. Next, in a unique process, the computer application using engineering and look-up table algorithms chooses light sources and places them on the fixture to obtain the desired light distribution.

[0333] In practice the customer inputs the lighting application geometry, fixture mounting position, living space elements and projected usage answering a live questionnaire. Digital camera pictures of the living space uploaded to the site may aid the program in generating the architectural CAD lighting layout. The customer assigns visual task information to areas of the room, e.g. reading chair, adult over 50 years old etc. The layout process ends with a map of the room surfaces now assigned with illuminance levels. The program assigns a specific orientation of the luminaire within the living space e.g. fixture orientation mark facing east window. The luminaire in practice must be

hung in the room in the instructed orientation. A preliminary grid is assigned to the room surfaces based on the distances from the luminaire to the surface and the light intensity limits of the light sources. By using the inverse square and cosine law with known illuminance, distances and angles the program solves for the luminous intensity. By working a luminaire design program such as Photopia™ from LTI Optics in reverse, the light source ray distribution properties are obtained. The program then looks up in the light source library the light source with the best matching spatial intensity distribution for illuminating the specific grid area. The design program then arranges the selected light sources on a fixture skeleton structure to obtain the overall necessary illumination. The web application next simulates the fixture performance through lighting design software applications known in the art such as AGI32™ from Lighting Analysts. The computer routine checks the lighting layout against best practice guidelines for visual comfort from glare, lighting levels and recommends need for additional light modules, luminaires or reflective satellite light sources. The customer can review the simulated lighting output in their application and after a few fine-tuning iterations a final design can be satisfactorily achieved. Now that the fixture skeleton and light source positions thereon are known, the customer then chooses from the available candidates of aesthetic luminaire outer façade choices that can be used with the dictated skeletal structure. The final fixture outer design and lighting performance is simulated. Should the customer be unhappy with the aesthetics or performance they may begin again with the option of forcing an aesthetic design which may dictate a less than optimal skeletal structure. When satisfied, the customer orders the luminaire to be assembled by the manufacturer to spec. In the DIY version the web application generates the fixture parts list for the kit to be sent to the customer. It is clear that the application is not only web based but can be a downloadable version run from a computer.

[0334] In another version of this Do-It-Yourself lighting designer application, the main skeleton lighting fixture with the power supply electronics and the camera-based vision system and controller is supplied to the customer. The camera vision system measures the room geometry and identifies room contents as described earlier via algorithms known in the art for measuring distances with a camera and pattern recognition techniques for identification. Based on the information garnered about the lighting application such as by following a computerized lighting application design questionnaire and checklist (activities performed in the room, age of the occupants etc.), the lighting layout is specified and the lighting fixture design with the light source layout is determined using the

lighting design software. The answers to the question are input via a speaker microphone system on the lighting fixture or via come other input device such as a computer or smart-phone in communication with the controller. Once the illumination needs have been determined and the fixture designed the rest of the light sources are ordered up and the DIY fixture similar to **470** in FIG. 24 is assembled

[0335] While the preferred embodiment of this invention comprises an adjustable luminaire having means for changing the spatial light distribution as well as the spectral light distribution, it is clear that embodiments of this invention may offer only the spatial light output distribution adjustability as for example when using a single color spectrum LED for all the light sources or only color spectrum adjustability where spectrally differentiated light sources have been used but there is no means for adjusting the spatial light distribution. Many of the novel features of this invention disclosed herein in this continuation in part of the earlier disclosure of the Multiple light illuminating system included herein by reference apply to the lighting fixture embodiments of that disclosure as well.

CONCLUSION

[0336] We have been disclosed a luminaire with control of at least one of the light intensity, light spectrum and light direction and that further being combined with a controller and directional sensors such as a camera having an artificial vision system capability is uniquely able to effect the provision of lighting on an as needed basis in the optimal intensity, spectrum and placement.

[0337] There has thus been shown and described, among other things, a multiple-source lighting technology which allows for the design and construction of illuminating devices. Many changes, modifications, variations and other uses and applications of the subject invention will, however, become apparent to those skilled in the art after considering this specification and the accompanying drawings which disclose the preferred embodiments thereof. All such changes, modifications, variations and other uses and applications which do not depart from the spirit and scope of the invention are deemed to be covered by the invention without departing from the spirit or scope of the following claims.

[0338] Although a limited number of preferred embodiments of the present invention have been illustrated in the accompanying drawings and described in the foregoing detailed description, it is possible mix and combine the features of one embodiment with another to create a DLF with differing characteristics as taught in the method herein. Therefore, it will be understood that the invention is not limited to the embodiments disclosed, but is capable of numerous rearrangements, modifications, and substitutions without departing from the spirit of the invention as set forth and defined by the following claims. The invention should therefore not be limited by the above described embodiment, method, and examples, but by all embodiments and methods within the scope and spirit of the invention.

[0339] While exemplary embodiments are described above, it is not intended that these embodiments describe all possible forms of the invention. Rather, the words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the invention. Additionally, the features of various implementing embodiments may be combined to form further embodiments of the invention.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
17/152,399	01/19/2021	2875	3540	TRCH0103PUSP3	33	3

CONFIRMATION NO. 6274

FILING RECEIPT

22045
Brooks Kushman
1000 Town Center
22nd Floor
Southfield, MI 48075

OC000000123395777

Date Mailed: 02/24/2021

Receipt is acknowledged of this non-provisional utility patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF FIRST INVENTOR, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection.

Please verify the accuracy of the data presented on this receipt. If an error is noted on this Filing Receipt, please submit a written request for a corrected Filing Receipt, including a properly marked-up ADS showing the changes with strike-through for deletions and underlining for additions. If you received a "Notice to File Missing Parts" or other Notice requiring a response for this application, please submit any request for correction to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections provided that the request is grantable.

Inventor(s)

Yechezkal Evan Spero, Tifrach, ISRAEL;

Applicant(s)

Yechezkal Evan Spero, Tifrach, ISRAEL;

Power of Attorney: None

Domestic Priority data as claimed by applicant

This application is a CON of 15/961,861 04/24/2018 PAT 10894503
which is a CON of 13/357,549 01/24/2012 PAT 9955551
which is a CIP of 10/604,360 07/14/2003 PAT 8100552
which claims benefit of 60/395,308 07/12/2002
and said 13/357,549 01/24/2012
claims benefit of 61/535,981 09/17/2011

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 02/23/2021

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 17/152,399**

Projected Publication Date: 06/03/2021

Non-Publication Request: No

Early Publication Request: No

Title

ADAPTIVE HEADLIGHT SYSTEM

Preliminary Class

362

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific

countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

SelectUSA

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The U.S. offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to promote and facilitate business investment. SelectUSA provides information assistance to the international investor community; serves as an ombudsman for existing and potential investors; advocates on behalf of U.S. cities, states, and regions competing for global investment; and counsels U.S. economic development organizations on investment attraction best practices. To learn more about why the United States is the best country in the world to develop

technology, manufacture products, deliver services, and grow your business, visit http://www.SelectUSA.gov or call +1-202-482-6800.

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 17/152,399

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	320
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	700
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	800
TOTAL CLAIMS (37 CFR 1.16(i))	33 minus 20 =	* 13			OR	x 100 =	1300
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*				x 480 =	0.00
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						420
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	3540

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)		RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
17/152,399	01/19/2021	Yechezkal Evan Spero	TRCH0103PUSP3

CONFIRMATION NO. 6274

22045
Brooks Kushman
1000 Town Center
22nd Floor
Southfield, MI 48075

PUBLICATION NOTICE

Title:ADAPTIVE HEADLIGHT SYSTEM

Publication No.US-2021-0162912-A1
Publication Date:06/03/2021

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Public Records Division. The Public Records Division can be reached by telephone at (571) 272-3150 or (800) 972-6382, by facsimile at (571) 273-3250, by mail addressed to the United States Patent and Trademark Office, Public Records Division, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently https://portal.uspto.gov/pair/PublicPair. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/152,399	01/19/2021	Yechezkal Evan Spero	TRCH0103PUSP3	6274

22045 7590 07/07/2021

Brooks Kushman
1000 Town Center
22nd Floor
Southfield, MI 48075

EXAMINER	
LE, TUNG X	

ART UNIT	PAPER NUMBER
2844	

NOTIFICATION DATE	DELIVERY MODE
07/07/2021	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

docketing@brookskushman.com
kdilucia@brookskushman.com

Office Action Summary	Application No. 17/152,399	Applicant(s) Spero, Yechezkal Evan	
	Examiner TUNG X LE	Art Unit 2844	AIA (FITF) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☑ Responsive to communication(s) filed on 1/19/2021.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☐ This action is **FINAL.** 2b) ☑ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5) ☑ Claim(s) 1-33 is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6) ☐ Claim(s) _____ is/are allowed.

7) ☑ Claim(s) 1-5,12-16 and 23-27 is/are rejected.

8) ☑ Claim(s) 6-11,17-22 and 28-33 is/are objected to.

9) ☐ Claim(s) _____ are subject to restriction and/or election requirement

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to **PPHfeedback@uspto.gov.**

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☑ Notice of References Cited (PTO-892)

2) ☐ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date _____.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date _____.

4) ☐ Other: _____.

DETAILED ACTION

Notice of Pre-AIA or AIA Status

The present application is being examined under the pre-AIA first to invent provisions.

This Office Action is in response to the Applicant's communication filed on January 19, 2021. In virtue of this communication, claims 1-33 are currently presented in the instant application.

Claim Rejections - 35 USC § 103

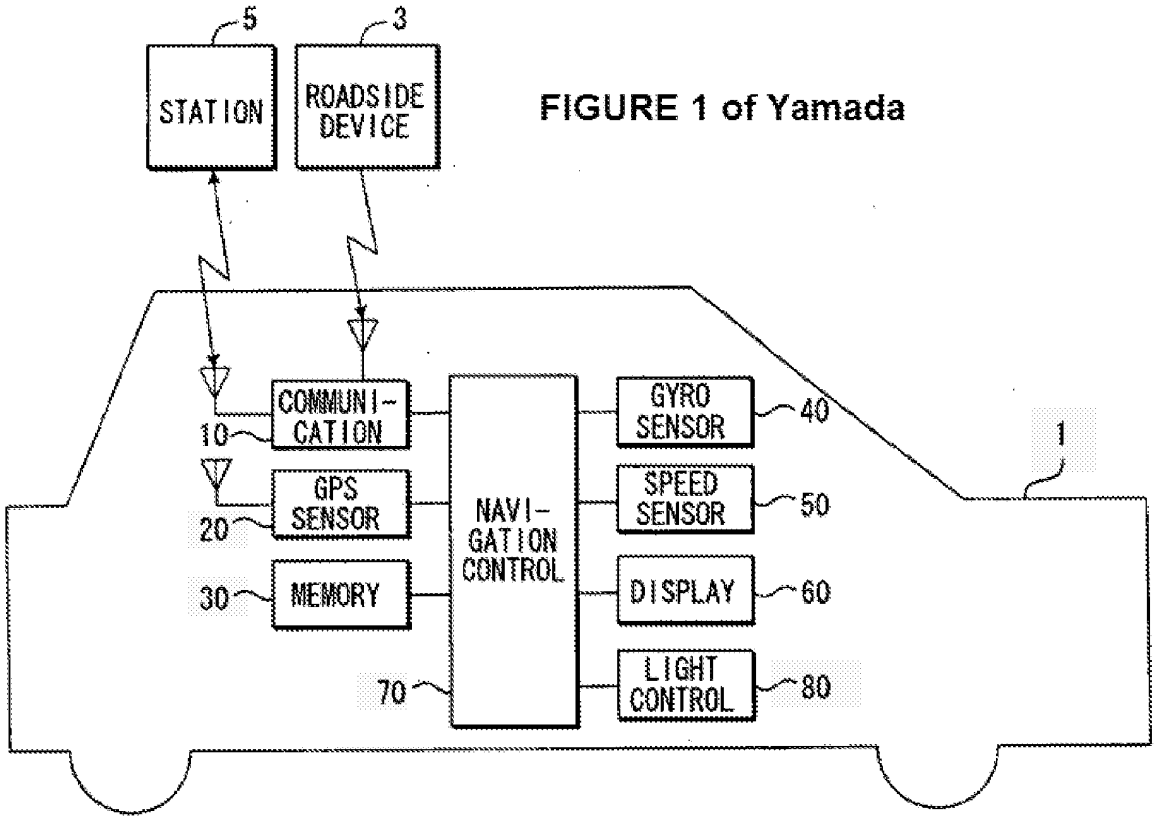
1. The following is a quotation of pre-AIA 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

2. Claims 1-5, 12-16 and 23-27 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Yamada (US 2010/0286896) in view of Nishitani et al. (US 2012/0001547).

With respect to claim 1, Yamada discloses in figures 1-2 a system, for a motor vehicle (1, e.g., vehicle), comprising a plurality of headlamps (paragraph 0023, e.g., "the light control unit 80 controls headlights mounted on the right and left sides of the front end of the vehicle 1"); one or more processors (70, e.g., a navigation control or processor or CPU); and a memory (30, e.g., memory) storing instructions (see paragraph 0022, e.g., "the position matches a road map indicated based on the map data stored in the memory unit 30") that, when executed by one or more of the one or more processors, enable the one or more processors to: receive first data (having a first road map data sensed by a GPS sensor 20 thereof), including at least map data, indicating a road curvature upcoming along a road on which the motor vehicle is traveling (see paragraphs 0022-0023); determine a light change, the change adapting a light pattern of the

headlamps in at least one of color, intensity or spatial distribution to increase light in a direction of the road curvature ahead of the motor vehicle and shaping light based at least in part on the road curvature (paragraph 0023, e.g., the output light of the headlights being adjusted based on the sensed map road condition); and control at least a first plurality of the LED light sources to provide light based at least in part on the determined light change and prior to the motor vehicle reaching the road curvature (see paragraph 0023 and figure 2).



Yamada does not explicitly disclose that each comprising a plurality of LED light sources.

Nishitani discloses in figure 1 a vehicle system comprising headlamps (11), wherein each comprising a plurality of LED light sources (figure 2 show each headlamp 11 comprising a plurality of LEDs thereof).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the system of Yamada with LED headlights as taught by Nishitani for the purpose of improving the brightness, power consumption and long life of the headlights since this configuration for the stated purpose would have been deemed obvious to a person skilled in the art.

FIG. 2B of Yamada

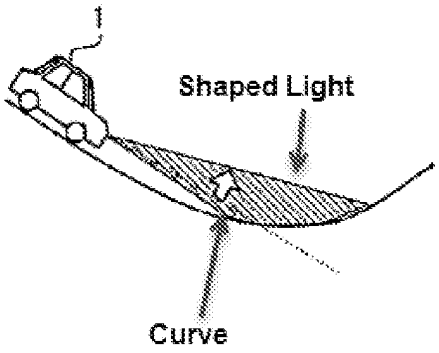
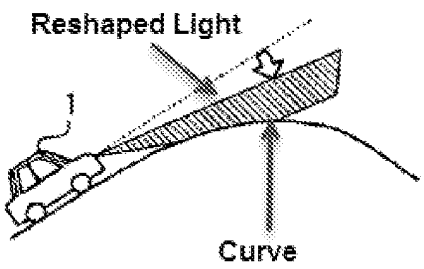


FIG. 2C



With respect to claim 2, the combination of Yamada and Nishitani disclose that wherein the determination of the light change includes selection of the first plurality of the LED light sources (see paragraph 0023 of Yamada).

With respect to claim 3, the combination of Yamada and Nishitani disclose that wherein the instructions include instructions that, when executed by the one or more processors, enable the one or more processors to reshape light based on the road curvature as the motor vehicle travels at least to or through the road curvature (see paragraph 0023 of Yamada).

With respect to claim 4, the combination of Yamada and Nishitani disclose that wherein the reshaping of light further includes control to at least one of the first plurality of LED light sources, or a second plurality of LED light sources, including at least one LED light source

different from the LED light sources of the first plurality of LED light sources, to provide reshaped light (see figure 2 of Nishitani).

With respect to claim 5, the combination of Yamada and Nishitani disclose that wherein the increase of light in the direction of the road curvature includes at least an increase of light emitted at a level below high-beam light and directed in the direction of the road curvature (see figure 2 and paragraph 0023 of Yamada).

With respect to claims 12 and 23, Yamada discloses in figures 1-2 a non-transitory computer-readable storage medium and a method thereof, storing instructions that, when executed by one or more processors (70, e.g., a navigation control or processor or CPU) of a motor vehicle (1, e.g., vehicle) that includes a plurality of headlamps (paragraph 0023, e.g., "the light control unit 80 controls headlights mounted on the right and left sides of the front end of the vehicle 1"), enable the one or more processors to receive first data (having a first road map data sensed by a GPS sensor 20 thereof), including at least map data, indicating a road curvature upcoming along a road on which the motor vehicle is traveling (see paragraph 0022-0023); determine a light change, the change adapting a light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction of the road curvature ahead of the motor vehicle and shaping light based at least in part on the road curvature (paragraph 0023, e.g., the output light of the headlights being adjusted based on the sensed map road condition); and control at least a first plurality of the LED light sources to provide light based at least in part on the determined light change and prior to the motor vehicle reaching the road curvature (see paragraph 0023 and figure 2).

Yamada does not explicitly disclose that each comprising a plurality of LED light sources.

Nishitani discloses in figure 1 a vehicle system comprising headlamps (11), wherein each comprising a plurality of LED light sources (figure 2 show each headlamp 11 comprising a plurality of LEDs thereof).

It would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the system of Yamada with LED headlights as taught by Nishitani for the purpose of improving the brightness, power consumption and long life of the headlights since this configuration for the stated purpose would have been deemed obvious to a person skilled in the art.

With respect to claims 13 and 24, the combination of Yamada and Nishitani disclose that wherein the determination of the light change includes selection of the first plurality of the LED light sources (see paragraph 0023 of Yamada).

With respect to claims 14 and 25, the combination of Yamada and Nishitani disclose that wherein the instructions include instructions that, when executed by the one or more processors, enable the one or more processors to reshape light based on the road curvature as the motor vehicle travels at least to or through the road curvature (see paragraph 0023 of Yamada).

With respect to claims 15 and 26, the combination of Yamada and Nishitani disclose that wherein the reshaping of light further includes control to at least one of the first plurality of LED light sources, or a second plurality of LED light sources, including at least one LED light source different from the LED light sources of the first plurality of LED light sources, to provide reshaped light (see figure 2 of Nishitani).

With respect to claims 16 and 27, the combination of Yamada and Nishitani disclose that wherein the increase of light in the direction of the road curvature includes at least an increase of

light emitted at a level below high-beam light and directed in the direction of the road curvature (see figure 2 and paragraph 0023 of Yamada).

Allowable Subject Matter

3. Claims 6-11, 17-22 and 28-33 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Conclusion

4. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

Prior art Bechtel et al. – US 2012/0050074

5. Any inquiry concerning this communication or earlier communications from the examiner should be directed to TUNG X LE whose telephone number is (571)272-6010. The examiner can normally be reached on Monday to Friday from 10am to 6pm.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Amy C Johnson can be reached on 571-272-2238. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished

applications is available through Private PAIR only. For more information about the PAIR system, see https://ppair-my.uspto.gov/pair/PrivatePair. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/TUNG X LE/
Primary Examiner, Art Unit 2844
July 1, 2021

Notice of References Cited	Application/Control No. 17/152,399	Applicant(s)/Patent Under Reexamination Spero, Yechezkal Evan	
	Examiner TUNG X LE	Art Unit 2844	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-20120050074-A1	03-2012	Bechtel; Jon H.	G06K9/00798	340/988
*	B	US-20120001547-A1	01-2012	Nishitani; Daisuke	H05B45/52	315/82
*	C	US-20100286896-A1	11-2010	Yamada; Kazunao	G01C21/30	701/117
	D					
	E					
	F					
	G					
	H					
	I					
	J					
	K					
	L					
	M					

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/152,399	Spero, Yechezkal Evan
	Examiner	Art Unit
	TUNG X LE	2844

CPC - Searched*		
Symbol	Date	Examiner
B60Q: 1/04, 1/085, 1/1423, 2300/112, 2300/134	07/01/2021	TXL

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	Date	Examiner
EAST (see search history printout)	07/01/2021	TXL
CPC Searches	07/01/2021	TXL
Inventor and Assignee Searches	07/01/2021	TXL
Citations: Forward and Backward	07/01/2021	TXL

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/152,399	Spero, Yechezkal Evan
	Examiner	Art Unit
	TUNG X LE	2844

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

CLAIMS

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	07/01/2021								
	1	✓								
	2	✓								
	3	✓								
	4	✓								
	5	✓								
	6	O								
	7	O								
	8	O								
	9	O								
	10	O								
	11	O								
	12	✓								
	13	✓								
	14	✓								
	15	✓								
	16	✓								
	17	O								
	18	O								
	19	O								
	20	O								
	21	O								
	22	O								
	23	✓								
	24	✓								
	25	✓								
	26	✓								
	27	✓								
	28	O								
	29	O								
	30	O								
	31	O								
	32	O								
	33	O								

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L3	6	"17152399"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/07/01 22:56
L4	16,237	(B60Q1/04 or B60Q1/085 or B60Q1/1423 or B60Q2300/112 or B60Q2300/134).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/07/01 23:15
L5	2,760	4 and ((adjust$4 or chang$3 or shap$3) near2 light)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/07/01 23:15
L6	77	5 and (map with data) and (road with (curvature or curv$3))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/07/01 23:16
L7	15	("20060267502" | "20090141513" | "20090296415" | "20120275173" | "20130057149" | "20140029791" | "20160010998" | "6459387" | "7697027" |	US-PGPUB; USPAT; USOCR	OR	ON	2021/07/01 23:16

		"9227553" | "9387796" | "9415718" | "9527429").PN. OR ("9809154").URPN.				
L8	7	("20040230358" | "20080294315" | "20140257644" | "20150127227" | "20150151669").PN. OR ("9527429").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2021/07/01 23:16
L9	28	("10131267" | "20080084286" | "20090141513" | "20110210665" | "20120116632" | "20120275172" | "20150003087" | "20150009694" | "20150028741" | "20150028742" | "20150055357" | "20150124465" | "20150197139" | "20150241013" | "20160023592" | "20160090024" | "20160090025" | "20160238210" | "20160332559" | "20160368414" | "20170043702" | "20170225608" | "20170282783" | "9162610" | "9387796" | "9527429" | "9809154" | "9896022").PN. OR ("10864847").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2021/07/01 23:17
S1	17	"10604360"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	ON	2021/07/01 10:35

			DERWENT; IBM_TDB			
S2	21,552	vehicle with (headlamp or headlight or lamp or (light near2 source)) and (memory with (data or instruction))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/07/01 10:42
S3	6,085	S2 and (map with data)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/07/01 10:43
S4	1,088	S2 and (map with data) and (road with (curvature or curv$3))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/07/01 10:44
S5	452	S4 and ((adjust$4 or chang$3 or shap$3) near2 light)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/07/01 10:45
S6	21,552	vehicle with (headlamp or headlight or lamp or (light near2 source)) and (memory with (data or instruction))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/07/01 17:35
S7	1,088	S6 and (map with data) and (road with (curvature or curv$3))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	ON	2021/07/01 17:35

			DERWENT; IBM_TDB			
S8	4	S7 and ((adjust$4 or chang$3 or shap$3) near2 light) and ((headlight or headlamp) with LED.u/c.)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/07/01 17:35
S9	186	S6 and ((adjust$4 or chang$3 or shap$3) near2 light) and ((headlight or headlamp) with LED.u/c.)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/07/01 17:38

7/1/2021 11:17:30 PM
C:\Users\tle16\Documents\EAST\Workspaces\17152399.wsp

PTO/SB/08a (02-18)
Approved for use through 11/30/2020. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	17152399
Filing Date	2021-01-19
First Named Inventor	YECHEZKAL EVAN SPERO
Art Unit	2844
Examiner Name	LE, TUNG X
Attorney Docket Number	TRCH0103PUSP3

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	3,316,442	A	1967-04-25	Konrad	
	2	4,597,033	A	1986-06-24	Meggs et al.	
	3	5,018,290	A	1991-05-28	Kozek et al.	
	4	5,033,099	A	1991-07-16	Yamada et al.	
	5	5,130,909	A	1992-07-14	Gross	
	6	5,546,475	A	1996-08-13	Bolle et al.	
	7	5,561,346	A	1996-10-01	Byrne	
	8	5,577,832	A	1996-11-26	Lodhie	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17152399
	Filing Date	2021-01-19
	First Named Inventor	YECHEZKAL EVAN SPERO
	Art Unit	2844
	Examiner Name	LE, TUNG X
	Attorney Docket Number	TRCH0103PUSP3

	9	5,749,646	A	1998-05-12	Brittell	
	10	5,785,243	A	1998-07-28	Cross	
	11	5,803,579	A	1998-09-08	Turnbull	
	12	5,921,660	A	1999-07-13	Yu	
	13	5,969,754	A	1999-10-19	Zeman	
	14	5,983,161	A	1999-11-09	Lemelson et al.	
	15	5,994,844	A	1999-11-30	Crawford et al.	
	16	6,046,549	A	2000-04-04	James	
	17	6,149,283	A	2000-11-21	Conway et al.	
	18	6,166,496	A	2000-12-26	Lys et al.	
	19	6,227,679	B1	2001-05-08	Zhang et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17152399
	Filing Date	2021-01-19
	First Named Inventor	YECHEZKAL EVAN SPERO
	Art Unit	2844
	Examiner Name	LE, TUNG X
	Attorney Docket Number	TRCH0103PUSP3

	20	6,281,632	B1	2001-08-28	Stam et al.	
	21	6,340,868	B1	2002-01-22	Lys et al.	
	22	6,346,777	B1	2002-02-12	Kim	
	23	6,379,022	B1	2002-04-30	Amerson et al.	
	24	6,385,352	B1	2002-05-07	Roustaei	
	25	6,394,614	B1	2002-05-28	Chang	
	26	6,406,172	B1	2002-06-18	Harbers et al.	
	27	6,483,439	B1	2002-11-19	Vukosic	
	28	6,498,440	B2	2002-12-24	Stam et al.	
	29	6,499,860	B2	2002-12-31	Begemann	
	30	6,528,954	B1	2003-03-04	Lys et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17152399
	Filing Date	2021-01-19
	First Named Inventor	YECHEZKAL EVAN SPERO
	Art Unit	2844
	Examiner Name	LE, TUNG X
	Attorney Docket Number	TRCH0103PUSP3

	31	6,601,982	B1	2003-08-05	Begemann et al.	
	32	6,676,282	B2	2004-01-13	Begemann et al.	
	33	6,820,998	B2	2004-11-23	Chen	
	34	7,524,097	B2	2009-04-28	Turnbull et al.	
	35	8,045,760	B2	2011-10-25	Stam et al.	
	36	8,115,394	B2	2012-02-14	Kobayashi	
	37	8,665,079	B2	2014-03-14	Pawlicki et al.	
	38	9,398,270	B2	2016-07-19	Liken et al.	
	39	6,587,573	B1	2003-07-01	Stam et al.	
	40	6,861,809	B2	2005-03-01	Stam	

If you wish to add additional U.S. Patent citation information please click the Add button. Add

U.S.PATENT APPLICATION PUBLICATIONS Remove

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	17152399
Filing Date	2021-01-19
First Named Inventor	YECHEZKAL EVAN SPERO
Art Unit	2844
Examiner Name	LE, TUNG X
Attorney Docket Number	TRCH0103PUSP3

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20010014019	A1	2001-08-16	Begemann	
	2	20020022774	A1	2002-02-21	Karnieli	
	3	20020022927	A1	2002-02-21	Lemelson et al.	
	4	20020039238	A1	2002-04-04	Chang	
	5	20020046100	A1	2002-04-18	Kinjo	
	6	20020047646	A1	2002-04-25	Lys et al.	
	7	20020047628	A1	2002-04-25	Morgan et al.	
	8	20020057340	A1	2002-05-16	Fernandez et al.	
	9	20020130326	A1	2002-09-19	Tamura et al.	
	10	20040052076	A1	2004-03-18	Mueller	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17152399
	Filing Date	2021-01-19
	First Named Inventor	YECHEZKAL EVAN SPERO
	Art Unit	2844
	Examiner Name	LE, TUNG X
	Attorney Docket Number	TRCH0103PUSP3

	11	20040061605	A1	2004-04-01	Howard	
	12	20040105264	A1	2004-06-03	Spero	
	13	20040138726	A1	2004-07-15	Savage et al.	
	14	20040230358	A1	2004-11-18	Stam et al.	
	15	20060222213	A1	2006-10-05	Kiyohara et al.	
	16	20080136356	A1	2008-06-12	Zampini et al.	
	17	20090315485	A1	2009-12-24	Verfuerth et al.	
	18	20100302779	A1	2010-12-02	Chemel	
	19	20100052550	A1	2010-03-04	Kobayashi	
	20	20110211110	A1	2011-09-01	Doublet	
	21	20120001566	A1	2012-01-05	Josefowicz	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17152399
	Filing Date	2021-01-19
	First Named Inventor	YECHEZKAL EVAN SPERO
	Art Unit	2844
	Examiner Name	LE, TUNG X
	Attorney Docket Number	TRCH0103PUSP3

	22	20120091897	A1	2012-04-19	O et al.	
	23	20120262575	A1	2012-10-18	Champagne	
	24	20120283908	A1	2012-11-08	Schofield et al.	
	25	20120287493	A1	2012-11-15	Kuhlman et al.	
	26	20130258688	A1	2013-10-13	Kalapodas	

If you wish to add additional U.S. Published Application citation information please click the Add button. Add

FOREIGN PATENT DOCUMENTS Remove

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	2001070538	WO	A2	2001-09-27	Stam et al.		

If you wish to add additional Foreign Patent Document citation information please click the Add button Add

NON-PATENT LITERATURE DOCUMENTS Remove

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1		

If you wish to add additional non-patent literature document citation information please click the Add button Add

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17152399
	Filing Date	2021-01-19
	First Named Inventor	YECHEZKAL EVAN SPERO
	Art Unit	2844
	Examiner Name	LE, TUNG X
	Attorney Docket Number	TRCH0103PUSP3

EXAMINER SIGNATURE			
Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17152399
	Filing Date	2021-01-19
	First Named Inventor	YECHEZKAL EVAN SPERO
	Art Unit	2844
	Examiner Name	LE, TUNG X
	Attorney Docket Number	TRCH0103PUSP3

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

☒ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Bernard P. Tomsa/	Date (YYYY-MM-DD)	2021-07-07
Name/Print	Bernard P. Tomsa	Registration Number	60,121

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 September 2001 (27.09.2001)

PCT

(10) International Publication Number
WO 01/70538 A2

(51) International Patent Classification[7]: B60Q

(21) International Application Number: PCT/US01/08912

(22) International Filing Date: 20 March 2001 (20.03.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

09/528,389	20 March 2000 (20.03.2000)	US
09/800,460	5 March 2001 (05.03.2001)	US

(71) Applicant: **GENTEX CORPORATION** [US/US]; 600 North Contennial Street, Zeeland, MI 49464 (US).

(72) Inventors: **STAM, Joseph, S.**; 345 South Lakeshore Drive, Holland, MI 49424 (US). **BECHTEL, Jon, H.**; 136 Sunrise Drive, Holland, MI 49423 (US). **REESE, Spencer, D.**; 1710 Columbia Avenue, Fort Wayne, IN 46805 (US). **ROBERTS, John, K.**; 1061 Plymouth Avenue, S.E., East Grand Rapids, MI 49506 (US). **TONAR, William, L.**; 40 Cheyenne, Holland, MI 49424 (US). **POE, G., Bruce**; 3175 42nd Street, Hamilton, MI 49419 (US).

(74) Agent: **CARRIER, Robert, J.**; Price, Heneveld, Cooper, DeWitt & Litton, 695 Kenmoor, S.E., P.O. BOX 2567, Grand Rapids, Michigan 49501-2567 (US).

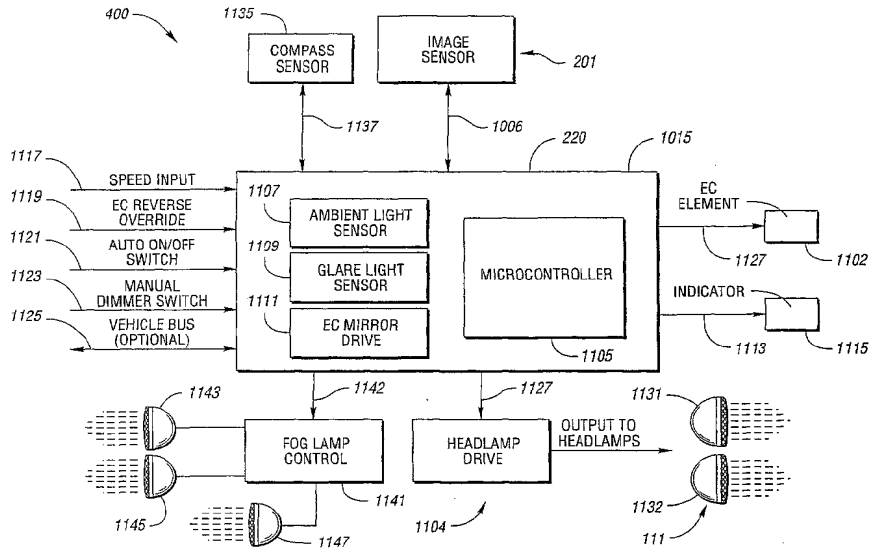
(81) Designated States *(national)*: AT, AU, BG, BR, CA, CH, CN, CZ, DE, DK, ES, FI, GB, GE, HU, ID, IL, IN, JP, KR, MX, NO, NZ, PL, PT, RO, RU, SE, SG, SI, SK, TR, UA, YU, ZA.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: SYSTEM FOR CONTROLLING EXTERIOR VEHICLE LIGHTS



(57) Abstract: A system and method of automatically controlling exterior vehicle lights includes an image sensor (201) and a controller (1105) to generate control signals. The control signals are derived based on information obtained from the image sensor as well as other detected parameters pertaining to the detected light source(s), the vehicle having the inventive control system, and the ambient environment. The control circuit may simply turn certain exterior lights on or off, or change the brightness, aim, focus, etc. to produce various beam patterns that maximize the illuminated area in front of the vehicle without causing excessive glare in the eyes of other drivers.

WO 01/70538 A2

SYSTEM FOR CONTROLLING EXTERIOR VEHICLE LIGHTS

BACKGROUND OF THE INVENTION

The present invention pertains to control systems for controlling the exterior lights of a vehicle and components that can be used with such a control system.

Modern automotive vehicles include a variety of different lamps to provide illumination under different operating conditions. Headlamps are typically controlled to alternately generate low beams and high beams. Low beams provide less illumination and are used at night to illuminate the forward path when other vehicles are present. High beams output significantly more light and are used to illuminate the vehicle's forward path when other vehicles are not present. Daytime running lights have also begun to experience widespread acceptance. In addition, super bright high beams have been proposed for use on fast rural roads. Foul weather lights, such as fog lights, are also commonly used. Other exterior vehicle lights include tail lights, brake lights center-mounted stop lights (CHMSLs), turn signals, back-up lights, cargo lights, puddle lights, license plate illuminators, etc.

Laws in various countries regulate vehicle illumination, and vehicle manufacturers must build cars that comply with these regulations. For example, regulations set forth by the United States Department of Transportation (DOT) regulate the light emissions of a vehicle's high beam headlamps. Various state regulations are used to control the amount of glare experienced by drivers due to preceding vehicles (other vehicles traveling in the same direction) and oncoming vehicles (vehicles traveling in the opposite direction).

Known vehicle high beam headlamp emissions in accordance with the DOT regulations limit the intensity to 40,000 cd at 0°, 10,000 cd at 3°, 3250 cd at 6°, 1500 cd at 9°, and 750 cd at 12°. An example of an emission pattern meeting this regulation is illustrated in Fig. 1 of U.S. Patent No. 5,837,994, entitled CONTROL SYSTEM TO AUTOMATICALLY DIM VEHICLE HEADLAMPS, issued to Joseph Scott Stam et al. on Nov. 17, 1998. In order to avoid an illuminance of 0.1 foot candles (fc) incident on another vehicle at these angles, the vehicle high beam headlamps should be dimmed within 700 feet of another vehicle if the vehicles are at an angle of 0°, within 350 feet of another vehicle if the vehicles are at a horizontal position of 3°, and 200 feet of the other vehicle if the position of the other vehicle is at an angle of 6° to the longitudinal axis of the controlled vehicle. It can thus be seen that a preceding vehicle directly in front of the

controlled vehicle (*i.e.*, at an angle of 0°) will need to be identified well prior to the controlled vehicle catching up to the preceding vehicle, although the distance by which the controlled vehicle's headlamps must be dimmed for a preceding vehicle can be somewhat less than for an oncoming vehicle because glare from behind is usually less disruptive than oncoming glare.

In order to automatically control the vehicle headlamps, various headlamp dimmer control systems have been proposed. In order to prevent drivers of other vehicles from being subjected to excessive glare levels, an automatic headlamp dimmer system must sense both the headlamps of oncoming vehicles as well as the tail lights of preceding vehicles. Some systems that effectively detect headlamps are unable to adequately detect tail lights. Most prior systems are unable to distinguish nuisance light sources, such as reflectors, street signs, streetlights, house lights, or the like, from light sources that require headlamp control. Accordingly, these systems are subject to undesirable dimming of the high beams when no other traffic is present and turning on the high beams when other vehicles are present. In addition to the undesirable performance, it is difficult for prior systems to comply with the legal requirements as described above for high beam control while avoiding unnecessary dimming of the vehicle headlamps.

Fog lights are examples of other vehicle lights that are difficult to control automatically. Vehicles are known to include forward and rearward directed fog lights. In Europe, it is known to provide a very bright red or white light on the back of the vehicle, which is illuminated under foggy conditions. The fog lights must be turned ON as soon as the fog reduces visibility by a predetermined amount and must turn OFF when the fog drops below that density. A reliable method of automatically controlling such fog lights has not been available.

Accordingly, there is a need for a more reliable and intelligent automatic lamp control for a vehicle.

SUMMARY OF THE INVENTION

According to one aspect of the present invention, a control system is provided to control exterior lights of a controlled vehicle. The control system comprises an imaging system configured to image the scene forward of the controlled vehicle, and a control circuit for processing the image of the scene obtained from the imaging system and for controlling the exterior lights to change their beam pattern in response to objects detected

in the processed scene, the control circuit disables automatic control of the exterior lights in response to activation of the vehicle windshield wipers.

According to another aspect of the present invention, a control system is provided to control exterior lights of a controlled vehicle. The control system comprises an imaging system configured to image the scene forward of the controlled vehicle, and a control circuit for processing the image of the scene obtained from the imaging system and for controlling the exterior lights to change their beam pattern in response to objects detected in the processed scene, the control circuit disables automatic control of the exterior lights when the vehicle windshield defroster is operating at full speed.

According to another aspect of the present invention, a control system is provided to control exterior lights of a controlled vehicle. The control system comprises an imaging system configured to image the scene forward of the controlled vehicle, and a control circuit for processing the image of the scene obtained from the imaging system and for controlling the exterior lights to change their beam pattern in response to objects detected in the processed scene, the control circuit disables automatic control of the exterior lights when snow is detected.

According to yet another embodiment, a method of detecting snowfall or fog outside a vehicle is accomplished. The method comprises the steps of: sensing light levels forward above the vehicle; comparing the relative brightness of the light levels forward and above the vehicle; and determining that it is snowing or foggy when a ratio of the relative brightness forward of the vehicle to that above the vehicle reaches a threshold.

According to another aspect of the present invention, a control system is provided to control the headlamps of a vehicle. The control system comprises an ambient light sensor for sensing the ambient light outside of the vehicle, and a control circuit for varying the beam pattern of daytime running lamps in response to the ambient light level sensed by the ambient light sensor.

According to another aspect of the present invention, a control system is provided to control the brightness of the tail lights of a vehicle. The control system comprises an ambient light sensor for sensing the ambient light outside of the vehicle, and a control circuit for varying the brightness of the tail lights in response to the ambient light level sensed by the ambient light sensor.

According to yet another aspect of the invention, a headlamp control system is provided for controlling the headlamps of a controlled vehicle that comprises: an imaging system configured to image the scene forward of the controlled vehicle; a control circuit

coupled to the imaging system for identifying and determining the brightness of light sources in images obtained from the imaging system and for controlling the headlamps to vary a beam pattern of the headlamps as a function of the brightness of light sources within the images; and a user input mechanism coupled to the control circuit for allowing a user to adjust a sensitivity at which the control circuit will control the headlamps in response to light sources within the images.

According to yet another aspect of the invention, a headlamp control system is provided for controlling the headlamps of a controlled vehicle that comprises an imaging system configured to image the scene forward of the controlled vehicle and to detect an ambient light level outside the vehicle, and a control circuit coupled to the imaging system for determining an ambient light level outside the vehicle, for identifying and determining the brightness of light sources in images obtained from the imaging system, and for controlling the headlamps to vary a beam pattern of the headlamps as a function of the brightness of light sources within the images when the ambient light level is above a threshold level.

According to another aspect of the present invention, a control system is provided to control exterior lights of a vehicle. The control system comprises an image array sensor including a plurality of pixels, an optical system configured to image the scene forward of the controlled vehicle onto the image array sensor, the optical system including a forwardmost surface, and a control circuit for processing the image of the scene obtained from the image array sensor and for controlling the exterior lights in response to objects detected in the processed scene, wherein the optical system includes a hydrophilic coating on the forwardmost surface.

According to yet another aspect of the present invention, a vehicle control system is provided to control the brightness of continuously variable headlamps that have a brightness that varies continuously between a high beam state and a low beam state. The control system comprises an imaging system configured to image the scene forward of the controlled vehicle, a control circuit for identifying and determining the brightness of light sources in images obtained from the imaging system and for controlling the brightness of the headlamps as a function of the brightness of light sources within the images, and an indicator coupled to the control circuit and positioned inside the vehicle for indicating to the driver the relative brightness of the headlamps.

According to another aspect of the invention, an imaging system for a vehicle is provided that comprises an image sensor having an array of pixels and at least one other

component, and an optical baffle disposed between the images sensor and a scene to be imaged for preventing light from the scene from reaching the at least one other component.

According to a further aspect of the invention, a headlamp control system for a vehicle is provided that comprises an imaging system configured to image the scene forward of the controlled vehicle, a switching mechanism for manual input of a driver's selection of a feature affecting the control of the vehicle headlamps, and a control circuit coupled to the switching mechanism and the imaging system for identifying and determining the brightness of light sources in images obtained from the imaging system and for controlling the brightness of the headlamps as a function of the brightness of light sources within the images and as a function of the status of the switching mechanism.

Another aspect of the present invention is to provide a headlamp control system for a vehicle that comprises a control circuit coupled to the vehicle headlamps for fading the headlamps of the vehicle to an off state in response to the turning off of the vehicle ignition or exiting the vehicle.

According to another aspect of the invention, a control system is provided to control exterior lights of a vehicle. The control system comprises an image array sensor including a plurality of pixels, an optical system configured to image the scene forward of the controlled vehicle onto the image array sensor, the optical system including a forwardmost surface, and a control circuit for processing the image of the scene obtained from the image array sensor and for controlling the exterior lights in response to objects detected in the processed scene, the optical system includes a photocatalytic coating on the forwardmost surface.

Another aspect of the present invention is to provide a control system to control the headlamps of a vehicle. The control system comprises a manually actuated switch mechanism for receiving input from a driver to temporarily increase the brightness of the vehicle headlamps in a flash-to-pass state, an ambient light sensor for sensing the ambient light outside the vehicle, and a control circuit coupled to the ambient light sensor and the manually actuated switch mechanism for varying the beam pattern of the headlamps during the flash-to-pass state in response to the ambient light level sensed by the ambient light sensor.

According to yet another aspect of the present invention, a control system is provided to control the headlamps of a vehicle where the vehicle has a microwave receiver for receiving signals from satellites. The control system comprises a control circuit for

receiving signals from the microwave receiver indicative of the location of the vehicle, the control circuit controls the headlamps to limit the perceived brightness of the headlamps from exceeding a predetermined level less than their capacity when the vehicle is travelling on a residential street.

These and other features, advantages, and objects of the present invention will be further understood and appreciated by those skilled in the art by reference to the following specification, claims, and appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter that is regarded as the invention is particularly pointed out and distinctly claimed in the claim portion that concludes the specification. The invention, together with further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings, where like numerals represent like components, and in which:

Fig. 1 illustrates vehicles traveling on a common road;

Figs. 2a and 2b illustrate an optical sensor system, Fig. 2b showing a perspective view and Fig. 2a showing a cross section of the optical sensor system taken along plane 2a-2a in Fig. 2b;

Fig. 3 is a plan view illustrating an image sensor used in the optical sensor system according to Figs. 2a and 2b;

Fig. 4 is a top plan view illustrating a lens structure used in the optical sensor system according to Figs. 2a and 2b;

Fig. 5 is a side elevation view illustrating the lens structure according to Fig. 4;

Fig. 6 is a graph illustrating wave transmissivity as a function of light wavelength for the lens;

Fig. 7 shows a light sensitive surface of the image sensor and illustrates the regions of the image array which are impacted by the light from each of the lenses;

Fig. 8 is a cross section illustrating another image sensor assembly taken along the same plane as the assembly in Fig. 2a;

Fig 9 is a cross section illustrating yet another light sensor assembly taken along the same plane as the assembly in Fig. 2a;

Fig. 10 is a partial cross section of a rearview mirror assembly illustrating an optical sensor system;

Fig. 11 is a circuit schematic illustrating a circuit for an optical sensor system and an electrochromic mirror;

Fig. 12 is a circuit schematic illustrating a headlamp drive for the circuit according to Fig. 11;

Fig. 13 is a circuit schematic illustrating a microcontroller circuit for the circuit according to Fig. 11;

Fig. 14 is a flow chart illustrating operation of an electrochromic mirror and headlamp control;

Fig. 15 is a flow chart illustrating operations to acquire and analyze an image;

Fig. 16 is a flow chart illustrating operations to analyze an image and find a light source;

Fig. 17a is a flow chart illustrating a seed fill algorithm;

Fig. 17b illustrates a pixel array impacted by a light source;

Fig. 18 is a flow chart illustrating operation to determine if light sources are oncoming or preceding vehicles;

Fig. 19 is a state diagram illustrating the duty cycle associated with states for a variable high beam lamp;

Fig. 20 illustrates operation rules for changes of state in Fig. 19;

Fig. 21 is a flow chart illustrating operation to provide speed varying thresholds;

Fig. 22 is a chart illustrating the different regions of the image array;

Fig. 23 is a flow chart illustrating operation of the microcontroller to shift the regions in Fig. 22;

Fig. 24 is a front perspective view illustrating an image sensor assembly including an electronically alterable filter;

Fig. 25 is a side elevation view of the liquid crystal filter in the image sensor assembly according to Fig. 24;

Fig. 26a is an exploded perspective view illustrating an LED headlamp;

Fig. 26b is a fragmentary cross section taken along plane 26b-26b in Fig. 26a;

Fig. 26c is a front plan view illustrating an alternate embodiment of an LED lamp;

Fig. 26d is a fragmentary cross section taken along plane 26d-26d in Fig. 26c;

Fig. 27 is a top, front perspective view of an LED headlamp for projecting light in more than one horizontal direction;

Fig. 28 is a top, front perspective view of an LED headlamp for projecting light in more than one vertical direction;

Figs. 29a-29d illustrates a method of manufacturing surface mounted filters for an image sensor;

Fig. 30 is a chart illustrating the wavelengths passed by a red filter surface mounted to an image sensor;

Fig. 31 is a chart illustrating the wavelengths passed by a cyan filter surface mounted to an image sensor;

Fig. 32 illustrates another image sensor assembly;

Fig. 33 illustrates an electrical system including a wave sensitive headlamp control;

Fig. 34 is a circuit schematic illustrating an alternative circuit for an optical sensor system and an electrochromic mirror;

Fig. 35 is a state diagram illustrating a first control scheme for manually or automatically controlling the vehicle headlamps in response to activation of various manual switches;

Fig. 36 is a state diagram illustrating a second control scheme for manually or automatically controlling the vehicle headlamps in response to activation of various manual switches;

Fig. 37 is a state diagram illustrating a third control scheme for manually or automatically controlling the vehicle headlamps in response to activation of various manual switches;

Fig. 38 illustrates an exemplary indicator for use with the headlamp control system of the present invention;

Fig. 39 is a representative pictorial view of an imaged scene taken in several superimposed frames;

Fig. 40 is a functional block diagram of one embodiment of the present invention;

Fig. 41 is front elevational view of a mirror mount accessory housing according to another embodiment of the present invention;

Fig. 42 is top plan view of the mirror mount accessory housing shown in Fig. 41;

Fig. 43 is a cross-sectional view of the mirror mount accessory housing shown in Figs. 41 and 42 taken along line 43-43′ in Fig. 42;

Fig. 44 is an exploded perspective view of the mirror mount accessory housing;

Fig. 45 is rear elevational view of the mirror mount accessory housing;

Fig. 46 is a side elevational view of the mirror mount accessory housing with the housing cover removed;

Fig. 47 is a top plan view of the mirror mount accessory housing with the housing cover removed;

Fig. 48 is a front elevational view of the mirror mount accessory housing with the housing cover removed;

Fig. 49 is a rear elevational view of the mirror mount accessory housing with the housing cover removed; and

Figs. 50A-50C are pictorial representations of various illumination patterns produced by exterior lights of a vehicle.

DETAILED DESCRIPTION OF THE INVENTION

The present invention generally pertains to a control system for controlling the exterior lights of a vehicle. As noted above, such exterior lights may include headlamps, tail lights, foul weather lights such as fog lights, brake lights, center-mounted stop lights (CHMSLs), turn signals, back-up lights, cargo lights, puddle lights, license plate illuminators, etc. The headlamps may be operated in several different modes including conventional low-beam and high-beam states. They may also be operated as daytime running lights, and additionally as super-bright high beams in those countries where they are permitted. The headlamp brightness may also be continuously varied between the low, high, and super-high states. Separate lights may be provided for obtaining each of these headlamp states or the actual brightness of the headlamps may be varied to provide these different headlamp states. In either case, the "perceived brightness" of the headlamps is varied. As used herein, the term "perceived brightness" means the brightness of the headlamps as perceived by an observer outside the vehicle. Most typically, such observers will be drivers or passengers in a preceding vehicle or in a vehicle traveling along the same street in the opposite direction. Ideally, the exterior lights are controlled such that if an observer is located in a vehicle within a "glare area" relative to the vehicle (*i.e.*, the area in which the observer would perceive the brightness of the exterior lights as causing excessive glare), the beam illumination pattern is varied such that the observer is no longer in the glare area. The perceived brightness and/or glare area of the headlamps (and/or other exterior lights) may be varied by changing the illumination output of one or more lights forming the headlamps, by steering one or more lights to change the aim of one or more of the lights forming the headlamps, activating or deactivating some or all of the lights, altering the illumination pattern forward of the vehicle, or a combination of the above. Fig. 50A shows a typical low beam pattern as would be used when other vehicles are nearby and forward of the controlled vehicle 5000. Fig. 50B shows an examplary composite beam pattern including both high and low beam patterns and side bending light patterns, which may be individually activated as the vehicle 5000 approaches a turn. Fig.

50C illustrates another composite beam pattern including a low beam pattern and an intermediate, side-aimed pattern, which may be produced by changing the focus or aim of the high beams as well as the brightness of the high beams. The composite beam pattern shown in Fig. 50C is useful when another vehicle is approaching in an oncoming and adjacent lane. As will be apparent to those skilled in the art, a large number of other beam patterns can be achieved using known headlamp mechanisms. Other mechanisms for adjusting the perceived brightness and glare area of the headlamps will also be apparent to those skilled in the art.

Although the present invention primarily addresses the control of the vehicle headlamps, embodiments are described below for controlling the tail lights and foul weather lights. In some embodiments, the present invention is generally described as controlling the "exterior lights," which broadly includes any exterior lighting on the vehicle. For example, the present invention may be used in some circumstances to control the perceived brightness of a turn signal mounted in an outside rearview mirror assembly so as to provide sufficient light output for signaling a driver in another vehicle without causing excessive glare in the eyes of the driver of the vehicle having the signal mirrors. Also, the present invention may be employed to control the instrument panel lights as well as other interior display lights based upon the sensed ambient light. Other examples will be apparent to those skilled in the art.

A controlled vehicle 100 (Fig. 1) having an automatic headlamp dimmer includes an optical sensor system 102 for detecting the headlamps 104 of an oncoming vehicle 105 and the tail lights 108 of a preceding vehicle 110. The headlamps 111 of the controlled vehicle 100 are controlled automatically to avoid shining the high beams, or bright lights, directly into the eyes of a driver of oncoming vehicle 105 or by reflection into the eyes of the driver of the preceding vehicle 110. The optical sensor assembly 102 is illustrated mounted in the windshield area of the vehicle, but those skilled in the art will recognize that the sensor could be mounted at other locations that provide the sensor with a view of the scene in front of the vehicle. One particularly advantageous mounting location is high on the vehicle windshield to provide a clear view, which view can be achieved by mounting the optical sensor assembly 102 in a rearview mirror mount, a vehicle headliner, a visor, or in an overhead console. Other views that may be advantageously employed include mounting the optical sensor assembly 102 on the A-pilar, the dashboard, or at any other location providing a forward viewing area. However, the most advantageous

mounting locations are those that position the image sensor to view a forward scene through an area kept clean by the vehicle's windshield wipers.

With reference to Figs. 2a and 2b, the optical sensor assembly 102 includes an electronic image sensor 201 and an optical system to direct light onto the image sensor 201. The image sensor 201 generally comprises an array of light sensitive components and associated circuitry to output electronic pixel light level signals responsive to light impacting on the surface of the image sensor 201. The optical system generally contains four components: lens structure 202; aperture stop member 203; far field baffle 204; and optional infrared filter 206. The optical system controls the scene viewed by the image sensor 201. In particular, the optical system focuses light rays 205 passing through opening 207 of the far field baffle onto the array 201 contained within the image sensor assembly 201.

THE IMAGE SENSOR

The configuration of the image sensor 201 is illustrated in Fig. 3. The image sensor includes an image array 301 (Fig. 3) that can be made from any one of a variety of sensors, such as CMOS image sensors, charge coupled device (CCD) image sensors, or any other suitable image sensor. In one embodiment, the image sensor is a CMOS photogate active pixel image sensor. A CMOS photogate active pixel image sensor is described in U.S. Patent No. 5,471,515, entitled ACTIVE PIXEL SENSOR WITH INTER-PIXEL CHARGE TRANSFER, issued to Eric R. Fossum et al., on November 28, 1995. Sensor systems including arrays are disclosed in U.S. Patent Application No. 09/448,364, entitled CONTROL CIRCUIT FOR IMAGE SENSORS, filed November 23, 1999, by Jon Bechtel et al.; U.S. Patent Application No. 08/933,210, entitled CONTROL CIRCUIT FOR IMAGE SENSORS, filed on September 16, 1997, by Jon Bechtel et al., now U.S. Patent No. 5,990,469; and U.S. Patent Application No. 08/831,232, filed April 2, 1997, entitled CONTROL SYSTEM TO AUTOMATICALLY DIM VEHICLE HEADLAMPS, by Joseph Stam et al., now U.S. Patent No. 5,837,994.

The array 301 may for example comprise photogate active pixels, such as 10 to 50 μm pixels. It is advantageous for the array to be a low resolution array, which is an array that has a resolution of less than 7000 pixels per square millimeter and more preferably less than 2500 pixels per square millimeter. The array may have 25μm or larger photogate active pixels. In particular, the array may include 30 μm or larger pixels arranged in a grid smaller than 200 rows by 200 columns, and may advantageously comprise a rectangular

array having 64 columns and 80 rows of pixels. Such an image sensor is described in detail in U.S. Patent No. 5,471,515. The optically active region of array 301 is approximately 1.9 mm in the X direction by 2.4 mm in the Y direction. Using such a low resolution image sensor array to monitor the forward field of the controlled vehicle 100 results in a relatively low resolution sensor system that can be supported by high speed processing in a cost effective manner while enabling a vehicle headlamp control to be highly reliable and accurate. The low resolution array reduces the memory and processor requirements of associated circuitry. The use of such larger pixels increases sensitivity and thus allows the use of slower, and thus lower cost, optics. However, one skilled in the art will recognize that the use of a higher resolution array with smaller pixels may be advantageous to reduce the area of the sensor array and thus potentially reduce the cost at the array itself. In the case where a high resolution image sensor is employed, faster components and higher quality optics may be required to accommodate the high resolution image sensor. With advances in optical manufacturing, such optics may become cost effective such that use of a higher resolution array becomes economically practical. Additionally, it is expected that in future years the cost of a processor and memory required to process an image containing more pixels will be reduced making a higher resolution system feasible. A higher resolution array may improve the ability to detect distant tail lights. However, at this time it is preferred to use a low resolution array with relatively few pixels to maintain the economy of the invention and thus enable widespread acceptance in the market place.

An image sensor and control circuit therefore will be described in greater detail herein below, and such a system is disclosed in U.S. Patent No. 5,990,469.

In addition to the array 301, the image sensor 201 includes: serial timing and control circuit 309; column output circuit 302; bias generating digital-to-analog converters (DACs) 305; flash analog-to-digital converters (ADCs) 304; and analog amplifier 303. Serial timing and control circuitry 309 provides a high-speed synchronous bi-directional interface between a microcontroller 1105 (Fig. 11) and the image sensor 201. As described in U.S. Patent No. 5,990,469, the control circuit 309 allows the microcontroller 1105 to output parameters that control the selection of pixels exposed for measurement (*i.e.*, selects the area of array 301 exposed; which area is referred to herein as the "window"); exposure time which affects sensitivity; bias voltages generated by the bias voltage generation DACs 305; and the analog gain of amplifier 303. Additional features include the ability to expose two windows simultaneously, using the same or different gain

settings for the amplifier 303 for pixels of the respective windows, and the ability to acquire a sequence of multiple frames. The control circuit 309 also enables a sleep feature that disables the analog components of the image sensor assembly 201 to reduce power consumption when the image sensor is not in use. The image sensor also includes: a power supply input Vdd; a ground input; serial data bus input/output (I/O) 308; serial data clock I/O 311; slave select input 307; and clock input 306.

THE LENS STRUCTURE

Lens structure 202 (Fig. 2a) includes lenses 208 and 209. Although two lenses are disclosed, the image sensor 201 could use a single lens or more than two lenses. The two lenses 208,209 are used to produce two different images of the same scene through different color filters to assist in properly discriminating headlamps from tail lights using the image sensor 201 as described below and in U.S. Patent Nos. 5,837,994 and 5,990,469. The image system allows the acquisition of an image of a scene through at least one color filter 208, 209. In one embodiment, the lens structure is constructed to image the forward scene onto one region of the image array 301 through a first color filter and to image the forward scene onto another region of the image array through a second filter. For example, filter 209 (Figs. 2a and 2b) may be a red filter and filter 208 may be either a blue filter, a green filter, a cyan filter, a clear filter (which is for example the absence of a color filter), or any other suitable filter. There are various places within the optical system that the filters could be incorporated other than the lens 208, 209, such as on the image sensor surface. However, incorporating the filters into the lens structure has the advantage that the light is not focused at the point of the filter. Locating the filter in the image plane, *i.e.*, on the sensor, would leave an organic filter susceptible to thermal damage should the sun fall within the sensor's field of view such that the sun's rays are focused on the filters. Typically, filter materials are much more vulnerable to thermal damage than the image sensor itself. A possible exception would be dichroic interference filters, which are highly resistant to thermal damage. A method by which such thermal resistant filters can be deposited onto a semiconductor image sensor surface is described in greater detail herein below with respect to an alternate embodiment of the present invention.

An example of a filter that could be incorporated on the image sensor surface is a dichroic filter array of the type disclosed in U.S. Patent No. 5,711,889 to Philip E. Buchsbaum. The dichroic filter array disclosed in this U.S. patent is resistant to thermal damage and therefore would be suitable for use in an image sensor used for detecting light sources in the control of a vehicle's headlamps. Such a dichroic filter array may include a

checkerboard or mosaic pattern may be deposited on to the array such that neighboring pixels are exposed to separate bands of light. A technique for depositing interference filters of different colors onto neighboring pixels is disclosed in the above-referenced U.S. Patent No. 5,711,889. In one embodiment, neighboring pixels are alternatively coated with a red filter (R) and no filter (clear (C)) as illustrated in the table below.

R	C	R	C
C	R	C	R
R	C	R	C
C	R	C	R

In this embodiment, the optics do not include the lens structure and color filters discussed above, since the color filtering function is performed by the filter pattern. Likewise, the optics do not need to separately image the forward scene onto two portions of the image sensor. Thus, the twice as much of the image sensor array may be used to image a single image of the forward scene. It should be noted however, that in accordance with yet another embodiment of the present invention, the optics may still image the forward scene onto two separate portions of the image sensor array as discussed above, but instead of incorporating the color filter into the lens, the color filter may be provided as a patterned or non-patterned multi-layer interference filter on the sensor.

The optics in this embodiment are slightly defocused such that the spot size from a distant point light source covers at least two pixels. In this way, an accurate reading of the red component of the object can be determined. The inventors have discovered that common color filter array technologies, typically employing polymer filters, will not withstand direct focused sunlight. In many automotive applications, the sun may be focused onto the array if a vehicle is traveling or parked such that the sun is within the field of view of the camera. Interference filters are far more robust and reflect the unwanted spectral bands of light rather than absorb them. As a result, their use overcomes the limitations of the prior filtering technologies and allows the construction of an automotive camera. These filters can be used not only with cameras which are used in applications which control vehicle equipment, but also in applications where images are acquired and displayed to the driver for visual assistance.

In another embodiment, three-color interference filters can be used to construct a red, green, and blue (RGB) pixel array (or their complements) as illustrated in the table below.

G	R	G	R
B	G	B	G
G	R	G	R
B	G	B	G

A full color value for each pixel is determined by using the color of the current pixel and interpolating the other two colors from neighboring pixels with different filter colors. Techniques for performing this interpolation are well known in the art. In a simpler scheme, groups of four pixels are treated as one "super pixel." The lens is defocused enough such that the image of a point light source is blurred over a 2 x 2 block of pixels. For each block of 2 x 2 pixels, the red, green, and blue color components are determined from the individual pixels. This data can be represented either as three separate values or as an intensity and color value.

The use of a 2x2 super pixel simplifies processing and reduces the total number of values stored. This technique can be combined with any of the other techniques in an application requiring color imaging. For an application such as a high beam headlamp control system, traditional color interpolation can be used near the center of the image for increased resolution and the technique of using super pixels can be used away from center. Super pixels larger than 2 x 2 blocks can be used where substantially decreased resolution is acceptable.

The lens structure 202 will now be described in greater detail with reference to Figs. 2a, 4, 5, and 7. The lens structure 202 includes a first lens 208 and a second lens 209 that focus light from other vehicles onto the image array 301 (Fig. 7). The two lens elements 208, 209 image the forward scene onto different respective regions 702, 703 of the image sensor image array 301. Each lens element 208, 209 contains a spectral band pass filter, such that the forward image scene projected onto the respective regions of the image array 301 each represents a different color component of the image, where it is advantageous to determine the relative color of objects in the field of view. It is particularly advantageous for the lens elements 208 (Fig. 2a) and 209 to comprise cyan

and red filters, respectively, as mentioned above and shown in Figs. 4 and 5. Alternatively, it may be advantageous for lens 209 to contain a red spectral filter and for lens 208 to be clear.

The sensor system may for example employ lens elements 208 and 209 that are 0.5 mm to 2.5 mm in diameter, and may advantageously comprise lenses that are 1.0 to 2.5 mm in diameter, such as being 2.2 mm in diameter. In the Y direction, the lens center axes C_1 and C_2 may be spaced by 0.6 to 1.6 mm, and may for example be spaced by 1.1 to 1.4 mm, and may advantageously be spaced 1.3 mm in the Y direction (as indicated in Fig. 5). A portion of the lens may be truncated on one side to achieve this spacing. The lens center C_1, C_2 may be aligned in the X direction as shown in Fig. 4, or be offset. Lens element 208 may for example include a cyan filter with an aspheric lens having a curvature of 0.446 mm^{-1} and a conic constant of -0.5 to achieve the desired focal length. Lens element 209 may in contrast, be a red filter, aspheric lens with a curvature of 0.450 mm^{-1} and a conic constant of –0.5 to achieve the same desired focal length. At the center, each lens is 0.5 to 1.5 mm thick, and may advantageously be 1.0mm thick. The difference in curvature of the two lenses compensates for the dispersion in the lens material and optimizes each lens for the spectral band passed by the filter. These parameters result in a lens with an effective focal length of 4.5 mm and thus have an F# of 2. It will be recognized that these optics are exemplary, and that other optics could be provided, such that the focal length and F# could be different.

The lens structure 202 may be molded out of a light-transmissive plastic such as acrylic, manufactured from glass, or may be produced by any other suitable construction. Where the lenses 208, 209 are molded from plastic, the filters may be formed integrally with the plastic by the inclusion of dyes within the material or they may be molded of a clear transparent material, particularly where the image sensor has a surface mounted filter as described herein below. An example of an acrylic material, which includes a red filter dye, is part number RD-130 available form OptiColor, Inc. of Huntington Beach, California, USA. An acrylic material incorporating a cyan filter is OptiColor part number BL-152. The spectral transmission of these two materials is shown in Fig. 6. Using the optional infrared filter 206 will remove light with wavelengths greater than approximately 700 nm.

The lens structure 202 including integral filters may be manufactured using a bi-color injection molding process. First one-half of the lens, for example the red half including lens 209, is molded in a tool containing features to form the red half of the lens.

Next, the molded red half of the lens is inserted into a tool containing features for the cyan half of the lens structure 202 in addition to features to hold the red lens 209. The cyan lens 208 half of the lens structure 202 is then injection molded against the red lens 209 half forming one bi-color lens. Alternatively, each of the lenses 208 and 209 can be provided by lens elements such as disclosed in copending U.S. Patent No. 6,130,421, entitled IMAGING SYSTEM FOR VEHICLE HEADLAMP CONTROL, filed June 9, 1998, by Jon H. Bechtel et al.

While red and cyan filtered lens elements are used in the illustrated embodiment, other combinations of lenses may also be suitable for this application. For example, it is possible to replace cyan lens element 208 with a clear lens. Also, it is possible to use three lenses with respective color filters, and in particular red, green, and blue filters, to obtain a full color image. Such an arrangement could use a sequence of three lenses aligned along the Y axis of Fig. 4, with one lens positioned on the center axis and the other two lenses positioned adjacent this center lens. The spacing of the lenses might advantageously be uniform to provide uniformly spaced regions on the light sensitive surface of the image array 301. The red and cyan filter colors described above are thus only presented herein as an example, and any combination of filters which pass at least two isolated or overlapping spectral bands of light and allow for the distinction of tail lights from headlamps may be used. Those skilled in the art will recognize that other methods can be used to incorporate the filters, such as screen printing dyes applied to the flat back surface of the lens structure 202, or application of a filter material to the surface of a clear lens structure. Additionally, an advantageous system using a single lens is described herein below with reference to Figs. 24 and 25.

THE APERTURE STOP

Aperture stop 203 comprises an opaque member, including apertures 240 (Fig. 2a) and 242, positioned over lenses 208, 209. The aperture stop 203 can be manufactured of any suitable material, such as molded plastic, and it can be painted or otherwise treated so as to block the passage of light if the material of which the plastic is manufactured is not opaque. Aperture stop 203 defines the apertures 240, 242 for lens elements 208 and 209. Aperture stop 203 also prevents passage of stray light through regions of lens structure 202 other than the lens elements 208 and 209. It will be recognized that the aperture stop 203 can be paint applied directly to the surface of lens structure 202, and optionally to the sidewalls of light sensor assembly 250, such that the paint blocks passage of stray light through regions of lens 202 other than the lens elements 208 and 209. The aperture stop

may also be stamped from a rigid material such as Mylar and placed over the lens structure. Such an aperture stop may include a pair of registration holes for engaging posts extending from the lens structure such that the aperture stop may be properly positioned relative to the lens structure with the apertures 240, 242 aligned with the corresponding lens elements 208, 209 of lens structure 202.

The aperture stop and/or the window may define a transparent window in an otherwise opaque mask in which the transition from the opaque region to the transparent region may be graded. By providing such a gradient, spatial thresholding of the received and processed image may be readily accomplished. The purpose for such spatial thresholding is discussed in more detail below.

THE FAR FIELD BAFFLE

The far field baffle 204 (Figs. 2a and 2b) is an opaque enclosure to be positioned over the image sensor 201. The baffle includes an opening 207, which is the sole light passage into the image sensor. The illustrated far field baffle 204 is a generally rectangular box including four sidewalls 215 (only two of the four being visible in Fig. 2b), an end wall 217 including opening 207, and an open end 219. The open end is secured to the support 220 on which image sensor 201 is carried. The support 220 may be, for example, a circuit board or housing, and is preferably opaque to block the passage of light into the chamber defined by the far field baffle. The walls 215, 217 of the far field baffle 204 are opaque, and may be of any suitable construction such as stamped from metal, molded from plastic, or the like. If the material from which the walls are made is not opaque, it may be painted or otherwise treated to block the admission of light. The far field baffle defines the forward scene viewed by image sensor array 208. The side walls 215 and end wall 217 prevent light at angles outside of the desired field of view from entering and are also used to keep light input through one lens from crossing over to the region of the array reserved for the other lens. The far field baffle aperture 207 is ideally about 4-6 focal lengths, or approximately 18 mm in the illustrated embodiment, from the front of the lens (for the sake of clarity, the figures of the application are not to scale). The field of view through aperture 207, aperture stop 203, and lenses 208 and 209, in the illustrated embodiment, is about 10° in the vertical direction and 25° in the horizontal direction in front of the vehicle. This field of view can be achieved with a rectangular or elliptical far field baffle opening 207 that is 6 to 7mm in the Y direction and 9 to 10 mm in the X direction, in the above described embodiment.

In particular the far field baffle 204 has an opening 207 in an end wall 217. The sidewalls 215 of the image array sensor extend orthogonally from the end wall 217. The walls 215, 217 may be formed integrally in a molding or stamping process or they may be joined after construction using an adhesive, fasteners or the like. The far field baffle is preferably a black plastic molded member, although it may be provided using any material that will absorb most or all of the light striking the sidewalls. By providing wall surfaces on the inside of the far field baffle that absorb light, the walls will not reflect light that enters though opening 207 onto the image array sensor 201. In the illustrated embodiment, the baffle is rectangular, but those skilled in the art will recognize that the baffle could be square, cylindrical, or any other suitable shape. An imaging system including a far field baffle is described in co-pending U.S. Patent No. 6,130,421, entitled IMAGING SYSTEM FOR VEHICLE HEADLAMP CONTROL, filed on June 9, 1998, by Jon H. Bechtel et al.

Far field baffle 204 and aperture stop 203 preferably configured to prevent light from reaching components other than image sensor array 201 that may be mounted on circuit board 221. Certain sensors, such as CMOS sensors, often include other components besides the image sensor array on the printed circuit board that may be damaged from exposure to light. Additional baffle structures may be incorporated for this purpose.

INFRARED FILTER

The far field baffle holds an optional infrared filter 206 (Fig. 2a). Infrared filter 206 prevents light of wavelengths longer than about 700 nm from being imaged by the optical system. This is advantageous as light above 700 nm (Fig. 6) will pass through the red and cyan filters. By removing this light, the only light that will be considered is visible light in the pass band of the red and blue filters. The infrared filter has become more important due to the recent commercialization of LED tail lights. Because incandescent light sources emit infrared light while LED light sources do not, the infrared filter is desirable to balance out the detected brightness of these two types of light sources.

Infrared filters are available from Optical Coating Laboratories of Santa Rosa, California, and are called Wide Band Hot Mirrors. The infrared filter 206 may be mounted to the end wall 217 using an adhesive, mechanical fasteners such as a snap connector, or the like, and may seal off the chamber within the far field baffle to prevent dust and moisture from entering the system and degrading the performance of the system.

Alternatively infrared filter 206 may be incorporated as a dye within the lens, a coating on the lens, a coating on the image sensor surface, a lid on an image sensor package, or elsewhere in the image sensor assembly. If the IR filter is not such that it can be used to close the opening 217 of far field baffle 204, it may be desirable to place a clear window, such as glass, plastic, or the like in the opening 217 to prevent dust from entering into the interior of the far field baffle and interfering with the performance of the sensor system 102.

HYDROPHILIC/PHOTOCATALYTIC COATINGS

In addition to functioning as an infrared filter, filter 206 serves to prevent debris and liquid from reaching the image sensor assembly through opening 207. In the event an infrared filter is not utilized, a transparent window may be used in its place for this purpose.

Whether an infrared filter 206 or window is utilized, it is desirable to keep liquid drops from attaching to the outer surface of filter/window 206 within opening 207 since such liquid drops distort the image that is received and processed by the image sensor and because such liquid drops tend to dry and leave spots on the outer surface of filter/window 206. Such liquid drops may form on filter/window 206 when, for example, an individual sprays a cleaning fluid on the inside of the windshield, which is in close proximity to the outer surface of filter/window 206. It is very possible that the individual cleaning the windshield would forget to wipe the cleaning fluid from the filter/window of the image sensor, thus leaving a fine mist of water droplets over the surface of the filter/window, which would blur the images obtained by the image sensor.

To overcome this problem, the present invention may employ a hydrophilic coating on the outer surface of filter/window 206. Hydrophilic coatings have a porous outer layer(s) that absorb the water or other liquid uniformly across its surface such that water droplets/spots do not form on its surface. One problem many such hydrophilic coatings experience is that the pores in the outer layer(s) may become clogged by oil, grease, or other contaminants thereby eliminating the effectiveness of the hydrophilic coating. To overcome that problem, a photocatalytic layer may be used in conjunction with the hydrophilic coating. Such photocatalytic layers break down the oil, grease, or other contaminants within the hydrophilic layer when exposed to ultraviolet light. This tends to clear the pores in the hydrophilic layer of the contaminant and allow it to operate effectively as a hydrophilic layer. Examples of hydrophilic/photocatalytic coatings that may be employed for this purpose are disclosed in U.S. Patent Application No. 09/602,919

entitled ELECTRO-OPTIC DEVICE HAVING A SELF-CLEANING HYDROPHILIC COATING filed on June 23, 2000, by William L. Tonar et al.

ASSEMBLY OF THE IMAGE SENSOR ASSEMBLY

Assembly of the image sensor will now be described with reference to image sensor assembly 801 of Fig. 8, which is identical to the image sensor assembly 250 except for the gel 805 in image sensor assembly 801. The image sensor 201, lens structure 202, and aperture stop 203 are combined to form an integral image sensor assembly 250 (Fig. 2) or 801 (Fig. 8). The image sensor 201, which is advantageously a single integrated circuit (IC), is attached to printed circuit board 220 by any suitable conventional means such as using chip-on-board technology. Connections to the image sensor chip are made by any suitable means, such as wire bonds 804. The bonded IC is then optionally covered with an optically clear stress relieving gel 805. Examples of materials that can be used for this coating are Silicon Semi-Gel type C from Transene Co. of Danvers, Massachusetts, or Dielectric Gel 3-6211 from Dow Corning Corp. of Midland, Michigan. The coated IC is then encapsulated in a hard optically clear enclosure 802, which may for example comprise epoxy. The epoxy is formed into a desired shape and may form, for example, a cube. The cube can be dimensioned to occupy a very small volume, and may for example have length and width dimensions of about 1 cm on a side, and a thickness of about 5mm. The enclosure 802 (Fig. 8) may be selected to have approximately the same index of refraction as the stress relieving gel 805 to prevent any refraction at the interface between these two materials. Examples of suitable epoxies are: Epo-Tek 301-2FL from Epoxy Technology, Inc. of Billerica, Massachusetts, Epoxy 50 from Transene Co, or Dexter-Hysol OS 1900, or 300H from Nitto Denko Corporation. If the coefficient of thermal expansion of the enclosure 802 is sufficiently low that its expansion and contraction will not break wire bonds 804 at the expected operating temperature range for the image array sensor 201, stress-relieving gel 805 can be omitted, as is shown by enclosure 230 over wire bonds 234 in image sensor assembly 250 in Fig. 2a.

Lens structure 202 is attached to the enclosure 802 (Fig. 8) or enclosure 230 (Fig. 2) using a UV curable optically clear adhesive 232. UV curable adhesive 232 is dispensed onto the epoxy cube 802 and lens 202 is juxtaposed with UV curable adhesive 232. Lens structure 202 is spaced from the image sensor 201 by a distance such that images at "infinity" are focused on the desired image regions 702 and 703. The UV curable adhesive 232 is exposed to UV light and cured, locking lens structure 202 into position and permanently attaching lens structure 202 to enclosure 802. The total distance between

the back surface of the lens structure 202 and the top of the image sensor 201 die is 6.7 mm in the illustrated example. This distance is significantly longer than the effective focal length of 4.4 mm because the entire optical path between the back of the lens 202 and the front of the image array 201 is through a material with a higher index of refraction than air. Ideally the process of aligning the lens to the image sensor and curing the UV adhesive to hold it in place is accomplished while actively focusing the lens to accommodate variations in the manufacture of the lens and other image sensor assembly components. This process is accomplished by powering the image sensor during assembly and acquiring images of a far field scene from the image sensor into a host computer. The UV curable adhesive is dispensed onto the surface of the sensor and the lens is positioned on the UV curable adhesive using a multi-axis robot or positioner. The position of the lens is adjusted by the robot until the images acquired by the sensor appear in focus. At this point, the UV curable adhesive is exposed to UV light, cementing the lens into place. Micropositioning equipment suitable for this purpose is available from Physik Instremente GmbH and Company of Germany.

UV curable adhesive 232 serves to fill the space between the lens 202 and enclosure 802, and thus fills in any ripples or other non-planar surfaces of enclosure 802 thereby precluding the creation of air gaps between the lens 202 and the enclosure 802. To accomplish the desirable optical characteristics described hereinabove, UV curable adhesive 232 should have approximately the same index of refraction as enclosure 802. This structure has the distinct advantage of minimizing the number of optical surfaces wherein a significant mismatch of indices of refraction between two different mediums can occur, thus increasing the optical efficiency of the imaging system and reducing stray light. A suitable optically clear UV cured adhesive is Norland Optical Adhesive 68 manufactured by Norland Products, Inc., of New Brunswick, New Jersey. Other materials suitable for making the image sensor assembly 801 are available from Dymax.

The block 802 is completed by attaching the aperture stop 203 to lens 202. If the aperture stop is a member, it may be attached to the outer surface of the lens using an adhesive, one or more mechanical fasteners, or the like. If the aperture stop is paint, it may be applied directly to the surface of the lens element 202 after the lenses 208 and 209 are covered with a removable mask, such as tape. After the paint dries, the mask can be removed. The optical assembly 801 is then mounted to a support 220. In particular, the image sensor array 201 is physically mounted on a base substrate 221 by conventional means, and electrically connected to circuitry (not shown in Fig. 2b) by electrical

connectors such as wire bonds, solder, one or more connectors, or the like. The base substrate 221 may for example be a printed circuit board.

The support 220 may be constructed of the same material as the far field baffle 204, or it may be constructed of a different material. The base substrate 221 may be omitted if the far field baffle and the image sensor are mounted directly to either the support 220 or the housing (not shown) that carries the optical sensor assembly. For example, the support 220 may be a printed circuit board to which the image sensor 201 and the far field baffle are connected. Regardless of whether the base substrate is provided, the far field baffle is mounted to the support 220 or the housing (not shown) using an adhesive, a snap connector, a mechanical fastener, or the like.

An image sensor assembly 901 according to an alternate embodiment is illustrated in Fig. 9. In this embodiment, the image sensor 201 is packaged using more conventional electronic packaging, such as a ceramic package with a glass lid or a clear plastic package, which may for example be a quad flat pack or a dual-in-line (DIP) package. The packaged image sensor 901 is mounted, by suitable conventional means such as by soldering, to printed circuit board 902. An ultraviolet (UV) curable adhesive 905 is then dispensed onto the packaged image sensor 901. The adhesive used can be the same adhesive described above with respect to adhesive 232. The thickness of the UV curable adhesive is dependent on the packaged image sensor 901 type. If the required thickness is too great, layers of the UV curable adhesive can be built up or another material, such as an epoxy layer, can be sandwiched between the UV curable adhesives to decrease the thickness of the adhesive layer 905. The epoxy may be the same material described above with respect to the enclosure 230, 802. The lens structure 202 is juxtaposed with the UV curable adhesive 905 and focused in the manner previously described. Finally, the aperture stop 203 is attached to the lens structure 202 using an adhesive (not shown), mechanical fastener or the like.

In addition to the means described herein above, the lens structure 202 may be supported relative to the image sensor by other means, such as a mechanical support. Such a structure is disclosed in U.S. Patent No. 6,130,421, entitled IMAGING SYSTEM FOR VEHICLE HEADLAMP CONTROL, filed on June 9, 1998. The same may also be used to position and maintain the relative relationship between the components of the optical assembly including the aperture stop and the far field baffle. A mechanical fastening arrangement is disclosed below with respect to Fig. 24.

MIRROR MOUNTED IMAGE SENSOR ASSEMBLY

As mentioned above, the headlamp dimmer can be advantageously integrated into a rearview mirror 1000 as illustrated in Fig. 10, wherein the light sensor assembly 201 is integrated into an automatic dimming electrochromic (EC) mirror subassembly 1001, or other variable reflectance mirror assembly. This location provides an unobstructed forward view through a region of the windshield of the vehicle that is typically cleaned by the vehicle's windshield wipers (not shown). Additionally, mounting the image sensor in the mirror assembly permits sharing of circuitry such as the power supply, microcontroller and light sensors. More specifically, the same ambient light sensor may be used to provide an ambient light measurement for both the auto-dimming mirror function and the headlamp control function.

Referring to Fig. 10, light sensor assembly 801 is mounted within a rearview mirror mount 1003, which is mounted to the vehicle windshield 1002. The rearview mirror mount 1003 provides an opaque enclosure for the image sensor. The infrared filter 206 can be mounted over a hole 1007 in the rearview mirror mount 1003, as is shown. Alternatively, the far field baffle 214 can be used with the infrared filter 206 mounted therein. If the far field baffle 214 is used, it is mounted to the circuit board 1008 with the image sensor assembly 202. Regardless of whether the far field baffle is used, the circuit board 1008 is mounted to rearview mirror mount 1003 using mounting brackets 1020 and 1021. The mounting brackets may be implemented using any suitable construction, such as metal brackets, plastic brackets which can be formed either integrally with the housing 1003 or as separate components, mechanical fasteners which engage the circuit board 1008, or the like. The separate brackets can be attached using an adhesive, metal fasteners or other mechanical fastening means. Image sensor assembly 201 is thus attached to, and held stationary by, the rearview mirror mount 1003 which is securely attached to the vehicle windshield or roof by conventional means.

A connector 1005 is connected to circuit board 1008 using a suitable commercially available circuit board connector (not shown), which in turn is connected to the image sensor 201 through circuit board 1008. The connector 1005 is connected to a main circuit 1015 through a cable 1006. The main circuit board is mounted within rearview mirror housing 1004 by conventional means. Power and a communication link with the vehicle electrical system, including the headlamps 111 (Fig. 1), are provided via a vehicle wiring harness 1017 (Fig. 10).

THE ELECTRICAL SYSTEM

The image sensor 201 electrically connected to the main circuit board 1015 and mounted in the vehicle rearview mirror housing 1004 (Fig. 10) is represented in Fig. 11. The microcontroller 1105 receives image signals from the image sensor 201, processes the images, and generates output signals. Although described with reference to a circuit board mounted in a rearview mirror housing, the circuit board 1105 can be mounted in a vehicle accessory, such as a sun visor, overhead console, center console, dashboard, prismatic rearview mirror, A-pillar, or at any other suitable location in the vehicle. Should the controlled vehicle (100 in Fig. 1) include an electrochromic mirror, the circuitry for the electrochromic mirror preferably shares the circuit board 1015 (Fig. 10) with microprocessor 1105. Thus, the main circuit board 1015 is mounted within the mirror housing 1004. The EC circuitry further includes ambient light sensor 1107 and glare light sensor 1109, which may advantageously be digital photodiode light sensors as described in United States Patent Application No. 09/307,191 entitled PHOTODIODE LIGHT SENSOR, filed January 25, 2000, and U.S. Patent Application No. 09/491,192 entitled VEHICLE EQUIPMENT CONTROL WITH SEMICONDUCTOR LIGHT SENSORS, filed May 7, 1999. Microcontroller 1105 uses inputs from ambient light sensor 1107 and glare lights sensor 1109 to determine the appropriate state for the electrochromic mirror element 1102. The mirror is driven by EC mirror drive circuitry 1111, which may be a drive circuit described in U.S. Patent No. 5,956,012, entitled SERIES DRIVE CIRCUIT, filed by Robert R. Turnbull et al. on September 16, 1997, and PCT Application No. PCT/US97/16946, entitled INDIVIDUAL MIRROR CONTROL SYSTEM, filed by Robert C. Knapp et al. on September 16, 1997; and U.S. Patent Application No. 09/236,969, entitled AUTOMATIC DIMMING MIRROR USING SEMICONDUCTOR LIGHT SENSOR WITH INTEGRAL CHARGE COLLECTION, filed May 7, 1999, by Jon H. Bechtel et al.. Other driver circuits are known that can be used to drive the EC element 1102. The EC mirror drive circuit 1111 provides current to the EC element 1102 through signal output 1127.

The mirror may communicate with a light control module over a serial link therebetween in a manner similar to that disclosed in commonly-assigned U.S. Patent Application No. 09/368,325, entitled "VEHICLE COMMUNICATION SYSTEM," filed on August 3, 1999, by Robert C. Knapp et al.

The microcontroller 1105 can take advantage of the availability of signals (such as vehicle speed) communicated over the vehicle's electrical bus in making decisions

regarding the operation of the headlamps 111, which are represented by high beams 1131 and low beams 1132 in Fig. 11, and the electrochromic mirror 1102. In particular, speed input 1117 provides vehicle speed information to the microcontroller 1105, from which vehicle speed criteria can be used for determining the control state for the headlamps 111. The reverse signal 1119 informs microcontroller 1105 that the vehicle is in reverse, responsive to which the microcontroller 1105 clears the electrochromic mirror element 1102 regardless of the signals output from the light sensors 1107, 1109. Auto ON/OFF switch input 1121 is connected to a switch having two states to dictate to microcontroller 1105 whether the vehicle headlamps 1131, 1132 should be automatically or manually controlled. The auto ON/OFF switch (not shown) connected to the ON/OFF switch input 1121 may be incorporated with the headlamp switches that are traditionally mounted on the vehicle dashboard or incorporated into steering wheel column levers. Manual dimmer switch input 1123 is connected to a manually actuated switch (not shown) provides a manual override signal for the high beam state. Should the current controlled state of the high beams be ON, the microcontroller will respond to actuation signal manual override signal control input 1123 to turn the high beams OFF temporarily until the driver restores operation or, optionally, until a predetermined time has elapsed. Alternatively, should the high beams be OFF, the microcontroller 1105 will respond to an actuation signal on input 1123 to turn the high beams ON. The manual high beam control switch can be implemented using a lever switch located on the steering column of controlled vehicle 100 (Fig. 1).

The circuit board 1101 has several outputs. The control signal on electrochromic output 1127 provides current to the electrochromic element 1102. Additional outputs (not shown) may optionally be provided to control exterior electrochromic rearview mirrors (not shown) if such additional mirrors are provided. The microcontroller 1105 communicates the current state of the low beam headlamps 1131 and the high beam headlamps 1132 to the headlamp drive 1104 via headlamp control output 1127. The microcontroller 1105 generates control signals communicated over conductor 1113 (Fig. 11) to an optional visual indicator 1115 which displays the current state of the high beam headlamps to the driver of controlled vehicle 100. The high beam indicator is traditionally located in or near the vehicle's instrument cluster on the vehicle dashboard. As described further below, a separate indicator may be provided to indicate whether the automatic headlamp control is active. A compass sensor 1135 may be connected to the circuit board 1015 via a bi-directional data bus 1137. The compass can be implemented using a

commercially available compass of the type generating digital or analog signals indicative of the vehicle's heading, such as those described in U.S. Patent No. 5,239,264 entitled ZERO-OFFSET MAGNETOMETER HAVING COIL AND CORE SENSOR CONTROLLING PERIOD OF AN OSCILLATOR CIRCUIT; U.S. Patent No. 4,851,775 entitled DIGITAL COMPASS AND MAGNETOMETER HAVING A SENSOR COIL WOUND ON A HIGH PERMEABILITY ISOTROPIC CORE; U.S. Patent No. 5,878,370 entitled VEHICLE COMPASS SYSTEM WITH VARIABLE RESOLUTION; U.S. Patent No. 5,761,094, entitled VEHICLE COMPASS SYSTEM; U.S. Patent No. 5,664,335, entitled VEHICLE COMPASS CIRCUIT; U.S. Patent No. 4,953,305 entitled VEHICLE COMPASS WITH AUTOMATIC CONTINUOUS CALIBRATION; U.S. Patent No. 4,677,381 entitled FLUX-GATE SENSOR ELECTRICAL DRIVE METHOD AND CIRCUIT; U.S. Patent No. 4,546,551 entitled ELECTRICAL CONTROL SYSTEM; U.S. Patent No. 4,425,717 entitled VEHICLE MAGNETIC SENSOR; and U.S. Patent No. 4,424,631 entitled ELECTRICAL COMPASS. A fog lamp control 1141 can be connected to receive via fog light control output 1142 control signals generated by microcontroller 1105. Fog lamp control 1141 controls front fog lamps 1143 and rear fog light 1145 to turn ON and OFF.

Some or all of the inputs 1117, 1119, 1121, 1123, and 1135, and outputs 1127, 1113, 1127, and 1142, as well as any other possible inputs or outputs, such as a steering wheel input, can optionally be provided through a vehicle communications bus 1125 shown in Fig. 11. Vehicle bus 1125 may be implemented using any suitable standard communication bus, such as a Controller Area Network (CAN) bus. If vehicle bus 1125 is used, microcontroller 1105 may include a bus controller or the control interface may be provided by additional components on the main control board 1015.

Fig. 12 illustrates a headlamp drive 1104 including a drive circuit 1203 for low beam headlamps 1131 and a drive circuit 1201 for high beam headlamps 1132. Bus 1127 includes respective wires 1206 and 1207 carrying pulse width modulated (PWM) signals generated by microcontroller 1105 for driving low beam headlamps 1131 and high beam headlamps 1132. Alternatively, headlamp drive 1104 may contain a DC power supply to vary the voltage supplied to the lamps 1131, 1132, and thus their brightness, in response to control signals on output 1127. Yet another alternative envisioned is to vary the aim of the high beam headlamps 1131 as is described hereinbelow and as taught in U.S. Patent No. 6,049,171, entitled CONTINUOUSLY VARIABLE HEADLAMP CONTROL, filed by Joseph Stam et al. on September 18, 1998.

Headlamp drive 1104 provides power to the high beam 1131 and low beam 1132 headlamps. In the simplest case, the headlamp drive contains relays engaged in response to signal 1127 to turn ON or OFF the headlamps. In a more preferred embodiment, high beam headlamps 1131 and 1132 fade ON or OFF under the control of headlamp drive 1104 which generates a variable control signal. Such a control system is described in copending U.S. Patent No. 6,049,171. In general, the patent teaches variable emission control of the headlamps can be provided by energizing the headlamps using a pulse width modulation (PWM) supply, wherein the duty cycle of the drive varied between 0% and 100% to effect a continuously variable brightness from the headlamps 1131, 1132.

The microcontroller 1105 analyzes images acquired by the image sensor assembly 201 responsive to which it detects oncoming or preceding vehicles in the forward field of view. The microcontroller 1105 uses this information in conjunction with the various other inputs thereto to determine the current control state for the headlamps 1131, 1132. The current control state of the headlamps refers to the brightness of the high beams and the low beams. In a variable control system, this brightness is varied by changing the duty cycle of the beams or the DC voltage applied to the lamps as described above. In a non-variable system, the control state refers to whether the high beams and low beams are ON or OFF. A more detailed schematic showing the connections to the microcontroller 1105 is shown in Fig. 13. The microcontroller 1105 can be implemented using a microcontroller, a microprocessor, a digital signal processor, a programmable logic unit, a discrete circuitry, or combination thereof. Additionally, the microcontroller may be implemented using more than one microprocessor.

OPERATION

The combined effect of the lens structure 202 and the far field baffle 204 will first be described with respect to Figs. 2a and 7. As mentioned above, in one embodiment, the image array 301 contains 64 columns and 80 rows of 30 μm pixels. The forward scene imaged through the red lens 209 is located on one region 703 of the image array 301. The forward scene imaged through the other lens element 208 is located on region 702 of the image array 301. In the embodiment illustrated, each of these regions is a 60 wide by 20 high pixel subwindow of the image array. The centers of the two regions 702 and 703 are separated 1.2 mm in the Y direction, the same spacing as the center axis of lens 208 and 209. Fourteen pixel rows 704 define a band that lies between the two regions 702, 703 and serves as a border, or buffer, separating these two regions.

The image sensor assembly 250 provides several advantages. Because the block will be solid, it eliminates any surfaces between the image sensor 201 die and the lens structure 202. By eliminating these surfaces, stray light is reduced. Second, the preferred embodiment allows for the active alignment of the lens, which allows for compensation of various manufacturing variances, as is described in greater detail herein above. Finally, the assembly is inexpensive, eliminating the need for costly ceramic packaging. Some or all of the above-mentioned advantages can be realized through variations on this structure. For example, the enclosure 230, UV curable adhesive 232 and possibly the stress relieving gel 805 (Fig. 8) can be replaced with a UV cured epoxy adhesive.

In operation, an image is exposed onto the image array 301 (Fig. 3) for an exposure period, which may also be referred to herein as an integration period. At the end of the exposure period, an output signal is stored for each of the pixels, and preferably is stored in the pixels as is the case with the photogate pixel architecture described in U.S. Patent No. 5,471,515. The output signal from each of the pixels is representative of the illumination sensed by each pixel. This output signal is transferred to the column output circuitry 302 one row at a time. The column output circuitry includes capacitors storing the respective pixel output signals for each pixel in the row. Next, the pixel output signals are successively amplified by an analog amplifier 303. The amplifier gain is advantageously adjustable, and may for example be controlled to selectively increase the amplitude of the amplifier input signal by 1 (unity gain) to 15 times, in integer increments. Adjustment of the gain of the amplifier permits adjustment of the system sensitivity. The amplified analog signals output from amplifier 303 are sampled by a flash analog-to-digital converter (ADC) 404. The flash ADC 404 converts each of the amplified analog signals, which correspond to respective pixels, into eight-bit digital gray scale values. Various bias voltages for the sensor are generated by digital-to-analog converter (DAC) 105. Two of the voltages generated by the bias generators are the ADC high and low reference values, which determine the analog voltages that will correspond to digital values of 255 and 0, respectively, thus setting the range of the ADC.

Serial timing and control circuitry 309 dictates the timing sequence of the sensor operation, and is described in detail in co-pending U.S. Patent No. 5,990,469, entitled CONTROL CIRCUIT FOR IMAGE ARRAY SENSORS, issued to Jon H. Bechtel et al on November 23, 1999.

The image sensor control process will now be described beginning with reference to Fig. 14. The control process may include control of an electrochromic (EC) mirror.

However, because processes for controlling an EC mirror are well known, such processes are not completely described herein. Electrochromic devices are generally known, and examples of electrochromic devices and associated circuitry, some of which are commercially available, are disclosed in Byker U.S. Patent No. 4,902,108; Bechtel et al. Canadian Patent No. 1,300,945; Bechtel U.S. Patent No. 5,204,778; Byker U.S. Patent No. 5,280,380; Byker U.S. Patent No. 5,336,448; Bauer et al. U.S. Patent No. 5,434,407; Tonar U.S. Patent No. 5,448,397; Knapp U.S. Patent No. 5,504,478; Tonar et al. U.S. Patent No. 5 679,283, Tonar et al. U.S. Patent No. 5,682,267; Tonar et al. 5,689,370; Tonar et al. U.S. Patent No. 5,888,431; Bechtel et al. U.S. Patent No. 5,451,822; U.S. Patent No. 5,956,012; PCT application Serial No. PCT/US97/16946; and U.S. Patent Application No. 09/236,969.

The forward ambient light sensor 1107 and rear glare sensor 1109 measure the forward and rear light levels, as indicated in step 1401 (Fig. 14). The forward ambient measurement is used to control both the low beam and high beam headlamps 1131, 1132 and the electrochromic mirror 1102. Additionally, the forward ambient measurement may be used to control the brightness of the daytime running lights and the brightness of the tail lights. The rear glare measurement is used for the control of the electrochromic mirror 1102 reflectivity. The forward ambient light level measurement is averaged with prior measurements to compute a forward time averaged ambient light level. This average light level is computed as the average of measurements taken over a 25-30 second interval. Responsive thereto, the microcontroller 1105 computes the control state for electrochromic element 1105 as a function of the light level measured by sensors 1107 and 1109 in step 1202. Where the microcontroller 1115 is a microcontroller selected from the Motorola MCS912, the electrochromic element drive state can be set by programming a pulse width modulated (PWM) duty cycle corresponding to the desired reflectance level of the electrochromic element into a pulse width modulated peripheral to the Motorola MCS912 family microcontroller. This PWM output is then fed to a series drive circuit in a manner similar to that disclosed in U.S. Patent No. 5,956,012, entitled SERIES DRIVE CIRCUIT, filed by Robert R. Turnbull et al. on September 16, 1997. If the headlamps 1131, 1132 are not in auto mode as determined in step 1403, which is manually set responsive to the signal 1121, the microcontroller 1105 returns to step 1401, such that the microcontroller will continue to control the variable reflectance of the electrochromic element 1102. Decision 1403 provides the user with a manual override if the high beams

are ON. Additionally, the high beam automatic control will be skipped in step 1403 (the decision will be NO) if the high beams are not ON.

If it is determined in step 1403 that the automatic mode is active, the microcontroller 1105 uses the average ambient light level measured in step 1401 to determine whether the ambient light level is below a low beam minimum threshold in step 1404. The threshold may for example be 1-3 lux, and in one implementation was 2 lux. If the ambient light level is above the threshold, indicating that high beam headlamps would not provide significant advantage, high beam control will not be used, and the microcontroller 1105 returns to step 1401. If the ambient light level is below the low beam minimum, for example below approximately 2 lux, the use of high beam headlamps may be desired. In this case, the microcontroller 1105 will operate to control the headlamps 1131, 1132. In addition to the average ambient light level discussed above, it is also advantageous to consider the instantaneous ambient light level. Should the instantaneous ambient light level suddenly drop to a very low value, for example less than 0.5 lux, automatic high beam operation may begin immediately rather than waiting for the average ambient light level to reach the threshold for operation of the high beams. This situation may occur when a vehicle sitting under a well lit intersection suddenly crosses the intersection into a dark street where high beam operation is desired immediately. The microcontroller 1105 analyzes images of the forward scene acquired by image sensor 201 to detect the presence of oncoming or preceding vehicles as indicated in step 1405. Based upon the results of step 1405, the microcontroller sets the control state of the headlamps in step 1406. Setting the control state requires setting a duty cycle for the pulse drive in the preferred embodiment. The Motorola MCS912 family microcontroller includes timer/counter peripherals which can be used to generate pulse width modulated signals 1206 and 1207. In some vehicles, the low beam headlamps will always be ON regardless of the state of the high beams. In such a vehicle, only the duty cycle of the high beams will be varied. Other vehicles will have the low beams OFF when the high beams are ON, in which case the duty cycle of the low beams will be reduced as the high beam duty cycle is increased. Control of the vehicle headlamps using a PWM signal is disclosed in U.S. Patent No. 6,049,171, entitled CONTINUOUSLY VARIABLE HEADLAMP CONTROL, filed by Joseph Stam et al. on September 18, 1998.

Step 1405, which is the process of acquiring images in the forward field of the vehicle and analyzing such images, is described in greater detail with reference to Fig. 15. A first pair of images are acquired in step 1501 through both the red lens 209 and the cyan

lens 208, corresponding to the two fields 702 and 703 shown in Fig. 7. The field of view of the resulting images is approximately 25° horizontally and 15° vertically using the 64 by 26 pixels, the lens optics, and the far field baffle described above. These images are taken at a low sensitivity. Sensitivity of the image sensor 201 may for example be dictated by the frame exposure time, the analog amplifier gain, and the DAC high and low references. The image sensor should be just sensitive enough to image oncoming headlamps at the maximum distance for which the controlled vehicle's headlamps should be dimmed. These images will be sufficient to detect oncoming headlamps at any distance of interest and nearby tail lights without being washed out by bright headlamps or other noise light sources. In this mode, the sensor should not be sensitive enough to detect reflections off signs or reflectors except in rare cases where the reflecting object is very near to the controlled vehicle. During dark ambient light conditions, this sensitivity will be low enough to detect only lighted objects.

The sensitivity of the image sensor when acquiring the images in step 1501 may also be varied according to whether the high beams are currently ON. When controlling high beams manually, a driver will typically wait until an oncoming vehicle 105 (Fig. 1) or a preceding vehicle 110 is almost close enough for the controlled vehicle's high beams to be annoying before dimming the headlamps 111. However, if the high beams are OFF, most drivers will not activate their high beam headlamps even if an oncoming vehicle 105 is at a great distance. This is in anticipation that the oncoming vehicle 105 will soon come within a distance where the controlled vehicle's high beam headlamps will annoy the oncoming driver, such that the driver of the controlled vehicle 100 will have to turn the high beams OFF shortly after they were activated. To partially mimic this behavior, a higher sensitivity image is acquired if the high beams are OFF, enabling detection of vehicles at a greater distance, than if the high beams are ON. For example, the image sensor when the high beams are OFF can have 50% greater sensitivity than when the high beams are ON.

The images are analyzed in step 1502 (Fig. 15) to locate any light sources captured in the images. In step 1503, the properties of the light sources detected are analyzed to determine if they are from oncoming vehicles, preceding vehicles, or other objects. If a light source from a preceding vehicle 110 is bright enough to indicate that the high beams should be dim, the control process proceeds to step 1510 and the high beam state is set.

If no vehicles are detected in step 1503, a second pair of images is taken through lens 208, 209 at a greater sensitivity. First, a determination of the state of the high beams is made in step 1505. This determination is made because the sensitivity of the second pair of images may be five to ten times the sensitivity of the first pair. With a higher sensitivity image, more nuisance light sources are likely to be imaged by the image sensor 201. These nuisances are typically caused by reflections off road signs or road reflectors, which become much more pronounced with the high beams ON. When the high beams are ON, it is advantageous to limit the forward field of view to the area directly in front of the controlled vehicle such that it is unlikely that reflectors or reflective signs will be in the field of view. An ideal narrowed field of view is about 13° horizontally, which is achieved by a reduction of the width of regions 702 and 703 (Fig. 7) to about 35 pixels. If the high beams are OFF, an image with the same field of view as the low sensitivity images acquired in step 1501 can be used since the reflections of low beam headlamps off of signs and reflectors are much less bright than those when high beams are used. Thus, the decision step 1505 is used to select either a narrow field of view image in step1506 or a wide field of view in step 1507. For either field of view, a pair of images will be taken. As described above with respect to the acquisition of low sensitivity images in step 1501, the sensitivity of the high sensitivity images may also be varied according to the state of the high beam headlamps to provide additional control in avoiding nuisance light sources.

As with the low sensitivity images, the high sensitivity images are analyzed to detect light sources in step 1508. A determination is made if any of these light sources represent a vehicle close enough to the controlled vehicle to require dimming of the high beam headlamps.

Additional images, with greater sensitivity and/or different fields of view, may be acquired in addition to those mentioned above. Additional images may be necessary depending on the dynamic range of the image sensor. For example, it may be necessary to acquire a very high sensitivity image with a very narrow field of view to detect a preceding car's tail lights at a great distance. Alternatively, should the image sensor have sufficient dynamic range, only one pair of images at one sensitivity may be needed. It is advantageous to use three sets of images, a low sensitivity set, a medium sensitivity set, and a high sensitivity set. The medium sensitivity set has about 5 times the sensitivity of the low gain and the high gain has about 20 times the sensitivity of the low gain. The low

gain image set is primarily utilized for detection of headlamps while the medium and high gain images are primarily utilized for detection of tail lights.

Depending on the quantum efficiency of the image sensor at different wavelengths of light, and the filter characteristics of the filters used for the lens elements 208 and 209, it may be advantageous to use a different sensitivity for the two regions 702 and 703. The timing and control circuitry 309 described in the U.S. Patent No. 5,990,469 can be enhanced to provide the capability to acquire two different windows of pixels simultaneously and use different analog gains for each window. This is accomplished by adding a register which contains the gain values for the analog amplifier used during acquisition of each subwindow. In this way, the relative sensitivity of the two regions can be automatically balanced to provide a similar output when a white light source is imaged through both lens elements. This may be of particular advantage if the image for region 703 is acquired without filtering the light rays, for example by using a clear lens instead of a cyan filter for rays passing through lens element 208. For this lens set, the pixels in region 702 will receive approximately 3 times as much light when imaging a white light source as those pixels in region 703 which receive light that has passed through a red filter. The analog gain can be set 3 times as high for pixels in red filtered region 703 to balance the output between the two regions.

The analysis of images to detect light sources indicated in steps 1502 and 1508 is described with reference to Fig. 16. Analysis begins with the image in region 703 acquired through the red lens. It is advantageous to begin with the red filtered image because several nuisance light sources do not admit a significant amount of red light. These nuisance light sources include mercury vapor streetlights, green traffic lights, and reflections off green and blue highway signs. Therefore, a number of potential nuisance light sources are eliminated from consideration. Pixel locations are referred to by X and Y coordinates with the 0,0 pixel location corresponding to a top left pixel. Beginning with the 0,0 pixel 1401 and raster scanning through the image, each pixel is compared to a minimum threshold in step 1602. The minimum pixel threshold dictates the faintest objects in the image that may be of interest. If the current pixel is below the pixel threshold and it is not the last pixel in the red image window, as determined in step 1603, analysis proceeds to the next pixel as indicated in step1604. The next pixel location is determined by raster scanning through the image by first incrementing the X coordinate and examining pixels to the right until the last pixel in the row is reached, and then proceeding to the first pixel in the next row.

If it is determined that the current pixel value is greater than the minimum threshold, a seed fill analysis algorithm is entered in which step the size, brightness and other parameters of the identified light source are determined as indicated in step 1605. The seed fill algorithm is used to identify the pixels of the image sensor associated with a common light source, and thus identify associated pixels meeting a pixel criteria. This can be accomplished by identifying contiguous pixels exceeding their respective threshold levels. Upon completion of the seed fill algorithm, the properties of the light source are added to the light source list in step 1606 for later analysis (steps 1503 and 1509 in Fig. 15) to determine if certain conditions are met, which conditions are used to identify whether the light source represents an oncoming or preceding vehicle. A counter of the number of sources in the list is then incremented as indicated in step 1607. The microcontroller then goes to step 1603.

If it is determined in step 1603 that the last pixel in the red image has been examined, the microcontroller 1105 determines whether any light sources were detected, as indicated in step 1608. If no light source is detected, the analysis of the image terminates as indicated at step 1609. If one or more light sources are detected through the red lens 209, the cyan or clear image window 702 is analyzed to determine the brightness of those light sources as imaged through the other lens 208, in order to determine the relative color of the light sources. In this situation, the "brightness" of the sources refers to the sum of the gray scale values of all the pixels imaging the source; a value computed by the seed fill algorithm. The first source on the list is analyzed in step 1610. A seed fill algorithm is executed in step 1611, with the cyan image starting with the pixel having the same coordinates (relative to the upper left of the window) as the center of the light source detected in the red image. In this manner, only those pixels identified with a light source viewed through the lens associated with the red filter will be analyzed as viewed through the other filter, which is advantageous, as many nuisance light sources which would otherwise be analyzed when viewed through a clear or cyan filter will be removed by the red filter. By only considering light sources identified through the red filter, the amount of memory required to store information associated with light sources viewed through the other filter will be reduced. The ratio of the brightness of the source in the red image 703 to the brightness of the source in the other image 702 is stored in the light list, as indicated in step 1612, along with the other parameters computed in step 1605 for the current light source. This procedure continues for other sources in the light list 1613 until the red to

cyan ratios are computed for all sources in the list 1615, at which point the analysis terminates at step 1614.

As a further measure to reduce the required memory, the pixel data may be processed as it is received without storing the entire image in memory. Such a processing algorithm is disclosed in commonly assigned U.S. Patent Application No. _____ _____ [Attorney Docket No. GEN10 P380], entitled IMAGE PROCESSING SYSTEM TO CONTROL VEHICLE HEADLAMPS OR OTHER VEHICLE EQUIPMENT, filed on March 5, 2001, by Joseph S. Stam.

It will be recognized that where it is desirable to count the number of light sources to determine the type of driving environment, and in particular to identify city streets or country roads, it may be desirable to count all of the light sources viewed through the cyan or clear filter. In this way, nuisance light sources can be counted. Alternatively, the number of light sources viewed through the red filter can be counted for purposes of inhibiting turning ON the high beams if a threshold number of sources are identified.

The seed fill algorithm used in steps 1605 and 1611 is shown in Fig. 17a. The outer section of the seed fill algorithm is entered with the current pixel value at step 1605. The outer section of the seed fill algorithm is executed only once at each step 1605, while the inner recursive seed fill algorithm is entered many times until all contiguous pixels meeting a pixel criteria are identified. After the entry step 1701 of the outer section of the seed fill algorithm, several variables are initiated as indicated in step 1702. The variables XAVG and YAVG are set to zero. These variables will be used to compute the average X and Y coordinates of the pixels imaging a light source, which average coordinates will together correspond to the center of the light source. The TOTALGV variable is used to sum the gray scale values of all the pixels imaging the source. This value will define the brightness of the source. The SIZE variable is used to tally the total number of pixels imaging the source. The MAX variable stores the maximum gray scale value of any pixel imaging the source. A CALLS variable is used to limit the number of recursive calls to the recursive inner seed fill function to prevent memory overflow as well as for tracking.

The inner seed fill algorithm is first entered in step 1703. The start of the inner recursive seed fill function for the first and subsequent calls to the seed fill function is indicated by block 1704. The first step in the inner seed fill function is to increment the CALLS variable as indicated in step 1705. Next, microcontroller 1105 determines if the CALLS variable is greater than the maximum allowable number of recursive calls as determined in step 1706. The number of recursive calls is limited by the amount of

memory available for storing light source information. If it is determined that the number of recursive calls exceeds the threshold, the recursive function proceeds to step 1719, wherein the counter is decremented and then returns to the step from which the recursive function was called. Should this occur, a flag is set indicating that the current light source had too many recursive calls and parameters computed by the seed fill algorithm will be incorrect. This prevents too many levels of recursion from occurring, which would overflow the memory of the microcontroller. It is also possible to implement the algorithm non-recursively.

If the decision in step 1706 is that the CALL variable is not greater than the maximum allowable, the microcontroller 1105 next compares the current pixel with a minimum gray scale threshold in step 1707 to determine if the pixel is significantly bright to be included in the light source. The threshold considered in step 1707 can be constant or vary by position. If it varies, the variable thresholds may be stored in a spatial look-up table having respective pixel thresholds stored for each pixel, or each region of the image sensor. Where the threshold is variable by position, it is envisioned that where a pixel at one location exceeds its associated pixel threshold, the controller can continue to use that threshold for adjacent pixels while searching for a contiguous group of pixels associated with a single light source, or the controller can continue to use the respective pixel thresholds stored in the spatial look-up table.

If the condition in step 1707 is not met, this inner recursive seed fill function terminates by advancing to step 1719. If the pixel has a high enough gray scale value as determined in step 1707, its gray scale value is added to the global TOTALGV variable 1708, its X and Y coordinates are added to the XAVG and YAVG variables 1709 and 1710, and the size variable is incremented in step 1711. If the gray scale value of the pixel is greater than any other pixel encountered in the current seed fill, as determined in step 1712, the MAX value is set to this gray scale value 1713.

Following a no decision in step 1712, the gray scale value of the pixel is set to 0 to prevent further recursive calls from including this pixel. If a future recursive call occurs at this pixel, and the pixel is not zeroed, the pixel will be added the second time through. By zeroing the pixel, it will not be added again, as the pixel's gray scale value is no longer greater than the minimum threshold. Additionally, this pixel will be ignored in step 1602 should it be encountered again while scanning the image during analysis.

The inner recursive seed fill algorithm next proceeds to recursively call to itself until it has looked to the right, left, above and below each pixel until all of the contiguous

pixels exceeding the minimum pixel threshold value in decision step 1707 are considered. Step 1715 represents returning to step 1704 for the pixel to the right. The microcontroller will continue to look at pixels to the right until it reaches a pixel that does not meet the criteria of decision step 1706 or 1707. Step 1716 represents returning to step 1704 for the pixel to the left. Step 1717 represents returning to step 1704 to look at the pixel above. Step 1718 represents returning to step 1704 to look at the pixel below. The microcontroller will then look at the pixel to the left of the last pixel that did meet decision step 1707. The processor will look at pixels adjacent each pixel exceeding the threshold of step 1707 should the neighboring pixels exist (*i.e.*, the immediate pixel is not an edge pixel). Step 1719 decrements the CALLS variable each time the step is executed, and the microcontroller will return to the calling program until the CALLS value reaches 0. Returning to the function that called it may be another instance of the inner recursive function, or should this be the initial pixel examined, to the outer recursive algorithm 1721.

An example of how the inner and outer seed fill algorithms operate will now be described with reference to Fig. 17b. The example is made with respect to an exemplary very small image sensor having 30 pixels. Pixels 4, 9, 10, 11, 14, 15, 16, 17, 18, 21, 22, 23, and 28 exceed the threshold in step 1707 in this example. Additionally, the number of calls required does not exceed the threshold in step 1706. The image array 301 is impacted by a light source 1751, indicated by contour 1751. The microcontroller will operate as follows in evaluating the pixels. For pixel 1, the microcontroller 1105 will enter the seed fill algorithm at step 1701, initialize the variables in step 1702, and set the current pixel in step 1703. The microcontroller will next enter the inner seed fill function in step 1704. The CALLS variable will be incremented to 1 in step 1705, which is below the Maximum Calls threshold. Because there is no light on the pixel, the minimum threshold is not exceeded and the microcontroller will go to step 1719, decrement the CALLS variable in step 1720, and because this is the first time through the inner seed fill program, the microcontroller will continue to steps 1721 –1723. The process will be repeated for pixels 2 and 3, which are both below the minimum pixel threshold used in step 1707.

When the microcontroller gets to pixel 4, it will enter the outer seed fill at step 1701, set the variables to zero in step 1702, set the current pixel to pixel 4 in step 1703, and enter the inner seed fill algorithm. The CALLS variable will be incremented to 1, as it is the first pixel in this outer seed fill. The CALLS variable will be less than the

Maximum Calls threshold and the pixel's gray scale value will exceed the minimum threshold. Accordingly, the gray value will be added to TOTALGV, the pixel coordinates will be added to those that will be considered for XAVG and YAVG, and the SIZE will be incremented such that the size will be 1. The gray value for pixel 4 will be the MAX, as it is the only gray value in this outer seed fill. The gray value will be set to zero for pixel 4 in step 1714.

The microcontroller will then identify all of the contiguous pixels that exceed the threshold set in step 1707. In particular, through the inner seed fill routine disclosed in Fig. 17a, the microcontroller will add the pixels as follows. Pixel 4, added first as it is the first with a gray scale value greater than the threshold ("the threshold" in this paragraph referring to the minimum threshold in step 1707). The program then calls the recursive function for pixel 5 to the right, which is not added as it is below the threshold (as used in this paragraph, "added" means the pixel's coordinates are added to XAVG and YAVG, the pixel's gray scale value is added to TOTALGV, SIZE is incremented, and the pixel's gray scale value becomes the maximum pixel gray scale value if it exceeds MAX). Pixel 3 to the left is called next, and it is not added for the same reason. There is no pixel above pixel 4. Accordingly, the recursive function is next called for pixel 10 in step 1718. Pixel 10 will be added as its value is greater than the threshold. The microcontroller 1105 will then look to the right of pixel 10, namely at pixel 11, which is greater than the threshold, so it will be added. The microcontroller will then look to the right of pixel 11, which is pixel 12. Pixel 12 will not be added as its gray scale value is below the threshold. Looking to the left of pixel 11, pixel 10 will not be added as it was zeroed when it was added previously. Looking above pixel 11, pixel 5 will not be added. Looking below pixel 11, pixel 17 will be added. Next, the recursive routine will be called for the pixel to the right of pixel 17. Pixel 18 will be added. Moving on to the recursive routine for pixel 18, there is no pixel to the right of pixel 18. Looking to the left of pixel 18, pixel 17 will not be added as it was zeroed when it was added. Looking above pixel 18, pixel 12 will not be added. Looking below pixel 18, pixel 24 will not be added as it is below the threshold. Moving back to the previous recursive function that was not exhausted, the microcontroller 1105 will move back and look to the left of pixel 17, which is pixel 16. Pixel 16 is added. Calling the recursive function again, the microcontroller will look to the right of pixel 16. Pixel 17 will not be added as it was cleared after it was previously added. Looking to the left of pixel 16, pixel 15 is added. Calling the recursive function from pixel 15, the microcontroller will look to the right at pixel 16. Pixel 16 is not added,

as it was zeroed after it was previously added. Looking to the left, pixel 14 is added. Calling the recursive function from pixel 14, the microcontroller will look to the right at pixel 15, which will not be added. Looking to the left of pixel 14, pixel 13 is not added. Looking above pixel 14, pixel 8 is not added. Looking below pixel 14, pixel 20 is not added. Moving back to the function that called the recursive function for pixel 14, the microcontroller will look above pixel 15 at pixel 9. Pixel 9 is added. Calling the recursive function for pixel 9, looking to the right, pixel 10 is not added. Moving to the left, pixel 8 is not added as it is below the threshold. Looking above, pixel 3 is not added. Looking down, pixel 15 is not added as it was previously cleared. Moving back to the function that called the recursive function for pixel 9 has the microcontroller looking at the pixel below pixel 15. Pixel 21 is then added. Starting the recursive function for pixel 21, looking to the right, pixel 22 is added. Starting the recursive function for pixel 22, pixel 23 is added as it exceeds the threshold. Starting the recursive function for pixel 23, pixel 24 is not added as it is below threshold. Moving to the left, pixel 22 is not added as it was zeroed. Looking above, pixel 17 is not added as it was zeroed after it was added. Looking down, pixel 29 is not added as it is below the threshold. Moving back to the function that called the recursive function for pixel 23 has the microcontroller 1105 looking to the left of pixel 22. Pixel 21 is not added as it was cleared. Looking above pixel 22, pixel 16 is not added. Looking below pixel 22, pixel 28 is added. Performing the recursive function for pixel 28, pixel 29 to the right is not added, pixel 27 to the left is not added, pixel 22 above is not added, and there is no pixel below pixel 28. Moving back one function, the recursive function for pixel 22 was completed, so the microcontroller returns to pixel 21. Looking to the left of pixel 21, pixel 20 is not added. Pixel 15 above pixel 21 is not added and pixel 27 below pixel 21 is not added. The recursive function for pixel 15 was exhausted, so the microcontroller looks above pixel 16 to pixel 10 which is not added. Looking below pixel 16, pixel 22 is not added. Moving back one function has the microcontroller looking above pixel 17 at pixel 11, which is not added. Looking below pixel 17, pixel 23 is not added, if the recursive function for pixel 11 was completed, the microcontroller returns to the last non-exhausted pixel of the contiguous lighted pixels. The microcontroller looks to the left of pixel 10, and pixel 9 is not added. The microcontroller looks above pixel 10, and pixel 4 is not added. Looking below, pixel 16 is not added. The inner seed fill is complete.

After the last pixel is added, YAVG, XAVG and size are used to select the center of the light in steps 1722 and 1723.

The seed fill scheme just described is the preferred seed fill algorithm for analysis of the red image 703. It requires some modification for the other image 702. This need can be seen from the following example. Where a pair of oncoming headlamps is identified as two separate lights in the red image, it is possible that these sources may contain more light in the cyan half of the spectrum than the red half (as is the case with High Intensity Discharge headlamps). In this case, what was detected as two separate light sources in the red image can bloom into one source in the cyan image. Thus, there would only be one source in the cyan image to correspond to two light sources in the red image. After step 1611 is completed for the first source in the red image, the bloomed cyan image pixels would have been cleared in step 1714, such that they would not be available for the analysis of the second light source in the red image. Thus, after the source in the cyan image is determined to correspond to the first source in the red image, there would be no source on the cyan image to correspond to the second source in the red image. To prevent this, it is useful to preserve the image memory for the cyan image rather than setting the gray scale value to zero as in step 1714 so that the bloomed source is detected as corresponding to both of the sources in the red image.

Since the red image has already been processed, the memory that stored the red image can be used as a map to indicate which pixels in the cyan image have already been processed. All pixels in the red image memory will have been set to gray scale values less than the minimum threshold as a result of the processing. The pixels that were identified as light sources where zeroed whereas the light sources that were not cleared will have some low gray scale value. This characteristic can be used to set the pixels in the red image memory to serve as markers for processing pixels in the cyan image. In particular, when the seed fill algorithm is executed for the cyan image, step 1714 is replaced by a step that sets the value of the pixel in the red image memory corresponding to the currently analyzed cyan pixel to a marker value. This marker value could be, for example, 255 minus the index of the current light source in the light list. The number 255 is the largest value that can be stored for a gray scale value. In this way, there will be a unique marker stored in the red image memory for pixels analyzed each time step 1611 is executed for a light on the list. In addition to the above change to step 1714, a test must be added after step 1707 to determine if the value of the pixel stored in the red image memory corresponding to the currently analyzed pixel is equal to the marker value for the current light source index, indicating that this pixel has already been recursively visited, in which case the microcontroller would go to step 1719.

Steps 1501 and 1502 for the red image in region 703 and corresponding steps 1506, 1507 and 1508 for the other image in region 702, have now been explained in detail. In step 1503 and 1509, the light source list is analyzed to determine if any of the identified light sources indicate the presence of an oncoming or proceeding vehicle. Fig. 18 is a flow diagram of the series of tests applied to the information gathered on each light source in the light list during the previous analysis steps to determine the type of light source. The tests in Fig. 18 are applied to each source in the list independently.

First, a check is made to see if the recursive seed fill analysis of this light source exceeded the maximum number of subsequent recursive calls allowed as determined in step 1801. If so, the light source is labeled an extremely bright light in step 1803 since the number of pixels in the source must be large to cause a large number of subsequent recursive calls. Next, the TOTALGV variable is compared to a very-bright-light-threshold 1802. If TOTALGV exceeds this threshold, the light is also labeled as extremely bright in step 1803.

If neither of the conditions 1801 or 1802 are met, the light source is analyzed to determine if it has a 60 Hz alternating current (AC) intensity component, indicating that the light source is powered by an AC source, in step 1804, to distinguish it from vehicles which are powered by DC sources. Many streetlights, such as high-pressure sodium and mercury vapor lights, can be effectively distinguished from vehicle headlamps in this way. To detect the AC component, a series of eight 3 X 3 pixel images are acquired at 480 frames per second, for example. The 3 X 3 pixel window is centered on the center of the light source being investigated. The sums of the nine pixels in each of the 8 frames are stored as eight values. These eight values represent the brightness of the source at 1/4 cycle intervals over two cycles. The magnitude of the 60 Hz Fourier series component of these eight samples can be computed by the following formula:

$AC=(A^2+B^2)^{1/2}$

$A=1.0*(F1-FMIN)+(-1.0)*(F3-FMIN)+1.0*(F5-FMIN)+(-1.0)*(F7-FMIN)$

$B=1.0*(F0-FMIN)+(-1.0)*(F2-FMIN)+1.0*(F4-FMIN)+(-1.0)*(F6-FMIN)$

where F1 to F7 refer to the eight summed gray scale values of each of eight frames and FMIN refers to the minimum value of F1 through F7. The value AC is divided by the mean gray scale value of F1 to F8 to give the AC component of interest in step 1804. The scheme is of particular convenience since the sampling rate is exactly four times the frequency of modulation analyzed. If this were not the case, the coefficients for each of F1 through F7 would have to be changed to accommodate this. Additionally, if the system

were to be used in countries were the AC power is not at a 60 Hz frequency, the sampling rate or coefficients would be adjusted.

While the AC detection scheme is described for only one window, it is advantageous to perform the above analysis by imaging the source through both the cyan and red filters, or the red and clear filters, and then using the maximum computed AC component from the two sample sets to determine the AC component for step 1804. This allows for accurate measurement of sources that have either strong short or long wavelength components in their spectrum. If the light source AC component is greater than the minimum threshold as determined in step 1805, the light source is determined to be an AC source as indicated in step 1806. Additional measures may be taken to aid in distinguishing between such nuisance light sources and headlamps, such as to provide a lower AC component threshold for an upper area of the sensed image, while providing a higher threshold for the mid to lower right hand side and an intermediate threshold for the mid to lower left hand side.

The next step is to distinguish light sources which are reflections off road signs or other large objects. Road signs are large compared to the size of the headlamp or tail light. As a result, they tend to be imaged onto many more pixels than a vehicle lamp, unless the lamp is so bright as to bloom in the image. Sign reflection sources may have a large number of pixels, indicated by the SIZE variable, but a lower average gray scale value than vehicle lamps which have a much higher intensity. If the SIZE variable exceeds a given size threshold as determined in step 1807, the average gray scale value (TOTALGV/SIZE) is compared against an average pixel level threshold, which is the maximum sign average gray scale value, in step 1808. If the average gray scale value is less than this threshold, the light source is determined to be a reflection off a sign as indicated in step 1809.

An additional check for yellow signs, which typically occurs in the front of the vehicle when turning through a curved road, is to measure the color of bright objects and determine if they are likely yellow. Even when using the low gain image, the reflection off a nearby sign may saturate several pixels in both subwindows and make relative color discrimination difficult. However, the same high-speed images acquired when performing an AC validation can be used to accurately determine the relative color even for bright images. This is accomplished by looking at the average value of the F1 through F7 frames mentioned hereinabove through each lens. The ratio of the average of the F1 to F7 frames viewed through the red lens to the average of the F1 through F7 frames viewed through

the cyan or clear lens is computed. This ratio will be higher for yellow signs than for white lights but not as high as for tail lights. If this ratio is within a certain range indicating that it is likely a yellow sign, this object can be ignored or the threshold for dimming for this object can be decreased, allowing only extremely bright yellow objects to dim the high beams. By allowing the system to respond to bright yellow objects by dimming the high beams, the headlamp dimmer will respond to a light source in the event that a headlamp is misdiagnosed as a yellow sign.

Once potential nuisance sources are filtered out, the light source can be identified as a headlamp or a tail light. The red to cyan ratio computed in step 1612 is used to determine if the source has sufficient red component to be classified as a tail light in step 1810. If this ratio is lower than a tail light redness threshold, control proceeds to step 1811, where the threshold for consideration as a headlamp is determined. This threshold can be determined in a number of ways, but the most convenient method is to use a two dimensional look-up table if the microcontroller has sufficient read-only memory (ROM) to accommodate the table, as is the case with the Motorola MCS912 family of microcontrollers exemplified herein.

The center of the light source is used as the index into the look-up table to determine the threshold. The look-up tables are created to provide different thresholds for different regions of the field of view. For example, the thresholds for regions of the field of view directly in front of the vehicle are lower than those used for regions off to the side. The look-up table can be optimized for the particular vehicle's high beam emission pattern to determine how annoying the high beams will be to oncoming and preceding traffic at various angles. Ideally, the look-up table used when the vehicle's high beams are activated is different than when they are not. When high beams are off, the thresholds to the side of the vehicle can be lower than they are when high beams are activated. This will prevent the high beams from coming ON when there is a vehicle in front of, but off at an angle to, the controlled vehicle, such as happens when on a curve on an expressway. Also, different lookup tables are used for high and low sensitivity images for much of the same reasons. In fact, the lookup tables may indicate that for certain regions, or all regions of the field of view in high sensitivity image, headlamps be ignored completely. A high sensitivity image is only analyzed if the low sensitivity did not detect oncoming or preceding vehicles, so non-red light sources in a high sensitivity image are most likely very distant headlamps or nuisance sources. Therefore, the high sensitivity images may only be analyzed for red sources.

In step 1812, the TOTALGV variable, which is the total pixel level, is compared to the threshold total pixel level for headlamps as determined from the appropriate look-up table. If this variable is greater than the threshold, the value is compared to the threshold multiplied by a bright multiplier in step 1813. If TOTALGV is greater than this value, the light source is determined to be a bright headlamp in step 1815. If not the light source is a headlamp as indicated in step 1814. The need to distinguish between headlamps and bright headlamps will become clearer in the discussion of the control state of the headlamps. As an alternative to comparing TOTALGV to a threshold times a bright multiplier, yet another look-up table can be provided to dictate thresholds for bright headlamps.

A procedure similar to that just described is performed in step 1816 if the light source is determined to be red. A series of lookup tables are provided for tail light thresholds and the appropriate lookup table is used to determine the threshold for the given light source location. In 1817, the total pixel level for tail light threshold is compared to the TOTALGV variable to determine to light sources bright enough to be of interest. If so, the light source is labeled as a tail light in step 1819. If not, the light source is ignored in step 1820.

Should the cyan lens element 301 be replaced by a clear lens, a different ratio threshold is used in step 1810. In this case, a red light will have approximately the same brightness in both images, but a white or other color light will be substantially brighter when imaged through the clear lens. This ratio is determined based on the analog gain settings for both the red and cyan (or clear) images.

Once the images of the forward field have been acquired and analyzed in step 1405, the state of the headlamps must be determined in step 1406. This is best described by considering a state machine implemented in the microcontroller 1105, which state machine is illustrated in Fig. 19. In the following example it is assumed that headlamp drive 902 is a pulse width modulator drive and the high beam brightness can be varied by changing the duty cycle of the pulse width modulator drive. It is also assumed that the low beam headlamps remain on at 100% duty cycle at all times. Each of the states in Fig. 19 represents a control state of the high beam headlamps. The duty cycle of the high beam headlamps is set to the value indicated by the current control state. The distribution of the duty cycles amongst the control states is non-linear to compensate for the fact that headlamp brightness is a non-linear function of duty cycle and to provide the appearance of a constant percent change from cycle to cycle. Also, there are several states for both

0% and 100% duty cycle, indicating that several states must be traversed before the headlamps begin to go ON or OFF, providing a time delay verification insuring that the detected light source is persistent over several images. The number of states is exemplary only, and those skilled of the art will recognize that it may vary depending on the desired fade ON and OFF rate of the high beams and time between cycles. Additionally, the bright light indicator (which is typically located on the vehicle's dashboard) fades ON as the state moves from state 11 to state 14. The bright light indicator fades OFF as the states move from state 7 to state 4. This provides some hysteresis to avoid flashing the indicator ON and OFF. Alternatively, if the indicator does not fade ON and OFF, the state at which the bright light indicator turns ON will preferably be a higher state than the state at which the bright light indicator turns OFF. In either case, hysterisis is provided for the headlamp control.

After each control cycle, the headlamp control state can remain the same or move to a different state. The rules for moving between states are described with reference to Fig. 20. First, if any of the lights in the light list were determined to have been extremely bright lights in step 2001, the current control state is immediately set to a 0 state in step 2002. This behavior allows bypass of the fade out feature and rapid response to the sudden appearance of headlamps in the forward field of view, such as happens when driving over a hill. Step 2003 determines whether a headlamp or tail light was detected in the light source list. If not, control proceeds to step 2004, wherein it is determined whether the previous state was decremented in the last control cycle.

One of the advantages of the variable beam configuration is the ability to fade in and out high beams. If a reflection from a sign or reflector is misdiagnosed as a vehicle lamp, the high beams will begin to dim. When they do, the reflected source will no longer be present in the image and the high beams will fade back on, likely without bothering the driver. To prevent rapid oscillation between increasing and decreasing headlamp beam brightness, the control state must rest in the current state for one cycle before changing direction. Therefore, step 2004 considers the action during the previous cycle and the system will remain in the current state as indicated in step 2005 if the previous action was to decrement states.

If the action during the previous cycle was not to decrement states, vehicle speed is considered next in step 2006. If a vehicle is stopped at an intersection, it will annoy the driver if the high beams come ON, dim with a passing car, and then come ON again. To prevent this, the high beams are prevented from coming ON if a vehicle is traveling below

a certain speed, for example 20-mph. A decrease in speed below the minimum speed threshold will not necessarily cause the high beams to dim unless there is an oncoming or preceding car present. Alternatively, the high beams can be configured to fade OFF every time the vehicle comes to a stop and then fade ON again once the vehicle begins moving, provided no other vehicles are present. In step 2007, the number of lights in the light list (counted in step 1607) is checked as an indication of whether the driver is driving in city conditions. If there are a large number of lights in the forward field of view, the high beams will not be turned ON. The number of the lights that are alternating current sources may also be considered.

If the criteria of steps 2004, 2006, and 2007 are met, the current control state is incremented one state in step 2008. If this action results in the current control state exceeding state 12 as determined in step 2009, the current control state is set to 15 in step 2010 forcing several time verification states before the beams can be dimmed again.

Should the microcontroller 1105 detect a headlamp or tail light in step 2003, the microcontroller determines whether a bright headlamp was detected in step 2011. If not, the prior cycle action is considered in step 2012 to prevent rapid oscillation between incrementing and decrementing to avoid rapid ongoing oscillations between states. If the prior action was not to increment, the current control state is decremented by 1 state in step 2014. If the new control state is below state 3, as determined in step 2015, the current control state is set to 0 in step 2016.

Finally, if a bright headlamp is detected in step 2011, it is desirable to more rapidly fade out the high beams by decrementing 2 states in step 2018, provided the previous action was not to increment in step 2017, in which case the current state is decremented only one state.

A large number of variations of the scheme just described are possible. For example, more states can be added to increase or decrease the time it takes to fade the high beams in and out. The number of required states will depend upon the image acquisition and analysis cycle time. Ideally, the fade in/out period is about one to two seconds. Another alternative is to decrement states as a function of the brightest light source detected in the light list rather than to decrement a single state for every cycle. In this way, the brightness of the high beam is adjusted as a function of the distance of an oncoming or preceding vehicle rather than just fading in and out. This is particularly advantageous where the control mechanism is to vary the beam angle of the high beams rather than the intensity of the beams. Yet another alternative is to decrement states as a

function of the current speed of the controlled vehicle. The rate at which states are decremented could increase at high vehicle speeds, since oncoming cars will overtake the controlled vehicle at a more rapid rate. Yet another alternative is to decrement states as a vehicle slows down. This would allow the high beams to fade out as a vehicle comes to a stop: a feature that may be desirable for some drivers. Finally, it should be noted that the use of discrete states is only exemplary. The intensity and/or aim of the high beam headlamps can be controlled by continuum of values from fully ON to fully OFF.

The previous discussions described in detail the operation of one cycle of the headlamp dimmer control sequence. This sequence is repeated indefinitely as long as the device is on. Depending on the time to complete one cycle, the above procedure may be interrupted to acquire rear glare sensor measurements for the electrochromic mirror. Additionally, the driver may interrupt the above sequence by activating the manual high beam switch generating input signal 1123 (Fig. 11). This feature is necessary to allow the driver to override improper behavior of the control system or to use the high beams to alert other drivers through flashing the high beams.

Some additional features may be provided with the above-described hardware and software configuration. One such feature is daytime running lights (DRLs). On some vehicles, DRLs are provided by operating the high beams at a reduced intensity. By using the PWM drive circuitry provided, the high beams can be set to a reduced intensity during daylight conditions. The ambient light sensor 1107 can be used to determine daylight conditions and switch the headlamps to normal low beam operation at dusk. In particular, the ambient light level can have one or more light level thresholds associated therewith. When the ambient light level is a daytime one threshold, the daytime running lights will be ON. Below that threshold, but above another lower threshold, the low beams can be ON. Below that lower bright activate ambient light level threshold, the high beams may be operated automatically if the driver does not manually disable high beam operation.

Even without the use of DRLs, it is desirable to have automatic activation of the low beam headlamps at dusk. This control can be provided by the use of the ambient light sensor 1107. For better performance, an additional light sensor can be provided which senses light from a direction upwards rather than looking straightforward as the ambient light sensor 1107 does. Such a sky sensor arrangement is disclosed in U.S. Patent Application No. 09/491,192, entitled VEHICLE EQUIPMENT CONTROL WITH SEMICONDUCTOR LIGHT SENSORS, filed by Jon Bechtel et al. on January 25, 2000. Alternatively, a few rows of pixels in the image sensor can be used to image a region of

the sky above the horizon. An imaging system disclosing such an arrangement is described in U.S. Patent No. 6,130,421. The ability to image through both the red and cyan filters can help to distinguish between clear and overcast conditions and to detect a sunset.

It is envisioned that the system can detect a tunnel using the image sensor and a sky sensor. In particular, a potential tunnel condition is detected when a large area of contiguous dark pixels is detected that meets a size threshold level and is located in the center of the image, under daytime ambient light conditions. If the dark area grows while the ambient light conditions continue to sense day ambient light conditions, the potential tunnel condition will continue. If the image sensor continues to see a large dark area forward of the vehicle when the daylight ambient conditions are no longer detected, the vehicle will be determined to be in a tunnel, and the headlamps will be ON. The headlamps will remain on until the daylight ambient conditions are detected, at which time the headlamps will be turned OFF and daylight running lights will be turned ON if the controlled vehicle has daytime running lights.

SPEED VARYING THRESHOLDS

The speed input 1117 can be used in additional ways by microcontroller 1115. For example, when driving on an expressway, it is necessary to detect oncoming cars in the opposite lane, which is usually separated by a median. Therefore, the microcontroller must be more sensitive to oncoming headlamps at larger angles than would be necessary for back-road driving where there is no median separating oncoming traffic. Incorporating a wide field of view for back-road driving has the disadvantage of increasing the likelihood that the image sensor will detect house lights, which are typically incandescent. Incandescent light sources will not be filtered by the AC rejection algorithm. Such house lights are not typically present on the side of the freeway. By increasing the sensitivity of the device to objects at higher angles when the vehicle is traveling at higher speeds, such as speeds in excess of 50 to 60 mph, the system will be able to sense cross-median traffic on expressways without increased sensitivity to house lights on back roads. It is envisioned that the field of view could be increased when the vehicle speed exceeds 65 mph and decreased when the vehicle speed passes below 60 mph.

In particular, it is envisioned that prior to step 1601, additional steps can be provided to make the field of view speed sensitive. These steps are illustrated in Fig. 21. The vehicle speed is input in step 2101. The microcontroller determines in step 2103 whether the status is currently a wide view for expressway driving. If it is not, the

microcontroller 1105 determines whether the speed is greater than 55 mph. If not, the status does not change. If the vehicle speed is determined to be greater than 55 mph in step 2105, the field of view of the image sensor 201 is increased as indicated in step 2107. The field of view in the horizontal direction can be increased by 30 to 150 percent, and advantageously 60 to 125 percent, relative to the narrower field of view at lower speeds. If it was determined in step 2101 that the controlled vehicle 100 is in the expressway state, the microcontroller 1105 determines in step 2109 whether the vehicle speed has dropped below 45 mph. If it has, the microcontroller reduces the field of view of image sensor 201 to its narrower non-expressway field of view. In one advantageous embodiment, the field of view remains the same at all speeds but the thresholds for responding to lights at higher angles are decreased as speed increases. This is advantageous because it allows detection of very bright objects at high angles when the vehicle is traveling at slow speeds, but it is not sensitive to less bright objects, such as house lights or street signs, when traveling at slow speeds. In particular, at high speeds reducing the thresholds increases the sensitivity to cross-median traffic. The thresholds are reduced more significantly to the left than to the right since cross median traffic is to the left. This property can be reversed for left-hand-drive countries.

It is envisioned that the field of view will be varied by increasing and decreasing the width of the pixels used by the image sensor in the manner described above when the high beams are ON or OFF.

According to another aspect of the invention, the integration time for the pixels of the image array sensor can be increased at higher speeds. This increase in integration period increases the sensitivity of the image array sensor. The system is thus able to detect an oncoming vehicle sooner. This may be particularly advantageous, as oncoming cars are likely to be traveling faster when the controlled vehicle is traveling faster. Accordingly, providing the light control system with a higher sensitivity to shorten the response time will better emulate a desired dimming characteristic of the headlamps by dimming the headlamps at a desired vehicle distance. To provide this function, in step 2107 the microcontroller 1105 increases the sensitivity and/or widens the horizontal viewing angle, whereas in step 2111, the microcontroller decreases the sensitivity and/or narrows the horizontal viewing angle.

It is further envisioned that adjustments can be made to the threshold in step 1707 as a function of speed. Such a system can be implemented using a look-up table stored in read only memory. Fig. 22 illustrates regions of the image sensor array 301, with the

regions radiating outwardly from the center. The regions may not be symmetrical since oncoming traffic usually occurs more to the left and signs and nuisance light sources are more likely to the right in right side drive countries. The look-up table sets a respective threshold for each of the regions 1-6 with the regions having sequentially, incrementally greater thresholds moving outwardly from the center. Thus the center region 1 will have the lowest threshold and the outer peripheral 6 will have the highest threshold. In addition, the thresholds at different angles will vary as a function of speed, such that at higher speeds, the thresholds will be lower in regions 3 through 5 than they will be at higher speeds. For example, where two fields of view are provided, one table will contain respective thresholds for pixels in the regions for lower speeds and another table will contain respective thresholds in regions for the higher speeds. Each table will assign an integration time and/or thresholds for use in analyzing different portions of the field of view. Because the greater the distance from the center the greater the viewing angle of the scene image, lowering the threshold in the outer regions increases the system's responsiveness to light sources at wider angles to the controlled vehicle.

Either the thresholds or the integration times for the pixel sensors of the image array, or both the thresholds and the integration times, can be changed to increase the sensitivity of the sensor at different speeds. Thus, it is envisioned that the field of view can be the same at both high and low speeds. However, the thresholds or the sensitivity (*i.e.*, the integration period or the amplifier gain) can be altered such that at low speeds images viewed at wide angles will have little impact on the dimming decision whereas at high speeds the images viewed at wide angles will have substantially more impact on the dimming decision at high speeds. It is further envisioned that instead of using look-up tables, an algorithm can be used to alter the sensitivity of the light sensor as a function of the angle of the image being viewed. Such an algorithm can be used to reduce the memory requirements for the system at the expense of requiring greater processing power to implement the function.

TURNING

As indicated above, it is disadvantageous to have a wide field of view when traveling slowly, such as occurs when traveling on back roads. However, when turning, it is necessary to have a wide field of view so that the image sensor can detect other vehicles that will come in front of the controlled vehicle prior to the controlled vehicle's headlamps striking the other vehicle. It may also be desirable to lower the thresholds for those regions of the sensed image in the direction of the turn. A subroutine that the

microcontroller 1105 uses for changing the viewing angle of the image sensor is disclosed in Fig. 23. It is envisioned that the subroutine will be executed each time a turn condition is initiated. For example, the microcontroller may detect any one or more of the following: activation of a vehicle turn signal alone or in combination with braking; a change in vehicle heading detected by the compass; global positioning information; and change in direction of the vehicle steering wheel or front tires. Responsive to such an event, the microcontroller 1105 will input the criteria to be used in making a decision as to whether the field of view needs to be altered. For example, a compass input, an input from a turn signal, global positioning system (GPS) receiver information, wheel turn indication from the vehicle steering system, vehicle speed, gyroscope output, tire speed sensors of an anti-lock brake system (ABS), or a combination of these inputs may be input in step 2301. Additionally, motion analysis (discussed below) may be used to sense turning of the vehicle.

In step 2303, the microcontroller 1105 will determine whether the criteria input in step 2301 indicate that the field of view should be altered. For example, when the vehicle turn signal is ON, and the vehicle is slowing down, the viewing angle sensitivity can be altered in the direction of the turn signal. Alternatively, actuation of the vehicle brake system in combination with a change in vehicle heading greater than a threshold angle of change could trigger a change in sensor viewing angle. In particular, the compass sensor information can be compared to a threshold change of direction to determine if the controlled vehicle 100 is turning, and responsive thereto the microcontroller 1105 can increase the sensitivity of the image sensor 201 and associated circuitry to light sources in the direction that the vehicle is turning. In order to implement such a turning control, the compass must generate vehicle heading information that the microcontroller can use. Commercially available compasses of the type used in vehicles generate an output, which will operate within 2° to 3° of accuracy as the vehicle turns. As a consequence, the rate at which the vehicle heading is changing and the direction that the vehicle is turning can be determined from the compass output or GPS information. In one embodiment, a compass is integrated into an electrochromic mirror with an automatic headlamp dimmer and the compass sensor signal is utilized to enhance the performance of the automatic headlamp dimmer.

If it is determined in step 2303 that a shift of the sensitivity pattern is required, the image sensor will shift its sensitivity as indicated in step 2305. For example, the high

sensitivity region 1 of the image sensor will generally be in the center of the array such that lights straightforward of the vehicle will have the strongest impact on the light control process. This is particularly advantageous as the brightest light produced by the controlled vehicle illuminates straight out in front of the controlled vehicle. As the controlled vehicle turns, the center axis of each of the regions 1 through 5 will shift as indicated in step 2305. As a consequence, these regions shift in the direction that the vehicle is turning such that they are centered to the right or left instead of being centered on the Y axis (Fig. 22). The sensitivity of the pixels in array 301 will thus shift right as the vehicle turns right, and shift left as the vehicle turns left. The degree that the sensitivity field shifts can vary depending upon the rate of change of the vehicle as well as the speed of the vehicle.

It is envisioned that the sensitivity can be changed using the lookup table. In particular the lookup table can contain respective integration periods and thresholds according to the location of pixels such that the sensitivity is as shown in Fig. 22 when the vehicle is traveling straight. As the vehicle turns, the addresses associated with columns of pixels may be altered such that the integration periods and thresholds for pixels in the column will shift left or right.

If the change is not sufficient to change the sensitivity, as determined in step 2303, the microcontroller will determine in step 2307 if the vehicle is going straight. The microcontroller will continue to monitor the rate of change of the vehicle heading until the vehicle is heading generally straight, as indicated in step 2307. It will be recognized that subroutine may be run once as an interrupt routine such that other subroutines may be run in between execution of routine 2300.

It is further envisioned that adjustments may be made in the vertical direction, in addition to the horizontal direction, for example if a change in vehicle inclination is detected.

LIGHT LIST HISTORY

Information about lights from previous frames can be useful in evaluating current frames. However, there is typically insufficient memory in low cost microcontrollers to store previous frames so as to retain a complete history of each frame's content. To minimize the memory requirements for implementing the system, while retaining some useful historical information, the brightness and location of one or more of the brightest lights detected in one or more previous frames are stored for use when processing a later frame. The entire light list from a previous frame need not be stored, unless significant memory is available. It is also useful to store the brightness and location of only the

brightest lights detected in one or more preceding frames. This information can be used to provide fast return to bright. After an oncoming car 105 has passed the controlled vehicle 100, it is useful to return to the high beam state as soon as possible. The night vision of the driver in the controlled vehicle may be temporarily impaired by the lights of the oncoming vehicle. The impact of this loss of night vision may be minimized by providing as much scene illumination as possible, as soon as possible, following passage of a vehicle. The microcontroller 1105 uses the light list history information to implement a fast return-to-bright. In particular, after step 2007 in Fig. 20, the microcontroller 1105 can determine whether the current frame is suddenly clear of bright light sources following a preceding frame that contained a very bright headlamp. In such a case, it is likely that the bright headlamp has just passed the controlled vehicle. If this situation occurs, the normal gradual, delayed fade-in period can be bypassed, or partially bypassed, and the high beams can be incremented by more than one state, such as by eight states (Fig. 19), to return to bright high beams more quickly.

Another scenario where the opposite result is desired occurs when the controlled vehicle comes up behind a preceding vehicle 110. As the controlled vehicle 100 approaches the preceding vehicle 110, the image sensor will detect the preceding vehicle's tail lights and dim the controlled vehicle's high beams responsive thereto. When the controlled vehicle moves to the side to drive around the slower preceding vehicle, the tail lights of the preceding vehicle will move out of the field of view of the image sensor. However, if the controlled vehicle's bright lights are activated, they will shine into the eyes of the driver of the vehicle being passed via the exterior rearview mirror. This is particularly problematic when the controlled vehicle is passing a truck, as it may take a long time to pass the truck. In this situation, the microcontroller can include a decision step following step 2007 to determine whether the previous frame included a tail light, and if so, to set a predetermined delay before the high beam headlamps can be activated. Where the high beam lights are dimmed responsive to preceding tail lights, a long delay will thus be introduced before turning the high beams back ON. For example, the high beams may come on several seconds after the tail lights move out of the scene being imaged. Motion analysis (described below) may be used to determine the rate of overtaking a preceding vehicle or the rate at which a preceding vehicle may drive out of range to thereby enable additional control over the headlamps.

The light history can also be used to select an integration period for the image array sensor pixels. In particular, it is envisioned that the amplifier gain 303 for the pixels

can have different gains or different integration intervals to increase the dynamic range of the light sensor. For example, three different gains or integration periods could be supported. A bright light will saturate all but the lowest gain, whereas a dim light such as a tail light can not be detected at a low gain. The light history can be used to remember that the sensor was washed out even at low gain, and an ultra low sensitivity can be used to detect lights.

Another use for the light list history is determining traffic density. In particular, the traffic density can be ascertained from the time period count between detecting oncoming headlamps. Thus, in or near a city where traffic is heavier, the system can respond to that condition by having a relatively long delay period. On the other hand, where traffic is light, such that oncoming traffic is less likely, the delay to turn on the bright lights can be short. It is envisioned that as the traffic increases, the return-to-bright time period will lengthen, whereas as the traffic decreases, the return-to-bright period will shorten. It is further envisioned that a number of different criteria could be used, such as the number of frames since a vehicle was previously detected or the percentage of time that the bright lights were on over a predetermined sampling period. In these ways, the number of objects detected over time can be used in the control of the headlamps, and in particular, to at least partially inhibit turning on the high beams.

It is envisioned that where a vehicle includes an electrochromic mirror glare sensor to detect light from the rear of the vehicle, or any other device having a rearward directed optical sensor, such as a rear vision system, additional information can be accessed which is useful for controlling the return-to-bright interval. In particular, when the bright headlamps are dimmed because of tail lights from a preceding vehicle, the headlamps can return to bright a predetermined time after the tail lights disappear from in front of the vehicle or when headlamps are detected by the rear glare sensor in the rearview mirror, whichever occurs first. Where headlamps from a trailing vehicle are detected immediately prior to the disappearance of tail lights from a preceding vehicle, the use of the rearward sensor for detecting a return to bright condition will be precluded. Additional considerations can be used in making the return-to-bright decision. For example, a minimum and a maximum interval can be required before return-to-bright.

It is envisioned that the system will only provide a variable return-to-bright interval under certain conditions, such that the return-to-bright interval will typically be a default time interval. However, a fast return-to-bright interval will occur following a condition where really bright headlamps are detected and then disappear, as such bright

lights will reduce the driver's night vision. Additionally, a slow return to bright condition would be used following disappearance of a preceding tail light since the driver's vision will not have been impaired and it is desirable to avoid shinning the high beams into the eyes of a vehicle being passed.

It is further envisioned that integration periods in the current frame may be adjusted based upon measurements made in a previous frame. In particular, an extremely short integration period can be used for the image sensor 301 where the lowest sensitivity measurements in a previous frame resulted in saturation of the light sensor. To the other extreme, where the previous frame's most sensitive measurements did result in detection of tail lights, a very long integration interval can be used for the image sensor 301 to look for tail lights in the current frame. Thus where three integration periods are typically used, two additional integration periods can be selectively used when the conditions necessitate either an extremely short or long integration interval.

Another use of the light list history is to distinguish signs and reflectors based on the movement of the objects in the image over time. Over a sequence of frames, reflectors and signs will typically move more rapidly toward a side of the image than will vehicles traveling generally in parallel with the controlled vehicle. Object lists may be created as the images are captured as disclosed above and in commonly assigned U.S. Patent Application No. _____(Attorney Docket No. GEN10 P380), entitled IMAGE PROCESSING SYSTEM TO CONTROL VEHICLE HEADLAMPS OR OTHER VEHICLE EQUIPMENT, filed on March 5, 2001, by Joseph Stam et al. The object lists created may be stored in memory from frame to frame to determine the behavior of a particular object in the image over time. For instance, reflections from signs or other stationary objects can be identified by the motion of this object in subsequent frames. Flashing overhead stop or caution lamps can be identified by their rate of flashing. After each frame is analyzed, the object least created from this frame is kept in memory and light lists from new frames are stored in a different location. The techniques disclosed in U.S. Patent Application No. _____ (Attorney Docket No. GEN10 P380) greatly reduce the amount of memory required for image analysis by not requiring an entire frame to be stored. Therefore, it is practical to store the object lists from several subsequent frames in the amount of memory typically provided in low cost controllers. The number of object lists stored from previous frames depends on the available memory. As few as one previous object list can greatly assist in identifying the motion of an object.

To facilitate tracking of objects over time, additional properties of objects can be added as entries into the object list. For a headlamp control application, an object list entry may contain:

X Center	X coordinate of the center of the object
Y Center	Y coordinate of the center of the object
Total GV	Sum of all the gray scale values of all pixels in the object
Size	Total number of pixels in the object
Max	The gray scale value of the brightest pixel
Redness	Brightness ratio between the clear and the red images for this object
PrevFrameIndex	Index of a light in a previous frame which is the same light as this one (if any)
Gain	Which image in the cycle; high, medium, or low gain
Vector	The direction in which the light is traveling

The total number of objects that can be stored depends upon the available memory. For example, the list above would require 9 bytes per entry. If, for example, 500 bytes of memory are available, 50 objects could be tracked. The object list memory may be allocated as a contiguous array of object entries. Pointers indicate the start of the object lists for the current frame and previous frames. The newest objects identified replace the oldest objects in the list.

The objects in the new object list are then compared to the objects in the previous object list to determine if any of the new objects are the same as previous objects. A comparison is made by determining if the X and Y center of an object in the current list is within a radius of a certain number of pixels from an object in the previous list. The radius threshold is determined by calculating the maximum amount an object can reasonably move in an image from frame to frame. This number is a function of the resolution of the sensor and may also be a function of the vehicle speed and turn rate. It is possible for two lights in the current list to be daughters of the same light in the previous list. This may occur as a vehicle approaches from a distance and the two headlamps, which before were imaged as one blob, become separated in the image.

Once an object in a previous light list is determined to be the same object as in the current light list, a motion vector can be computed to quantify the rate and direction of

motion of the object. Motion detection can be used to distinguish between signs and reflectors, street lights, and vehicles. As illustrated in Fig. 39, the headlamps 3901 of oncoming vehicles tend to move down and to the left of the image over a sequence of frames, while signs and reflectors 3903 tend to move down and to the right. Overhead street lights 3905 tend to move upward. While other techniques are disclosed herein for distinguishing between these objects, motion detection can further increase the accuracy at which the system is able to make such distinctions.

Further, such motion detection can be used to distinguish between headlamps and tail lights of vehicles and thereby further enhance distinction that is otherwise based on color analysis.

Fig. 40 shows a functional block diagram of one embodiment of the present invention. As shown, the system 4000 includes an image sensor 201, an lens 202, a previous light list(s) 4001, and an image processing routine (seed fill) 4003, which receives data from image sensor 201 and accesses previous light list(s) 4001 to generate a new light list 4005. New light list 4005 includes information from which various parameters including the brightness 4007, position 4009, size 4011, color 4013, AC component 4015, and motion 4017 of each object may be derived. The system 4000 further includes decision rules 4020 that control the exterior vehicle lights including the low beam headlamps 4021 and the high-beam headlamps 4023 by adjusting their activation state, brightness, aim, and/or focus to vary the illumination pattern produced thereby. Decision rules 4020 may control the exterior lights as a function of any one or combination of parameters 4007-4017 as well as ambient light levels 4025, vehicle turn rate 4027, vehicle speed 4029, and the state of user actuated switches 4031 (as discussed further below). Decision rules 4020 may be implemented in a logic circuit (*i.e.*, microcomputer), a fuzzy logic circuit, or a neural network.

An example of how decision rules 4020 may use more than one parameter to control the exterior lights is to reduce the perceived brightness or otherwise modify the glare area of the present beam illumination pattern when a nearby headlamp is detected. Decision rules 4020 may determine that a nearby headlamp is present when the detected headlamp has high brightness and a relatively high amount of motion. A distant headlamp, on the other hand, would have low brightness and a relatively low amount of amount of motion. A sign would have a low level of brightness but have a relatively high amount of motion.

AUTOMATIC AIM CALIBRATION

Variations in the orientation of the image array sensor relative to the windshield angle may result in variations in aim of the sensor, which may negatively impact the performance of the dimmer. These variations can be calibrated out over time using a maximum bound placed on the expected variation in mounting. In general, on straight roads, distant oncoming headlamps will be coming from directly ahead of the optical sensor system 102. The calibration system uses faint headlamps detected near the center of the image, and preferably only those within a center window corresponding to the expected mounting variations. Such headlamps meeting certain criteria will have their position averaged with other faint headlamps meeting the same criteria. Over time, this average of these lights should correspond to the center of the field of view. This average value can be used to offset the image window relative to the X and Y-axis in Fig. 22.

More particularly, in order to detect a flat straight road, from which a misalignment of the optical sensor system can be detected, a variety of different orientation inputs can be used. The speed of the vehicle may be required to remain in a certain range between 35 to 50 mph. The vehicle can be determined to be traveling straight using the compass, GPS, or monitoring the operation of the vehicle steering system. If the heading changes during the test, the measurement will be considered to be in error. If the vehicle has equipment for providing an elevation measurement, any changes in the vehicle's elevation during the calibration process will result in an error. The elevation measurement may thus be used in determining whether to adjust the field of view.

A distant vehicle is initially detected by sensing white light near the center of the image, which is faint at the highest sensitivity (longest integration period) of the image sensor. As this light gets brighter, the system monitors the orientation inputs to detect whether the road continues to be flat and straight. If it remains flat and straight for a period of time which is at least twice the time period required for the vehicles 100, 105 to pass, the measurement will be valid. The center point detected initially will then be averaged with previous valid measurements, and the average measurement will be considered to be the center of the image. This will be the average X and Y coordinates, which together will mark the center of the image sensor. This location can be saved in EEPROM or flash ROM.

Another method of aiming calibration is to take a very high gain image and look for the reflection of the road. The average point where this reflection occurs can be used to calibrate the aim.

LIQUID CRYSTAL FILTER

An alternative optical system may include a liquid crystal filter 2405 that can be used to selectively provide both a red and a blue filter, whereby red and blue images may be viewed by an image sensor 2401 through a single lens structure 2403. In such a structure, the image sensor 2401 need only have one imaging area (*e.g.*, array area 702 instead of array areas 702 and 703 as required with two lenses). The filter 2405 is implemented using a liquid crystal colored light switch 2503 (Fig. 25) electrically connected to microcontroller 1105 through conductors 2413 and 2411. The filter includes a neutral polarizer 2501, a liquid crystal shutter 2503, a red polarizer 2505, and a blue polarizer 2507. The neutral polarizer 2501 and red polarizer 2505 are oriented with their polarizing axis aligned in one direction and the blue polarizer 2507 is oriented with its polarizing axis oriented orthogonally to the red and neutral polarizer. The liquid crystal shutter 2503 is implemented using a twisted neumatic (TN) liquid crystal shutter selectively energized under the control of microcontroller 1105. In particular, when the shutter is not energized, the liquid crystal device transmits the red light. When the liquid crystal is energized, the liquid crystal device transmits blue light.

It is thus possible to measure the relative intensities of two colors of light using a single photo sensor or image area. In the unenergized state all visible light is polarized in the horizontal direction by the neutral polarizer, rotated 90° by the unenergized TN liquid crystal cell to the vertical direction, and then all but the red light will be absorbed by the horizontal red polarizer. The red light will then pass through the vertical blue polarizer. In the energized state all visible light will be polarized in the horizontal direction by the horizontal neutral polarizer, and not rotated by the energized TN liquid crystal cell, all visible light will be transmitted by the horizontal red polarizer and all but blue light will be absorbed by the vertical blue polarizer. The liquid crystal device can be used as a high-speed light switch to alternate between transmission of blue light and red light. The relative intensities of the red and blue light components of an object or light source can then be determined. Alternatively, a green polarizer can be substituted for either the red or blue polarizer to switch between transmission of blue and green or red and green light respectively. Furthermore, a clear polarizer can be substituted for the blue polarizer to switch between red and clear.

WINDSHIELD WIPER

To improve dimmer performance when it is raining, it is useful to synchronize the acquisition of images with the windshield wipers. For example, a signal can be provided from the wiper motors to indicate the position of the wipers. Immediately after the wiper passes over the sensor, and image can be taken to look for cars. Most importantly, it is necessary to avoid taking images while the wiper is over the image sensor 301.

Where the controlled vehicle 100 includes a moisture sensor, the moisture sensor can monitor the windshield wiper. A moisture sensor providing such information is disclosed in U.S. Patent No. 5,923,027, entitled MOISTURE SENSOR AND WINDSHIELD FOG DETECTOR, issued to Joseph Stam et al. on July 13, 1999.

Information regarding the on/off status of the windshield wipers may also be used to control the vehicle headlamps. When the headlamp controller determines that the windshield wipers have been turned on, the headlamp controller may turn on the low beam headlamps of the vehicle assuming they are not already on. In addition, the headlamp controller may disable the headlamps from operation in a high beam state when the vehicle windshield wipers are activated. This may be accomplished by simply maintaining the headlamps in the low beam state when in an automatic control state or otherwise deactivating the automatic control state such that the high beams may not automatically be turned on while the wipers are activated. Additionally, the headlamp controller could disable any manual activation of the high beams so long as the windshield wipers are turned on. Also, foul weather lights, particularly the fog lights, may be automatically activated when the wipers are on.

The headlamp controller may receive a signal over the vehicle bus from the windshield wiper controller indicating that the windshield wipers are activated. Alternatively, the headlamp controller may determine that the windshield wipers are activated upon detecting a wiper within the scene imaged by the imaging system. As yet another alternative, the headlamp controller may receive a signal from a rain sensor that is used to control the windshield wipers indicating that a control signal has been transmitted to activate the windshield wipers.

DECELERATION

In addition to varying the image sensor operation depending upon the vehicle speed, other speed criteria can be used to control the operation of the vehicle headlamps. Turning on the high beams may be inhibited when the vehicle is decelerating, when the brakes are actuated, or when the vehicle is traveling slowly. This prevents high beams

from coming on when coasting to a stop or approaching an intersection. Deceleration can be detected from the speed input to the microcontroller 1105 (Fig. 11).

BAD PIXEL CALIBRATION

An image sensor may contain one or more bad pixels. These bad pixels may manifest themselves as extremely sensitive pixels, which may cause "white-spots" in the image. Such "white-spots" will cause false light detection in the image if the sensor is not calibrated to remove them from calculations. During production tests, the location of these white spots can be measured and stored in a programmable memory associated with microcontroller 1105. To compensate for such bad pixels during normal operation of the image array sensor, after an image is acquired, the pixel value at the white-spot location may be replaced with the average value of its neighboring pixels.

It is possible that a white-spot may form during use of the image sensor, such that it is not detected during production tests. Such a situation will cause the device to be inoperable. To avoid this problem, it is desirable to calibrate the white-spot out of the image after recognizing the bad pixel. In order to detect the white spot, it is necessary to detect that the pixel remains "lit-up" in several images, and preferably over an extended period of time. A bad pixel will stand out if it is repeatedly lit-up when neighboring pixels are dark. When such a pixel is detected, it can be added to the list of bad pixels.

It is envisioned that bad pixels can be periodically tested to determine if their performance has improved. This can be accomplished by monitoring a sequence of images to determine whether the center pixel is dark while the adjoining pixels are not dark.

"PICKET FENCE"

In controlling the vehicle headlamps, it is desirable to avoid a condition where the headlamp high beams flash ON and OFF at a relatively rapid rate, this is particularly important if non-variable two-state headlamps are used. For example, a sign along the road can cause flashing of the headlamps between bright and normal levels. This occurs when reflections of the bright high beams from a sign are bright enough to cause dimming of the high beams and reflections of headlamp low beams are low enough that the bright high beams are turned ON. The condition can be avoided by having the system look at the object that caused the high beams to turn OFF. When this condition occurs, the light level at that position is ignored while the pixels around the object are not ignored for a predetermined number of cycles, such as ten cycles. The length of time that the object is ignored can be variable as a function of the vehicle's speed. The higher the vehicle's

speed, the shorter the period that the object will be ignored. During the time period, the lights will be controlled using pixels other than those associated with the object being ignored.

A reflector can be distinguished from an active source of light by flashing the vehicle headlamps off. The time period that the headlamps are off is so short that the image sensor can sense the loss of light even though the human eye will not perceive, or barely perceive, that the lights were off. A light emitting diode headlamp described hereinbelow can be turned OFF and ON very rapidly, such that it will be off for such a short period of time. In operation, the microcontroller 1105 controls the headlamp high or low beams to turn OFF, and controls the image sensor to image the scene during that brief time period that the headlamps are off. The off time period may for example be 10 ms.

FOG DETECTOR

It is desirable for the vehicle to reliably detect a foggy condition, and in response thereto, to automatically turn ON or OFF front and rear fog lamps. Effective fog detectors have not been available heretofore. Fog may be detected by using the image sensor and optical system for the headlamp ON/OFF and headlamp dimmer control. Fog can be detected by a reduced scene contrast along with scene ambient light level determinations. The ambient light can be determined from the mean gray scale value of the pixels imaging the forward scene or by a separate ambient light sensor, such as the ambient light sensor used for the electrochromic mirror. It is envisioned that the mean can be a clipped mean value. The variance of the gray scale values of the pixels provides a measure of the contrast in the image. Alternatively, the variance can be determined from the standard deviation of the pixels, and in particular, when the standard deviation is less than a standard deviation threshold level, the presence of fog is identified responsive to which the fog lights can be turned ON. Alternatively, the individual differences between the average pixel level and each individual pixel level can be added for the entire image sensor, and when this total variance exceeds a variance threshold level, the presence of fog is detected. Either of these examples of fog criteria can be used as a measure of contrast.

Several additional factors may also be considered. The contrast value may be an average contrast value over several images. The contrast may be determined in row-wise fashion to determine the level of fog. Various regions of the scene may be considered independently. If two color lenses are present as in the headlamp dimmer, color information may be used. The actual values of the brightness/contrast ratios and the proper image sensor exposure times should be determined experimentally. The device can

be set to only operate between a predetermined range of brightness levels, such that if the ambient level is too high or too low, the fog detector will not operate, and manual override will be required. The ambient light conditions for fog may for example be between 1 and 1000 lux. Both the image sensor and the ambient light sensor can be used to detect fog. If the ambient light level detected by the ambient light sensor is within the appropriate range, an image of the forward scene is acquired with a sensitivity set to the average gray scale value of the pixels (*e.g.*, 128 lux). If the contrast at a given brightness level is below a predetermined threshold level, it is determined that fog is present.

SNOW AND FOG DETECTOR

It is also desirable for a vehicle to detect when it is snowing. Typically, in heavy snow conditions, it is not desirable to activate the high beams. Further, even if it is not snowing heavily, the snow may reflect the light from the high beams in such a way that the headlamp controller mistakenly perceives an oncoming vehicle based upon the reflected light from the controlled vehicle's own headlamps.

To detect snowfall, it is preferable to provide a sensing system that senses light levels forward and above the vehicle. To obtain the light level above the vehicle, a separate light sensor may be positioned to sense light from the sky above the vehicle. Such a sky sensor may include a single pixel sensor positioned at a 45° angle relative to the sensor used to sense light forward of the vehicle. The sensor used to sense light forward of the vehicle may be a single pixel sensor or the image array sensor used to image the scene forward of the vehicle for headlamp control. The values sensed by the forward and sky sensor may be averaged over a period of time. Theses sensors may be constructed in accordance with the teachings of U.S. Patent Application No. 09/307,191, entitled PHOTODIODE LIGHT SENSOR, filed on May 7, 1999 by Robert H. Nixon et al. and U.S. Patent Application No. 09/491,192, entitled VEHICLE EQUIPMENT CONTROL WITH SEMICONDUCTOR LIGHT SENSORS, filed on January 25, 2000, by Jon H. Bechtel et al.

The controller is coupled to receive the output of both the forward sensor and the sky sensor and compares the relative brightness in front of the vehicle with that above the vehicle. In some conditions, it may be desirable to compare the relative brightness as the brightness of the vehicle's headlamps increases. The headlamp controller determines that it is snowing or foggy when a ratio of the relative brightness forward of the vehicle to that

above the vehicle reaches a threshold as the brightness of the vehicle's headlamps increases due to the reflection of the headlamp light off the snow in the forward scene.

When the controller determines that snow is falling, it may activate the low beam headlamps if they are not already activated and can disable the high beams from being activated either through automatic control or manually. Further, automatic control may be disabled and foul weather lights may be activated. Additionally, the brightness of the vehicle's tail lights and/or brake lights may be increased to increase the visibility of the vehicle to other rearward vehicles.

The headlamp controller may also infer that the conditions outside of the vehicle are snowy or foggy when the driver turns the front windshield defroster fan to full speed. In such an event, the controller may also disable the headlamps from operation in a high beam state and may disable further automatic control.

The techniques described in this section are particularly well-suited for detecting fog at night, while the techniques described in the preceding section is better suited for detecting fog during daytime.

DAYTIME RUNNING LIGHT AND TAIL LIGHT CONTROL

As discussed above, daytime running lights (DRLs) are provided on some vehicles. As also discussed above, DRLs are provided by operating the high beams at a reduced intensity by changing the PWM drive signal delivered to the high beams during daylight conditions. For this purpose, an ambient light sensor 1107 can be used to determine daylight conditions and switch the headlamps to DRL operation when daylight is detected.

The controller may also utilize the sensed ambient light level to turn on the low beams when it is sufficiently dark. Additional the DRLs may be controlled to vary their intensity during daylight conditions. Ambient light levels may vary considerably from the brightest of daylight conditions to the conditions existing just prior to activation of the low beam headlamps at dusk. There have been complaints about the brightness of DRLs when the ambient light levels are relatively dark. In the brightest conditions, however, the DRLs are less bothersome because they appear to be less bright relative to the ambient light levels surrounding the vehicle. Accordingly, the headlamp control circuit may be configured to vary the brightness of the DRLs in response to the ambient light levels sensed by an ambient light sensor. Specifically, the control circuit may increase the brightness of the DRLs in response to increasing ambient brightness.

A similar problem exists with respect to a vehicle's tail lights and brake lights. Tail lights and brake lights preferably have brightness levels that are sufficient to allow

drivers to the rear of the controlled vehicle to easily determine whether the tail lights and brake lights are on or off regardless of the ambient light level. On the other hand, at nighttime, tail lights and brake lights can be too bright so as to adversely affect the night vision of drivers to the rear of the vehicle. Accordingly, it is preferable to decrease the intensity of tail lights and brake lights with decreasing ambient light levels. Such intensity variation may be continuous or accomplished in discrete steps. Additionally, it may be desirable to increase the intensity of the tail lights and/or brake lights when foul weather, such as rain, fog, or snow, is detected.

USER CONTROL AND FEEDBACK

An alternative embodiment of the present invention is shown in Fig. 34. The same reference numerals are used to illustrate common elements as in the embodiment shown in Fig. 11. Like the embodiment shown in Fig. 11, this alternative embodiment shown in Fig. 34 includes an image sensor chip 201 and a lens 202 preferably mounted in a mirror mount 1003. A compass sensor 1135 is also preferably mounted in mirror mount 1003. The compass sensor may alternatively be mounted in mirror body 1000. A microcontroller 1105 is preferably mounted in mirror body 1000 and is coupled to image sensor chip 201 and compass sensor 1135. Mirror body 1000 may further include an electrochromic element 1102 and a compass display 3404, both of which may be controlled by microcontroller 1105.

A forward-facing ambient light sensor 1107 and a rearward-facing glare sensor 1109 are also preferably provided in mirror body 1000. Additionally, a sky sensor 3402 may be provided in mirror housing 1000, which is inclined at an angle to view the scene of the sky above and slightly in front of the vehicle. Such a sky sensor 3402 may be used for detecting snow or other ambient light conditions. Sky sensor 3402 may be a single pixel sensor or may optionally be incorporated in the mirror mount as an optical element that images a view of the sky onto a designated area of the image sensor chip. Such a structure is disclosed in commonly assigned U.S. Patent No. 6,130,421.

Microcontroller 1105 is coupled to the vehicle bus 3406 for exchange of various information and control signals. As indicated, a switch control module 3408 may be coupled to the bus for providing the states of various switches that may be manipulated by the user to microcontroller 1105. For example, a high/low beam switch 3410 may be coupled to switch control module 3408, as may be a headlamp on/off switch 3412. Such switches are common in vehicles with the high/low beam switch typically being mounted

to the steering wheel column and the headlamp on/off switch being positioned on the vehicle instrument panel.

The present invention also provides for a user sensitivity selection switch 3414 that is coupled to switch control module 3408 to allow a user to adjust the sensitivity of the headlamp control system. Microcontroller 1105 may respond to changes in the sensitivity setting set by the user by adjusting the thresholds that the microcontroller utilizes to compare to detected light sources to determine when to turn off or on or fade in or out the high beams. Alternatively, microcontroller 1105 may utilize the sensitivity setting to change the rate at which it changes headlamp brightness states or may change the duty cycles associated with those states. Further still, microcontroller 1105 may adjust the sensitivity by changing the integration time of some or all of the pixels in the CMOS image array sensor. Also, the sensitivity to light in various portions of the scene in front of the vehicle may be adjusted by varying the thresholds/integration times for pixels in the image array sensor that image the peripheral regions of the forward scene. Other adjustments may also be programmed into microcontroller 1105 to determine how it should respond to adjustment of a user-sensitivity switch 3414.

As will be explained further below, the present invention also provides for the inclusion of an automatic headlamp control on/off switch 3415 by which a user may disable the automatic control of the vehicle headlamps.

Also coupled to vehicle bus 3406 is a lighting control module (or body controller) 3416, which controls the state and possibly the perceived brightness of the low beam headlamps 3418, the high beam headlamps 3420, and the brightness of the tail lights 3422. Front control module 3416 may also be used to control the on/off status or perceived brightness of fog lamps. As mentioned above, the brightness of daytime running lights may be adjusted by controlling the perceived brightness of high beams 3420.

Fig. 35 shows a state diagram for operation of microcontroller 1105 in response to various states of the switches coupled to switch control module 3408. As illustrated, the microcontroller 1105 may operate in an automatic mode or a manual mode in response to the activation of the automatic control on/off switch 3415. Such a switch may be provided on the steering wheel column and integrated into the same column switch that is utilized to manually activate the high beams. For example, if such a column switch is in a middle position, microcontroller 1105 will operate in a manual mode. If, for example, this column switch is moved to a forward position, microcontroller 1105 will respond by entering an automatic control mode. As discussed above, during an automatic control

mode, microcontroller 1105 varies the headlamp state between a high beam on state 3502 and a high beam off state 3504 based upon the light sources detected by the image sensor or upon other events. In the manual mode, however, the headlamps are operated manually in a conventional manner. For example, the high beams may initially be in an off state 3508 and be turned on by manual toggling of the column switch or other mechanism such that the high beams are in an on state (3510). Toggling a switch back would turn the high beams off. If the column switch includes a flash-to-pass feature, flashing the column switch would temporarily turn the high beams (on state 3512) whereas when the user releases the column switch, the high beams are turned off and returned to state 3508.

Fig. 36 shows a state diagram showing a more complex control scheme. As with the control scheme shown in Fig. 35, microcontroller 1105 may operate in either an automatic mode or a manual mode. Transition between the automatic or manual modes is generally manually selected using a switch 3415 that may, for example, be provided on the steering wheel column or on the vehicle instrument panel. In the manual mode, microcontroller 1105 operates in the same manner as described above with respect to Fig. 35. In the automatic mode, however, microcontroller 1105 initially operates in an automatic high beam control state 3602 whereby the high beams are automatically controlled to transition between on and off states, as well as states of intermediate brightness if the headlamps are capable of this feature. When operating in the automatic mode in accordance with the scheme shown in Fig. 36, when a user toggles the column switch 3410 for manually turning on the high beams, microcontroller 1105 turns on the high beams in a manual override state 3604 until such time that the user again toggles the column switch, at which point microcontroller 1105 returns to the automatic high beam control state 3602. In the event that the user manually activates the flash-to-pass column switch, microcontroller 1105 enters the high beam on flash-to-pass state 3606 and remains in this state so long as the flash column switch remains in the flash-to-pass position. Once the user releases the flash-to-pass column switch, microcontroller 1105 returns to the automatic high beam control state 3602.

While the high beams may be activated in their brightest state during the flash-to-pass state, it will be appreciated that, according to one embodiment of the present invention, the brightness of the headlamps during a flash-to-pass state may be less than full brightness. Specifically, the brightness of the headlamps during a flash-to-pass state may be varied as a function of the sensed ambient light level and also as a function of the current brightness level of the headlamps. In this manner, any time the flash-to-pass

switch is actuated, the perceived brightness of the headlamps will be increased by a predetermined increment above that of their current brightness level so as to provide a perceivable increase in the brightness of the headlamps to any preceding vehicles, but without causing a sudden and excessive glare in the eyes of the drivers of such vehicles.

Fig. 37 shows yet another state diagram for a more complex control scheme. Again, microcontroller 1105 operates in either an automatic or a manual mode. When in the manual mode, microcontroller 1105 allows the headlamps to be controlled in the same manner as discussed above with respect to Figs. 35 and 36. Again, operation in either the automatic or the manual mode may be manually selected by the user by manipulation of a switch 3415.

When in the automatic mode, microcontroller 1105 operates in an automatic high beam control state whereby the control state varies between a high beam on state 3702 and a high beam off state 3704. Microcontroller 1105 moves between states 3702 and 3704 in the manner discussed above responsive to the light sources detected by the image sensor. When microcontroller 1105 is operating in an automatic mode with the high beams on (state 3702) and then the column switch 3410 is toggled, microcontroller 1105 will interpret the toggling of the column switch as a request to turn the high beams off. Microcontroller 1105 thus enters a high beam off manual override state 3708. Microcontroller 1105 will maintain the high beams in their off manual override state 3708 for a predetermined time period, such as 30 seconds or until the column switch is again toggled. When the time period expires, microcontroller 1105 will initially maintain their high beams in the off state, but will move to state 3704 whereby the high beams may be automatically turned back on based upon the automatic headlamp control algorithm that is responsive to the light sources detected by the image sensor. If microcontroller 1105 is in the high beam off manual override state 3708 and the column switch is again toggled, microcontroller 1105 will interpret this action as a request by the user to move to a high beam on manual override state 3706. Microcontroller 1105 will maintain this manual override high beam on state 3706 for a predetermined time period, such as 15 seconds, or until the column switch is again toggled. If the column switch is again toggled, microcontroller 1105 will move to the high beam off manual override state 3708. Microcontroller 1105 will leave state 3076 and will enter state 3702 when the timer expires so as to initially maintain the high beams in their on status but allow for the automatic control algorithm to dim or turn off the headlamps in response to light sources detected by the image sensor.

If microcontroller 1105 is operating in the automatic control state with the high beams off (state 3704) and the column switch is toggled, microcontroller 1105 will interpret this as a command to enter the high beam on override state 3706. Microcontroller 1105 will then leave the high beam on manual override state 3706 based on the criteria discussed above.

If microcontroller 1105 is operating in the automatic control state with the high beams off (state 3704) and the user manually activates the flash-to-pass column switch, microcontroller 1105 will move to state 3710 by which the high beams are turned on in a flash-to-pass state. The high beams will remain on so long as the user holds the column switch in the flash-to-pass position. Once the user releases the flash-to-pass column switch, microcontroller 1105 will return to the automatic mode with the high beams off (state 3704). If the microcontroller is in the automatic control states with the high beams already on (state 3702), at such time that the user activates the flash-to-pass column switch, the high beams will remain on in state 3710 so long as the user holds the column switch in the flash-to-pass position. However, once the user releases the column switch, microcontroller 1105 returns to state 3704 rather than state 3702 so as to turn the high beams off. If conditions warrant, headlamp controller 1105 will turn the high beams back on under automatic control.

Other features that may be implemented would allow the automatic headlamp controller to gradually fade the brightness of the headlamps at such time that the headlamp switch 3412 is turned to an off position or if the vehicle ignition is turned off. Alternatively, the headlamp controller may fade the headlamps a designated time after it is detected that all occupants (or just the driver) have exited the vehicle. Such fading provides the benefits of illuminating the area in which the vehicle occupants will exit the vehicle. By fading the lights in this manner, rather than leaving the lights on in their full brightness states for a fixed time period, it is less likely an observer would suggest to the driver or other occupants that they had left their vehicle lights on since that observer would be able to see the fading of the headlamps during such time period.

Referring back to Fig. 34, an instrument control panel module 3424 may be coupled to vehicle bus 3402. An indicator 3426 may be coupled to instrument panel control module 3424 so as to receive control signals from microcontroller 1105 over vehicle bus 3406. Typically, vehicles have had a single indicator, often a blue light, which is activated when the vehicle's high beams are in an on state. Such single indicator, however, does not provide a user with any feedback as to the relative brightness of the

high beams when they are controlled automatically by a headlamp controller to have various intermediate brightness levels. To provide such feedback, the system may be configured such that indicator 3426 has a brightness that varies in proportion to the brightness level of the headlamps. Such variance may be along a continuum or may change in noticeable incremental steps. The brightness of indicator 3426 may also be doubled or increased significantly when the headlamps are in a high beam state as a result of manual activation of the high beams so as to provide the user with a clear indication that the system has appropriately responded to such manual activation. Another alternative indication scheme is to have the indicator change color as a function of the brightness of the headlamps. Yet another indication scheme is to configure indicator 3426 to include a scale that indicates a relative brightness of the headlamps. Such a scale may be provided as a multi-segmented display, such as the exemplary display shown in Fig. 38 in which the number of segments that are illuminated correspond to the relative brightness of the headlamps. Thus, for example, headlamp icon segment 3802 may be illuminated at all times that the headlamps are on and the various segments 3804-3812 are independently activated with the increasing brightness level of the headlamps. In addition, the color of the indicator shown in Fig. 38 may change to indicate manual activation or operation in either the manual or automatic modes or to indicate operation of the low beams, DRLs, fog lamps, etc. Another way to indicate to the driver that the headlamp controller is operating in an automatic control mode is to provide an indicator light in the auto/manual select switch 3415 such that when the user depresses the auto/manual select switch 3415, a light within or near by the switch is activated. Other indication techniques known in the art may similarly be utilized.

As discussed above, the vehicle headlamps may be operated in a super-high beam state in accordance with the laws of the various countries in which the vehicle may be used. Such super-high beams have been proposed to have an intensity of greater than 75,000 cd at 0° vertical and horizontal. Such super-high beams have been approved for use in Europe and found to be beneficial. In the event the vehicle is equipped with this capability and the appropriate headlamps, the control circuit may control the super-high beams to be activated when it detects that the vehicle is above a predetermined speed level. In this manner, the super-high beams can most typically only be activated when the vehicle is operated on an expressway.

Additionally, if such super-high beams are provided, the system may be programmed to have increased sensitivity to light sources detected forward of the vehicle. The super-high beams may also be faded as light sources are detected as coming closer to the vehicle.

As shown in Fig. 34, microcontroller 1105 may be coupled to a GPS receiver 3450 via vehicle bus 3406. Microcontroller 1105 may receive information from GPS receiver 3450 that is indicative of the location and possibly the direction of travel of the vehicle. GPS receiver 3450 may be part of a navigation system or may be part of any other system in the vehicle. The GPS receiver and antenna may be mounted to the rearview mirror assembly as disclosed in commonly assigned U.S. Patent No. 6,166,698.

The information received from GPS receiver 3450 may be in a form that already identifies the location and direction of the vehicle or it may be in the form of information received directly from the satellites from which the location would need to be computed by microcontroller 1105. If GPS receiver 3450 is part of a navigation system, the navigation system may process the information from the GPS receiver and provide exactly the information needed by microcontroller 1105. Such information may include, for example, an indication whether or not the road that the vehicle is currently traveling on is a residential road, a divided highway, or an expressway. Microcontroller 1105 may then utilize this information to control the exterior lights on the vehicle. Specifically, microcontroller 1105 may prevent actuation of the vehicle high beams or the super-high beams when the vehicle is traveling on a residential road. Microcontroller 1105 may also disable the super-high beams except when the vehicle is traveling on a divided highway or expressway. The location of the vehicle may also be utilized to automatically enable or disable the super-high beams based upon a determination of whether the vehicle is located in a country, state, or municipality that permits (or prohibits) the use of such super-high beams. Additionally, the location of the vehicle may be used to determine whether the vehicle is presently driving in a region where vehicles are driven on the left hand side of the road or in a region where vehicles are driven on the right hand side of the road.

LED HEADLAMPS FOR HEADLAMP STEERING AND HEADLAMP FLASHING

It has long been considered to be desirable to provide headlamps that can be steered in the direction that the vehicle is turning. It is also desirable to provide forward lighting that can be turned OFF, or substantially attenuated, for such a short period of time that the driver does not notice that the lights are OFF. In this way, reflections do not exist

during image acquisition. Although a light emitting diode (LED) lamp can be used to provide these features in a cost-effective manner, LED lamps producing enough light to implement a vehicle headlamp are not commercially available. LEDs suffer from a number of disadvantages that limit their application in vehicle headlamps, not the least of which are the relatively small amounts of light produced by LEDs and manufacturability limitations when incorporating LEDS having exotic constructions. Because of these disadvantages, LED lamps have not been used to implement a vehicle headlamp despite the fact that LEDs are more rugged, more energy efficient, and significantly longer lasting than other light technologies. Additionally, means of producing white light from LEDS have only recently become practical as discussed in U.S. Patent No. 5,803,579, entitled ILLUMINATOR ASSEMBLY INCORPORATING LIGHT EMITTING DIODES, issued to John K. Roberts et al. on September 8, 1998.

An LED headlamp 2600 is disclosed in Figs. 26a and 26b. The LED headlamp can be used to very briefly flash OFF, or dim, the headlamps during an image-sampling interval. The LED headlamp 2600 includes a heat extraction member 2601 that serves as a support for mounting semiconductor optical radiation emitters 2603, 2605. Where the semiconductor optical radiation emitters 2603, 2605 are electrically connected to the heat extraction member, the heat extraction member provides an electrical connection to the semiconductor optical radiation emitters in addition to providing a thermal path for removing heat generated within the semiconductor optical radiation emitters during operation. It is envisioned that the emitters 2603, 2605 can be electrically isolated from the heat extraction member such that the heat extraction member only provides a thermal path. Each of the emitters 2603 is connected to electrical conductor strip 2607 through a wire bond 2609 and a resistor 2611. Each of the emitters 2605 is connected to electrical conductor strip 2613 through a bonding wire 2615 and a resistor 2617.

The heat extraction member 2601 may be constructed of any suitable material, and may be formed in any desired configuration. The front face of the illustrated heat extraction member is generally rectangular in shape, including 33 wells, each of which receives semiconductor optical radiation emitters 2603, 2605. The back of the heat extraction member includes fins 2621 that provide a large surface for thermal dissipation to the ambient air. It is envisioned that the heat extraction member may alternatively have other configurations which enable light steering, such as being generally convex, shaped like a portion of a cylinder side wall, an elongate bar to extend across the front of the vehicle, or a plurality of joined planar surfaces extending at different angles, or the like.

The heat extraction member can be chamfered, or otherwise contain extensions, slots, holes, grooves and the like, and may incorporate depressions such as collimating cup or other form to enhance optical performance. The illustrated heat extraction member includes elliptical cups 2602. The heat extraction member may be composed of copper, copper alloys such as beryllium, aluminum, aluminum alloys, steel, or other metal, or alternatively of another high thermal conductivity material such as ceramic. Preferably, the heat extraction member is constructed from an electrically and thermally conductive metal. Such materials are commercially available from a wide variety of sources.

The cups 2602 are formed in the top surface of the heat extraction member for receipt of the semiconductor optical radiation emitters. The illustrated cups 2602 are elliptical to accommodate two emitter chips 2603, 2605 side-by-side. However, the cups may be of any suitable shape such as round, elliptical, rectangular, square, pentagonal, octagonal, hexagonal, or the like. The elliptical cups have the advantage of accommodating more than one emitter while providing an efficient reflector for projecting light outwardly in a desired radiation pattern. It is envisioned that the region of the heat extraction member directly underlying the point of attachment of the semiconductor optical radiation emitter may be coated with nickel, palladium, gold, silver or other material including alloys, in order to enhance the quality and reliability of the die attach. Other thin-layered materials may be optionally inserted between the emitter and the heat extraction member to achieve a variety of desired effects without departing from the scope and spirit of the present invention. The material preferably provides an electrical connection between the emitters and the heat extraction member whereby the heat extraction member can provide a reference potential, which may for example be ground potential. The materials are preferably adhesive, electrically insulative, and either conductive or patterned composite of electrically insulative and conductive materials, and without significantly impeding thermal transfer, may be used to support, bond, electrically connect or otherwise mount to the emitter to the heat extraction member. The region of the heat extraction member within optical-enhancement cup feature may be coated with silver, aluminum, gold or other suitable material to increase reflectance and improve the optical efficiency of the device. The area outside of the encapsulant may be coated with nichrome, black oxide or other high emissivity treatment to improve radiative cooling.

The connection of the semiconductor optical radiation emitter is preferably by the use of a special type of electrically conductive adhesive die-attach epoxy. These adhesives normally achieve good electrical conductivity by inclusion metallic fillers such

as silver in the adhesive. Suitable die-attach adhesives are well known in the art and may be obtained from Quantum Materials of San Diego, California, from Ablestik division of National Starch and Chemical, and EpoTek of Billerica, Massachusetts. Alternatively, solder may be used as a means of attaching the LED chip to the heat extraction member in some embodiments. Whether attached by electrically conductive adhesive or solder, the bond establishes good electrical and thermal conductivity between the emitter and the heat extraction member. In the case where the emitters having electrodes manifest as conductive bond pads at the top of the LED chips rather than at their base, the electrical attachment of all of the electrodes is by wire bond rather than by die attach to the heat extraction member.

The semiconductor optical radiation emitters comprise any component or material that emits electromagnetic radiation having a wavelength between 100 nm and 2000 nm by the physical mechanism of electroluminescence, upon passage of electrical current through the material or component. For purposes of generating headlamp illumination, different emitters can be used in the wells to generate the light, such as: all amber emitters the wells; or amber and cyan emitters positioned in each of the wells; or red-orange and cyan emitters placed in each of the wells; or cyan and amber emitters placed in some of the wells and red-orange and cyan emitters in other wells; phosphorous emitters in each of the wells; or the like. It is envisioned that four out of the five wells can have blue-green and amber emitters and one in five wells can have red-orange and amber emitters. Such an arrangement will produce a white light for illuminating the path of the vehicle.

The semiconductor optical emitter may comprise a light emitting diode (LED) chip or die as are well known in the art, light emitting polymers (LEPs), polymer light emitting diodes (PLEDs), organic light emitting diodes (OLEDs) or the like. Such materials and optoelectronic structures made from them are electrically similar to traditional inorganic materials known to those skilled in the art, and are available form a variety of different sources. Semiconductor optical radiation emitter, or emitter, as used herein refers to each of these and their equivalents. Examples of emitters suitable for headlamps include AlGaAs, AlInGaP, GaAs, GaP, InGaN, SiC, and may include emissions enhanced via the physical mechanism of fluorescence by the use of organic or inorganic dies or phosphors. LED chips suitable for use in the present invention are made by companies such as Hewlett-Packard, Nichia Chemical, Siemans Optoelectronics, Sharp, Stanley, Toshibe, Lite-On, Cree Research, Toyoda Gosei, Showa Denko, Tyntec, and others. Such chips are typically fashioned approximately in square base between 0.008" and 0.016" long on each

side, a height of about 0.008" to 0.020". To implement the headlamp, a larger chip having a square base larger than 0.020" may be used, and in particular it is advantageous to have a size greater that 0.025" to 0.035" to generate light. An array of such emitters mounted to a substantial heat sink permits an LED lamp to generate sufficient light to operate as a vehicle headlamp. Details of an emitter that can be used can be found in U.S. Patent Application No. 09/426,795, filed on October 22, 1999, entitled SEMICONDUCTOR RADIATION EMITTER PACKAGE, by John K. Roberts et al. An electrical path for supplying control signals to the emitters is provided through conductors. The conductors are electrical strips applied to a surface of an insulative layer. The insulative layer being mounted to the top surface of the heat sink. The insulative layer may be a circuit board including openings over the cups, or it may comprise an epoxy or plastic layer. The conductor may be any suitable electrically conductive material such as copper, aluminum, an alloy, or the like, and may advantageously comprise circuit traces applied to the insulating material by conventional means. The circuit traces disclosed in Fig. 26a illustrate a pattern that may be used where separate supply is provided for the different emitters.

An encapsulant is a material or combination of materials that serves primarily to cover and protect the semiconductor optical radiation emitter and wire bonds. The encapsulant is transparent to wavelengths of radiation. For purposes of the present invention, a substantially transparent encapsulant refers to a material that, in a flat thickness of 0.5 mm, exhibits greater than 20 % total transmittance of light at any wavelength in the visible light range between 380nm and 800nm. The encapsulant material typically includes a clear epoxy or other thermoset material, silicone or acrylate. Alternatively, the encapsulant may conceivably include glass or thermoplastic such as acrylic, polycarbonate, COC or the like. The encapsulant may include materials that are solid, liquid or gel at room temperature. The encapsulant may include transfer molding compounds such as NT 300H, available form Nitto Denko, or potting, encapsulation or other materials which start as a single part or multiple parts and are processed with a high temperature cure, two part cure, ultra-violet cure, microwave cure, or the like. Suitable clear encapsulants may be obtained from Epoxy Technology of Billerica, Massachusetts, from Nitto Denko America, Inc., of Fremont, California, or from Dexter Electronic Materials of Industry, California.

The encapsulant may provide partial optical collimation or other beam formation of electromagnetic energy emitted by the emitter and or reflected by the surface of heat

extraction member. The encapsulant also serves as a chemical barrier, sealant, and physical shroud providing protection of emitters, internal adhesives such as bonds, bond pads, conductor wires, wire bonds and internal surfaces of heat extraction member and electrical leads from environmental damage due to oxygen exposure, exposure to humidity or other corrosive vapors, solvent exposure, mechanical abrasion or trauma, and the like. Encapsulant provides electrical insulation. Encapsulant may also provide for attaching or registering to adjacent components such as secondary optics, support members, secondary heat extractors, and the like.

The encapsulant may comprise a heterogeneous mass of more than one material, wherein each material occupies a portion of the overall encapsulant volume and provides a specialized function or property. For example, a stress relieving gel such as a silicone "glob top" may be placed over the emitter and wire bonds. Such a localized stress relieving gel remains soft and deformable and may serve to cushion the emitter and wire bonds from stress incurred during subsequent processing of the component or due to thermal expansion to shock. A hard molding compound such as an epoxy, may then be formed over the stress relieving gel to provide structural integration for the various features of the component, to retain the electrical leads, to protect the internal mechanisms of the component from environmental influences, to electrically insulate the semiconductor radiation emitters, to provide various optical moderation of radiant energy emitted by the emitter if desired.

Additionally, the filler used within the stress relieving gel may advantageously include a high thermal conductivity material such as diamond powder. Diamond is a chemically inert substance with an extremely high thermal conductivity. The presence of such a material may significantly increase the thermal conductivity of the gel and provide an additional path for heat generated in the emitter chip to reach the heat extraction member and ambient environment where it can be dissipated. Such additional heat extraction path will increase the efficiency of the emitter, and thus the light output of the lamp. The encapsulant, and manufacture of a device using such an encapsulant is described in greater detail in U.S. Patent Application No. 09/426,795.

A steerable light emitting diode headlamp 2700 is illustrated in Fig. 27. The headlamp includes a heat extraction member 2701 having two lamp sections 2703 and 2705. The heat extraction member 2701 is configured to include the two lamp sections

2703 and 2705 each of which is substantially identical to lamp 2601, presenting two front faces at an angle of 5° to 45°, and may advantageously be angled at approximately 15°.

Another alternative design for a headlamp for providing low and high beams is illustrated in Fig. 28. The headlamp 2800 includes a heat extraction member 2801 having two lamp sections 2803 and 2805. The heat extraction member 2801 is configured to include the two lamp sections 2803 and 2805, each of which is substantially identical to lamp 2601. The heat extraction member provides two front faces at an angle of 1° to 2°, and may advantageously be angled at approximately 1.5°. The angle is exaggerated in Fig. 28 so that the angled surfaces are readily visible.

By controlling the selection of the LEDs that are illuminated, the headlamps can be aimed. It is also envisioned that the front of the car can have LED chips positioned in a bar running across the front grill.

Whereas the above embodiment takes advantage of directly mounting a number of chips on a common heat sink, it is also envisioned that an array of discrete LED lamps can be used to implement an LED headlamp 2650 (Figs. 26c and 26d). Each discrete LED lamp preferably includes a heat extraction member for dissipating power generated by the emitters to obtain a brighter light level without damaging the LED components. A particularly advantageous high power LED lamp which is uniquely adapted for conventional manufacturing processes is disclosed in U.S. Patent Application No. 09/426,795, entitled SEMICONDUCTOR RADIATION EMITTER PACKAGE, filed on October 22, 1999, by John K. Roberts et al. Other LED lamps that could be used are commercially available from LED manufacturers such as Hewlett Packard Company.

The LED lamps 2650 (only some of which are numbered) are mounted to a circuit board 2652 and heat sink 2654 (Fig. 26d). The circuit board can provide a secondary heat sink, where the conductive layer 2660 of the circuit board exposed to ambient air, by thermally coupling the heat extraction member 2664 of each LED lamp to the conductive layer 2662 of the circuit board. The heat extraction member of the LED lamp is also thermally coupled to the heat sink 2654. In the illustrated embodiment of Figs. 26c and 26d, the thermally conductive material 2670 is positioned in a hole through the circuit board below the heat extraction member. The thermally conductive material is thicker than the circuit board, and resilient. For example, the thermally conductive material can be provided using a preformed thermal coupler such as a silicon based, cut resistant material commercially available from Bergquist, and identified as Silipad 600. Packages

for LED lamps using the heat extraction member are disclosed in U.S. Patent Application No. 09/425,792, entitled INDICATORS AND ILLUMINATORS USING A SEMICONDUCTOR RADIATION EMITTER, filed on October 22, 1999, by John K. Roberts et al.

Where red-green-blue or binary complementary lighting is used, it is envisioned that only selected chips will be flashed OFF when attempting to distinguish reflective objects from lamps. Thus, for binary complementary emitters, only amber emitters need to have a briefly reduced intensity. Additionally, it will be recognized that instead of turning the headlamps OFF, the light level can be reduced to a level at which reflections will be below the pixel threshold at which the image sensor assembly will detect an object.

Other LED device/component structures that may be employed are disclosed in commonly assigned U.S. Provisional Application No. _____ (Attorney Docket No. GEN10 PP375), entitled HIGH POWER RADIATION EMITTER DEVICE AND HEAT DISSIPATING PACKAGE FOR ELECTRONIC COMPONENTS, filed on February 1, 2001, by John K. Roberts et al. and in commonly assigned U.S. Provisional Application No. _____ (Attorney Docket No. GEN10 PP391), entitled RADIATION EMITTER DEVICES AND METHOD OF MAKING THE SAME, filed on January 22, 2001, by John K. Roberts et al.

SURFACE MOUNTED FILTER FOR SENSOR

A method by which a filter can be directly deposited onto a semiconductor light sensor 201 will now be described with respect to Figs. 29a through 29d. In the first step, a photoresist 2877 is deposited over the entire wafer 2972. The photoresist may be any suitable commercially available photoresist material. Portions of the photoresist may be removed such that the remaining photoresist 2877 is patterned to cover only those areas on the surface of the wafer requiring protection from the optical coating deposition, such as the bonding pad 2975, as shown in Fig. 29b. The optical film coating 2979 is then applied to the surface of the die 2972 as shown in Fig. 29c.

The thin film 2979 is deposited directly on the light sensor 2932 in multiple layers. The red and cyan filters, if red and cyan filters are desired, will be applied separately. An example of a cyan filter will be now be described. To make a cyan filter, the layers of titanium dioxide (TiO_2) and silicon dioxide (SiO_2) described in Table 1 can be used. To make a red filter, the layers described in Table 2 can be used. The layer number is the

order in which the material is applied to the wafer surface.

Table 1

Layer	Material	Thickness(nm)
1	SiO_2	170
2	TiO_2	124
3	SiO_2	10
4	TiO_2	134
5	SiO_2	160
6	TiO_2	79
7	SiO_2	164
8	TiO_2	29
9	SiO_2	168
10	TiO_2	68
11	SiO_2	164
12	TiO_2	33
13	SiO_2	163
14	TiO_2	69
15	SiO_2	154
16	TiO_2	188
17	SiO_2	148
18	TiO_2	88
19	SiO_2	319

Table 2

Layer	Material	Thickness(nm)
1	TiO_2	68
2	SiO_2	64
3	TiO_2	35
4	SiO_2	138
5	TiO_2	57
6	SiO_2	86
7	TiO_2	50
8	SiO_2	78
9	TiO_2	73
10	SiO_2	94
11	TiO_2	54
12	SiO_2	89
13	TiO_2	52
14	SiO_2	87
15	TiO_2	50
16	SiO_2	74
17	TiO_2	28
18	SiO_2	61
19	TiO_2	49
20	SiO_2	83
21	TiO_2	48
22	SiO_2	78
23	TiO_2	48
24	SiO_2	91

After all of the layers are deposited, the photoresist is lifted off using a conventional lift off process, leaving the film deposited over the light sensitive region, but not over the bonding pads, as shown in Fig. 29d. The resulting die can be encapsulated to provide the image array sensor in conventional packaging.

The characteristics of the filters produced according to Table 1 and Table 2 are illustrated in Figs. 30 and 31. In particular, the red filter will attenuate light below 625 nm whereas the blue filter will pass light between approximately 400nm and 625 nm. Both filters will pass light above 800 nm. An infrared filter can be utilized to reduce the effect of infrared light on the performance of the headlamp dimmer.

Those skilled in the art will recognize that the filters described herein are exemplary, and that other filters, materials, or material thickness could be used to implement the filter function. Other materials could be applied in a similar manner to provide these or other filter characteristics.

Those skilled in the art will also recognize that the layer thicknesses are rounded to the nearest nanometer. Although there will be some tolerance permitted, good precision in the stack construction is required. It will also be recognized that the layer thicknesses are exemplary. By surface mounting the filters, the cost of providing the image sensor can be greatly reduced, as components and manufacturing complexity are reduced. Additionally, an infrared filter can be applied as a coating between the pixels and the red and blue filters.

PACKAGE

An alternate optical sensor assembly 3200 is disclosed in Fig. 32. Optical sensor assembly 3200 includes a base substrate 3202, which is transparent. The substrate may be manufactured of any suitable material such as a transparent polymer, glass, or the like. Alternately, it is envisioned that the base substrate may be manufactured of a commercially available infrared interference filter such as those described hereinabove. Alternatively, a thin film filter may be attached to a transparent glass element to make the base substrate 3202.

The lower surface of the base substrate has conductive strips 3210 for connection to the image array sensor 3212. The base substrate is preferably an electrical insulator, whereby the strips can be any suitable electrically conductive material applied directly to the lower surface of the base substrate by conventional manufacturing processes. Alternatively, if the base substrate is an electrical conductor, the strips can be applied to an electrical insulator, which is in turn applied to the base substrate.

The image array sensor 3212 is flip chip bonded to the lower surface of the base substrate 3202 by soldering pads 3211. A dielectric material 3214, such as an epoxy, encloses the image array sensor. The dielectric material preferably bonds with the conductive strips 3210 and the transparent element 3202. Clips 3204 and 3206 clip onto the edges of the base substrate and make electrical contact with respective conductive strips 3210. A respective clip can be provided for each of the conductive strips 3210. Leads 3213, 3215 extend from the clips for insertion into support substrate 3201, which can be a printed circuit board, a housing, or the like. The support substrate is preferably a printed circuit board carried in a housing, such as a rearview mirror mount housing. The stops 3205, 3207 limit the length of the leads that can be inserted into the support substrate. Alternatively, the clips can be configured for surface mounting. Examples of surface mountable clips include NAS Interplex Edge Clips, from NAS Interplex, an Interplex Industries Company located in Flushing, New York, USA.

Packages for mounting the image array sensor are described in U.S. Patent No. 6,130,448, OPTICAL SENSOR PACKAGE AND METHOD OF MAKING THE SAME, filed on August 21, 1998, by Fred Bauer et al.

The assembly of the lens to the base substrate can be provided in the same manner as described hereinabove. In particular, the lens structure is carried on the base substrate 3202. The lens structure can be identical to the lens structure 202, and thus can be half clear and half red, or half cyan and half red, or entirely clear where a color filter is applied directly to the surface of the image sensor as described above with respect to Figs. 29a-29d. To make the lens assembly, a transparent member and a UV curable adhesive can be used. The transparent member can be an epoxy member like members 230, 802. The UV curable adhesive can be identical to adhesive 232.

RADAR

A wave transceiver 101 (Fig. 1) can be used to acquire additional intelligence usable for controlling the operation of the controlled vehicle 100. The wave transceiver can be used without the image array sensor 102, or it can be used with the image array sensor. The wave transceiver device 101 is mounted on a vehicle 100 and oriented in a generally forward direction. The wave transceiver device 101 is positioned to receive the reflections of waves emitted by the transceiver device after they have reflected off objects in front of the vehicle 100. The wave-emitting device may be a radar system operating, for example, in a frequency range exceeding 1 GHz (77 GHz is designated for vehicular radar in many European countries) or an optical radar utilizing, for example, laser diodes for the wave-emitting device. Alternatively, the wave-emitting device 101 may be an ultrasonic transducer emitting ultrasonic waves. The wave-emitting device may be scanned across the forward field to cover various angles. For the purposes of this invention, the term "radar" will be used to encompass all of these concepts. The wave transceiver should not be interpreted as being limited to any specific type or configuration of wave transmitting or wave receiving device. The transmitter and receiver may each be mounted within a different respective housing or they both may be mounted in a common housing.

A radar processing system 3300 (Fig. 33) controls the wave transmitting section 3301, 3302 and interprets the signal received by the wave receiving section 3304, 3305 to determine the presence of objects as well as the speed and direction of such objects. A headlamp controller 3303 receives target information from the radar processing system, and may optionally also receive signals from the vehicle speed sensor (such as a

speedometer) and a vehicle direction sensor (such as a compass) and generates a control signal which determines the state of the vehicle headlamps 111. The communication between the radar processing system, the vehicle speed sensor, the vehicle direction system and the vehicle headlamps may be by one of many mechanisms including direct wiring through a wiring harness or by a vehicle communication bus such as the CAN bus. Additionally, systems such as the radar processing system and the headlamp controller may be implemented by a single integrated processor, multiple processors, digital signal processors, microcontrollers, microprocessors, programmable logic units, or combinations thereof.

More particularly, the system contains a radar system that includes a wave transmitting section and a wave receiving section. The wave transceiver 101 includes an emitter 3301 and a receiver 3304. The transmitter may be implemented using an antenna for a conventional radar, a light source for optical radar, an ultrasonic emitter, an antenna system for a Doppler radar system, or the like. The receiver 3304 may be implemented using an antenna in a conventional radar system, a light receiving element in an optical radar system, an ultrasonic receiver, a wave guide antenna in a Doppler radar system, or the like. A driver 3302 is connected to the emitter 3301 to condition signals from controller 3303 so that emitter 3301 produces signals, which, when reflected, can be detected by the receiver 3304. The driver 3302 may be implemented using a pulse modulator, a pulse shaper, or the like. The receiver 3304 is connected to a conditioning circuit 3305 which conditions the signals detected by the receiver for further processing by controller 3303. The conditioning cirucit may include a demodulator, a filter, an amplifier, an analog-to-digital converter (ADC), combinations thereof, and the like. The controller 3303 may be implemented using a microprocessor, a digital signal processor, a microcontroller, a programmable logic unit, combinations thereof, or the like.

The operation of radars to determine the presence of objects relative to a vehicle are well known, and will not be described in greater detail hereinbelow. For example, the time between the transmitted wave and the detection of the reflected wave may be used to determine the distance of an object. The movement of an object over successive transmission/reception cycles may be used to determine an object's relative speed and direction. Doppler radar may also be used to determine the objects speed. The magnitude of the reflected wave may be used to determine the size or density of the detected object. Operation of radars is well known, and will not be described in greater detail herein.

In order to properly control the high beam state of the controlled vehicle 100 it is necessary to determine if an object detected by the radar is a vehicle or a stationary object and, if a vehicle, whether the vehicle is an oncoming vehicle 105 or preceding vehicle 110. This can be accomplished by comparing the speed and direction of the object with the speed and direction of the controlled vehicle 100. The speed and direction of travel of the object is obtained using the radar principles described above. The speed of the controlled vehicle 100 may be obtained from a speed sensor on the vehicle, a global positioning system (GPS) system, or the like. The direction of the control vehicle 100 may be obtained from a compass sensor, a steering wheel turn indicator, a GPS, or the like.

Once this information is obtained, a simple set of criteria is applied to determine if the object is a vehicle or a stationary object. If an object is stationary, it will be moving in a direction opposite the controlled vehicle 100 at the same speed as the controlled vehicle. If an object is an oncoming vehicle 105, it will be traveling in a direction approximately opposite the controlled vehicle 100 at a speed substantially faster than that of the controlled vehicle. Finally, if an object is not moving relative to the controlled vehicle or the object is moving at a rate substantially slower than the controlled vehicle, the object is likely a preceding vehicle 1110. The distance at which the high beams are dimmed may be a function of the speed of the controlled vehicle and may be a function of the angle between an axis straight forward of the controlled vehicle 100 and the oncoming vehicle 105 or preceding vehicle 110.

In a more advanced system the headlamp control system not only controls the high/low beam state of the headlamps 3311, 3312 and high beam lamps 3314, 3315 based on the presence of one or more vehicles, but may vary the brightness of the high beam headlamps and low beam headlamps to provide a continuous transition between the two beams as a function of the distance to the nearest other vehicle, thus maximizing the available luminance provided to the driver of the controlled vehicle without distraction to the other driver. A continuously variable headlamp system is disclosed in U.S. Patent No. 6,049,171 entitled CONTINUOUSLY VARIABLE HEADLAMP CONTROL, filed on September 18, 1998, by Joseph S. Stam et al. The system may also vary the aim of the controlled vehicle headlamps in the vertical direction. The system may be configured to transition between more than two beams or may be configured to perform a combination of aiming and varying the brightness or one or more lamps. The headlamp processing system may also use the vehicle direction input to determine the proper horizontal aim of

the headlamps to provide better illumination when traveling on curves. An LED headlamp that facilitates aiming is described above.

A light sensor 3320 can be used to detect ambient light levels and may optionally provide other light conditions. The light sensor may be implemented using a non-imaging sensor such as a silicon photodiode, a particularly advantageous photodiode disclosed in U.S. Patent Application No. 09/237,107, entitled PHOTODIODE LIGHT SENSOR, filed by Robert Nixon et al., although other non-imaging photocells could be used such as cadmium sulphide (CdS) cells, or the like. The light sensor 3320 can be alternately be implemented using an optical image sensor 102 in addition to, or instead of, a non-imaging light sensor.

The optical system may contain filters to determine the color of a light source. The combination of an optical system with a radar system may better overcome the limitations present if only one or the systems are used independently. For example, if a radar system is used independently of an imaging system, an oncoming or preceding vehicle waiting at an intersection would be perceived by the radar system as a stationary object. However, by combining an optical sensor with the radar system, the lights on the waiting vehicle would indicate that a vehicle is present and the radar can determine the actual distance to the vehicle. In general, if an optical system is used, the optical system may be used to determine the presence of oncoming or preceding vehicles and the radar system may be used to determine the actual distance to such oncoming or preceding vehicle as well as the speed of that vehicle. In this manner, the radar detector and the imaging sensor can be used to verify the presence of other objects. Additionally, the light sensors can be used to determine light conditions, such as ambient light levels.

The presence of the radar system on the vehicle may enable other features other than headlamp control to be implemented utilizing the same components as the headlamp radar, thus reducing the cost of the two systems combined. Such system may include, for example, adaptive cruise control, obstacle warning systems, collision avoidance systems, autonomous driving systems, or the like. In this case, the wave transmitting section, wave receiving section, and radar processing systems could be shared by all features while each feature has its own processing system for determining a course of action based upon the information received from the radar processing system. It is also possible to integrate the processing systems from each feature into a single processor.

A radar system is described in U.S. Patent Application No. 09/531,211, entitled AUTOMATIC HEADLAMP CONTROL SYSTEM.

MIRROR MOUNT ACCESSORY HOUSING

A preferred mounting structure for mounting the headlamp dimmer system of the present invention is shown in Figs. 41-49. As illustrated, this structure includes a mount 4101 having a slot 4103 for receiving a mounting puck (not shown) that is adhesively secured to the vehicle windshield. An aperture 4105 is formed in mount 4101 and opens into slot 4103 to allow a mount screw 4107 to extend through aperture 4105 and engage a surface of the mounting puck so as to securely hold mount 4101 on the puck and thus on the vehicle windshield. Mount 4101 includes a ball 4109 to which the socket of a mirror mounting stem (not shown) may be secured in conventional fashion. The mounting stem may be secured to a similar ball extending from the rearview mirror housing or the stem may include a ball for engaging a socket formed in the mirror housing body.

As described in more detail below, a mirror mount accessory housing 4111 is secured to mount 4101 and includes a housing cover 4113 consisting of a right half portion 4113a and a left half portion 4113b. As best shown in Fig. 44, mount 4101 includes a plurality of laterally extending pegs 4115, which are inserted in corresponding holes 4117 provided in housing cover portions 4113a and 4113b. Additionally, housing cover portions 4113a and 4113b include resilient tabs 4119, which extend through a pair of slots 4121 on mount 4101 to securely hold housing cover 4113 on mount 4101. Housing cover portions 4113a and 4113b further include a plurality of tabs 4123 and a plurality of slotted tongues 4125, which snap together to thereby hold together portions 4113a and 4113b. Housing portion 4113a includes a forward facing aperture 4127 in which a glass filter 4129 may be mounted. As explained further below, aperture 4127 and glass filter 4129 provide a window through which the inventive camera senses images.

The inventive mirror mount accessory housing structure further includes a baffle/printed circuit board (PCB) holder 4130 (also generally referred to herein as a support structure) that is adjustably mounted to mirror mount 4101 and contained within housing cover 4113. As shown in Fig. 44, baffle/PCB holder 4130 includes a pair of slots 4133 for engaging laterally extending pins 4135 on mirror mount 4101. Baffle/PCB holder 4130 further includes a pair of elongated slots 4137 through which screws 4139 are inserted. Screws 4139 extend through slots 4137 and are threadably engaged in holes 4141 provided in mount 4101. By providing slots 4137 as elongated apertures, the tilt of baffle/PCB holder 4130 may be selectively adjusted relative to mount 4101. Such tilt adjustability is desirable given the variance of the slope of vehicle windshields from one model to another. As discussed further below, the image sensor and its associated circuit

board is securely mounted to baffle/PCB holder 4130, and thus, the image sensor tilt relative to the vehicle windshield may be adjusted by adjusting the tilt of baffle/PCB holder 4130.

As illustrated in Fig. 44, baffle/PCB holder 4130 includes a baffle 4143 similar to the baffle discussed above. A forward end of baffle 4143 is positioned proximate aperture 4127 and glass filter 4129 while an image sensor 4145, which includes image chip 201, encapsulation block 230, UV cure epoxy 232, lens 202, and an aperture stop 203, as shown in Fig. 2a), extends into the opposite and rearward end of baffle 4143. Image sensor 4145 is mounted on a PCB 4147 having a connector 4149 mounted thereon. Also mounted on PCB 4147 is an image sensing die (not shown), which functions as a sky sensor in the manner discussed above. To provide light from a skyward view relative to the vehicle, a light pipe 4151 is mounted over the die on PCB 4147 within a light pipe mount 4153, which engages a corresponding light pipe support 4155 on baffle/PCB holder 4130. Light pipe 4151 includes a pair of laterally extending protrusions 4157 that engage corresponding apertures 4159 in a light pipe filler 4161, which has an aperture 4163 through which the distal end of light pipe 4151 extends. Light pipe filler 4161 is mounted within an aperture 4165 formed in an upper surface of housing cover 4113. As will be apparent to those skilled in the art, light pipe 4151 captures the skyward light in its distal end that extends through filler 4161 towards the sky, and the skyward light is then directed through light pipe 4151 to the die on PCB 4147.

As discussed above, a processor may be mounted on PCB 4147 to preprocess some of the image data obtained from image sensor 4145.

A compass PCB 4171 may optionally be mounted within the inventive housing structure 4111. Compass PCB 4171 includes a pair of compass sensors 4173, which may be magneto resistive sensors, magneto inductive sensors, flux-gate sensors, or the like. By mounting compass PCB 4171 on baffle/PCB holder 4130, the relative tilt of sensors 4173 may be adjusted relative to the vehicle horizontal to ensure accurate sensing. Compass PCB 4171 includes a connector (not shown) to which a corresponding connector 4175 may be coupled. Connector 4175 connects compass PCB 4171 to a processor (not shown) in the mirror body via cable 4177. Cable 4177 also connects the same or a different processor within mirror body to PCB 4147 via a coupler 4179 and coupler 4149. A pair of resilient prongs 4181 of a clip structure 4183 is disposed behind PCB 4147 and secures to baffle/PCB holder 4130. Baffle/PCB holder 4130 includes a lateral extension 4187, which extends around connectors 4149 and 4179 and provides a ledge upon which resilient

prongs 4181 may latch to secure the clip 4183 and PCB 4147 to baffle/PCB holder 4130 and to assist in securing the engagement of couplers 4149 and 4179.

The above-described mounting structure provides several advantageous features. Specifically, the tilt angle of the image sensor may be selectively adjusted while not requiring movement of the housing cover relative to the mirror mount. This avoids the need to have mounting screws accessible from the exterior of the housing and thus reduces the possibility of someone tampering with the adjustment subsequent to final adjustment by the manufacturer. Further, the interior components shown in Figs 46-49 may be secured to mirror mount 4101 after it has been secured to the vehicle windshield and the adjustment may then be made with the housing cover subsequently snapped into place following final adjustment.

An additional advantage is provided by the use of light pipe 4151. In the absence of light pipe 4151, an additional circuit board would need to be mounted at an angle relative to PCB 4147 to aim the die mounted on such an inclined PCB towards the sky above the vehicle.

Although the mirror mount accessory housing has been described for mounting an image sensor, sky sensor, and compass sensors, it will be appreciated that any one or combination of these components may be disposed in the housing. Further, other components may be disposed in the housing in addition to, or in place of, any or all of the above components.

While the present invention has generally be described as preferably utilizing the full capability of the exterior lights to produce a large number of potential beam patterns that may change discretely or through a continuum, it is possible to use the system to simply turn headlamps on and off, as disclosed, for example, in U.S. Patent Application No. 09/491,192, entitled VEHICLE EQUIPMENT CONTROL WITH SEMICONDUCTOR LIGHT SENSORS, filed by Jon Bechtel et al. on January 25, 2000.

While the invention has been described in detail herein in accordance with certain embodiments thereof, many modifications and changes may be effected by those skilled in the art without departing from the spirit of the invention. Accordingly, it is intended that the appended claims not be limited by way of details and instrumentalities describing the embodiments shown herein.

CLAIMS

The invention claimed is:

1. A control system to control exterior lights of a controlled vehicle comprising:

an imaging system configured to image the scene forward of the controlled vehicle; and

a control circuit for processing the image of the scene obtained from said imaging system and for controlling the exterior lights to change their beam pattern in response to objects detected in the processed scene, said control circuit disables automatic control of the exterior lights in response to activation of the vehicle windshield wipers.

2. The control system of claim 1, wherein said control circuit is coupled to receive a signal from said windshield wipers when they are activated.

3. The control system of claim 1, wherein said control circuit determines that the windshield wipers are activated upon detecting a wiper within the scene imaged by said imaging system.

4. The control system of claim 1, wherein said control circuit determines that the windshield wipers are activated upon receiving a wiper activation signal from a rain sensor provided in the vehicle.

5. The control system of claim 1, wherein said imaging system is disposed in a rearview mirror assembly.

6. The control system of claim 1, wherein said control circuit changes the beam pattern of the exterior lights by turning on or off at least one of the exterior lights.

7. The control system of claim 1, wherein said control circuit changes the beam pattern of the exterior lights by continuously varying the brightness of at least one of the exterior lights.

8. The control system of claim 1, wherein the exterior lights include headlamps operable in at least high and low beam states, and wherein said control circuit prevents the headlamps from operation in a high beam state when the vehicle windshield wipers are activated.

9. The control system of claim 1, wherein said control circuit is responsive to the speed of the windshield wipers to disable automatic control of the exterior lights when the windshield wipers are operating above a threshold speed.

10. The control system of claim 1, wherein the exterior lights include foul weather lights and said control circuit activates the foul weather lights when the vehicle windshield wipers are activated.

11. The control system of claim 10, wherein the foul weather lights include fog lights and said control circuit activates the fog lights when the vehicle windshield wipers are activated.

12. A control system to control exterior lights of a controlled vehicle comprising:

an imaging system configured to image the scene forward of the controlled vehicle; and

a control circuit for processing the image of the scene obtained from said imaging system and for controlling the exterior lights to change their beam pattern in response to objects detected in the processed scene, said control circuit disables automatic control of the exterior lights when fog is detected on the windshield.

13. The control system of claim 12, wherein fog is detected to be on the windshield when the vehicle windshield defroster is operating at a speed above a threshold.

14. The control system of claim 12, wherein said imaging system is disposed in a rearview mirror assembly.

15. The control system of claim 12, wherein said control circuit is disposed in a rearview mirror assembly.

16. The control system of claim 12, wherein the exterior lights include headlamps operable in at least high and low beam states, and wherein said control circuit prevents the headlamps from operation in a high beam state when the vehicle windshield defroster is operating at full speed.

17. The control system of claim 12, wherein said control circuit changes the beam pattern of the exterior lights by turning on or off at least one of the exterior lights.

18. The control system of claim 12, wherein said control circuit changes the beam pattern of the exterior lights by continuously varying the brightness of at least one of the exterior lights.

19. The control system of claim 12, wherein the exterior lights include foul weather lights and said control circuit activates the foul weather lights when the vehicle windshield defroster is operating at full speed.

20. The control system of claim 19, wherein the foul weather lights include fog lights and said control circuit activates the fog lights when the vehicle windshield defroster is operating at full speed.

21. A method of detecting snowfall or fog outside a vehicle comprising the steps of:

sensing light levels forward of the vehicle and light levels above the vehicle;

comparing the relative brightness of the light levels forward and above the vehicle; and

determining that it is snowing or foggy when a ratio of the relative brightness forward of the vehicle to that above the vehicle reaches a threshold.

22. The method of claim 21, wherein the relative brightness of the light levels forward and above the vehicle are compared as the brightness of the vehicle's headlamps is increased.

23. A control system to control exterior lights of a controlled vehicle comprising:

a light sensing system configured to sense light levels forward of the controlled vehicle; and

a control circuit for light levels obtained from said sensing system and for controlling the exterior lights to change their beam pattern in response to the obtained light levels, said control circuit disables automatic control of the exterior lights when snow is detected.

24. The control system of claim 23, wherein said sensing system senses light levels forward of the vehicle and above the vehicle.

25. The control system of claim 24, wherein said sensing system includes a single pixel sensor for sensing the light level above the vehicle.

26. The control system of claim 25, wherein said sensing system includes a second sensor for sensing the light level forward of the vehicle.

27. The control system of claim 26, wherein said single pixel sensor is positioned at about a 45° angle relative to said second sensor.

28. The control system of claim 24, wherein said sensing system includes a second sensor for sensing the light level forward of the vehicle.

29. The control system of claim 24, wherein said control circuit compares the relative brightness of the light forward of the vehicle with that of the light above the vehicle as the brightness of the vehicle's headlamps increases, and determines that it is snowing when the ratio of relative brightness forward of the vehicle to that above the vehicle reaches a threshold.

30. The control system of claim 23, wherein the exterior lights include headlamps operable in at least high and low beam states, said control circuit disables the headlamps from operation in a high beam state when the vehicle windshield defroster is operating at full speed.

31. The control system of claim 23, wherein the exterior lights include headlamps operable in at least high and low beam states, said control circuit disables the headlamps from operation in a high beam state when the vehicle windshield wipers are activated.

32. The control system of claim 25, wherein said single pixel sensor senses the ambient light outside of the vehicle, and said control circuit varies the brightness of daytime running lamps in response to the ambient light level sensed by said single pixel sensor.

33. The control system of claim 23, wherein the exterior lights include daytime running lights, said imaging system comprising an ambient light sensor for sensing the ambient light outside of the vehicle, and said control circuit varies the brightness of daytime running lamps in response to the ambient light level sensed by said ambient light sensor.

34. The control system of claim 23, wherein said imaging system includes an image array sensor including a plurality of pixels, and an optical system configured to image the scene forward of the controlled vehicle onto said image array sensor, said optical system including a forwardmost surface, said optical system includes a hydrophilic coating on said forwardmost surface.

35. The control system of claim 23, wherein the exterior lights include headlamps operable in at least high and low beam states, said control circuit disables the operation of the headlamps in the high beam state when it is snowing.

36. A method of controlling vehicle headlamps comprising the steps of:
detecting whether it is snowing; and
disabling the headlamps from operation in a high beam state when it is snowing.

37. A control system to control the brightness of the tail lights of a vehicle comprising:
an ambient light sensor for sensing the ambient light outside of the vehicle; and
a control circuit for varying the brightness of the tail lights in response to the ambient light level sensed by said ambient light sensor.

38. The control system of claim 37, wherein said ambient light sensor is disposed in a rearview mirror assembly.

39. The control system of claim 37, wherein said control circuit is disposed in a rearview mirror assembly.

40. A headlamp control system for controlling the headlamps of a controlled vehicle, said headlamp control system comprising:

an imaging system configured to image the scene forward of the controlled vehicle;

a control circuit coupled to said imaging system for identifying and determining the brightness of light sources in images obtained from said imaging system and for controlling the headlamps to vary a beam pattern of the headlamps as a function of the brightness of light sources within the images; and

a user input mechanism coupled to said control circuit for allowing a user to adjust a sensitivity at which said control circuit will control the headlamps in response to light sources within the images.

41. The headlamp control system of claim 40, wherein said imaging system is disposed in a rearview mirror assembly.

42. The headlamp control system of claim 40, wherein said control circuit is disposed in a rearview mirror assembly.

43. The headlamp control system of claim 40, wherein said imaging system includes a plurality of sensors that integrate the light levels sensed during a predetermined integration time period, said control circuit adjusts the integration time period of said sensors in response to user adjustment of the sensitivity.

44. The headlamp control system of claim 40, wherein said control circuit adjusts the brightness of the headlamps when the brightness of light sources in the obtained images exceeds a threshold, said control circuit varies said threshold in response to user adjustment of the sensitivity.

45. The headlamp control system of claim 40, wherein said control circuit continuously varies the brightness of the headlamps as a function of the brightness of light sources within the images, said control circuit changes a rate at which the brightness of the headlamps is varied in response to user adjustment of the sensitivity.

46. The headlamp control system of claim 40, wherein said imaging system includes an array of pixel sensors, said control circuit being more sensitive to light sources detected within a predetermined area of the image obtained by said pixel sensor array, said control circuit varies the boundaries of said predetermined area in response to user adjustment of the sensitivity.

47. A headlamp control system for controlling the headlamps of a controlled vehicle, said headlamp control system comprising:

an imaging system configured to image the scene forward of the controlled vehicle and to detect an ambient light level outside the vehicle; and

a control circuit coupled to said imaging system for determining an ambient light level outside the vehicle for identifying and determining the brightness of light sources in images obtained from said imaging system, and for controlling the headlamps to vary a beam pattern of the headlamps as a function of the brightness of light sources within the images when the ambient light level is above a threshold level.

48. The headlamp control system of claim 47, wherein said imaging system includes:

an image array sensor;

an optical system configured to image the scene forward of the controlled vehicle onto said image array sensor; and

an ambient light sensor for sensing the ambient light level outside the vehicle.

49. The headlamp control system of claim 48, wherein said ambient light sensor is aimed generally upward towards the sky above the vehicle.

50. The headlamp control system of claim 47, wherein said imaging system is disposed in a rearview mirror assembly.

51. The headlamp control system of claim 47, wherein said control circuit is disposed in a rearview mirror assembly.

52. A control system to control the headlamps of a vehicle comprising:

an ambient light sensor for sensing the ambient light outside of the vehicle; and

a control circuit for varying the beam pattern of daytime running lamps in response to the ambient light level sensed by said ambient light sensor.

53. The control system of claim 52, wherein said control circuit increases the brightness of the daytime running lights in response to increasing ambient brightness.

54. The control system of claim 52, wherein said ambient light sensor is disposed in a rearview mirror assembly.

55. The control system of claim 52, wherein said control circuit is disposed in a rearview mirror assembly.

56. A control system to control exterior lights of a vehicle comprising:

an image array sensor including a plurality of pixels;

an optical system configured to image the scene forward of the controlled vehicle onto said image array sensor, said optical system including a forwardmost surface; and

a control circuit for processing the image of the scene obtained from said image array sensor and for controlling the exterior lights in response to objects detected in the processed scene,

wherein said optical system includes a hydrophilic coating on said forwardmost surface.

57. The control system of claim 56, wherein said optical system is disposed in a rearview mirror assembly.

58. The control system of claim 52, wherein said control circuit is disposed in a rearview mirror assembly.

59. The control system of claim 52, wherein said optical system further includes a photocatalytic coating proximate said hydrophilic coating.

60. A vehicle control system to control the brightness of continuously variable headlamps that have a brightness that varies continuously between a high beam state and a low beam state, said control system comprising:

an imaging system configured to image the scene forward of the controlled vehicle;

a control circuit for identifying and determining the brightness of light sources in images obtained from said imaging system and for controlling the perceived brightness of the headlamps as a function of the brightness of light sources within the images; and

an indicator coupled to said control circuit and positioned inside the vehicle for indicating to the driver the relative brightness of the headlamps.

61. The vehicle control system of claim 60, wherein said indicator has a brightness that varies in proportion to the brightness of the headlamps.

62. The vehicle control system of claim 60, wherein the brightness of said indicator doubles when the headlamps are in a high beam state as a result of manual activation of the high beams.

63. The vehicle control system of claim 60, wherein said indicator changes color as a function of the brightness of the headlamps.

64. The vehicle control system of claim 60, wherein said indicator includes a scale that indicates a relative brightness of the headlamps.

65. The vehicle control system of claim 64, wherein said indicator scale is a multi-segmented display in which the number of segments that are illuminated correspond to the relative brightness of the headlamps.

66. The vehicle control system of claim 60, wherein said imaging system is disposed in a rearview mirror assembly.

67. The vehicle control system of claim 60, wherein said control circuit is disposed in a rearview mirror assembly.

68. The vehicle control system of claim 60 and further including a second indicator for indicating when said control circuit is automatically controlling the brightness of the vehicle headlamps as a function of the brightness of light sources within the images.

69. An imaging system for a vehicle comprising:

an image sensor having an array of pixels and at least one other component; and

an optical baffle disposed between said image sensor and a scene to be imaged for preventing light from the scene from reaching said at least one other component.

70. The imaging system of claim 69, wherein said image sensor is a CMOS sensor.

71. The imaging system of claim 69, wherein said image sensor is disposed in a rearview mirror assembly.

72. A control system for controlling exterior lights of a controlled vehicle, said control system comprising:

an imaging system configured to image the scene forward of the controlled vehicle;

a switching mechanism for manual input of a driver's selection of a feature affecting the control of the exterior lights; and

a control circuit coupled to said switching mechanism and said imaging system for identifying and determining the brightness of light sources in images obtained from said imaging system and for controlling the exterior lights to vary the beam pattern of the exterior lights as a function of the brightness of light sources within the images and as a function of the status of said switching mechanism.

73. The control system of claim 72, wherein the exterior lights include headlamps and said switching mechanism includes a switch that allows a driver to select manual or automatic control of the vehicle headlamps.

74. The control system of claim 72, wherein, in response to selection of automatic control using said switch, said control circuit enters an automatic control mode in which the headlamps are automatically controlled in response to the detection of light sources within the images.

75. The control system of claim 74, wherein, in response to selection of manual control using said switch, said control circuit enters a manual control mode in which the headlamps are manually controlled by the driver.

76. The control system of claim 72, wherein the exterior lights include headlamps, said switching mechanism includes a switch for manually activating high beams of the vehicle headlamps, and wherein said control circuit responds to activation of said switch by turning on the high beams.

77. The control system of claim 76, wherein said switch is a toggle switch and said control circuit maintains the high beams in an on state when said switch is toggled until such time that it is again toggled at which point said control circuit automatically controls the brightness of the high beams.

78. The control system of claim 76, wherein said switch is a flash-to-pass switch, wherein said control circuit responds to manual activation of said switch by activating high beam headlamps for so long a time as the flash-to-pass switch is held in its activation position.

79. The control system of claim 72, wherein the exterior lights include headlamps, said switching mechanism includes a toggle switch for manually activating and deactivating high beams of the vehicle headlamps, and wherein said control circuit responds to toggling of said switch by changing the on/off state of the high beams from the current status of the high beams.

80. The control system of claim 79, wherein, upon switching the on/off state of the high beams in response to toggling of said switch, said control circuit maintains the high beams in the changed state for a predetermined time period at which point said control

circuit enables automatic changing of the brightness of the high beams in response to the brightness of light sources in images obtained from said imaging system.

81. The control system of claim 72, wherein the exterior lights include headlamps, said switch is a flash-to-pass switch, and wherein said control circuit responds to manual activation of said switch by turning on the high beam headlamps for so long a time as the flash-to-pass switch is held in its activation position.

82. The control system of claim 81, wherein, when said flash-to-pass switch is released from its activation position, said control circuit turns off the high beam headlamps regardless of whether the high beams were on or off before such activation and thereafter enables automatic changing of the brightness of the high beams in response to the brightness of light sources in images obtained from said imaging system.

83. The control system of claim 72, wherein said imaging system is disposed in a rearview mirror assembly.

84. The control system of claim 72, wherein said control circuit is disposed in a rearview mirror assembly.

85. A headlamp control system for a vehicle comprising:

a control circuit coupled to the vehicle headlamps for fading the headlamps of the vehicle to an off state in response to the turning off of the vehicle ignition.

86. The headlamp control system of claim 85, wherein said control circuit begins to fade the vehicle headlamps upon detecting the exit of the driver.

87. The headlamp control system of claim 85, wherein said control circuit begins to fade the vehicle headlamps upon detecting the exit of the last occupant to leave the vehicle.

88. The headlamp control system of claim 85 and further comprising an imaging system configured to image the scene forward of the controlled vehicle, wherein said control circuit is coupled to said imaging system for identifying and determining the

brightness of light sources in images obtained from said imaging system and for controlling the beam pattern of the headlamps as a function of the brightness of light sources within the images.

89. The headlamp control system of claim 85, wherein said control circuit is disposed in a rearview mirror assembly.

90. A control system to control exterior lights of a vehicle comprising:

an image array sensor including a plurality of pixels;

an optical system configured to image the scene forward of the controlled vehicle onto said image array sensor, said optical system including a forwardmost surface; and

a control circuit for processing the image of the scene obtained from said image array sensor and for controlling the exterior lights in response to objects detected in the processed scene,

wherein said optical system includes a photocatalytic coating on said forwardmost surface.

91. The control system of claim 90, wherein said optical system is disposed in a rearview mirror assembly.

92. The control system of claim 90, wherein said control circuit is disposed in a rearview mirror assembly.

93. A control system to control the headlamps of a vehicle comprising:

a manually actuated switch mechanism for receiving input from a driver to temporarily increase the brightness of the vehicle headlamps in a flash-to-pass state;

an ambient light sensor for sensing the ambient light outside of the vehicle; and

a control circuit coupled to said ambient light sensor and said manually actuated switch mechanism for varying the beam pattern of the headlamps during a flash-to-pass state in response to the ambient light level sensed by said ambient light sensor.

94. The control system of claim 93, wherein said ambient light sensor is disposed in a rearview mirror assembly.

95. The control system of claim 93, wherein said control circuit is disposed in a rearview mirror assembly.

96. A control system to control the headlamps of a vehicle, the vehicle having a microwave receiver for receiving signals from satellites, said control system comprising:

a control circuit for receiving signals from the microwave receiver indicative of the location of the vehicle, said control circuit controls the headlamps to limit the perceived brightness of the headlamps from exceeding a predetermined level less than their capacity when the vehicle is traveling on a residential street.

97. The control system of claim 96 and further comprising an imaging system configured to image the scene forward of the controlled vehicle, wherein said control circuit identifies and determines the brightness of light sources in images obtained from said imaging system and for controlling the headlamps to vary the perceived brightness of the headlamps as a function of the brightness of light sources within the images.

98. An imaging device assembly for a vehicle having a windshield, said assembly comprising:

a mounting structure configured for mounting to a vehicle in a fixed position relative to the windshield;

an imaging device; and

a support structure, said imaging device carried by said support structure, said support structure being attached to said mounting structure to allow positional adjustment of said support structure and said imaging device relative to the windshield.

99. The imaging device assembly of claim 98 and further including a housing secured to said mounting structure, said support structure and said imaging device being disposed in said housing.

100. The imaging device assembly of claim 99, wherein both said housing and said support structure being attached to said mounting structure such that positional adjustment of said support structure may be performed without changing the position of said housing relative to said mounting structure.

101. The imaging device assembly of claim 98, wherein said mounting structure is a rearview mirror assembly mounting structure.

102. The imaging device assembly of claim 101, wherein said rearview mirror assembly mounting structure is configured for securing a rearview mirror assembly to a vehicle windshield.

103. A sky sensor assembly for sensing light in the sky above a vehicle, said assembly comprising:

a housing configured for mounting to the vehicle;

a light sensor disposed within said housing;

a light pipe extending from said light sensor to an aperture formed in said housing that is directed upward towards the portion of the sky from which light is to be sensed.

104. The sky sensor assembly of claim 103, wherein said housing is a component of a rearview mirror assembly.

105. The sky sensor assembly of claim 104, wherein said housing is an accessory housing mounted to a mounting structure for a rearview mirror assembly.

106. The sky sensor assembly of claim 103 and further including a circuit board that is disposed vertically within said housing, wherein said light sensor is mounted to said circuit board.

107. The sky sensor assembly of claim 106, wherein an image sensor is mounted to said circuit board for sensing images forward of the vehicle.

108. A control system for controlling exterior lights of a controlled vehicle, said control system comprising:

an image sensor to detect light sources in a scene forward of the controlled vehicle; and

a control circuit coupled to said image sensor, said control circuit being operable to distinguish vehicle light sources from non-vehicle light sources, to distinguish between headlamps and tail lights based upon the color of the light, to detect movement of detected

vehicles, and to generate a control signal to cause the exterior vehicle lights to provide a selected illumination pattern, whereby the control signal is derived as a function of both the movement of any detected vehicles and the color of the light emanating from such vehicles.

109. The control system of claim 108, wherein the control signal is further derived as a function of any one or combination of the following parameters detected with respect to a detected light source: an AC component; brightness; relative position; and relative size.

110. The control system of claim 108, wherein the control signal is further derived as a function of any one or combination of the following parameters: turn rate of the controlled vehicle; speed of the controlled vehicle; and ambient brightness.

111. A method of automatically controlling vehicle headlamps in a system comprising an image sensor generating a plurality of pixel levels from a scene being imaged and a controller to generate headlamp control signals, the method comprising the steps of:

receiving pixel levels from the image sensor;

identifying at least one group of pixels that is associated with a light source;

analyzing the associated pixels to determine if at least one condition exists; and

selectively generating a headlamp control signal in accordance with the results of the analysis.

112. The method of claim 111, wherein the step of identifying a group of pixels associated with a single light source identifies a plurality of pixels meeting a pixel criteria.

113. The method of claim 112, wherein the step of identifying a group of pixels identifies a contiguous group of pixels meeting a pixel criteria.

114. The method of claim 111, wherein the step of analyzing identifies the centroid of at least one group of pixels.

115. The method of claim 111, wherein the step of analyzing determines the size of at least one group of pixels.

116. The method of claim 115, wherein the condition is whether the light source size is greater than a threshold size.

117. The method of claim 116, wherein a further condition is the average level of the pixel levels, and wherein the headlamps are not controlled responsive to a group of pixels that is greater than the threshold size if the average pixel level in that group of pixels is less than an average pixel level threshold.

118. The method of claim 111, wherein the step of analyzing includes determining the total pixel level for at least one group of pixels.

119. The method of claim 118, where the total pixel level is the sum of the gray scale values for all of the pixels in a group of pixels.

120. The method of claim 118, where the condition is that the total pixel level exceeds a threshold total pixel level.

121. The method of claim 120, further including a threshold total pixel level for the headlamps and a threshold total pixel level for tail lights.

122. The method of claim 111, wherein the step of analyzing includes determining the average pixel level for at least one group of pixels.

123. The method of claim 120, wherein the condition is a threshold average pixel level, and the controller ignores certain light sources where the average pixel level for the group of pixels is below the average pixel level.

124. The method of claim 112, wherein the step of identifying a plurality of pixels meeting a pixel criteria identifies individual pixels having levels above a pixel threshold level.

125. A method of automatically controlling vehicle headlamps in a system comprising an image sensor generating a plurality of pixel levels from a scene being imaged and a controller to generate headlamp control signals, the method comprising the steps of:

receiving pixel levels from the image sensor;

analyzing an image input with red filtering to identify objects of interest;

analyzing an image input without red filtering in those areas where objects were identified in the step of analyzing with red filtering; and

selectively generating a headlamp control signal in accordance with the results of the steps of analyzing.

126. The method of claim 125, further including the step of comparing pixels levels in the image generated with red filtering to pixel levels in the image generated without red filtering for each of the objects of interest.

127. The method of claim 125, wherein the step of analyzing an image input with red filtering includes identifying groups of contiguous pixels meeting a threshold criteria to identify objects.

128. The method of claim 127, wherein the step of analyzing an image input without red filtering includes searching for groups of contiguous pixels in areas corresponding to objects identified in the step of analyzing an image input without red filtering.

129. A method of automatically controlling vehicle headlamps in a system comprising an image sensor generating a plurality of pixel levels from a scene being imaged and a controller to generate headlamp control signals, the method comprising the steps of:

receiving pixel levels from the image sensor;

determining a vehicle speed criteria;

analyzing an image input from the image sensor according to the speed criteria; and

selectively generating a headlamp control signal in accordance with the results of the steps of analyzing.

130. The method of claim 129, wherein the speed criteria is whether the vehicle brakes are actuated.

131. The method of claim 129, wherein the speed criteria is whether the vehicle is traveling at highway speeds.

132. The method of claim 129, wherein the step of analyzing includes changing the size of the scene viewed by the image sensor as a function of the vehicle speed.

133. The method of claim 132, wherein the speed above which the scene is enlarged is higher than the speed below which the scene is decreased.

134. The method of claim 129, wherein the step of analyzing includes preventing the high beams from coming on if the vehicle speed is below a threshold level.

135. The method of claim 129, wherein the step of selectively generating a control signal comprises fading the high beams off as the vehicle decelerates to a stop.

136. A method of automatically controlling vehicle headlamps in a system comprising an image sensor generating a plurality of pixel levels from a scene being imaged and a controller to generate headlamp control signals, the method comprising the steps of:

receiving pixel levels from the image sensor;

receiving an ambient light level from an ambient light sensor;

analyzing an image input from the image sensor according to the ambient light level to selectively generate a headlamp control signal in accordance with the results of the analysis, wherein daytime running lights are enabled when the ambient light level is above a first threshold, low beam headlamps are enabled when the ambient light level is below the first threshold, and the low beam headlamps and high beam headlamps are enabled when the ambient light level is below a second threshold, and wherein the high beam headlamps are controlled automatically responsive to the pixel levels from the image sensor.

137. The method of claim 136, further including controlling one or more fog lights responsive to the ambient light sensor and the image sensor.

138. The method of claim 137, wherein the step of controlling includes evaluating the pixels of the image sensor to determine if they meet a fog criteria if the ambient light level measured by the ambient light sensor is within a predetermined range.

139. A method of automatically controlling vehicle headlamps in a system comprising an image sensor generating a plurality of pixel levels from a scene being imaged and a controller to generate headlamp control signals, the method comprising the steps of:

receiving pixel levels from the image sensor;

determining the number of objects in the image;

analyzing the image input from the image sensor to determine the number of objects in the image; and

selectively generating a headlamp control signal in accordance with the results of the steps of analyzing, wherein high beam headlamp operation is at least partially inhibited if the number of objects determined exceeds an object threshold.

140. The method as defined in claim 139, wherein the step of analyzing the image to detect objects monitors the frequency of occurrence of objects within a predetermined period.

141. The method as defined in claim 140, wherein the predetermined period is a predetermined number of frames.

142. The method as defined in claim 140, wherein the step of selectively generating includes inhibiting operation of the high beams when the number of objects exceeds a predetermined number.

143. The method as defined in claim 139, wherein the step of selectively generating includes inhibiting operation of the high beams when the number AC light source objects exceeds a threshold.

144. The method as defined in claim 139, wherein turning ON the high beam headlamps is inhibited if the number of objects determined exceeds an object threshold.

145. A method of automatically controlling vehicle headlamps in a system comprising an image sensor generating a plurality of pixel levels from a scene being imaged and a controller to generate headlamp control signals, the method comprising the steps of:

receiving pixel levels from the image sensor;

analyzing the image input from the image sensor to determine the number of objects in the image; and

selectively generating a headlamp control signal in accordance with the results of the steps of analyzing, wherein the vehicle headlamps are not adjusted responsive to detection of an object unless it appears in a threshold number of frames.

146. The method of claim 145, wherein the threshold number of frames is proportional to the brightness of the objects detected.

147. The method of claim 145, wherein the brighter the object detected, the smaller will be the threshold number of frames.

148. The method of claim 145, wherein the brightness of the headlamps are gradually altered after an object is detected for the threshold number of frames.

149. The method of claim 148, wherein after an object is detected for the threshold number of frames, the high beams may be adjusted responsive to each successive frame in which the object appears.

150. The method of claim 145, wherein the headlamp brightness is increased after the image clears for the threshold number of frames.

151. The method of claim 145, wherein the headlamp brightness is dimmed after an object is detected in the image for the threshold number of frames.

152. A method of automatically controlling vehicle headlamps in a system comprising an image sensor generating a plurality of pixel levels from a scene being imaged and a controller to generate headlamp control signals, the method comprising the steps of:

receiving pixel levels from the image sensor;

analyzing the image input from the image sensor using a spatial look-up table, the spatial look-up table having different thresholds for different pixels based on their pixel location; and

selectively generating a headlamp control signal in accordance with the results of the steps of analyzing, wherein the vehicle headlamps are controlled responsive to those pixels from the image sensor exceeding its respective threshold.

153. The method of claim 152, further including the step of shifting the pixels associated with the values stored in the spatial look-up table as the vehicle changes direction.

154. The method of claim 153, wherein the step of shifting the pixels includes shifting the pixels responsive to operation of the vehicle steering system.

155. The method of claim 153, wherein the step of shifting the pixels includes shifting the pixels responsive to a global positioning system input.

156. The method of claim 153, wherein the step of shifting the pixels includes shifting the pixels responsive to a compass input.

157. The method of claim 151, wherein the spatial look-up table has values which render the image sensor more sensitive to one side of the car than the other side of the car.

158. The method of claim 157, wherein the image sensor is more sensitive to the side of the car on which the driver sits.

159. The method of claim 151, wherein thresholds are dynamic such that if one pixel has a light level that is above its respective threshold, and the look-up table has a higher threshold for the adjacent pixel, the adjacent pixel will be compared to the lower of threshold said one pixel.

160. A method of automatically controlling vehicle headlamps in a system comprising an image sensor generating a plurality of pixel levels from a scene being imaged and a controller to generate headlamp control signals, the method comprising the steps of:

receiving pixel levels from the image sensor;

identifying pixels associated with a light source;

analyzing the pixels; and

selectively generating a headlamp control signal in accordance with the results of the analysis, wherein the system is more sensitive when high beams are ON than when the high beams are OFF.

161. The method of claim 160, wherein the sensitivity is adjusted by increasing the integration period for the image sensor when the high beams are ON.

162. The method of claim 160 wherein the sensitivity is adjusted by using different spatial look-up tables when the high beams are OFF and ON, wherein the spatial look-up table stores respective thresholds.

163. The method of claim 160, wherein the field of view of the image sensor is broader when the high beams are OFF than when the high beams are ON.

164. The method of claim 160, wherein the off-axis sensitivity is increased when the high beams are ON.

165. A method of automatically controlling vehicle headlamps in a system comprising an image sensor generating a plurality of pixel levels from a scene being imaged and a controller to generate headlamp control signals, the method comprising the steps of:

receiving pixel levels from the image sensor;

identifying pixels that are associated with an object;

analyzing the associated pixels and storing information associated with at least one detected object; and

selectively generating a headlamp control signal in accordance with the results of the analysis.

166. The method of claim 165, wherein the stored information includes the brightness of at least one object detected.

167. The method of claim 166, wherein the stored information includes the location of at least one object detected.

168. The method of claim 165, wherein the stored information includes the locations and brightness of the brightest object detected.

169. The method of claim 168, wherein if the present frame is determined to be clear of light sources, and the previous frame is determined to a bright light source, and the high beams are OFF, the high beams are controlled to produce a fast return to bright.

170. The method of claim 169, wherein the control of the high beams to produce a fast return includes an expedited fade to bright.

171. The method of claim 169, wherein the control of the high beams to produce a fast return comprises turning the high beams ON without delay.

172. The method of claim 165, wherein if the present frame is determined to be clear of light sources, and the previous frame is determined to have contained vehicle tail lights, and the high beams are OFF, the high beams are controlled to produce a tail light delayed return to bright.

173. The method of claim 172, wherein the tail light delayed return to bright is longer than a return to bright following detection of headlamps from an oncoming vehicle.

174. The method of claim 172, wherein the tail light delayed return to bright is variable.

175. The method of claim 172, wherein the tail light return to bright is dependent on the detection of glare light.

176. The method of claim 175, wherein the high beams are turned on when glare is detected.

177. The method of claim 176, wherein if glare is not detected in a maximum threshold time after detecting the cleared image, the brights are turned ON even if glare has not been detected.

178. A method of automatically calibrating the aim of an image sensor in a controlled vehicle, comprising the steps of:

detecting a distant light of an oncoming vehicle;

detecting a straight road condition; and

generating a new average value from the location of the distant oncoming light averaged with a stored average if the straight road condition is detected, and

storing the new average value as the stored average signal.

179. The method of claim 178, wherein the step of detecting a distant light comprises detecting a faint light near the center of the image sensor.

180. The method of claim 178, wherein the step of detecting a straight road detects the lateral movement of the controlled vehicle over a period of time.

181. The method of claim 180, wherein the period of time is from the time that the distant light is detected until a time period after the distant vehicle and the controlled vehicle have passed.

182. The method of claim 178, further including the step of detecting elevation change of the controlled vehicle.

183. The method of claim 180, wherein lateral movement is detected by determining the lateral movement of the distant headlamp.

184. The method of claim 180, wherein lateral movement is detected using a global positioning system.

185. The method of claim 180, wherein lateral movement is detected from a compass.

186. The method of claim 180, wherein lateral movement is detected from operation of the steering system.

187. A method of automatically controlling vehicle headlamps in a system comprising an image sensor generating a plurality of pixel levels from a scene being imaged and a controller to generate headlamp control signals, the method comprising the steps of:

receiving pixel levels from the image sensor;

analyzing the pixel levels associated with a scene, wherein the analysis is altered when the vehicle turns; and

selectively generating a headlamp control signal in accordance with the results of the analysis.

188. The method of claim 187, wherein the image analyzed is shifted when the vehicle turns.

189. The method of claim 187, wherein the image analyzed is shifted when the vehicle turn signal is actuated.

190. The method of claim 187, wherein the analysis of the image is altered when the vehicle heading as detected from a compass is altered.

191. The method of claim 189, wherein the analysis is altered after actuation of the vehicle brakes following actuation of the vehicle's turn signal.

192. A method of automatically controlling vehicle headlamps in a system comprising an image sensor generating a plurality of pixel levels from a scene being imaged and a controller to generate headlamp control signals, the method comprising the steps of:

receiving pixel levels from the image sensor, wherein the pixel levels are stored while the vehicle headlamps are off;

analyzing the pixels to detect objects; and

selectively generating a headlamp control signal in accordance with the results of the analysis.

193. The method of claim 192, wherein the vehicle includes semiconductor radiation emitter light source, wherein the light is flashed off for a very short interval.

194. The method of claim 193, wherein the off interval is less than 60 ms.

195. A method of automatically controlling vehicle headlamps in a system comprising an image sensor generating a plurality of pixel levels from a scene being imaged through a variable filter and a controller to generate headlamp control signals, the method comprising the steps of:

receiving pixel levels from the image sensor when the variable filter is filtering light of at least a first wavelength;

receiving pixel levels from the image sensor through the variable filter when the variable filter is not filtering light of at least the first wavelength;

analyzing the associated pixels to identify objects; and

selectively generating a headlamp control signal in accordance with the results of the analysis.

196. A method of automatically controlling vehicle headlamps in a system comprising an image sensor generating a plurality of pixel levels from a scene being imaged through a windshield, a windshield wiper for clearing the windshield, and a controller to generate headlamp control signals, the method comprising the steps of:

receiving signals indicative of the location of the windshield wiper;

receiving pixel levels from the image sensor when the windshield wiper is not in front of the image sensor;

analyzing the associated pixels to identify objects; and

selectively generating a headlamp control signal in accordance with the results of the analysis.

197. The method of claim 196, further including the step of monitoring the window using an image sensor focused on the window to detect the presence of the windshield wiper in the field of view of the image sensor for detecting objects.

198. The method of claim 196, further including the step of monitoring the windshield wipers to detect their position.

199. A vehicle system, comprising:

an image sensor for detecting lights;

an ambient light sensor;

a glare sensor;

an electrochromic element for controlling the reflectivity of a mirror;

headlamps; and

a controller coupled to the image sensor, the ambient light detector, the glare sensor, the electrochromic element, and the headlamps, wherein the controller is operable to control the headlamps responsive to the image sensor and the ambient light sensor, and the controller being further operable to control the transmittance of the electrochromic element responsive to the ambient light sensor and the glare sensor.

200. The vehicle system of claim 199, wherein at least one of said controller, glare sensor, ambient light sensor, and image sensor are supported by a rearview mirror assembly of the vehicle.

201. A method of operating an image sensor generating a plurality of pixel levels from a scene being imaged, the method comprising the steps of:

receiving pixel levels from the image sensor;

identifying a bad pixel if a pixel continuously detects light when adjacent pixels do not detect light; and

selectively compensating for the identified pixels.

202. The method of claim 201, wherein the step of identifying a pixel that continuously detects light comprises determining that the pixel detects light over a predetermined number of frames.

203. The method of claim 202, wherein the step of identifying includes detecting when a pixel detects light above a pixel threshold over a predetermined number of frames and adjacent frames do not detect light above a pixel threshold over the predetermined number of frames.

204. The method of claim 201, wherein the step of selectively compensating comprises generating an average of the adjacent pixels and substituting the generated average for the pixel level measurement of the bad pixel.

205. A vehicle system, comprising:

an image sensor focused at a distance for detecting lights;

an image sensor focused near the window;

windshield wipers;

headlamps; and

a controller coupled to the image sensor, the ambient light detector, the image sensor focused near the window, the windshield wipers, and the headlamps, wherein the controller is operable to control the headlamps responsive to the image sensor, control the windshield wipers to operate when rain is on the window, and the controller being further operable to control the image sensor to image a scene when the windshield wipers are not in front of the image sensor focused at a distance.

206. A method of making an optical sensor assembly package including an image sensor die comprising the steps of:

covering the die with an epoxy;

positioning an adhesive on the epoxy;

positioning a lens structure on the adhesive; and

curing the adhesive to form the integral package.

207. The method of claim 206, further including the step of molding the lens structure to include a lens.

208. The method of claim 207, further including the step of molding the lens structure to include a first lens having a filter for removing light of at least a first wave length.

209. The method of claim 208, further including the step of molding the lens structure to include a second lens passing at least light of the first wave length.

210. The method of claim 206, wherein the step of covering includes covering the die with a glob-top epoxy.

211. The method of claim 206, further including the step of applying at least one filter to the surface of the image sensor die.

212. The method of claim 211, wherein the step of applying at least one filter includes applying two or more filters to respective areas on the surface of the sensor.

213. The method of claim 206, further including the step of mounting an electronically controlled filter.

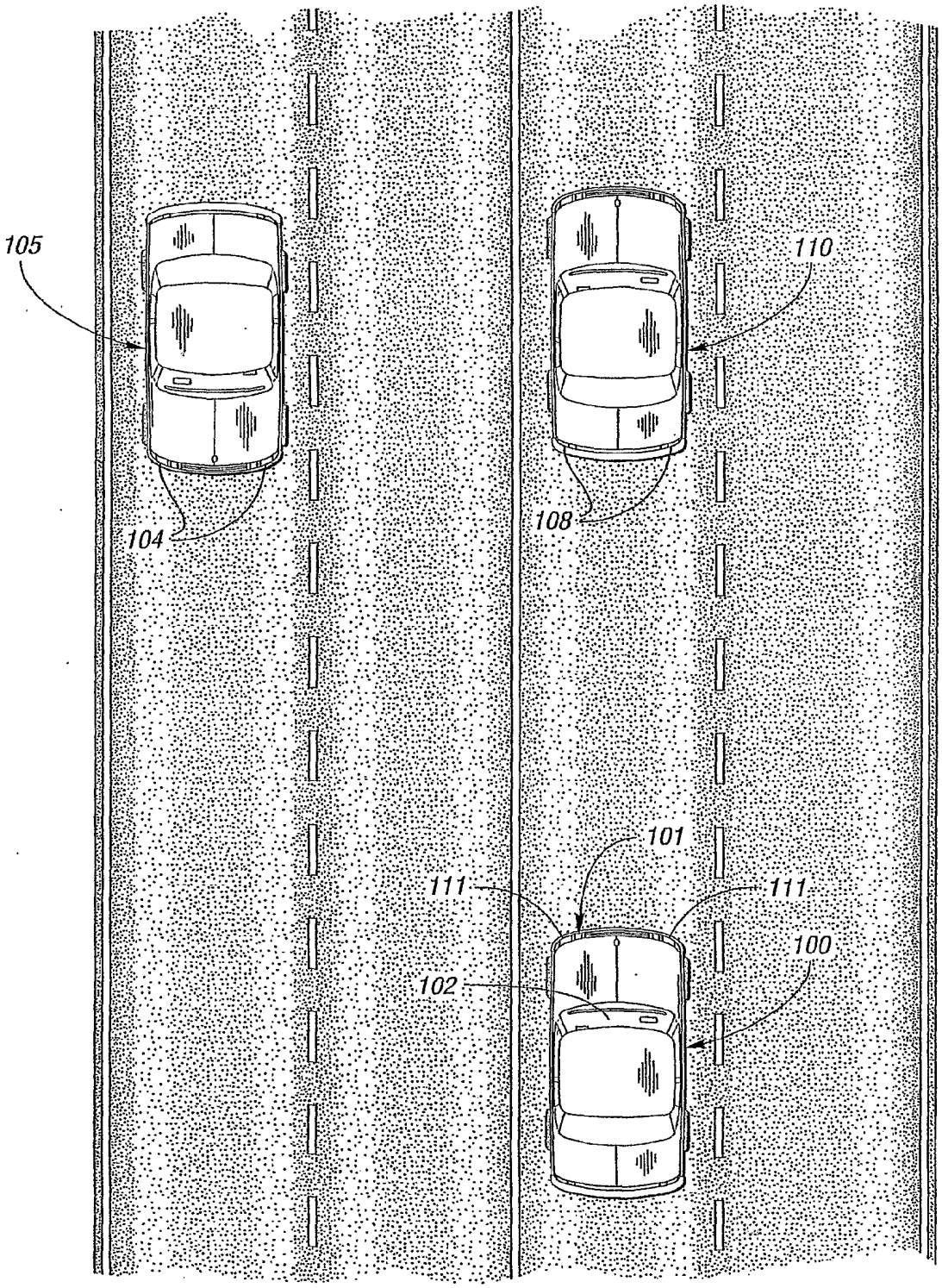


Fig. 1

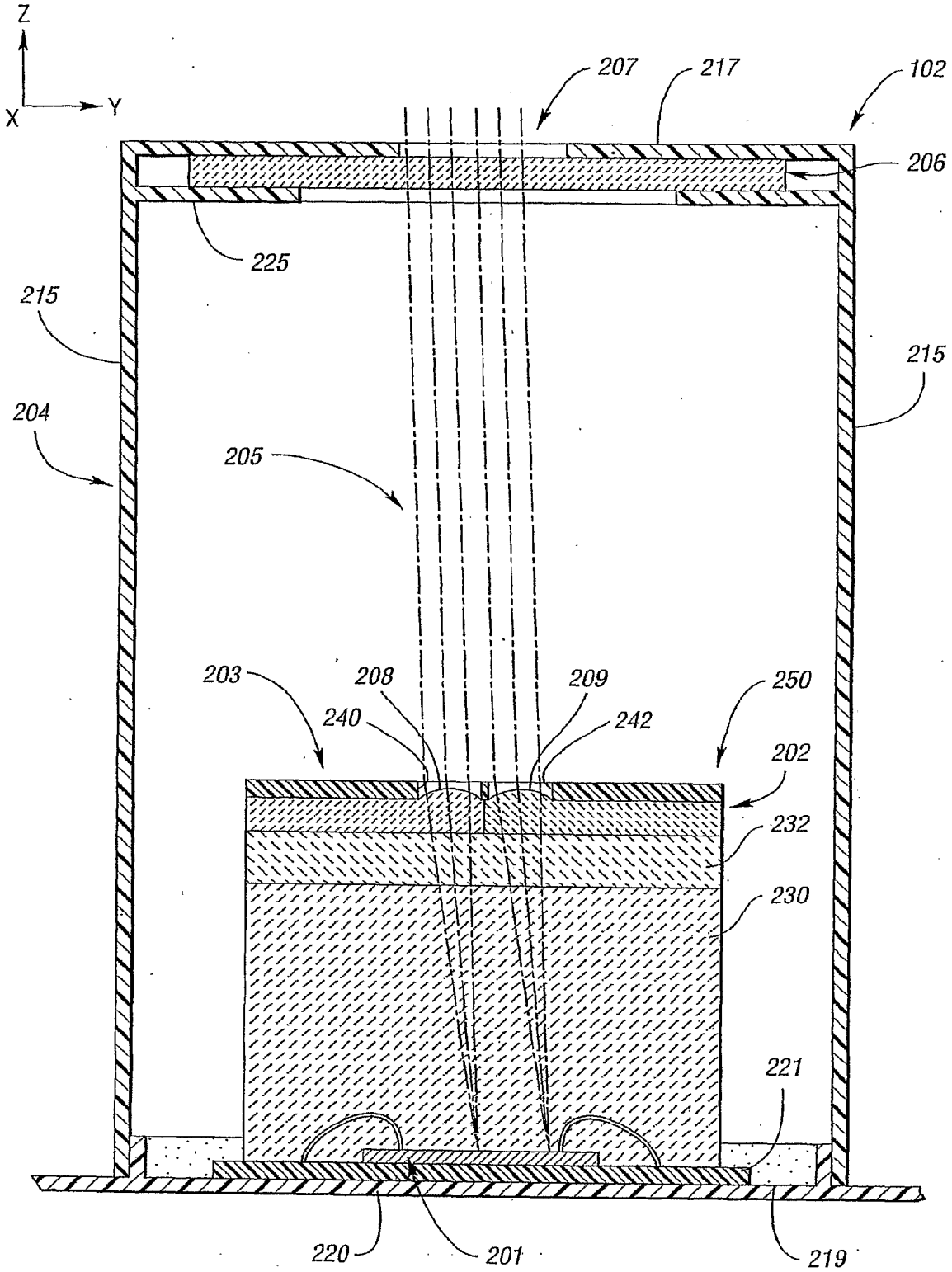

Z
X
Y
207
217
102
206
225
215
215
204
205
203
208
209
250
240
242
202
232
230
221
220
201
219

Fig. 2a

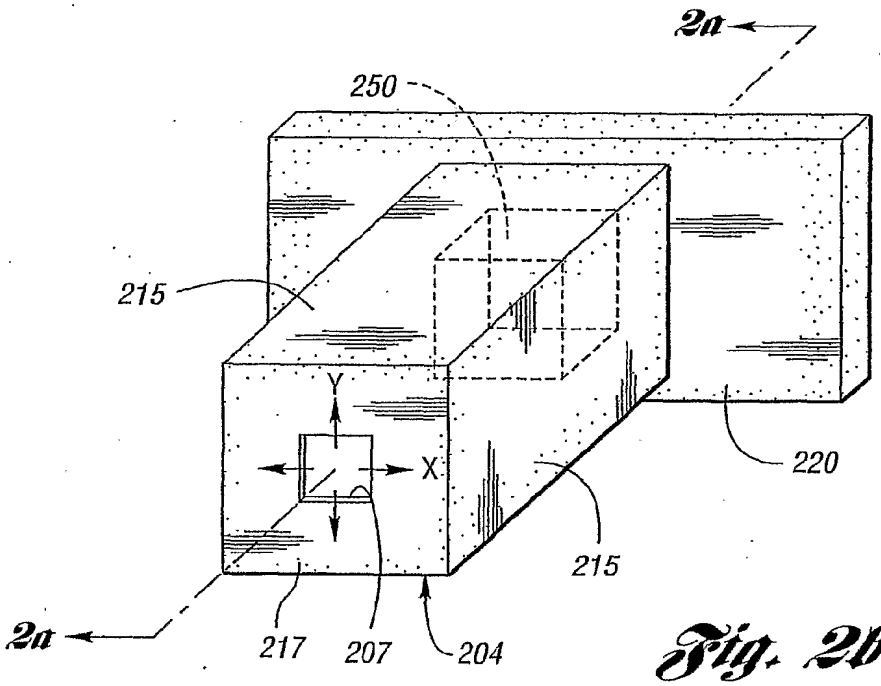

2a
250
215
Y
X
220
215
2a
217
207
204

Fig. 2b

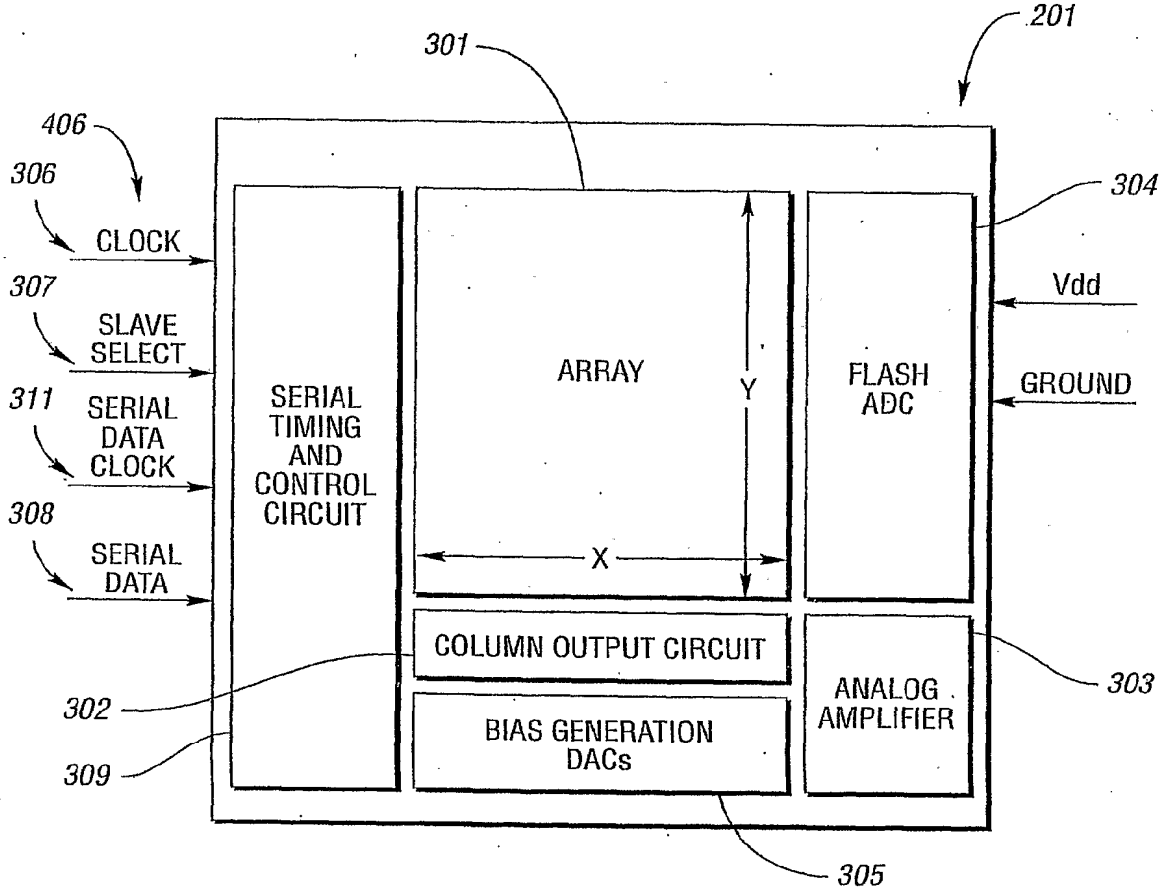

201
301
406
306
CLOCK
307
SLAVE SELECT
311
SERIAL DATA CLOCK
308
SERIAL DATA
SERIAL TIMING AND CONTROL CIRCUIT
ARRAY
Y
X
FLASH ADC
304
Vdd
GROUND
COLUMN OUTPUT CIRCUIT
BIAS GENERATION DACs
ANALOG AMPLIFIER
303
302
309
305

Fig. 3

Fig. 4

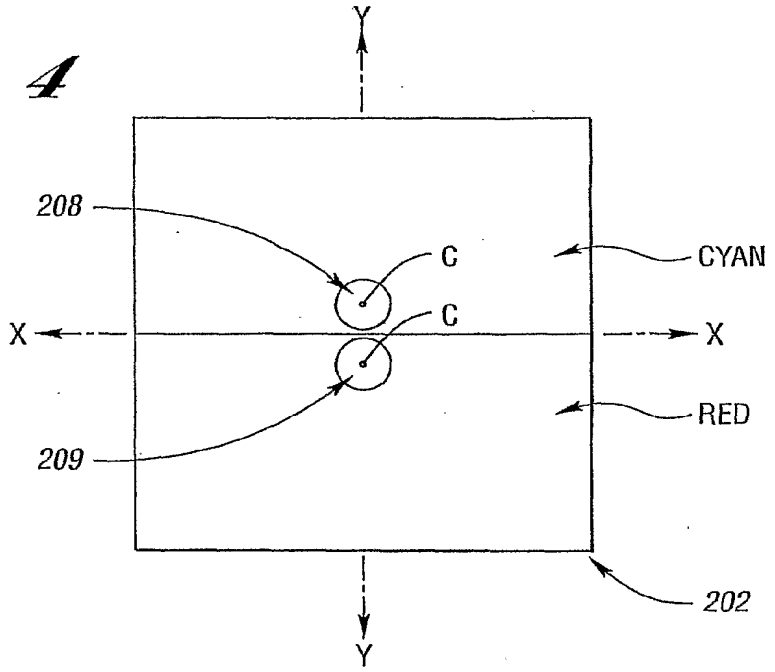


Fig. 5

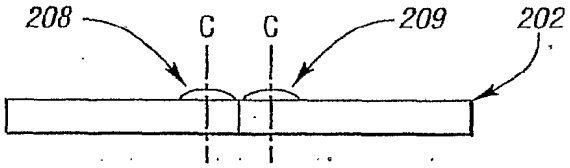


Fig. 6

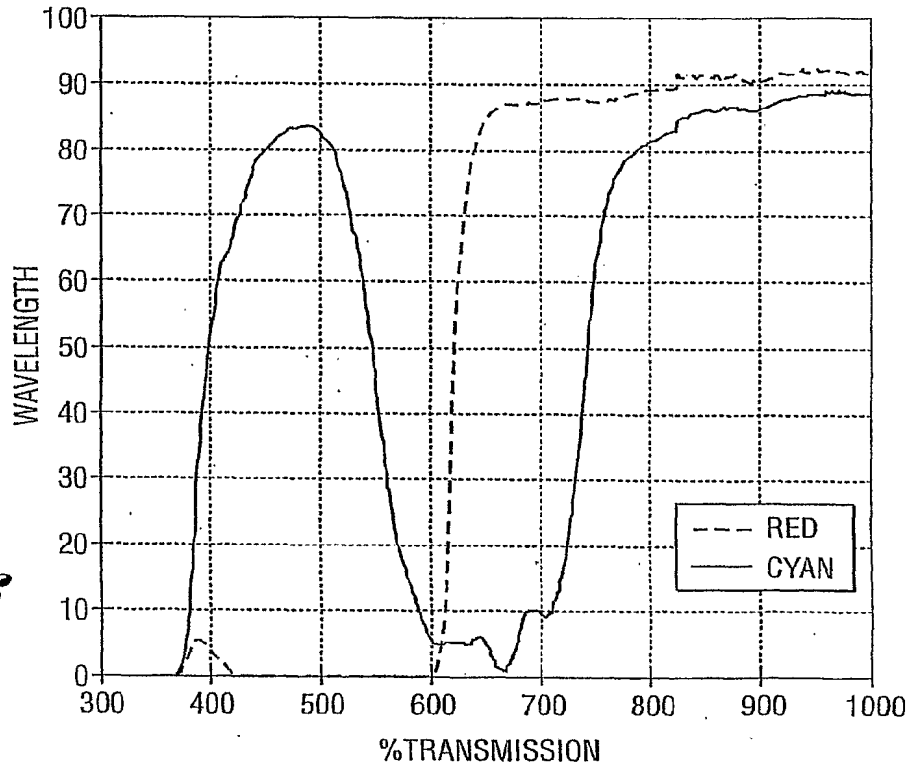


Fig. 7

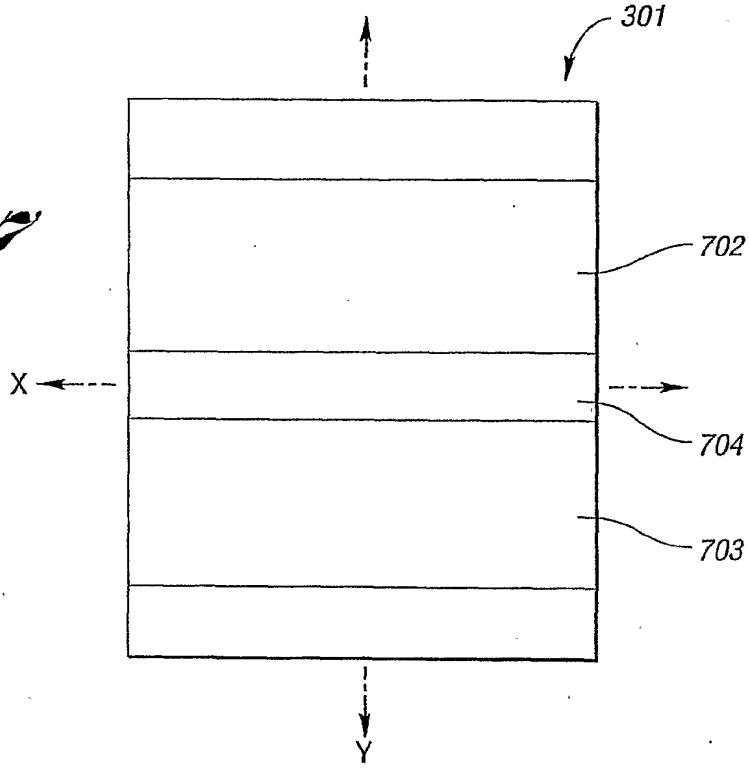
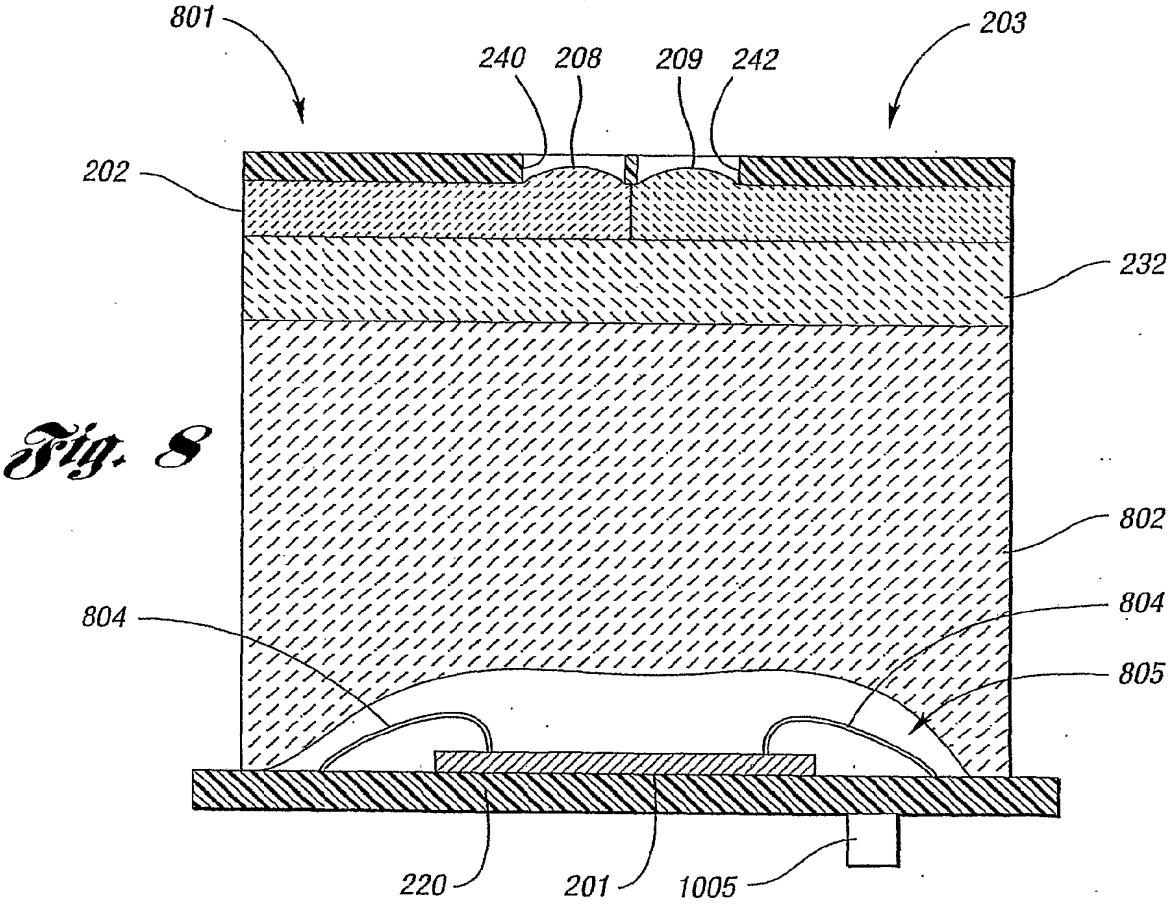

301
702
X
704
703
Y

Fig. 8


801
240
208
209
242
203
202
232
802
804
804
805
220
201
1005

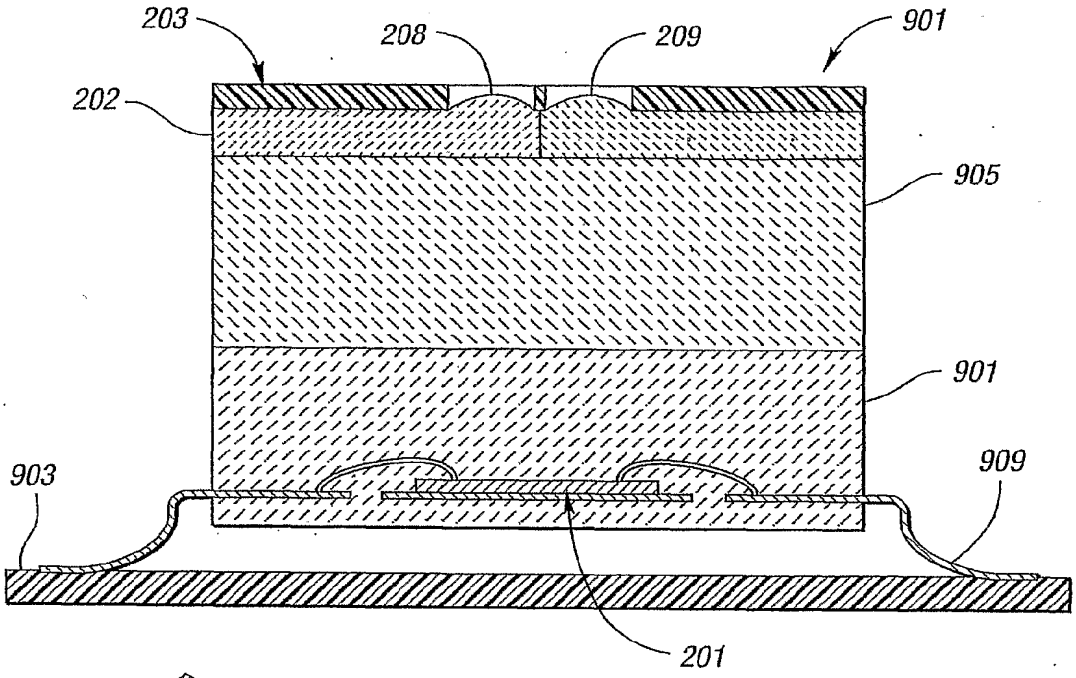

203
208
209
901
202
905
901
903
909
201

Fig. 9

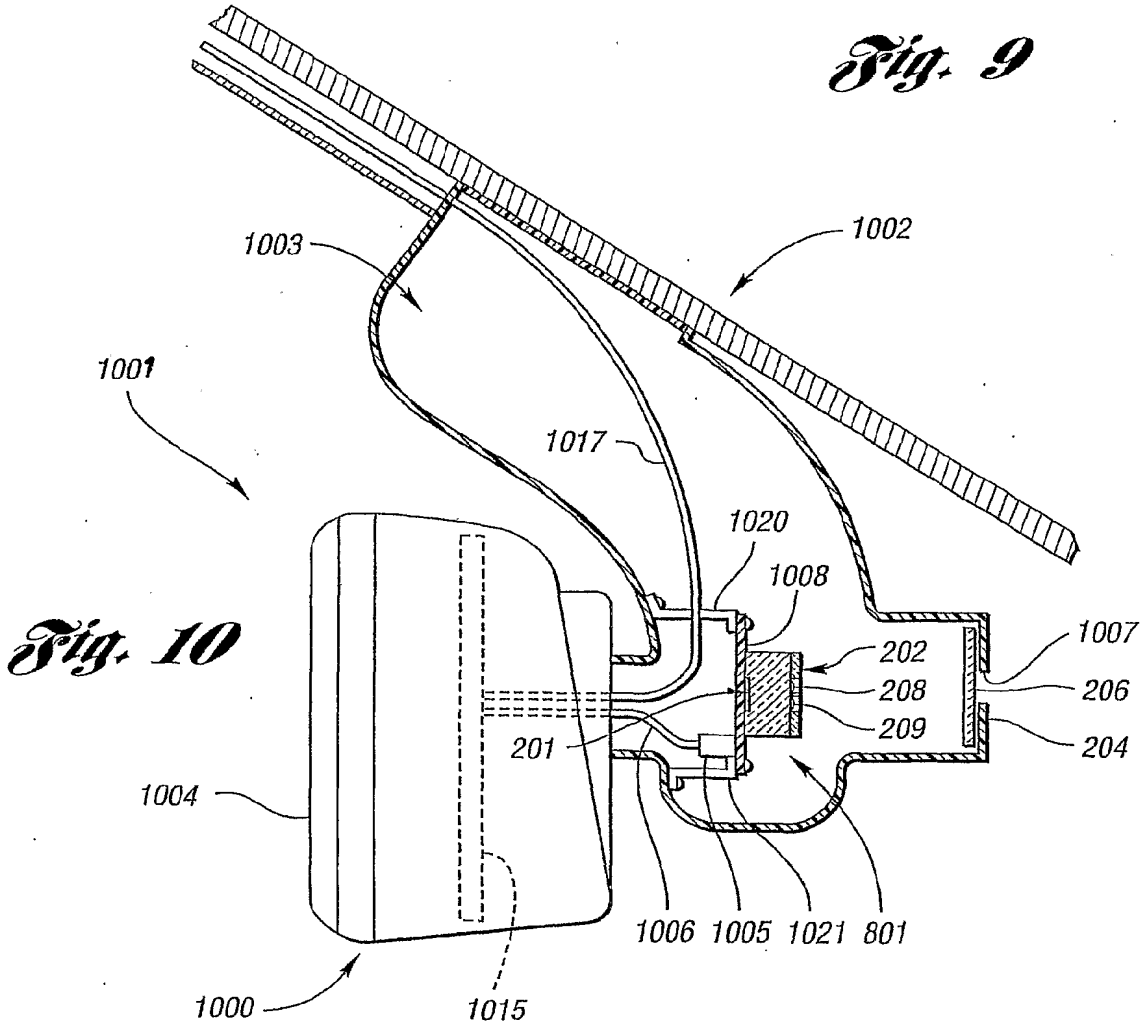

1003
1002
1001
1017
1020
1008
1007
202
206
208
209
204
201
1004
1006
1005
1021
801
1000
1015

Fig. 10

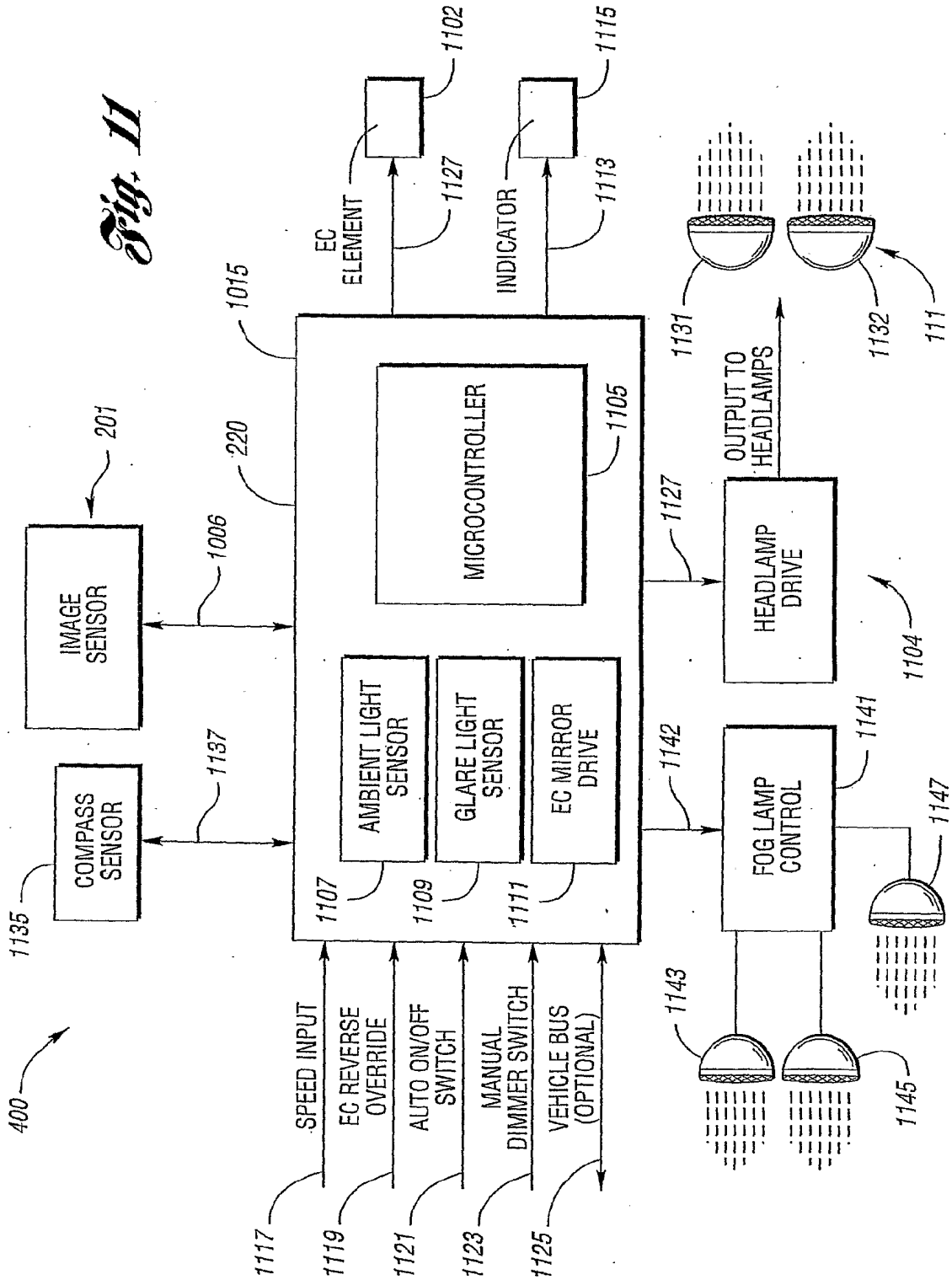

400
1135
COMPASS SENSOR
1137
IMAGE SENSOR
201
1006
220
1015
EC ELEMENT
1102
1127
INDICATOR
1115
1113
MICROCONTROLLER
1105
AMBIENT LIGHT SENSOR
1107
GLARE LIGHT SENSOR
1109
EC MIRROR DRIVE
1111
1127
HEADLAMP DRIVE
1104
OUTPUT TO HEADLAMPS
1131
1132
111
1142
FOG LAMP CONTROL
1141
1147
1143
1145
SPEED INPUT
1117
EC REVERSE OVERRIDE
1119
AUTO ON/OFF SWITCH
1121
MANUAL DIMMER SWITCH
1123
VEHICLE BUS (OPTIONAL)
1125

Fig. 11

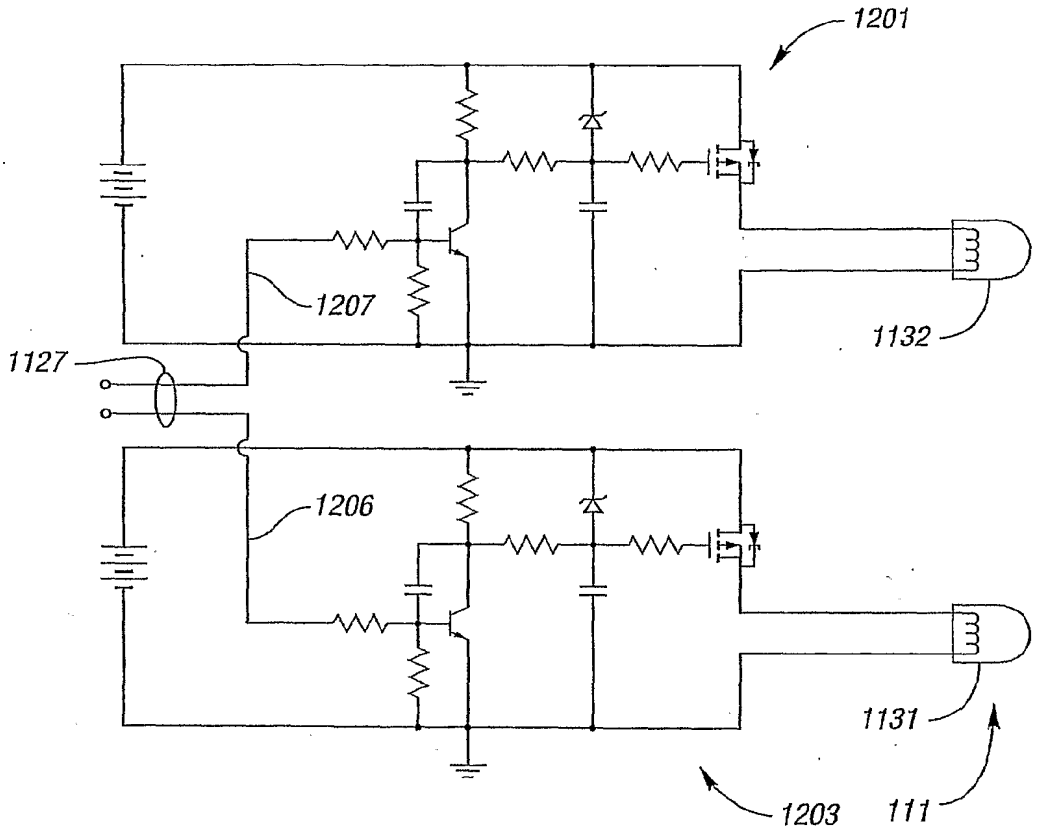


Fig. 12

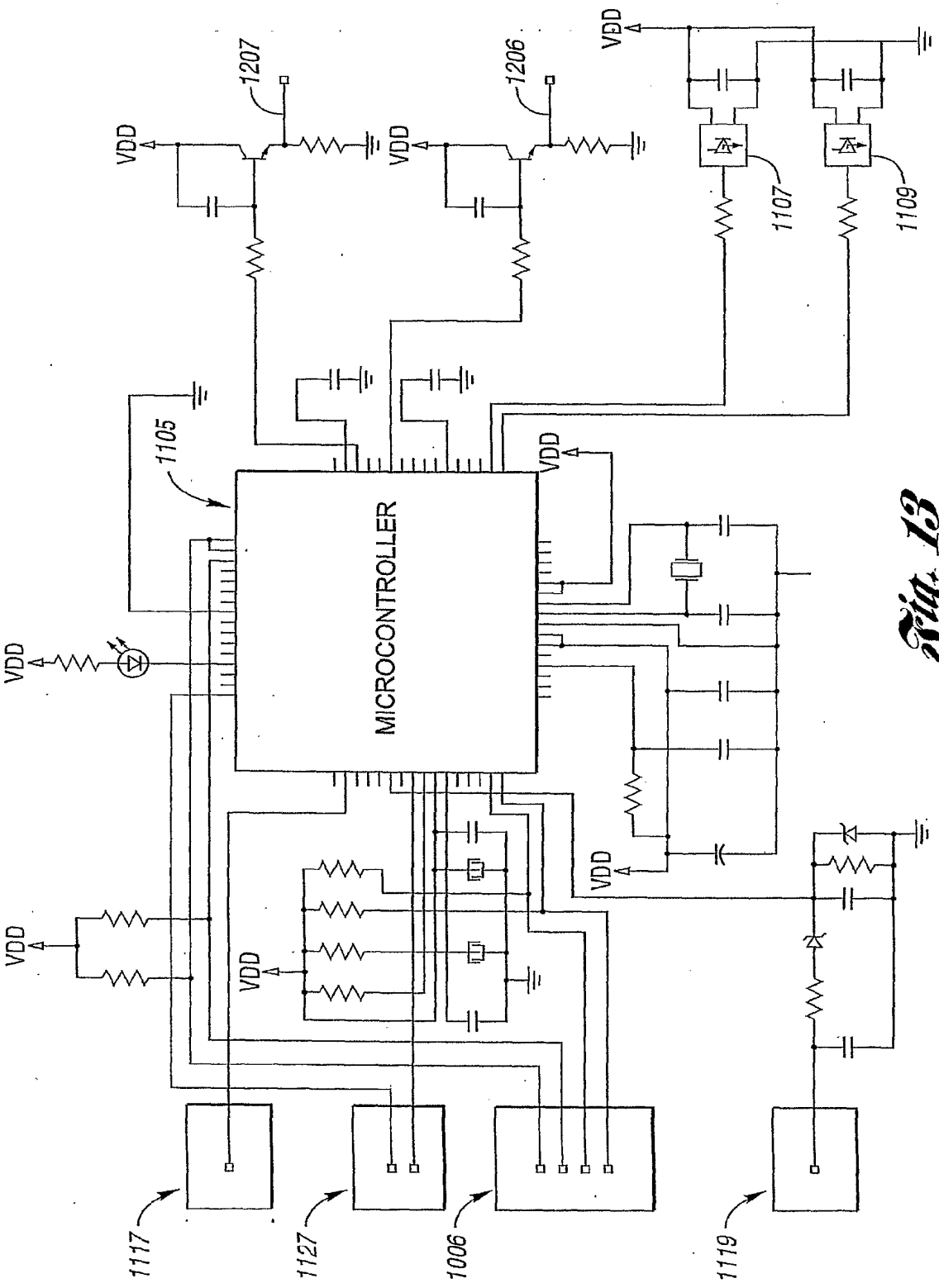

MICROCONTROLLER
1105
1207
1206
1107
1109
1117
1127
1006
1119
VDD

Fig. 13

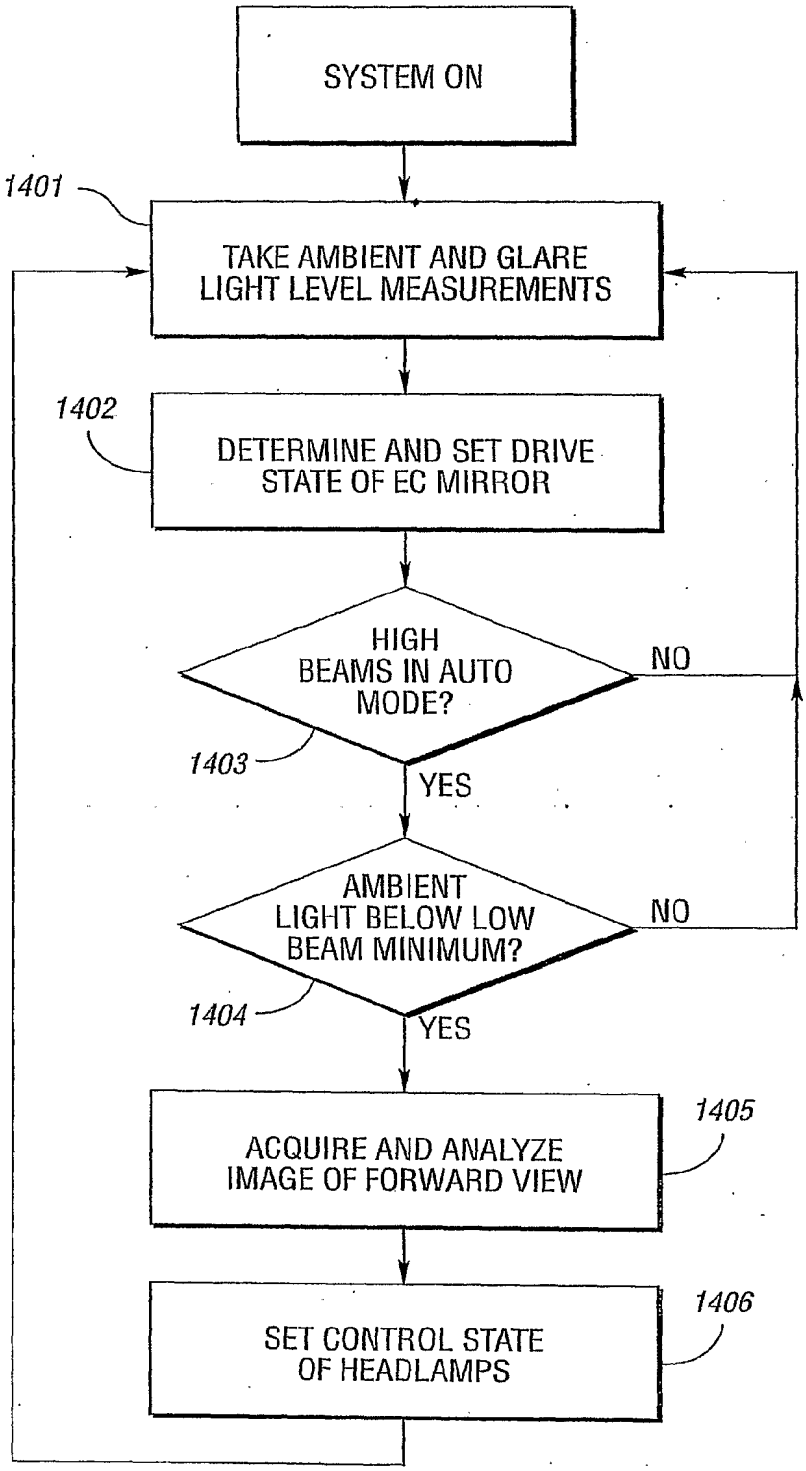

SYSTEM ON
1401
TAKE AMBIENT AND GLARE LIGHT LEVEL MEASUREMENTS
1402
DETERMINE AND SET DRIVE STATE OF EC MIRROR
HIGH BEAMS IN AUTO MODE?
NO
1403
YES
AMBIENT LIGHT BELOW LOW BEAM MINIMUM?
NO
1404
YES
1405
ACQUIRE AND ANALYZE IMAGE OF FORWARD VIEW
1406
SET CONTROL STATE OF HEADLAMPS

Fig. 14

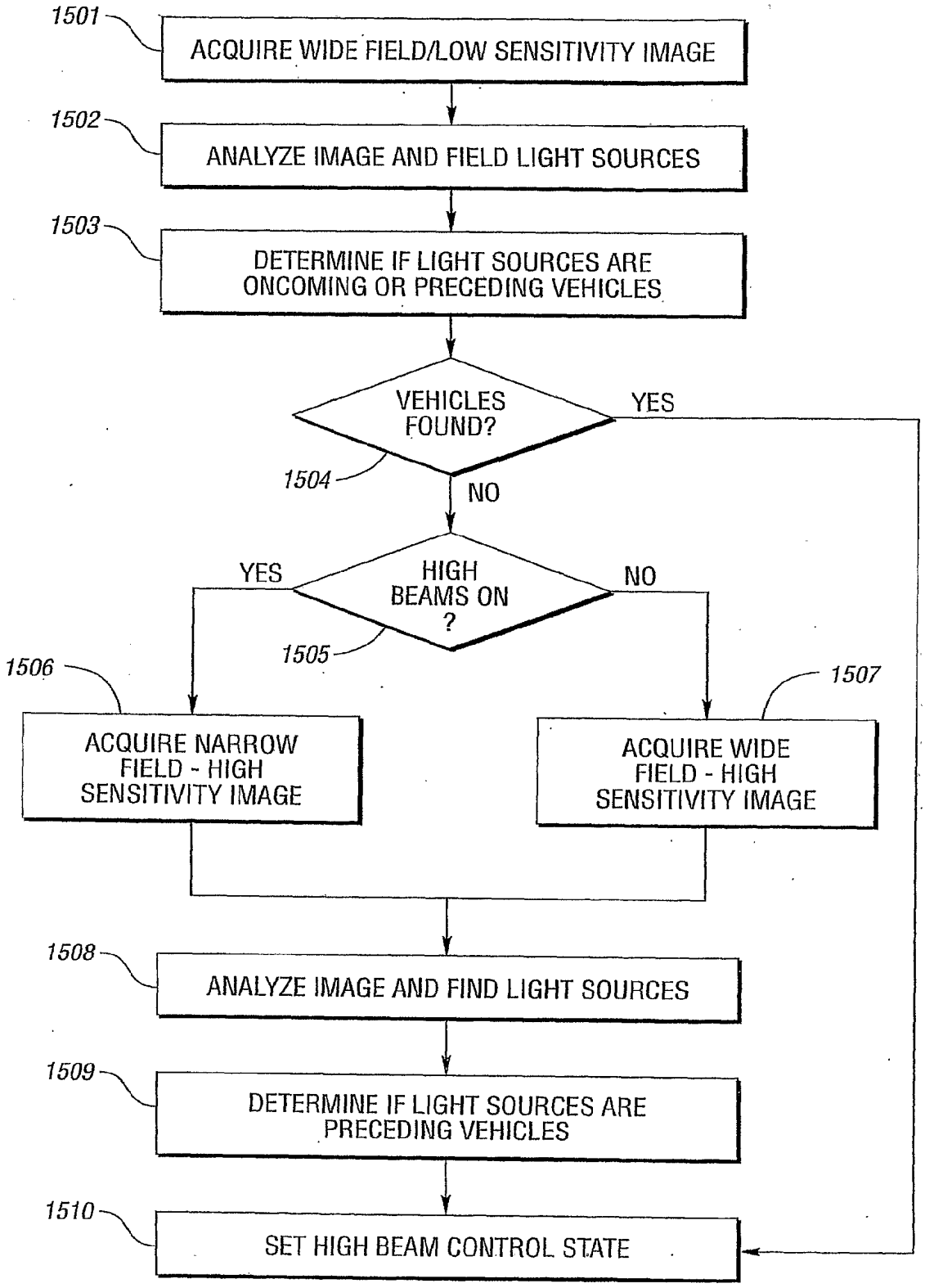

1501
ACQUIRE WIDE FIELD/LOW SENSITIVITY IMAGE
1502
ANALYZE IMAGE AND FIELD LIGHT SOURCES
1503
DETERMINE IF LIGHT SOURCES ARE ONCOMING OR PRECEDING VEHICLES
VEHICLES FOUND?
YES
1504
NO
YES
HIGH BEAMS ON ?
NO
1505
1506
ACQUIRE NARROW FIELD - HIGH SENSITIVITY IMAGE
1507
ACQUIRE WIDE FIELD - HIGH SENSITIVITY IMAGE
1508
ANALYZE IMAGE AND FIND LIGHT SOURCES
1509
DETERMINE IF LIGHT SOURCES ARE PRECEDING VEHICLES
1510
SET HIGH BEAM CONTROL STATE

Fig. 15

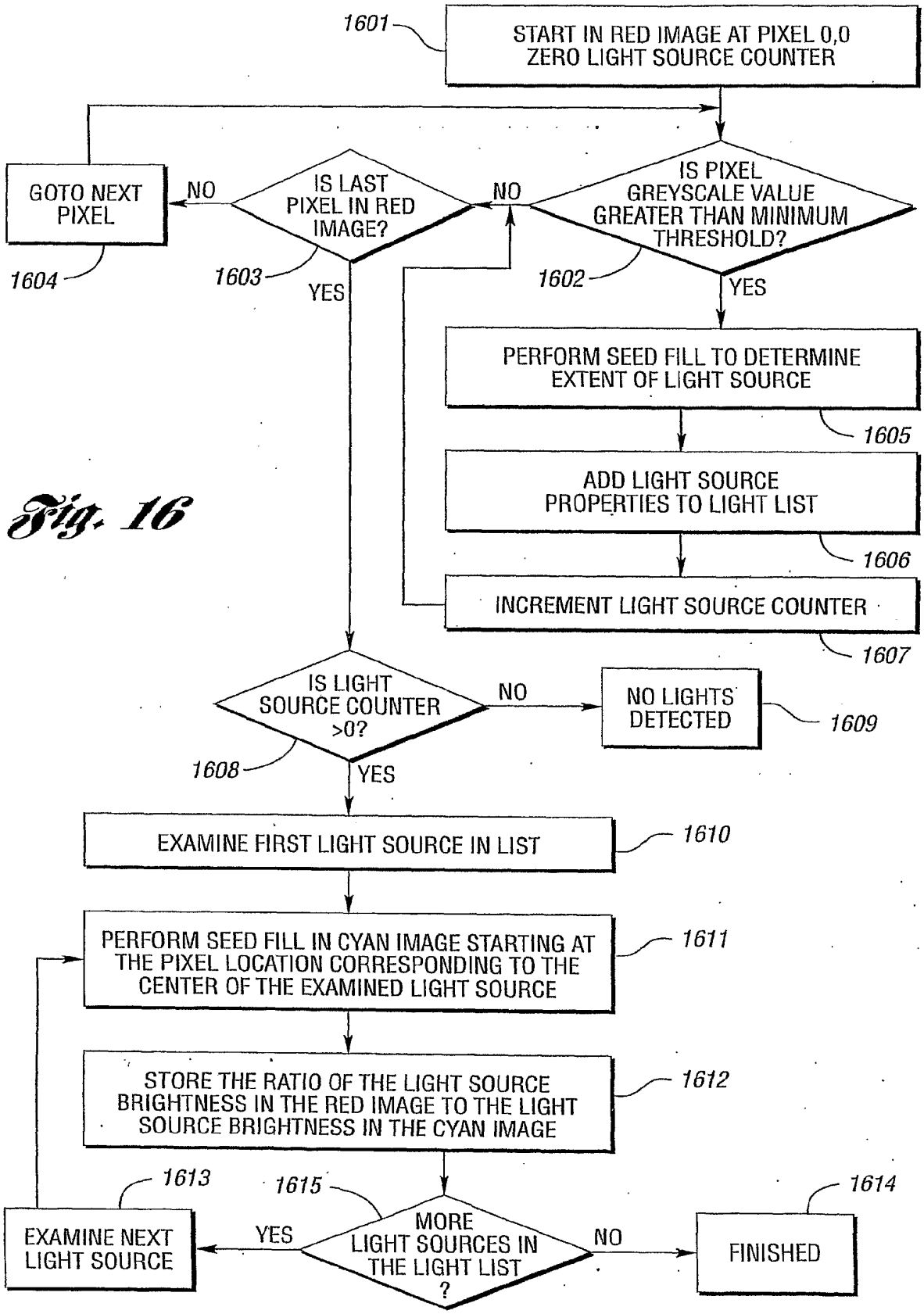

1601
START IN RED IMAGE AT PIXEL 0,0
ZERO LIGHT SOURCE COUNTER
IS PIXEL GREYSCALE VALUE GREATER THAN MINIMUM THRESHOLD?
1602
NO
YES
IS LAST PIXEL IN RED IMAGE?
1603
NO
YES
GOTO NEXT PIXEL
1604
PERFORM SEED FILL TO DETERMINE EXTENT OF LIGHT SOURCE
1605
ADD LIGHT SOURCE PROPERTIES TO LIGHT LIST
1606
INCREMENT LIGHT SOURCE COUNTER
1607
IS LIGHT SOURCE COUNTER >0?
1608
NO
YES
NO LIGHTS DETECTED
1609
EXAMINE FIRST LIGHT SOURCE IN LIST
1610
PERFORM SEED FILL IN CYAN IMAGE STARTING AT THE PIXEL LOCATION CORRESPONDING TO THE CENTER OF THE EXAMINED LIGHT SOURCE
1611
STORE THE RATIO OF THE LIGHT SOURCE BRIGHTNESS IN THE RED IMAGE TO THE LIGHT SOURCE BRIGHTNESS IN THE CYAN IMAGE
1612
MORE LIGHT SOURCES IN THE LIGHT LIST ?
1615
YES
NO
EXAMINE NEXT LIGHT SOURCE
1613
FINISHED
1614

Fig. 16

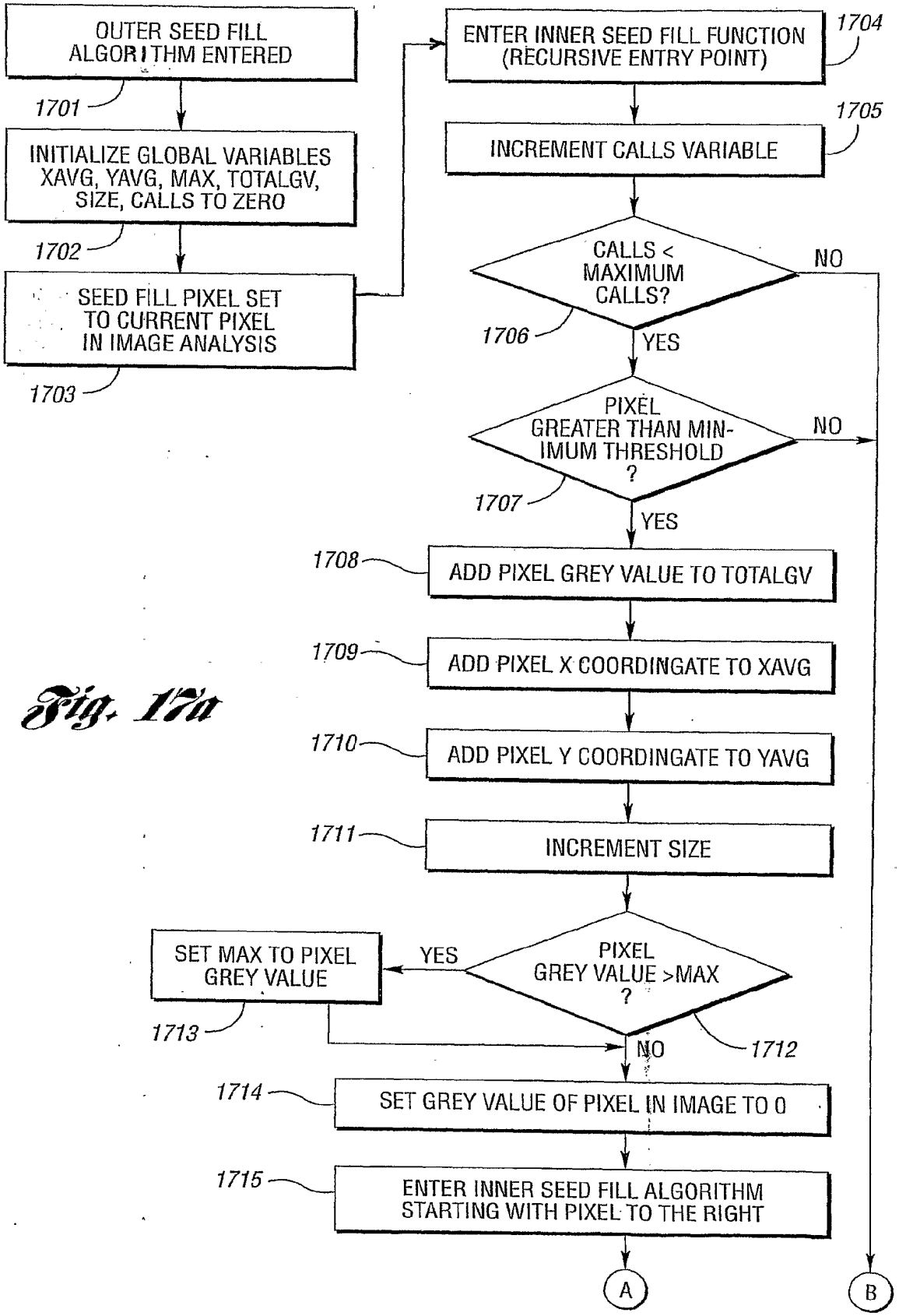

OUTER SEED FILL ALGORITHM ENTERED
1701
INITIALIZE GLOBAL VARIABLES XAVG, YAVG, MAX, TOTALGV, SIZE, CALLS TO ZERO
1702
SEED FILL PIXEL SET TO CURRENT PIXEL IN IMAGE ANALYSIS
1703
ENTER INNER SEED FILL FUNCTION (RECURSIVE ENTRY POINT)
1704
INCREMENT CALLS VARIABLE
1705
CALLS < MAXIMUM CALLS?
1706
NO
YES
PIXEL GREATER THAN MIN-IMUM THRESHOLD ?
1707
NO
YES
ADD PIXEL GREY VALUE TO TOTALGV
1708
ADD PIXEL X COORDINGATE TO XAVG
1709
ADD PIXEL Y COORDINGATE TO YAVG
1710
INCREMENT SIZE
1711
PIXEL GREY VALUE >MAX ?
YES
SET MAX TO PIXEL GREY VALUE
1713
NO
1712
SET GREY VALUE OF PIXEL IN IMAGE TO 0
1714
ENTER INNER SEED FILL ALGORITHM STARTING WITH PIXEL TO THE RIGHT
1715
A
B

Fig. 17a

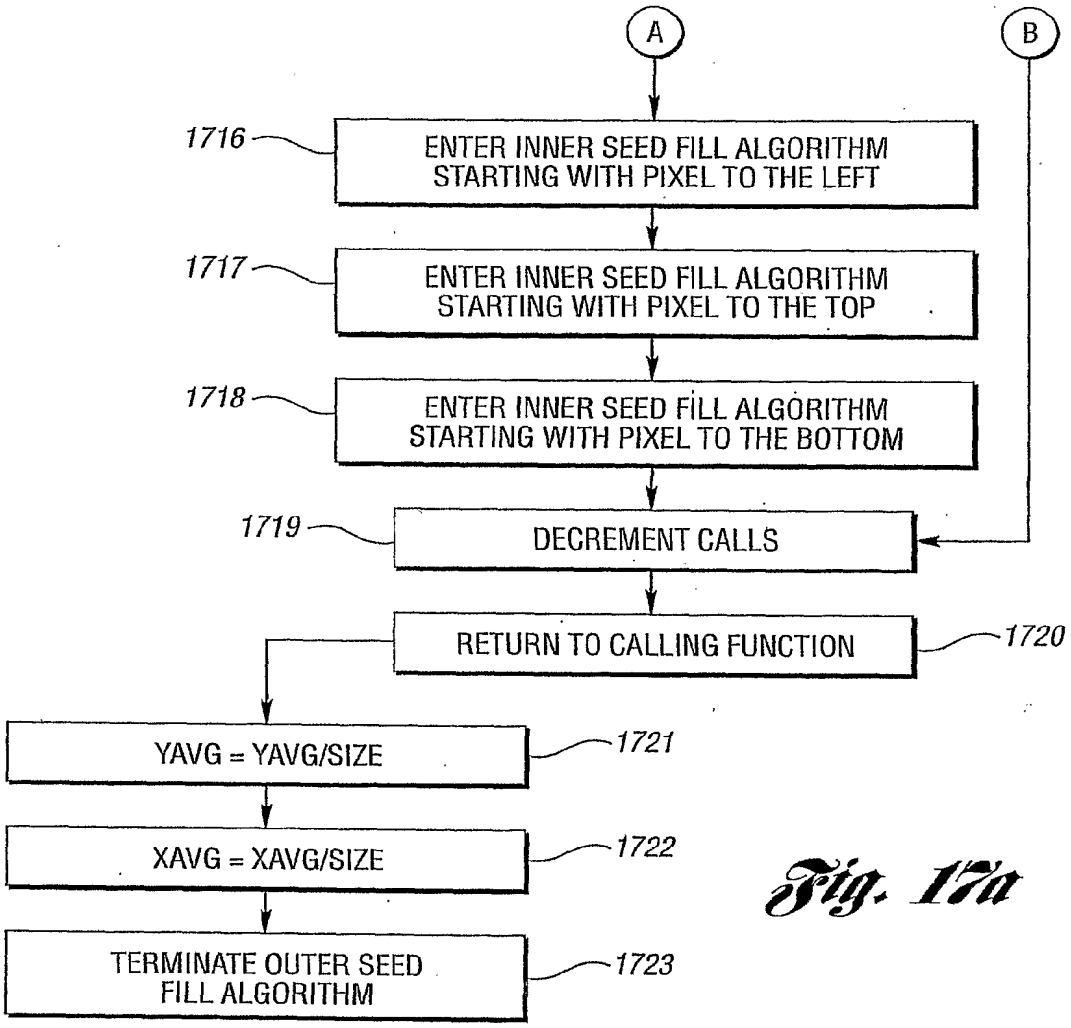


Fig. 17a

Fig. 17b

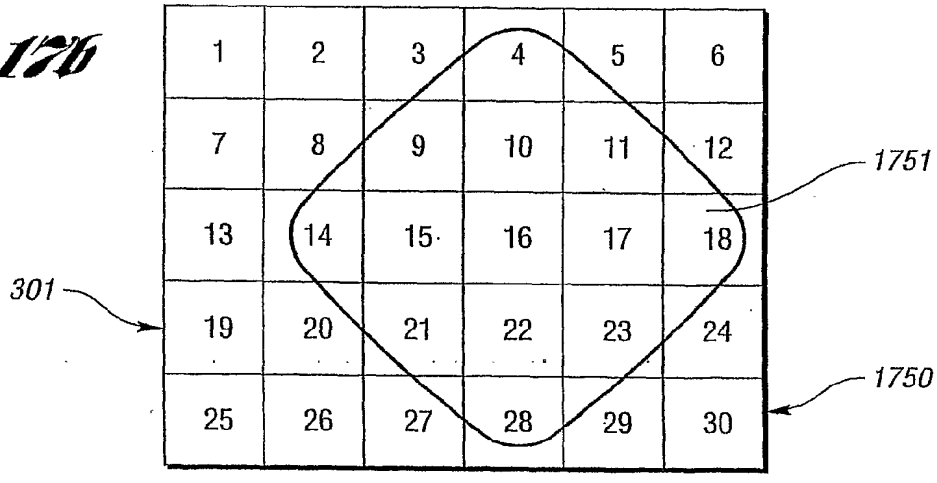
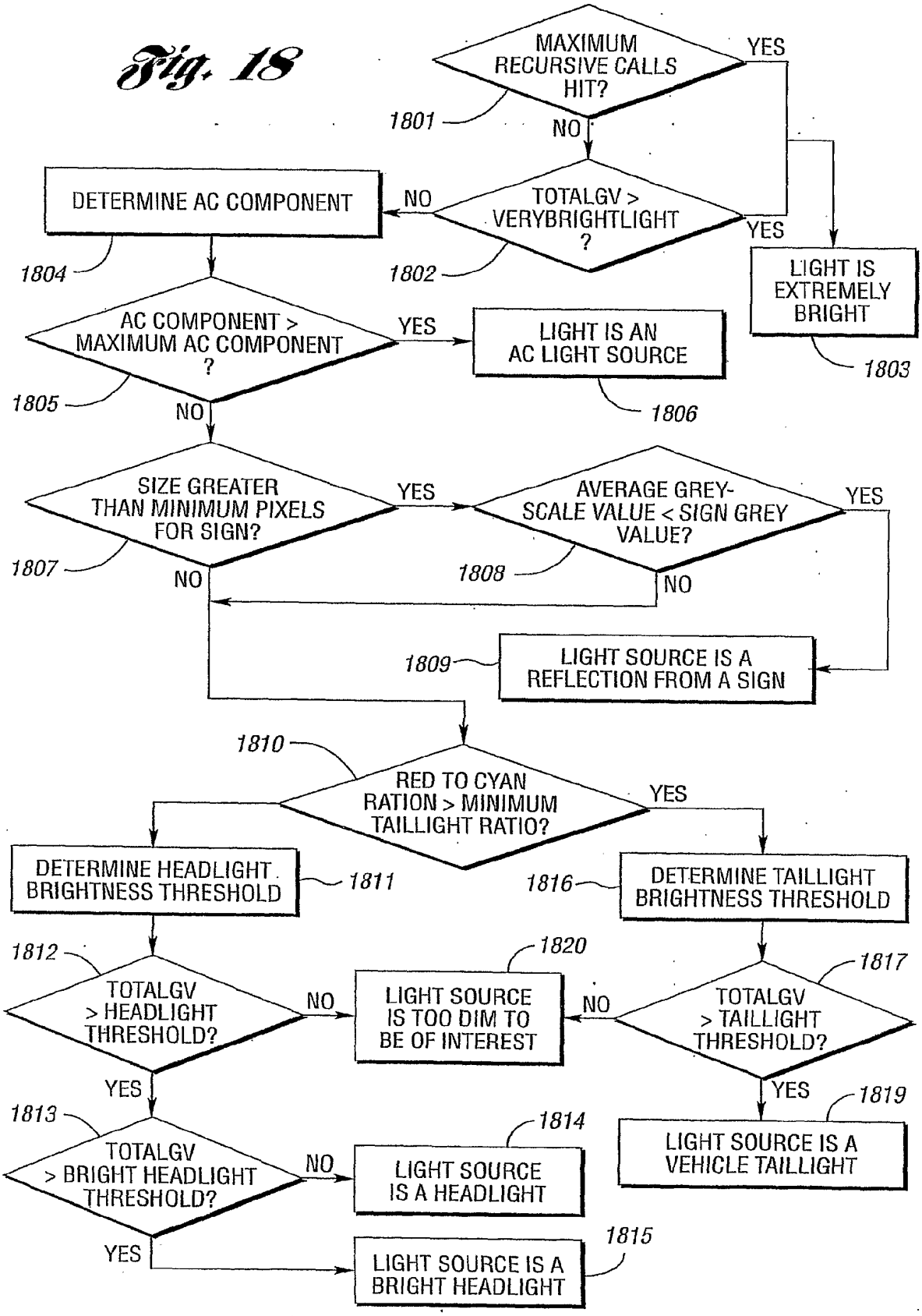


Fig. 18


MAXIMUM RECURSIVE CALLS HIT?
YES
1801
NO
TOTALGV > VERYBRIGHTLIGHT ?
NO
YES
1802
DETERMINE AC COMPONENT
1804
LIGHT IS EXTREMELY BRIGHT
1803
AC COMPONENT > MAXIMUM AC COMPONENT ?
YES
1805
LIGHT IS AN AC LIGHT SOURCE
1806
NO
SIZE GREATER THAN MINIMUM PIXELS FOR SIGN?
YES
1807
AVERAGE GREY-SCALE VALUE < SIGN GREY VALUE?
YES
1808
NO
NO
1809
LIGHT SOURCE IS A REFLECTION FROM A SIGN
1810
RED TO CYAN RATION > MINIMUM TAILLIGHT RATIO?
YES
DETERMINE HEADLIGHT BRIGHTNESS THRESHOLD
1811
1816
DETERMINE TAILLIGHT BRIGHTNESS THRESHOLD
1812
TOTALGV > HEADLIGHT THRESHOLD?
NO
1820
LIGHT SOURCE IS TOO DIM TO BE OF INTEREST
NO
1817
TOTALGV > TAILLIGHT THRESHOLD?
YES
YES
1813
TOTALGV > BRIGHT HEADLIGHT THRESHOLD?
NO
1814
LIGHT SOURCE IS A HEADLIGHT
YES
1819
LIGHT SOURCE IS A VEHICLE TAILLIGHT
YES
1815
LIGHT SOURCE IS A BRIGHT HEADLIGHT

16/40

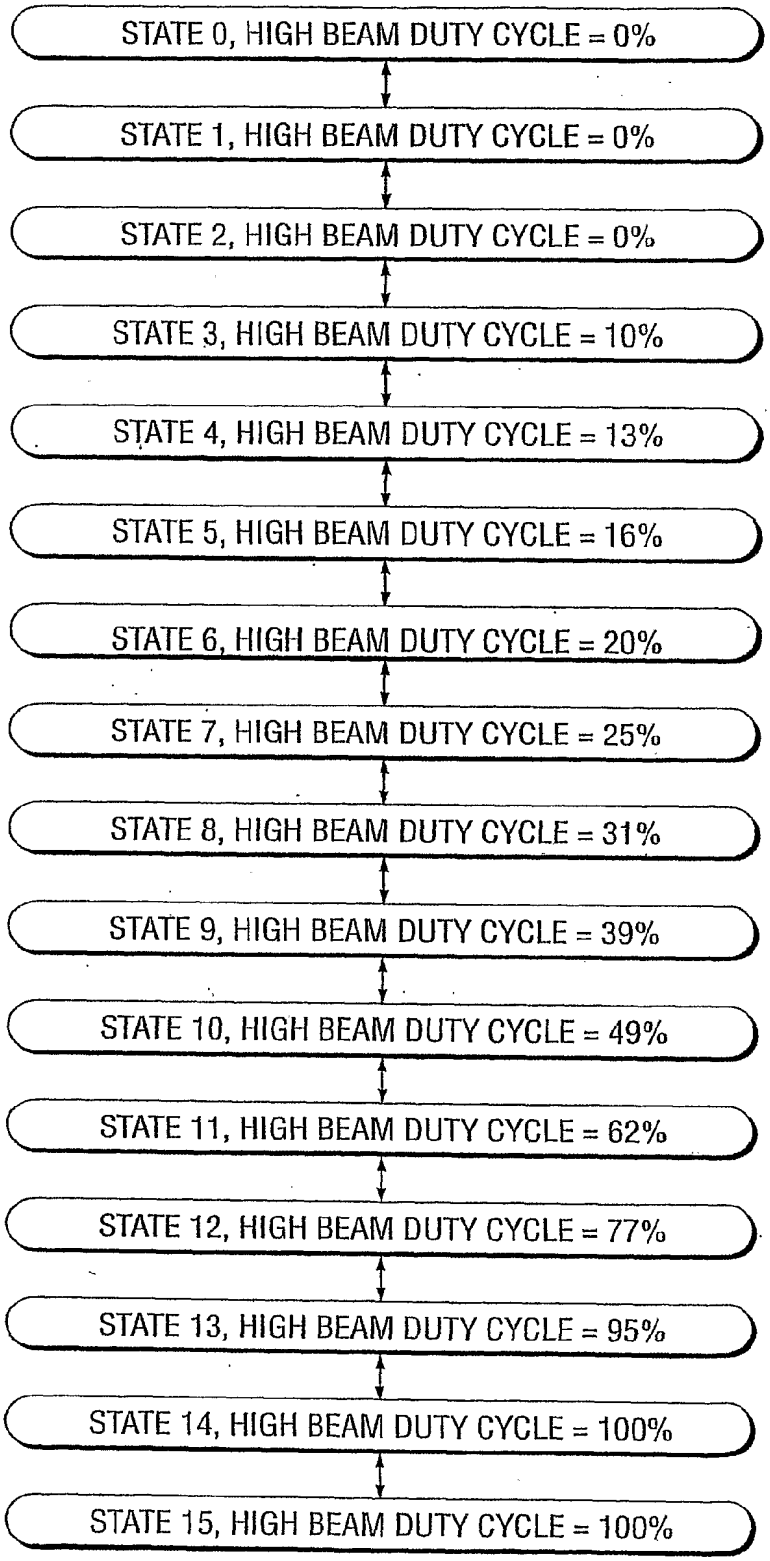

STATE 0, HIGH BEAM DUTY CYCLE = 0%
STATE 1, HIGH BEAM DUTY CYCLE = 0%
STATE 2, HIGH BEAM DUTY CYCLE = 0%
STATE 3, HIGH BEAM DUTY CYCLE = 10%
STATE 4, HIGH BEAM DUTY CYCLE = 13%
STATE 5, HIGH BEAM DUTY CYCLE = 16%
STATE 6, HIGH BEAM DUTY CYCLE = 20%
STATE 7, HIGH BEAM DUTY CYCLE = 25%
STATE 8, HIGH BEAM DUTY CYCLE = 31%
STATE 9, HIGH BEAM DUTY CYCLE = 39%
STATE 10, HIGH BEAM DUTY CYCLE = 49%
STATE 11, HIGH BEAM DUTY CYCLE = 62%
STATE 12, HIGH BEAM DUTY CYCLE = 77%
STATE 13, HIGH BEAM DUTY CYCLE = 95%
STATE 14, HIGH BEAM DUTY CYCLE = 100%
STATE 15, HIGH BEAM DUTY CYCLE = 100%

Fig. 19

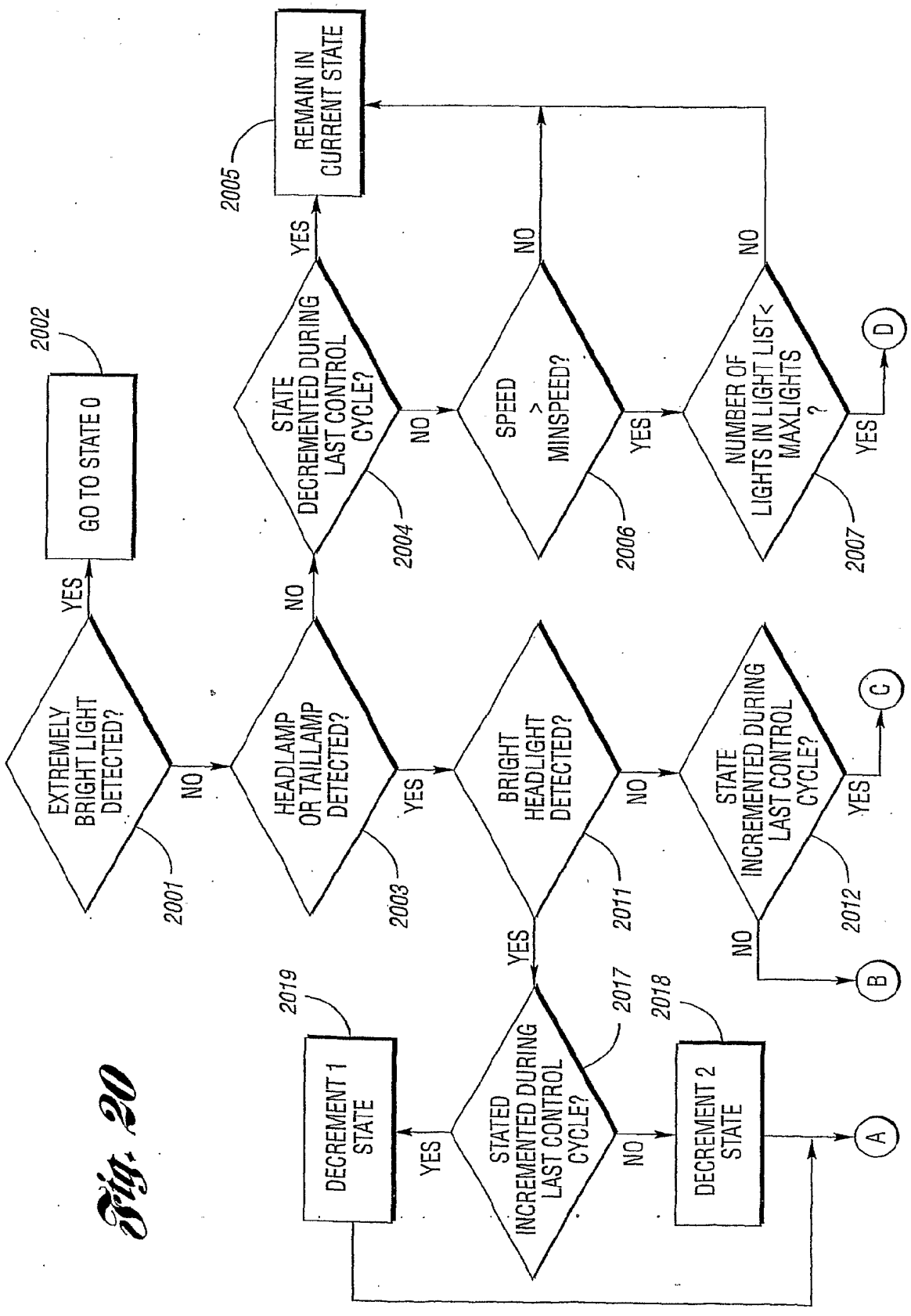

EXTREMELY BRIGHT LIGHT DETECTED?
2001
YES
GO TO STATE 0
2002
NO
HEADLAMP OR TAILLAMP DETECTED?
2003
YES
NO
STATE DECREMENTED DURING LAST CONTROL CYCLE?
2004
YES
REMAIN IN CURRENT STATE
2005
NO
SPEED > MINSPEED?
2006
YES
NO
NUMBER OF LIGHTS IN LIGHT LIST< MAXLIGHTS ?
2007
YES
D
BRIGHT HEADLIGHT DETECTED?
2011
YES
NO
STATE INCREMENTED DURING LAST CONTROL CYCLE?
2012
YES
C
NO
B
STATED INCREMENTED DURING LAST CONTROL CYCLE?
2017
YES
DECREMENT 1 STATE
2019
NO
DECREMENT 2 STATE
2018
A

Fig. 20

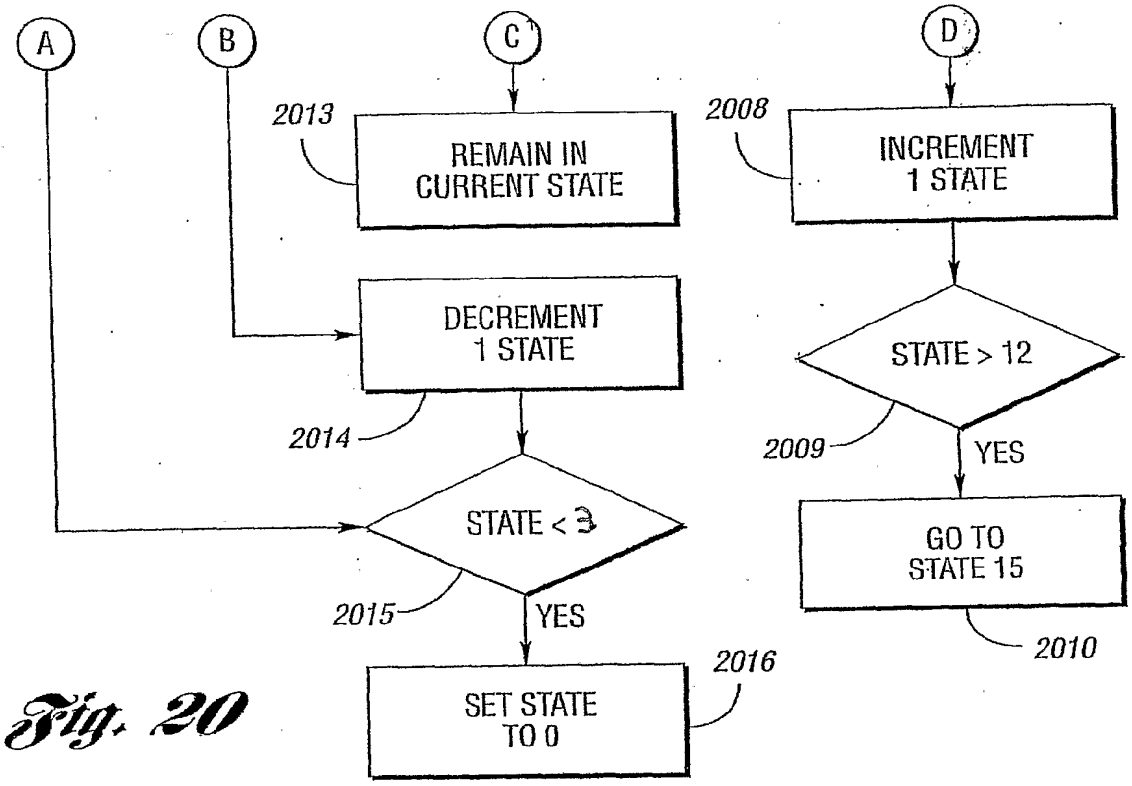

A
B
C
D
2013
REMAIN IN CURRENT STATE
2008
INCREMENT 1 STATE
DECREMENT 1 STATE
STATE > 12
2014
2009
YES
STATE < 3
GO TO STATE 15
2015
YES
2010
2016
SET STATE TO 0

Fig. 20

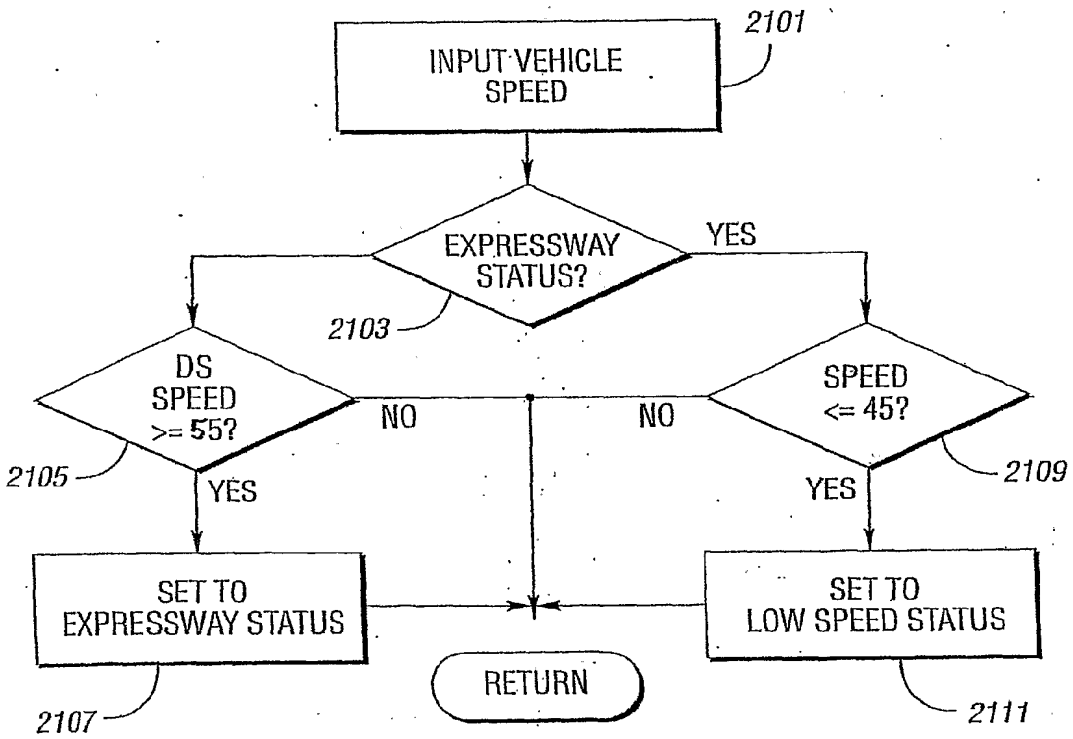

2101
INPUT VEHICLE SPEED
EXPRESSWAY STATUS?
YES
2103
DS SPEED >= 55?
NO
NO
SPEED <= 45?
2105
YES
2109
YES
SET TO EXPRESSWAY STATUS
SET TO LOW SPEED STATUS
RETURN
2107
2111

Fig. 21

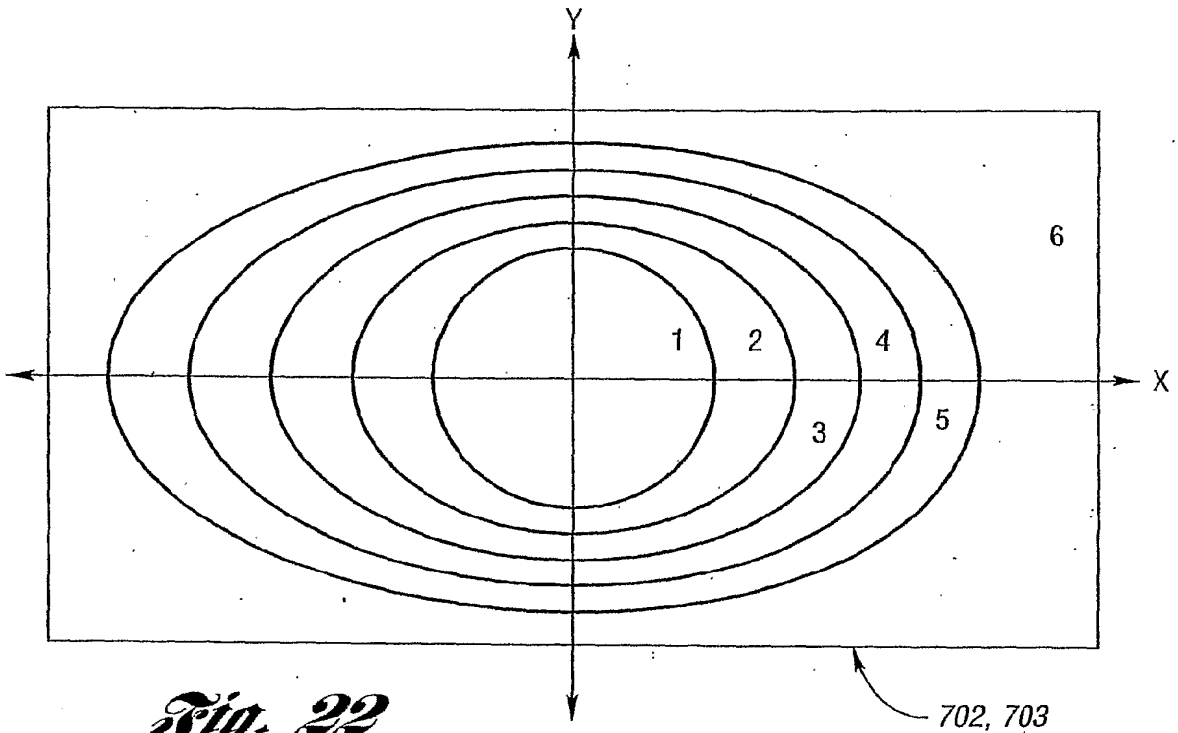

Y
X
1
2
3
4
5
6
702, 703

Fig. 22

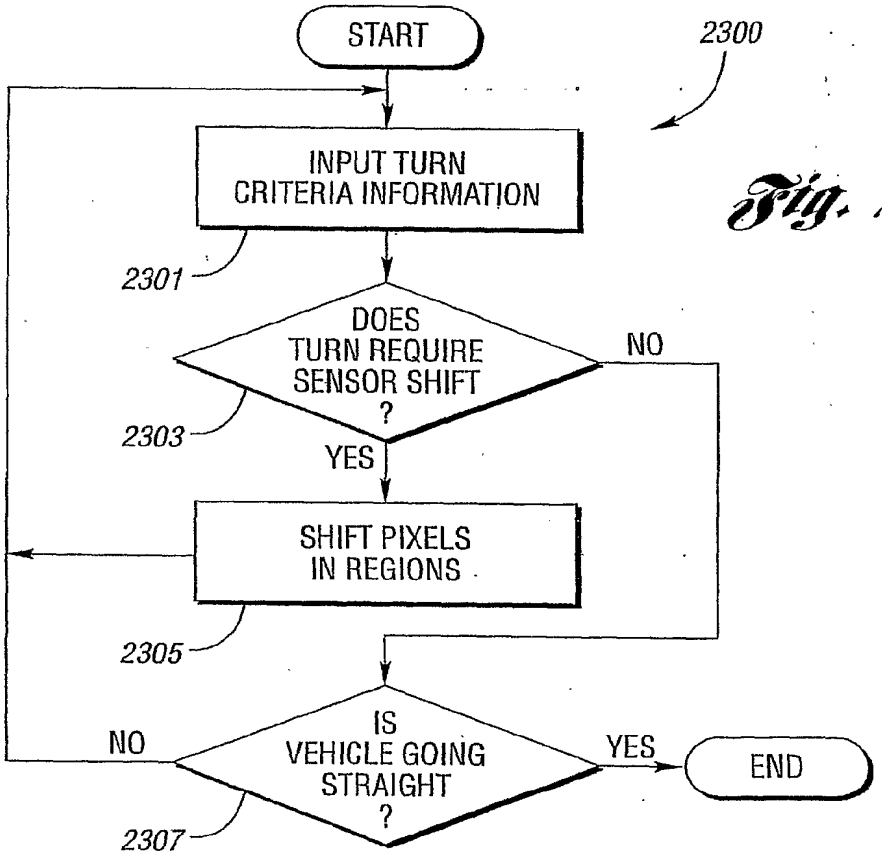
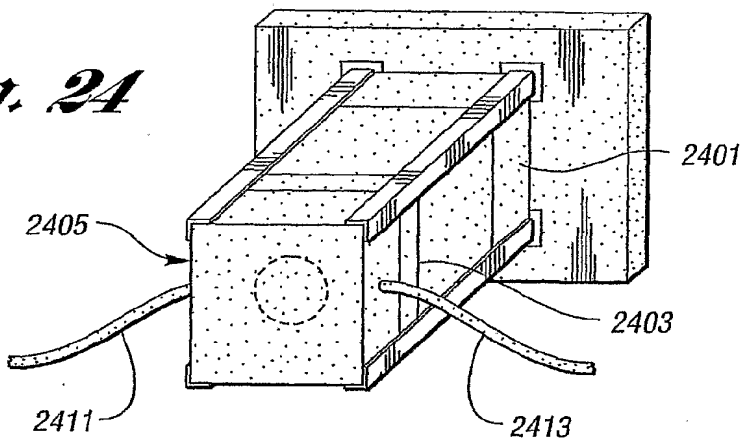

START
2300
INPUT TURN CRITERIA INFORMATION
2301
DOES TURN REQUIRE SENSOR SHIFT ?
2303
NO
YES
SHIFT PIXELS IN REGIONS
2305
IS VEHICLE GOING STRAIGHT ?
2307
NO
YES
END

Fig. 23

Fig. 24



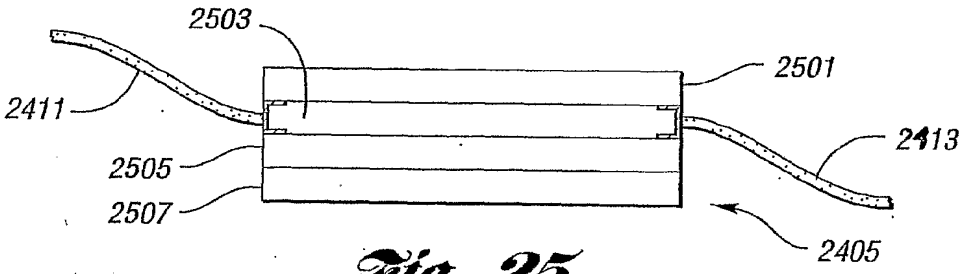
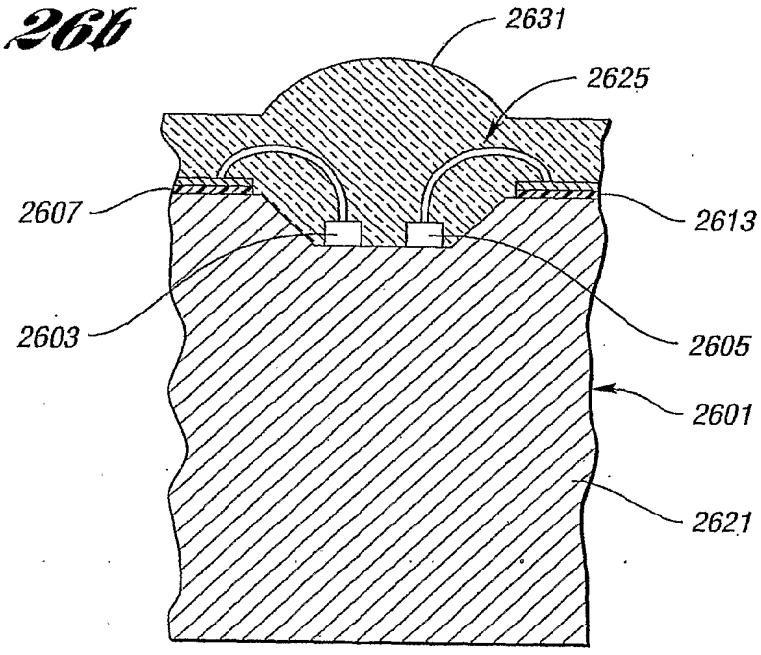


Fig. 25

Fig. 26b



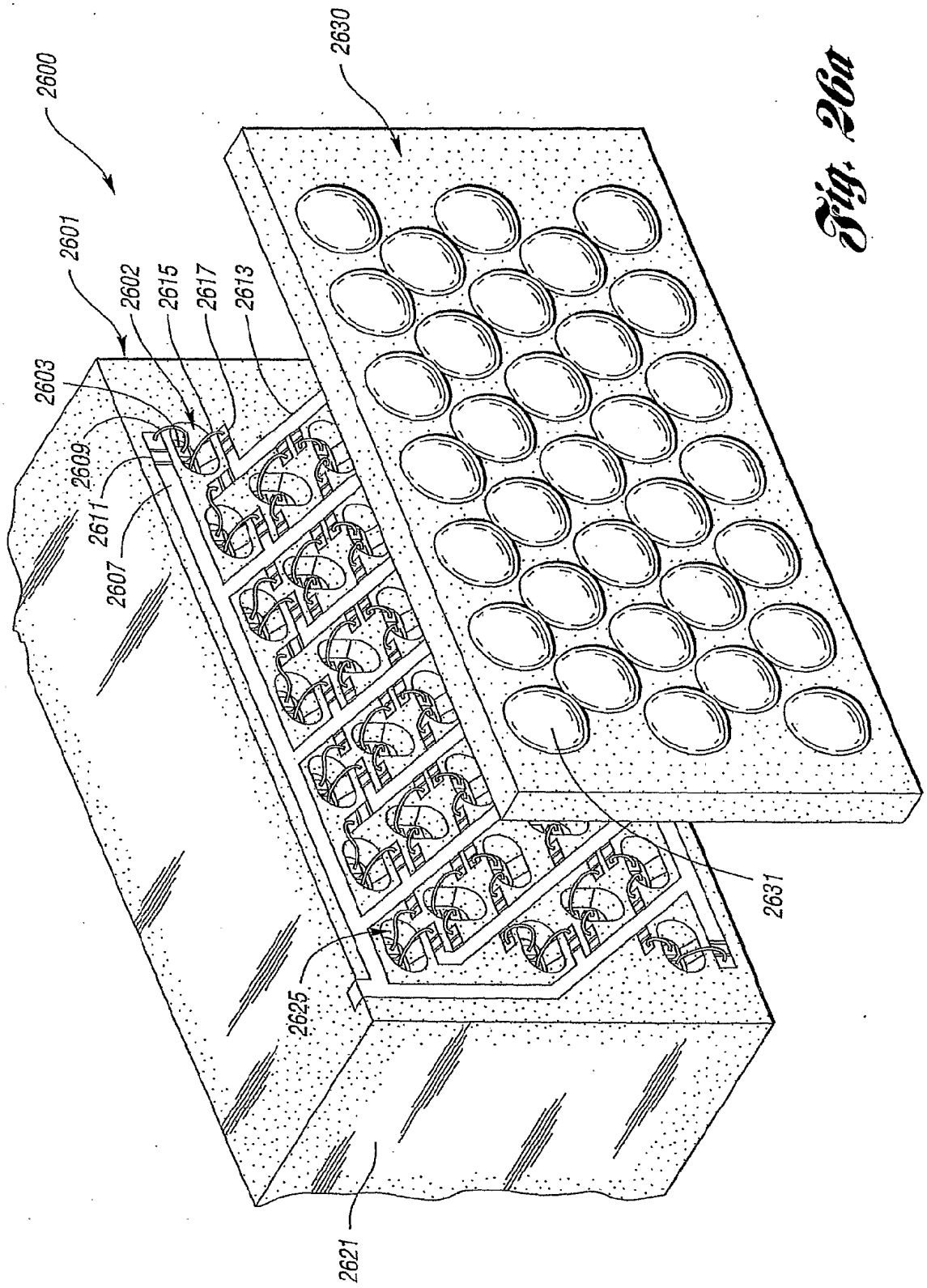

2600
2630
2601
2602
2615
2617
2613
2603
2609
2611
2607
2631
2625
2621

Fig. 26a

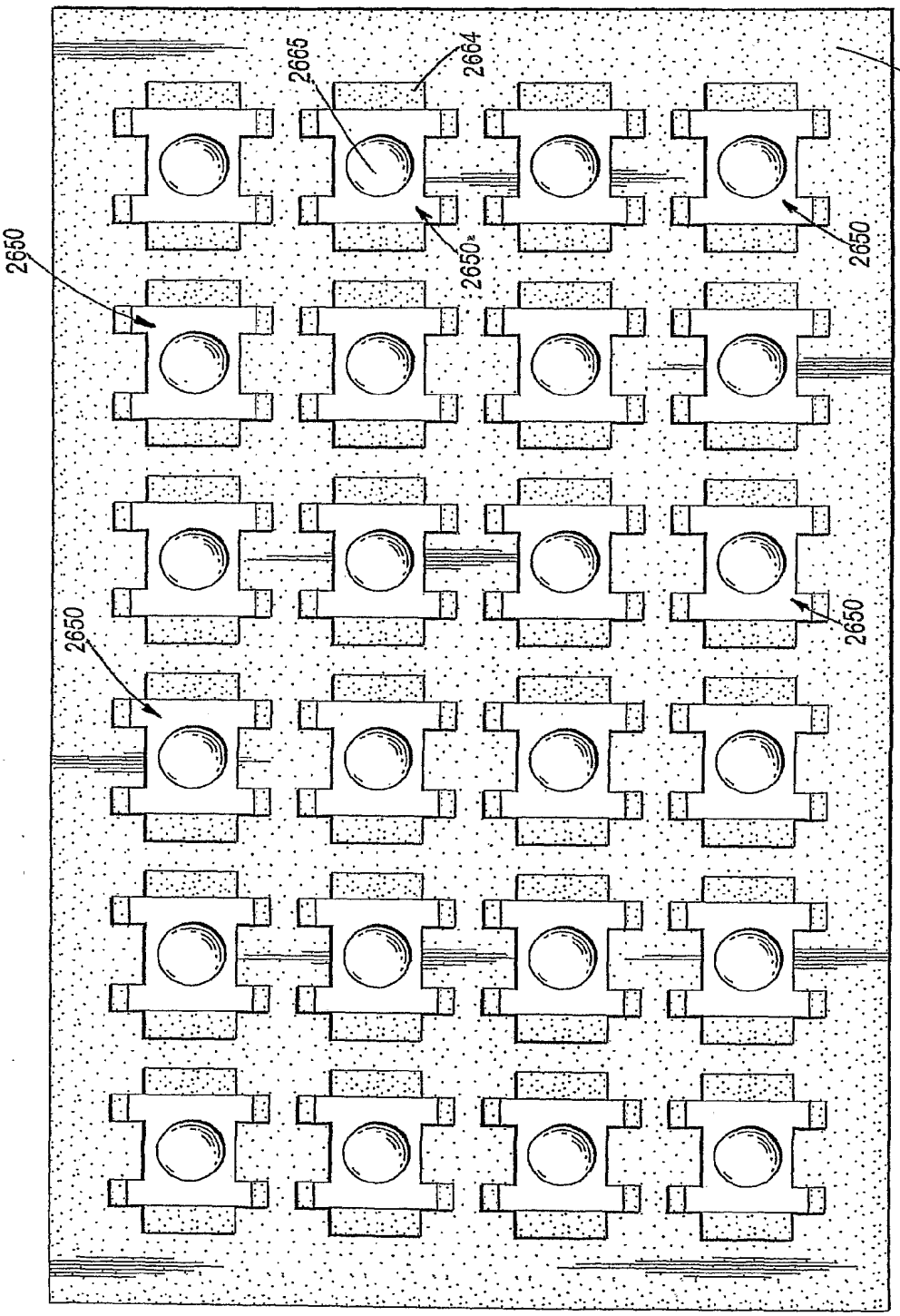


Fig. 26r

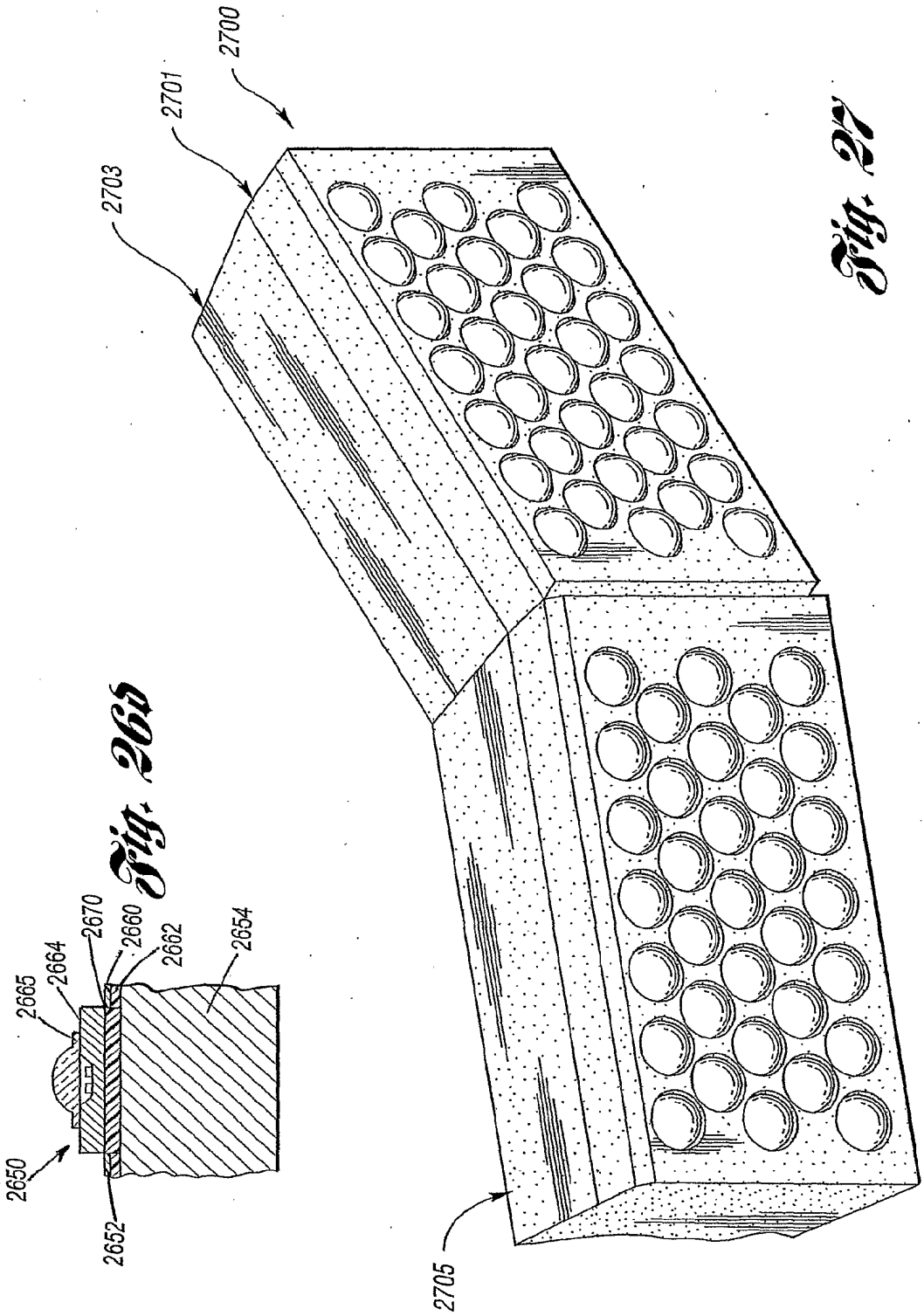


Fig. 27

Fig. 26b

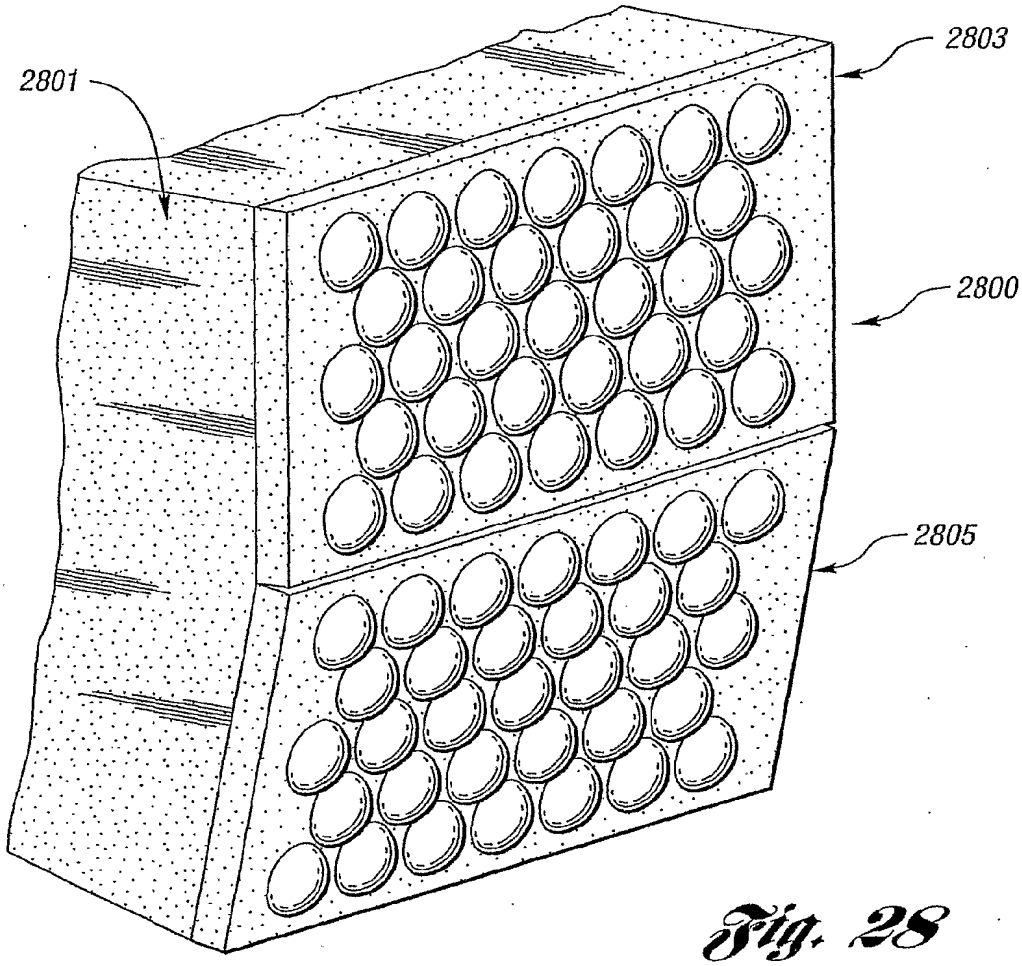

2801
2803
2800
2805

Fig. 28

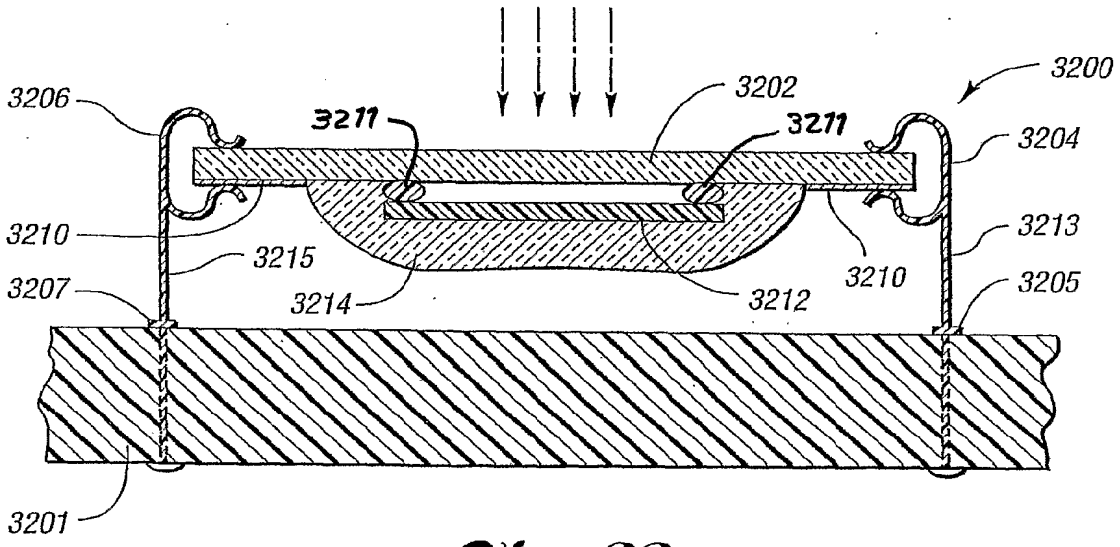

3206
3211
3202
3211
3200
3204
3210
3215
3213
3207
3214
3212
3210
3205
3201

Fig. 32

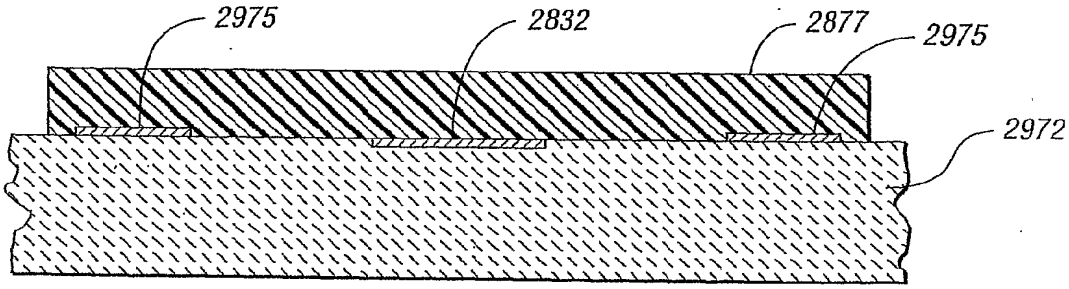


Fig. 29a

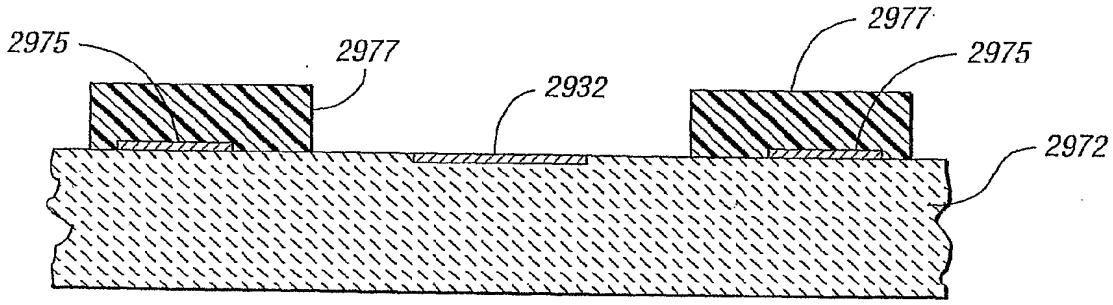


Fig. 29b

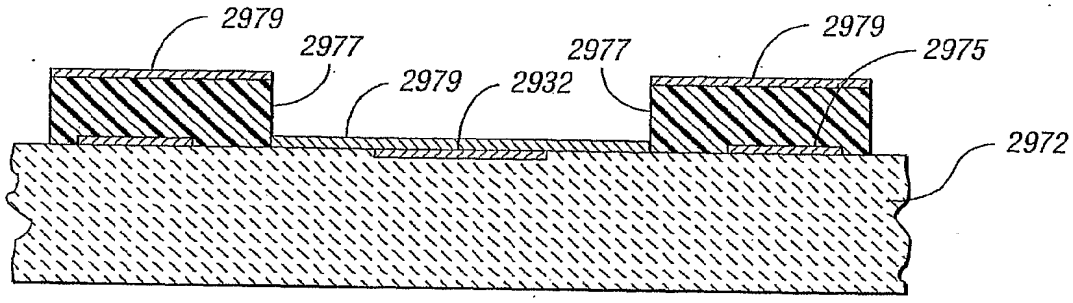


Fig. 29c

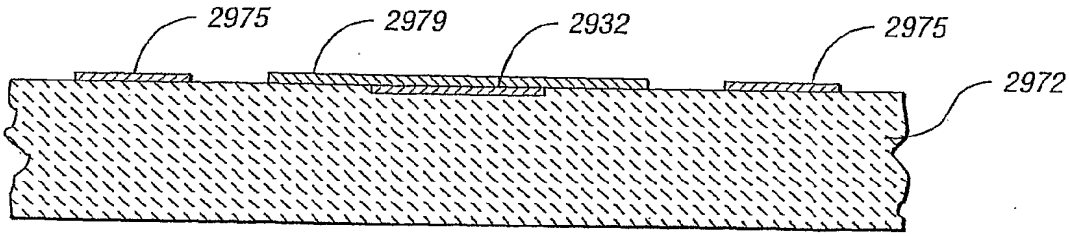


Fig. 29d

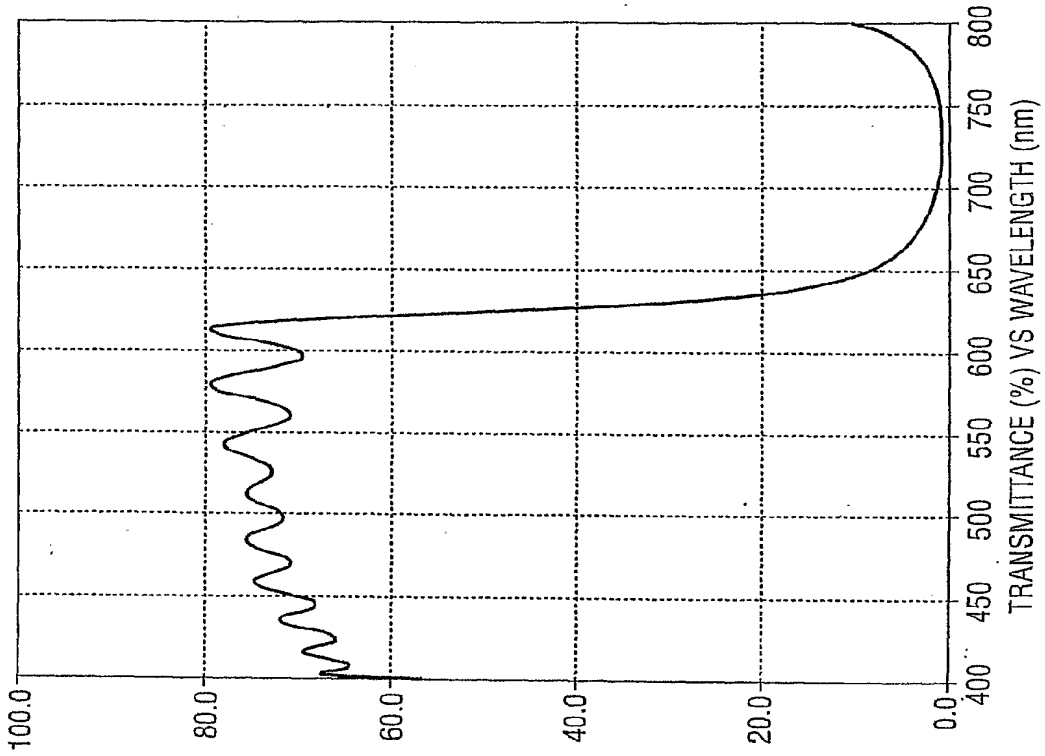

100.0
80.0
60.0
40.0
20.0
0.0
400
450
500
550
600
650
700
750
800
TRANSMITTANCE (%) VS WAVELENGTH (nm)

Fig. 31

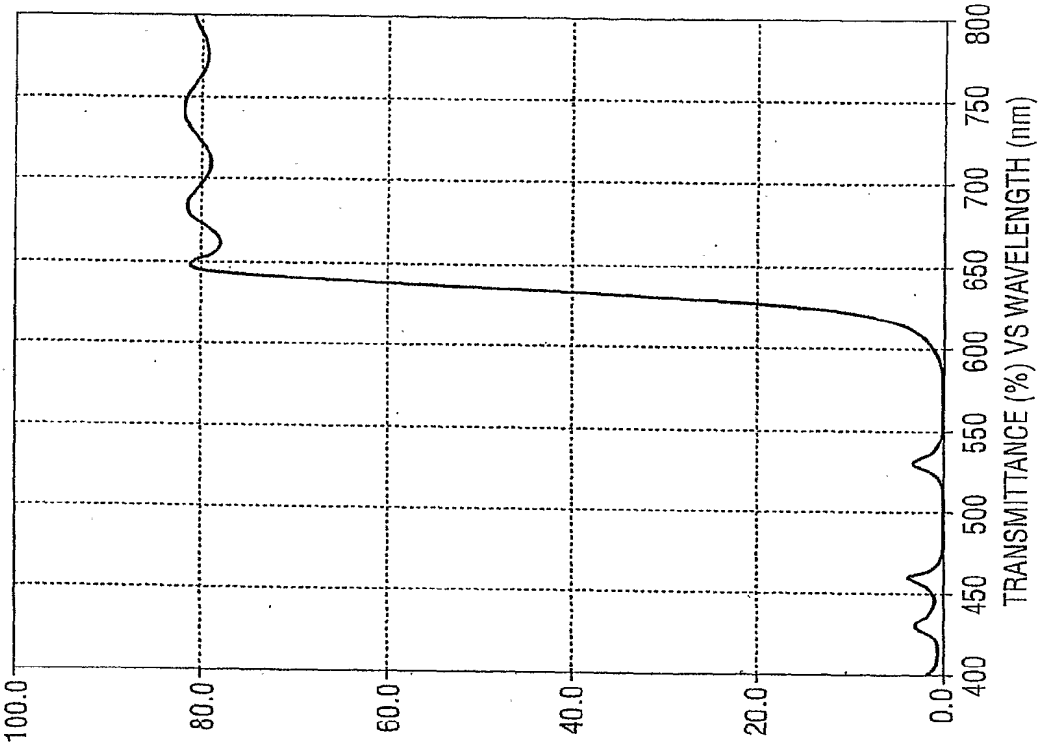

100.0
80.0
60.0
40.0
20.0
0.0
400
450
500
550
600
650
700
750
800
TRANSMITTANCE (%) VS WAVELENGTH (nm)

Fig. 30

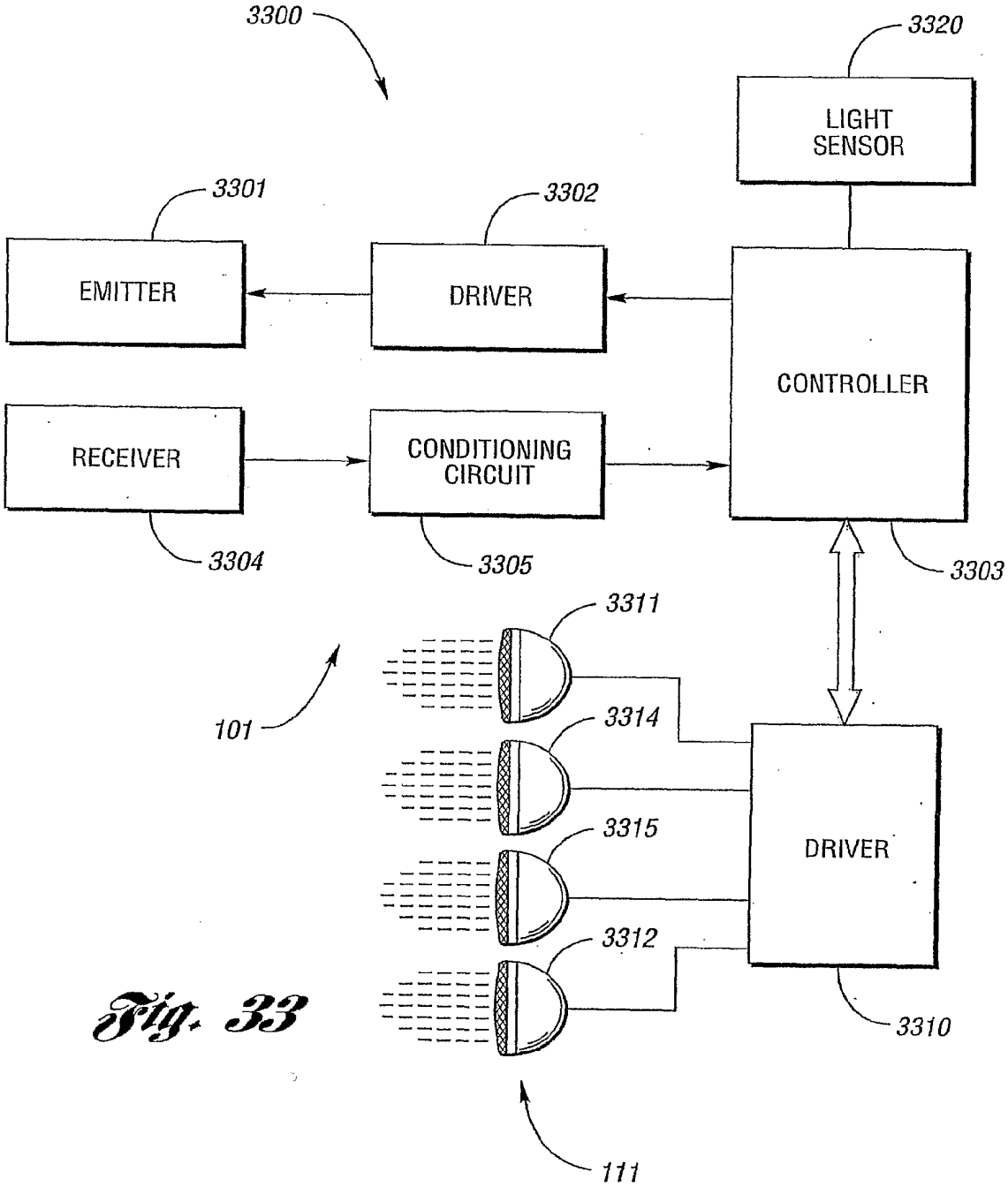

3300
3320
LIGHT SENSOR
3301
3302
EMITTER
DRIVER
CONTROLLER
RECEIVER
CONDITIONING CIRCUIT
3304
3305
3303
3311
101
3314
3315
DRIVER
3312
3310
111

Fig. 33

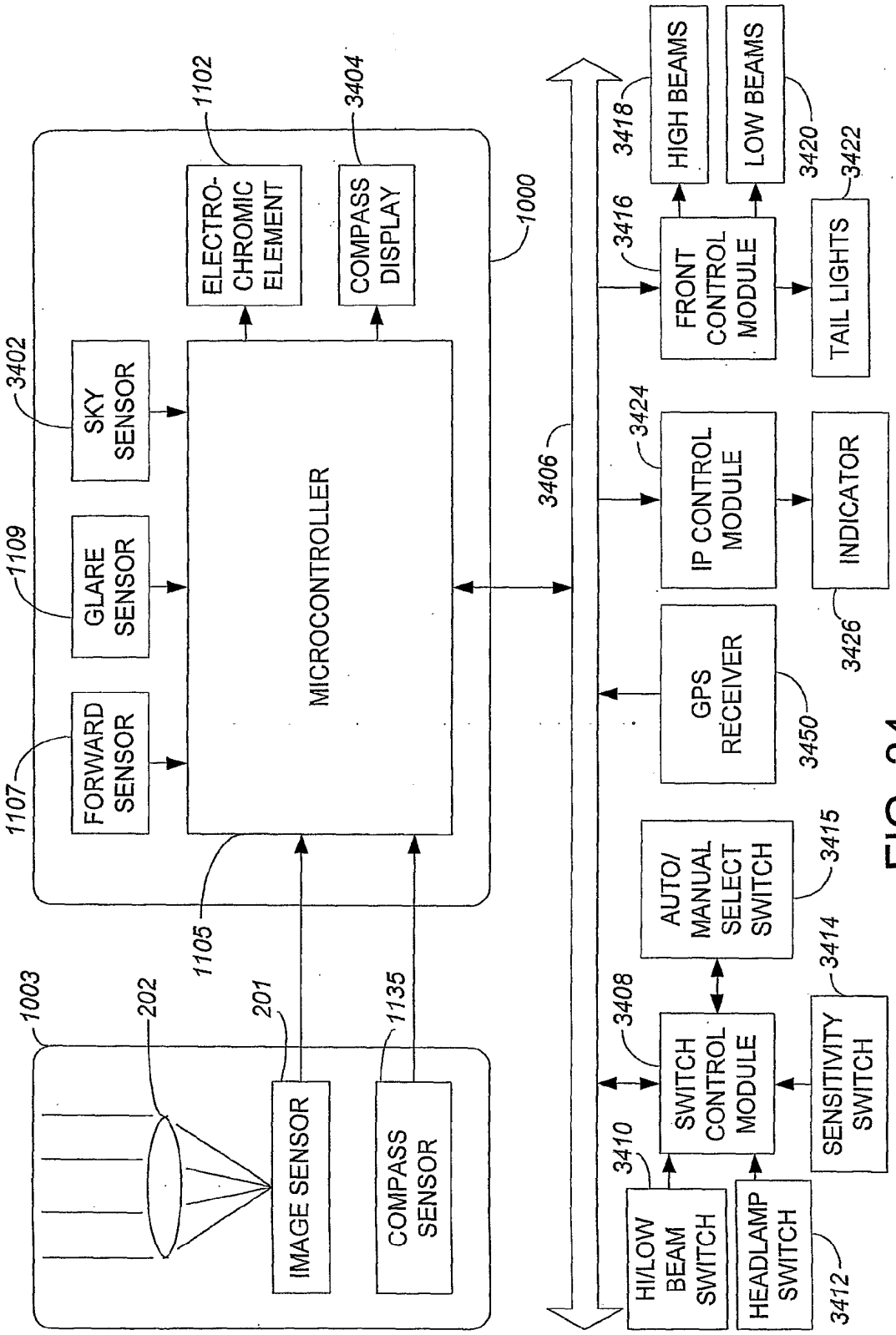

1102
3404
ELECTRO-CHROMIC ELEMENT
COMPASS DISPLAY
1000
3402
SKY SENSOR
1109
GLARE SENSOR
1107
FORWARD SENSOR
MICROCONTROLLER
1105
3406
1003
202
201
1135
IMAGE SENSOR
COMPASS SENSOR
3424
IP CONTROL MODULE
INDICATOR
3426
GPS RECEIVER
3450
AUTO/ MANUAL SELECT SWITCH
3415
3408
SWITCH CONTROL MODULE
3414
SENSITIVITY SWITCH
3410
HI/LOW BEAM SWITCH
HEADLAMP SWITCH
3412
3416
FRONT CONTROL MODULE
3418
HIGH BEAMS
3420
LOW BEAMS
TAIL LIGHTS
3422

FIG. 34

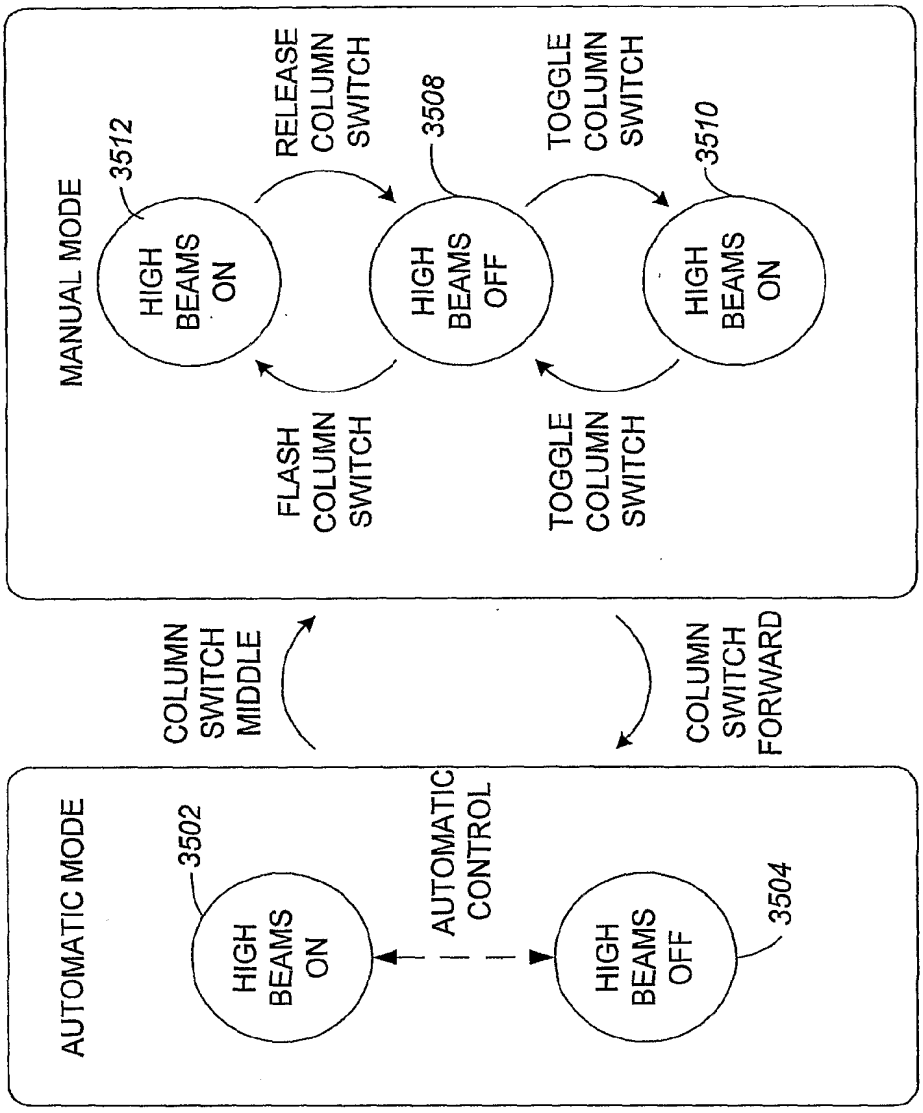

MANUAL MODE
3512
HIGH BEAMS ON
RELEASE COLUMN SWITCH
3508
HIGH BEAMS OFF
TOGGLE COLUMN SWITCH
3510
HIGH BEAMS ON
FLASH COLUMN SWITCH
TOGGLE COLUMN SWITCH
COLUMN SWITCH MIDDLE
COLUMN SWITCH FORWARD
AUTOMATIC MODE
3502
HIGH BEAMS ON
AUTOMATIC CONTROL
HIGH BEAMS OFF
3504

FIG. 35

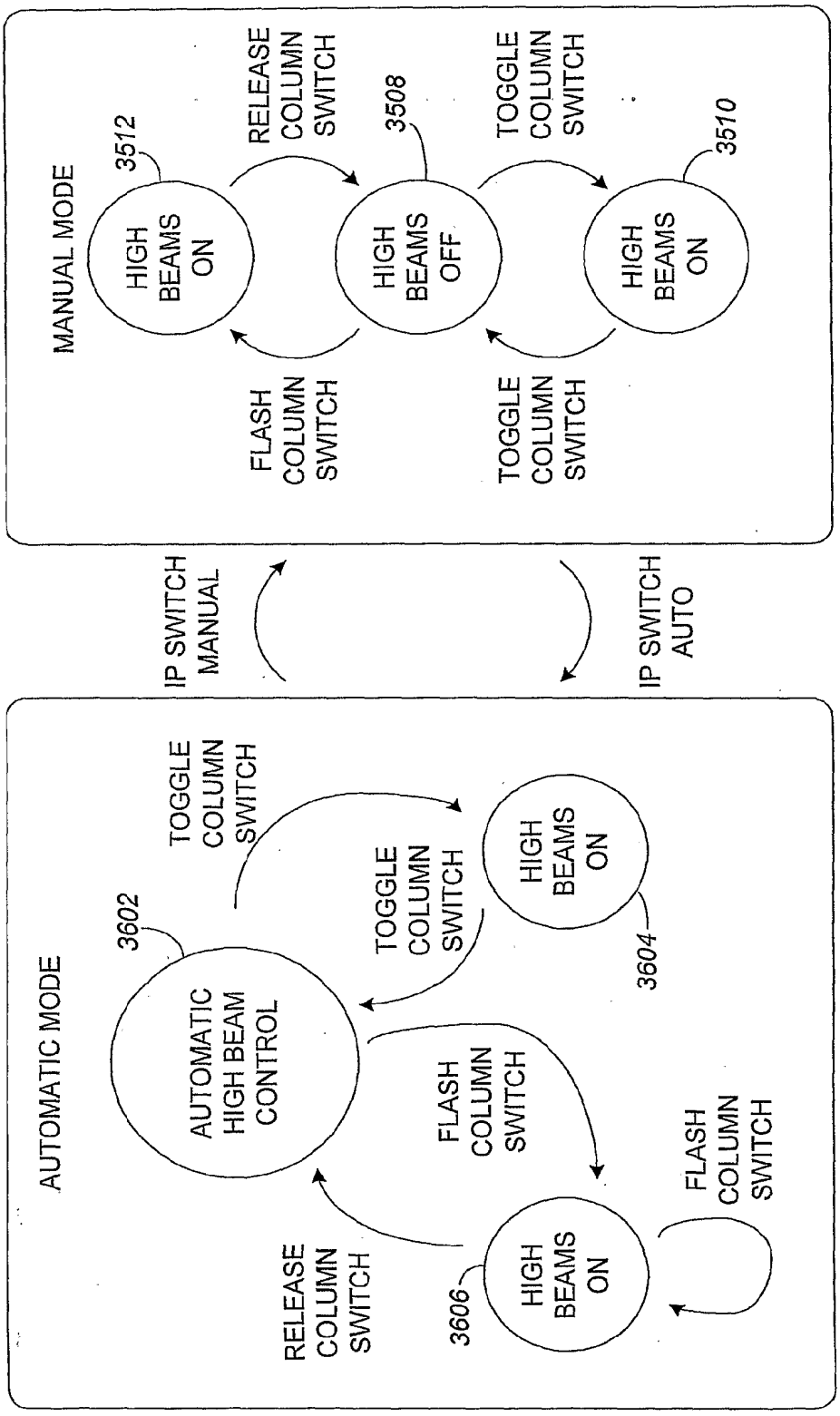

MANUAL MODE
3512
HIGH BEAMS ON
RELEASE COLUMN SWITCH
3508
HIGH BEAMS OFF
TOGGLE COLUMN SWITCH
3510
HIGH BEAMS ON
FLASH COLUMN SWITCH
TOGGLE COLUMN SWITCH
IP SWITCH MANUAL
IP SWITCH AUTO
AUTOMATIC MODE
3602
AUTOMATIC HIGH BEAM CONTROL
TOGGLE COLUMN SWITCH
TOGGLE COLUMN SWITCH
HIGH BEAMS ON
3604
FLASH COLUMN SWITCH
FLASH COLUMN SWITCH
RELEASE COLUMN SWITCH
3606
HIGH BEAMS ON

FIG. 36

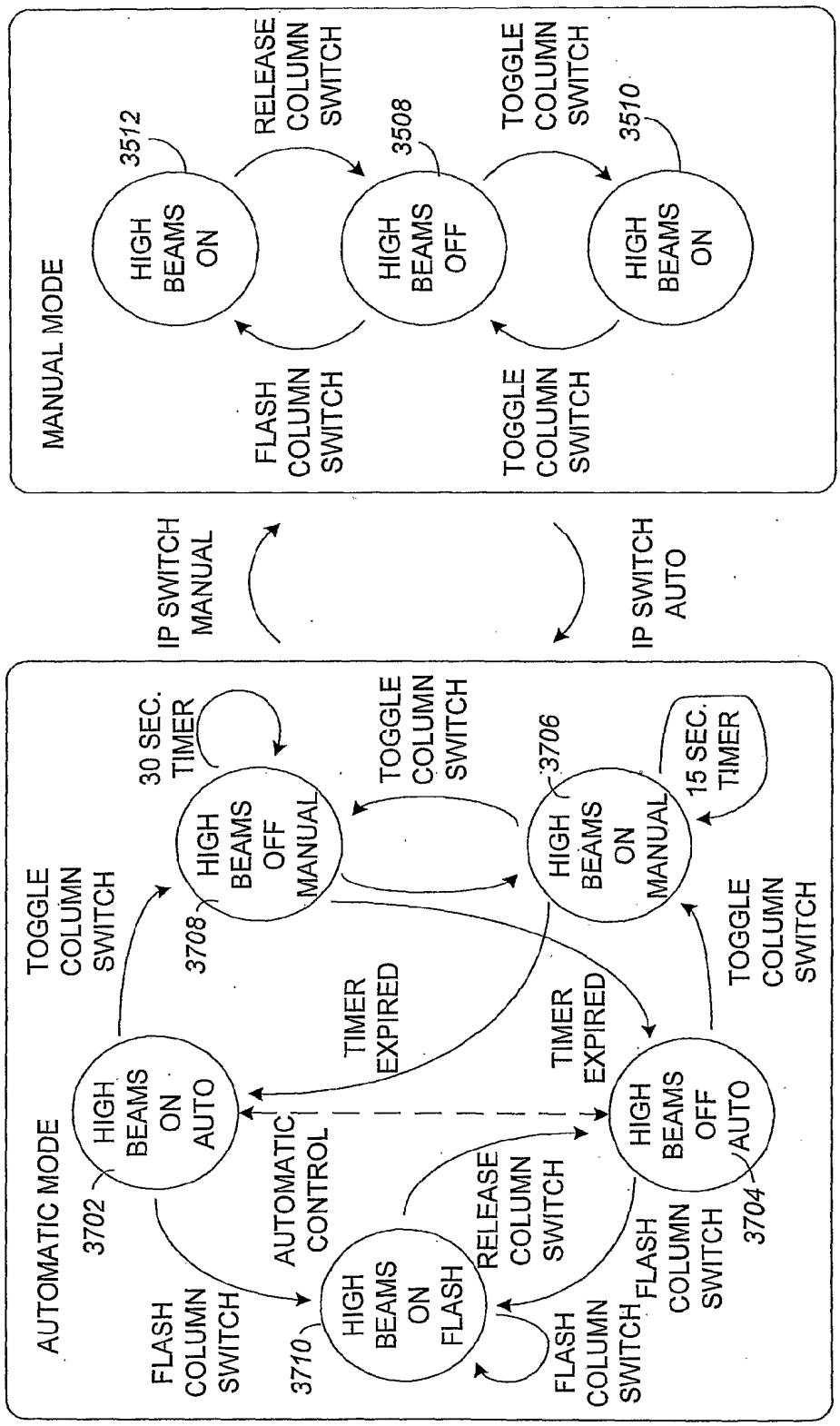

MANUAL MODE
HIGH BEAMS ON
3512
RELEASE COLUMN SWITCH
HIGH BEAMS OFF
3508
TOGGLE COLUMN SWITCH
HIGH BEAMS ON
3510
FLASH COLUMN SWITCH
TOGGLE COLUMN SWITCH
IP SWITCH MANUAL
IP SWITCH AUTO
AUTOMATIC MODE
3702
HIGH BEAMS ON AUTO
TOGGLE COLUMN SWITCH
30 SEC. TIMER
HIGH BEAMS OFF MANUAL
3708
TOGGLE COLUMN SWITCH
HIGH BEAMS ON MANUAL
3706
15 SEC. TIMER
TIMER EXPIRED
TIMER EXPIRED
TOGGLE COLUMN SWITCH
AUTOMATIC CONTROL
FLASH COLUMN SWITCH
HIGH BEAMS ON FLASH
3710
RELEASE COLUMN SWITCH
FLASH COLUMN SWITCH
HIGH BEAMS OFF AUTO
3704
FLASH COLUMN SWITCH

FIG. 37

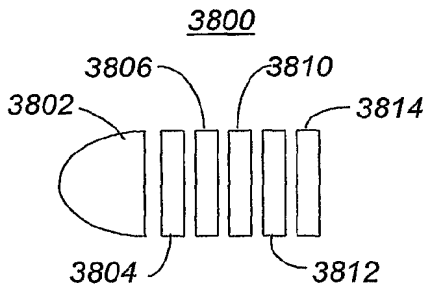


FIG. 38

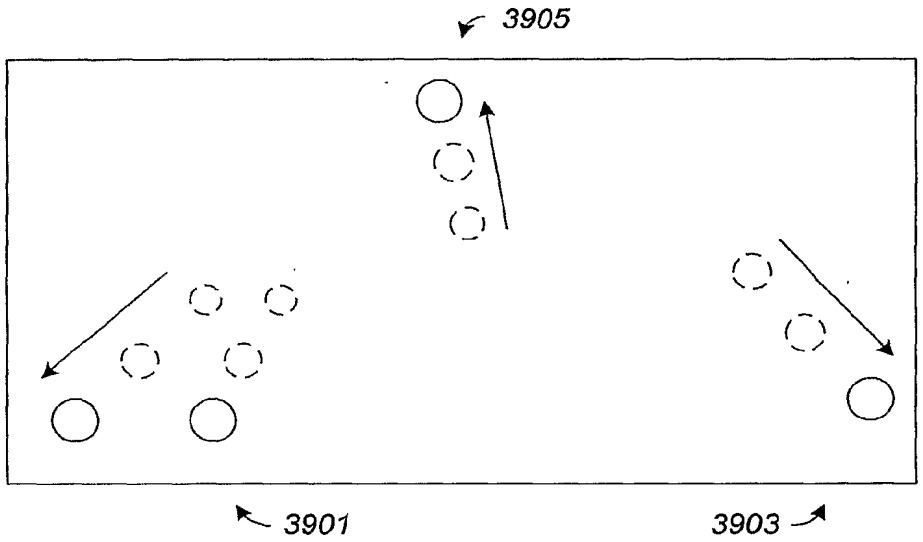


FIG. 39

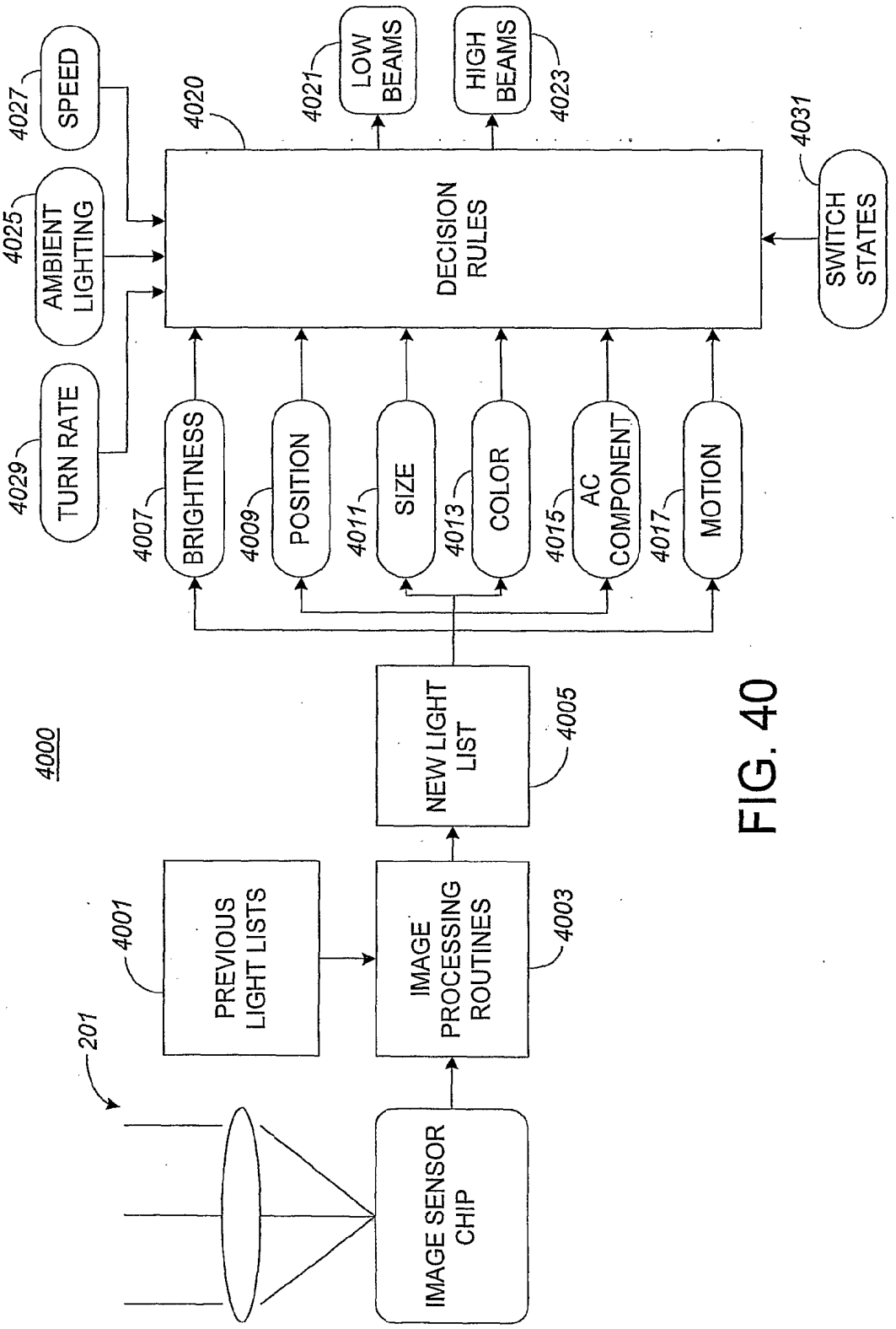

4000
201
IMAGE SENSOR CHIP
4001
PREVIOUS LIGHT LISTS
IMAGE PROCESSING ROUTINES
4003
NEW LIGHT LIST
4005
4007
BRIGHTNESS
4009
POSITION
4011
SIZE
4013
COLOR
4015
AC COMPONENT
4017
MOTION
4020
DECISION RULES
4021
LOW BEAMS
4023
HIGH BEAMS
4025
AMBIENT LIGHTING
4027
SPEED
4029
TURN RATE
4031
SWITCH STATES

FIG. 40

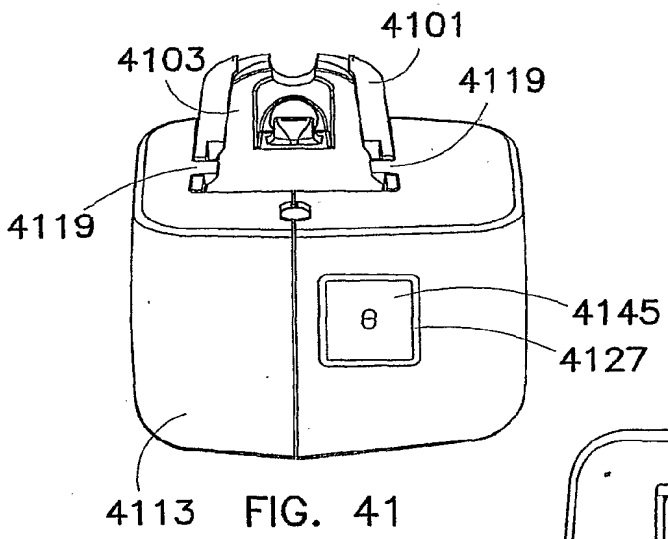


FIG. 41

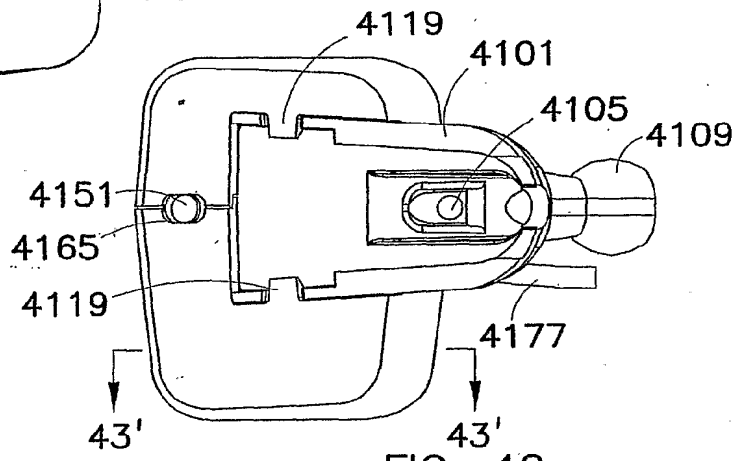


FIG. 42

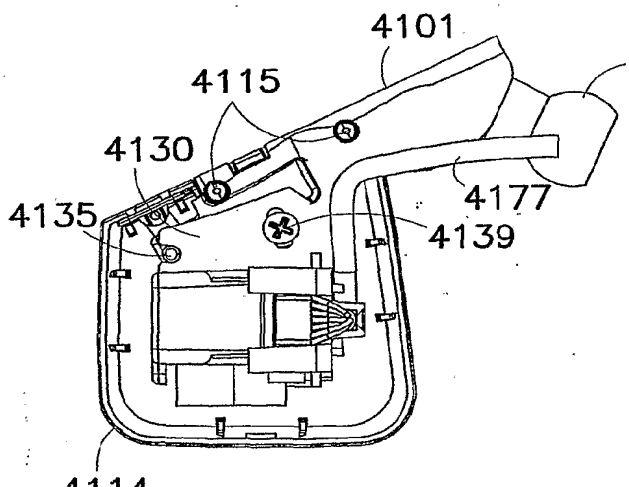


FIG. 43

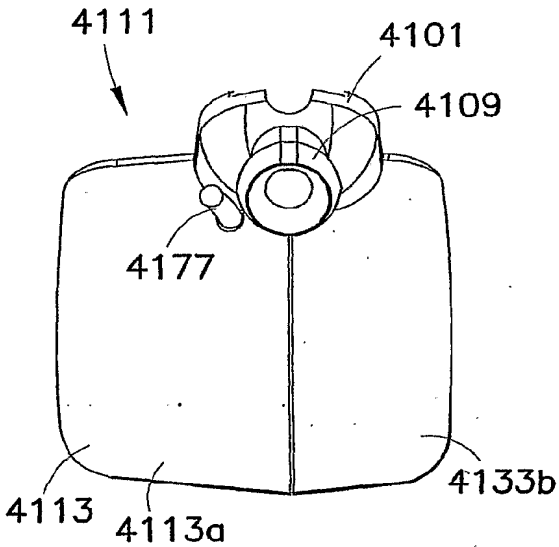


FIG. 45

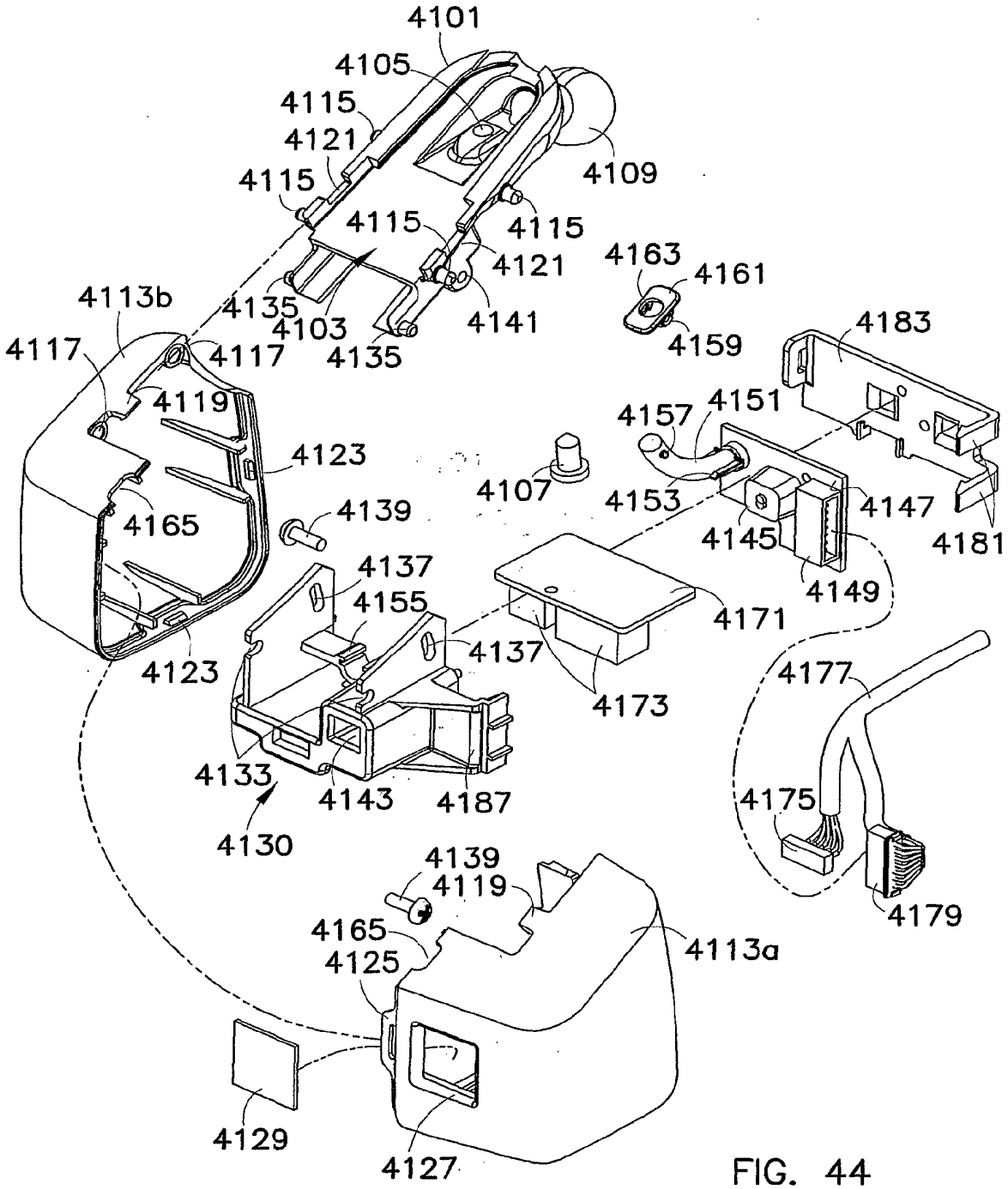

4101
4105
4115
4121
4115
4109
4115
4115
4121
4163
4161
4135
4103
4141
4135
4159
4113b
4117
4117
4183
4119
4157
4151
4123
4107
4153
4147
4139
4165
4145
4181
4137
4149
4155
4171
4137
4123
4173
4177
4133
4143
4187
4175
4130
4139
4119
4179
4165
4113a
4125
4129
4127

FIG. 44

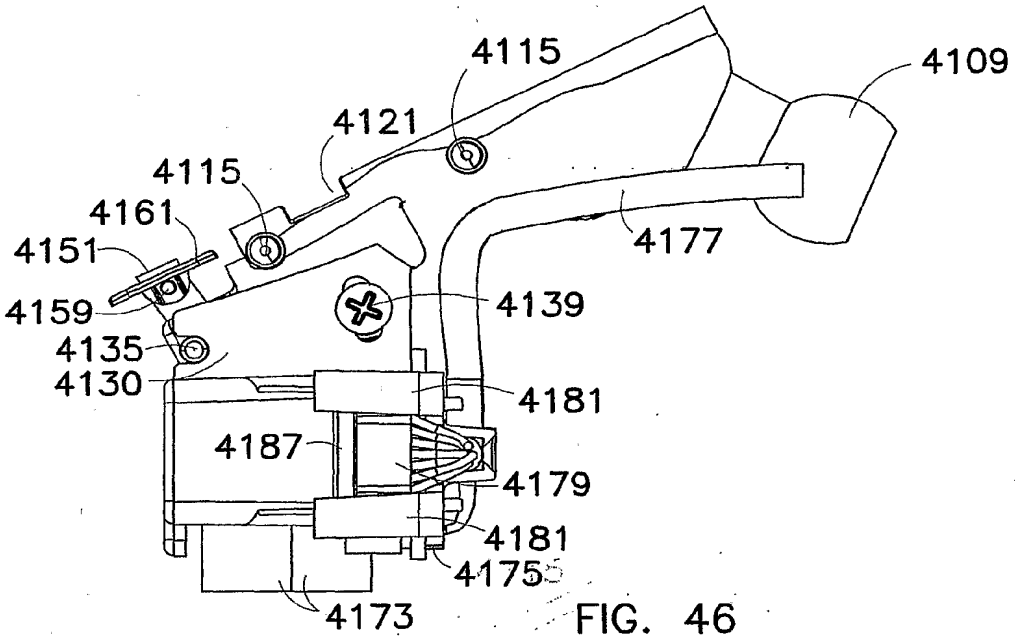

4115
4109
4121
4115
4161
4151
4177
4159
4139
4135
4130
4181
4187
4179
4181
4175
4173

FIG. 46

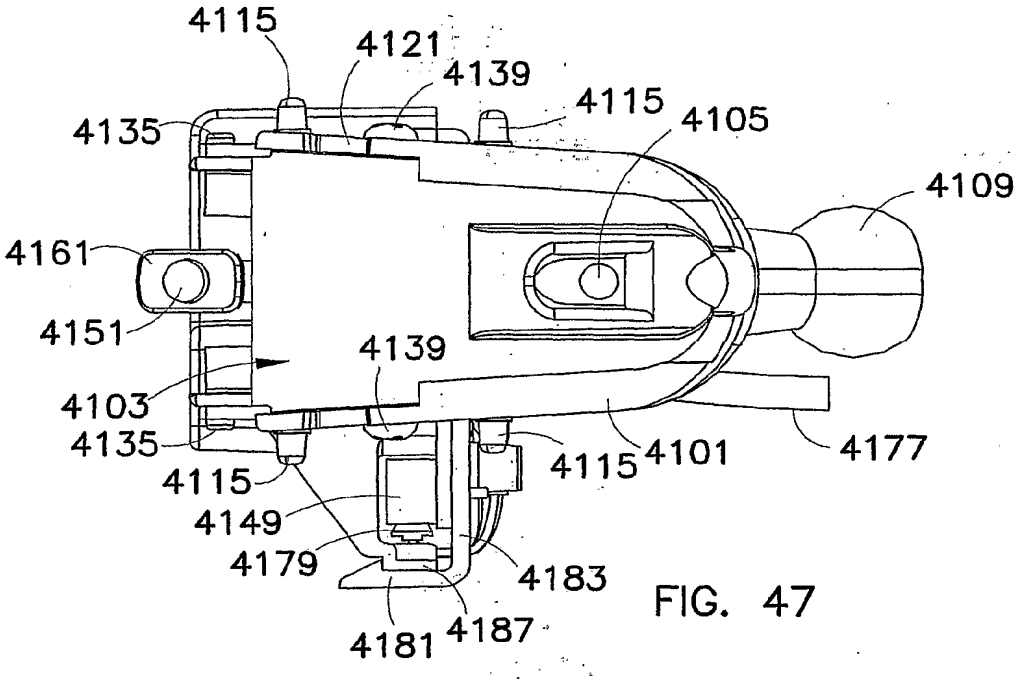

4115
4121
4139
4135
4115
4105
4109
4161
4151
4139
4103
4135
4115
4101
4177
4115
4149
4179
4183
4181
4187

FIG. 47

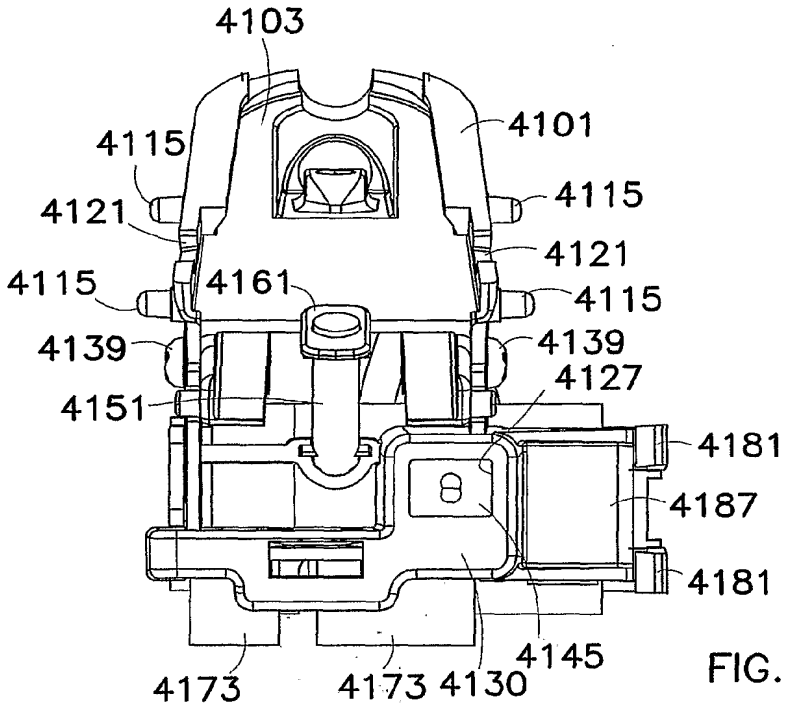

4103
4101
4115
4115
4121
4121
4115
4161
4115
4139
4139
4127
4151
4181
4187
4181
4145
4173
4173
4130

FIG. 48

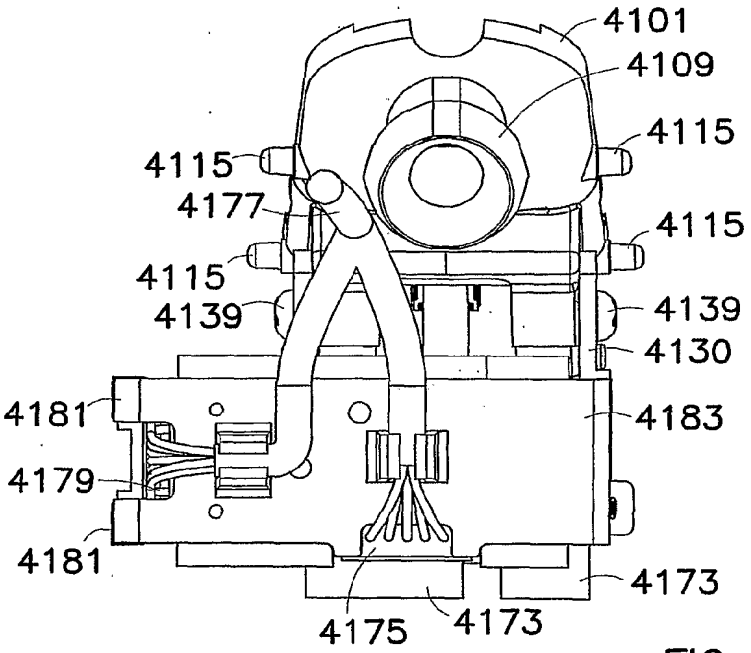

4101
4109
4115
4115
4177
4115
4115
4139
4139
4130
4181
4183
4179
4181
4173
4175
4173

FIG. 49

FIG. 50A

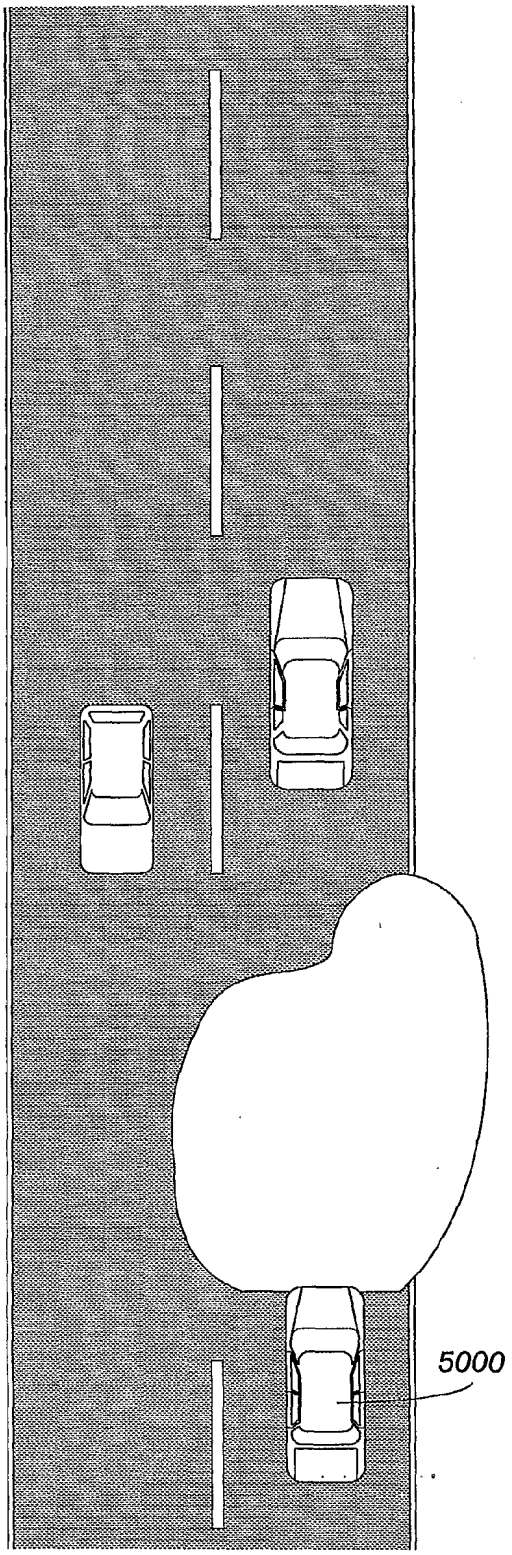


FIG. 50B

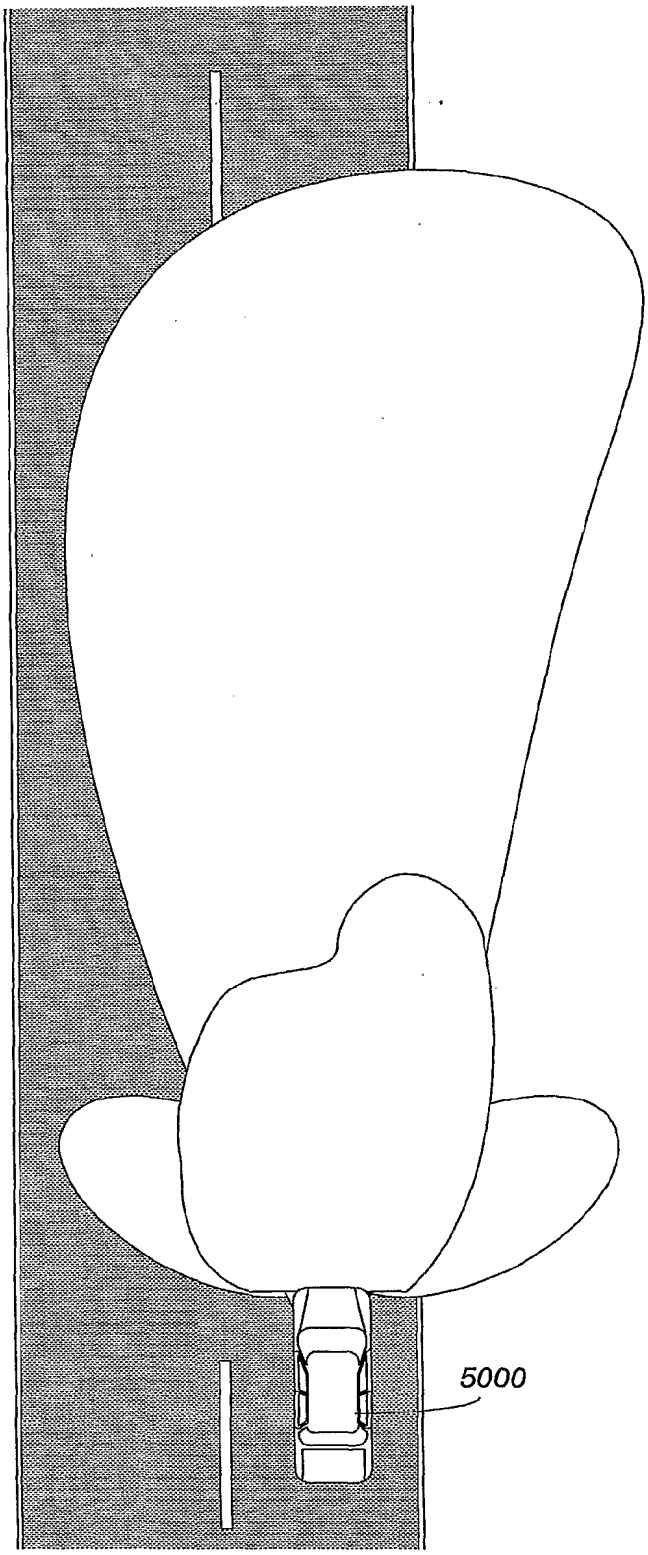
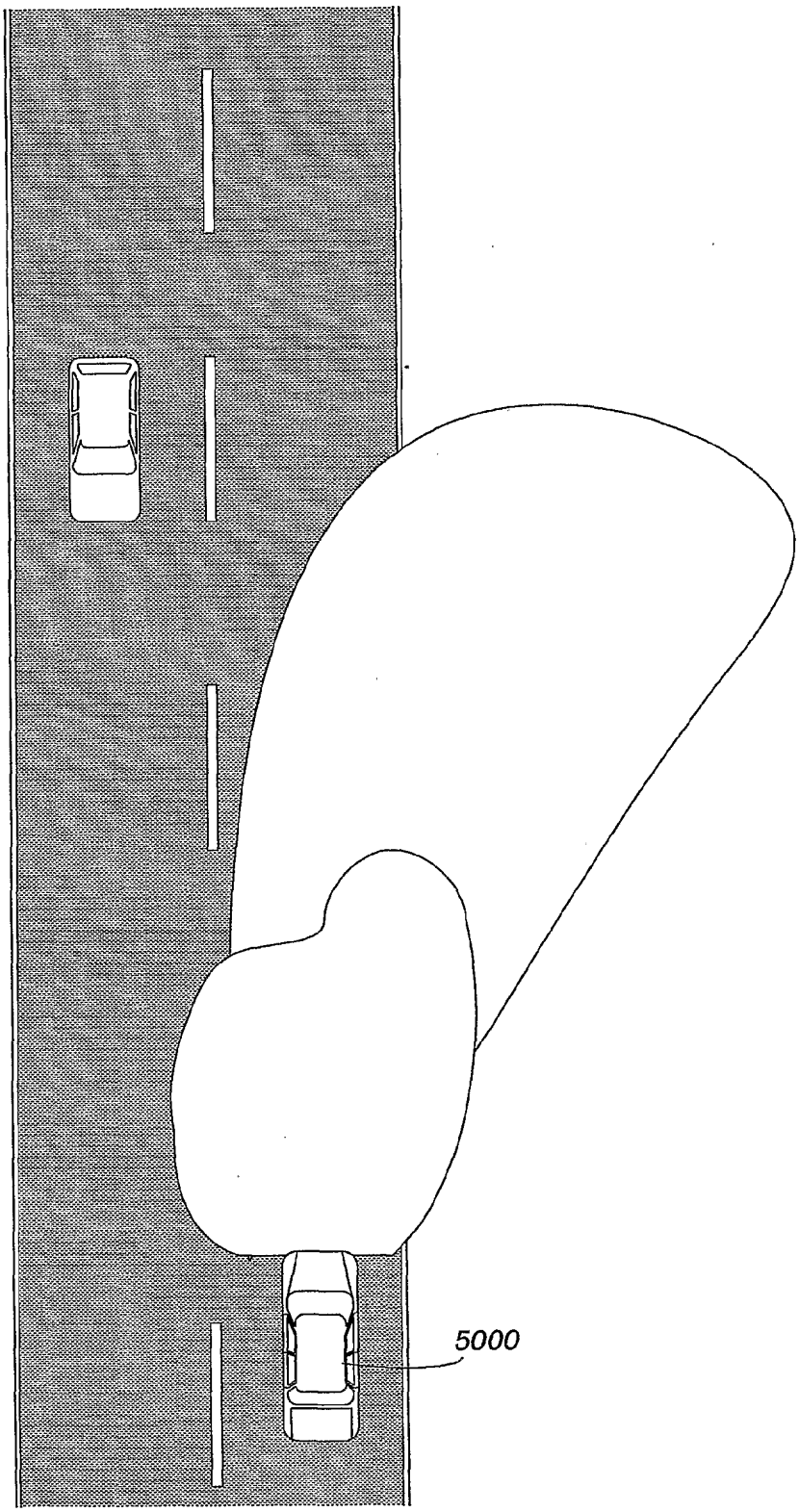


FIG. 50C



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

YECHEZKAL EVAN SPERO

Group Art Unit: 2644

Examiner: LE, TUNG X

Serial No.: 17/152,399

Filed: January 19, 2021

For: ADAPTIVE CONTROLLED HEADLIGHT SYSTEM

Attorney Docket No.: TRCH0103PUSP3

INFORMATION DISCLOSURE STATEMENT
UNDER 37 C.F.R. § 1.97(b)(1)

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

In compliance with the duty of disclosure under 37 C.F.R. § 1.56 and §§ 1.97-1.98, the references listed and identified on the attached Form PTO/SB/08a are being submitted herewith for consideration by the Examiner. This Statement is being filed in accordance with 37 C.F.R. § 1.97(b)(1).

While this Statement is being filed in compliance with the duty of disclosure, citation of the listed references is not to be construed as an admission that any of the references are "material" as defined under 37 C.F.R. § 1.56(b).

In accordance with 37 C.F.R. § 1.98(d), copies of the listed references are not being provided since the references were previously cited by or submitted to the Patent and Trademark Office in prior application Serial No. 15/961,861, filed April 24, 2018 patented as 10,894,503 B2, of which the present application is a continuation and in prior application Serial No. 13/357,549, filed January 24, 2012 patented as 9,955,551 B2, of which the present application is a continuation.

Respectfully submitted,

Yechezkal Evan Spero

By: /Bernard P. Tomsa/
Bernard P. Tomsa
Reg. No. 60,121
Attorney/Agent for Applicant

Date: July 8, 2021

BROOKS KUSHMAN P.C.
1000 Town Center, 22nd Floor
Southfield, MI 48075-1238
Phone: 248-358-4400
Fax: 248-358-3351

Electronic Patent Application Fee Transmittal

Application Number:	17152399
Filing Date:	19-Jan-2021
Title of Invention:	ADAPTIVE HEADLIGHT SYSTEM
First Named Inventor/Applicant Name:	Yechezkal Evan Spero
Filer:	Bernard Patrick Tomsa/Fiona Archer
Attorney Docket Number:	TRCH0103PUSP3

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
SUBMISSION- INFORMATION DISCLOSURE STMT	1806	1	260	260
		Total in USD ($)		**260**

Electronic Acknowledgement Receipt

EFS ID:	43195146
Application Number:	17152399
International Application Number:	
Confirmation Number:	6274
Title of Invention:	ADAPTIVE HEADLIGHT SYSTEM
First Named Inventor/Applicant Name:	Yechezkal Evan Spero
Customer Number:	22045
Filer:	Bernard Patrick Tomsa/Fiona Archer
Filer Authorized By:	Bernard Patrick Tomsa
Attorney Docket Number:	TRCH0103PUSP3
Receipt Date:	08-JUL-2021
Filing Date:	19-JAN-2021
Time Stamp:	09:32:06
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$260
RAM confirmation Number	E202178032454757
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	IDS_TRCH0103PUSP3.PDF	1036237 11d10b7ed71f5ed0ad1ac1a795b7ac281c65f1e6	no	10
Warnings:					
Information:					
2	Foreign Reference	WO2001070538A2.PDF	9193310 550923dc9c77b7aac99bfb4d9987a280cd76611e	no	159
Warnings:					
Information:					
3	Transmittal Letter	IDS_transmittal_TRCH0103PUSP3.PDF	114557 6ceae6be38ef7885e953753866fd699941b1fa4e	no	2
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	30780 0efaecef4cd76b8811168afc712b8bbeca356859	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	10374884		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

YECHEZKAL EVAN SPERO

Group Art Unit: 2844

Examiner: LE, TUNG X.

Serial No.: 17/152,399

Filed: January 19, 2021

For: ADAPTIVE HEADLIGHT SYSTEM

Attorney Docket No.: TRCH0103PUSP3

AMENDMENT UNDER 37 C.F.R. § 1.111

Mail Stop Amendment
Commissioner for Patents
U.S. Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

In response to the Office Action mailed July 7, 2021, please amend the above-identified application as follows:

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

1. (Original) A system, for a motor vehicle, comprising:

a plurality of headlamps, each comprising a plurality of LED light sources;

one or more processors; and

a memory storing instructions that, when executed by one or more of the one or more processors, enable the one or more processors to:

receive first data, including at least map data, indicating a road curvature upcoming along a road on which the motor vehicle is traveling;

determine a light change, the change adapting a light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction of the road curvature ahead of the motor vehicle and shaping light based at least in part on the road curvature; and

control at least a first plurality of the LED light sources to provide light based at least in part on the determined light change and prior to the motor vehicle reaching the road curvature.

2. (Original) The system of claim 1, wherein the determination of the light change includes selection of the first plurality of the LED light sources.

3. (Original) The system of claim 1, wherein the instructions include instructions that, when executed by the one or more processors, enable the one or more processors to reshape light based on the road curvature as the motor vehicle travels at least to or through the road curvature.

4. (Original) The system of claim 3, wherein the reshaping of light further includes control to at least one of the first plurality of LED light sources, or a second plurality of

LED light sources, including at least one LED light source different from the LED light sources of the first plurality of LED light sources, to provide reshaped light.

5. (Original) The system of claim 1, wherein the increase of light in the direction of the road curvature includes at least an increase of light emitted at a level below high-beam light and directed in the direction of the road curvature.

6. (Original) The system of claim 1, wherein the instructions include instructions that, when executed by the one or more processors, enable the one or more processors to:

determine a second light change, the second change adapting the light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction of a second road curvature ahead of the motor vehicle, determined based on at least one of the first data or second data including at least second map data, and the second change shaping light based at least in part on the second road curvature; and

control at least a second plurality of the LED light sources, having at least one LED light source different from the first plurality of LED light sources, to provide light based at least in part on the determined second light change and prior to the motor vehicle reaching the second road curvature.

7. (Original) The system of claim 1, wherein the increase of light in the direction of the road curvature includes at least one of expansion of the light pattern in the direction of the road curvature or an increase to intensity of light directed in the direction of the road curvature; and

wherein the determination of the light change includes determination of light changes to individual LEDs of the first plurality of LED light sources, at least one of the changes including at least one of:

a variation to at least one of intensity or color of individual LEDs of the first plurality of LED light sources, or

providing light directed in the direction of the road curvature from an LED not providing light directed in the direction of the road curvature prior to the change.

8. (Original) The system of claim 1, further comprising one or more cameras positioned to capture data indicating at least one other vehicle ahead of the motor vehicle;

wherein the instructions include instructions that, when executed by the one or more processors, enable the one or more processors to:

determine a position associated with the at least one other vehicle based at least in part on second data captured by at least one of the one or more cameras; and

control, based at least in part on the position, a second plurality of LED light sources providing light directed towards an area including at least a portion of the other vehicle to diminish glare to a driver of the other vehicle by a decrease to intensity of light directed towards and illuminating the area, the light that is directed towards and illuminating the area having lower intensity compared to light directed towards points laterally adjacent the area to either side.

9. (Original) The system of claim 8, wherein:

the first plurality and second plurality of LED light sources include at least one common LED light source;

the control of the second plurality of LED light sources is based at least in part on third data received from a non-camera sensor of the motor vehicle;

the position includes at least one of:

a distance associated with the at least one other vehicle,

at least one elevation associated with the at least one other vehicle, or

a position within image data captured by at least one of the cameras;

the first data includes data from a non-camera sensor of the motor vehicle;

either one of the control of the first plurality of LED light sources or control of the second plurality of LED light sources is subsequent to and accommodative of the other;

the control of the second plurality of LED light sources additionally includes termination of light from at least one LED providing light directed to the area prior to the termination; and

the light pattern includes at least one of an illumination pattern or an emission pattern of the headlamps.

10. (Original) The system of claim 1, further including one or more optical control elements for controlling light from one or more of the LED light sources.

11. (Original) The system of claim 10, wherein the optical control elements include at least one of one or more reflectors, refractors or lenses.

12. (Original) A non-transitory computer-readable storage medium, storing instructions that, when executed by one or more processors of a motor vehicle that includes a plurality of headlamps that each comprise a plurality of LED light sources, enable the one or more processors to:

receive first data, including at least map data, indicating a road curvature upcoming along a road on which the motor vehicle is traveling;

determine a light change, the change adapting a light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction of the road curvature ahead of the motor vehicle and shaping light based at least in part on the road curvature; and

control at least a first plurality of the LED light sources to provide light based at least in part on the determined light change and prior to the motor vehicle reaching the road curvature.

13. (Original) The storage medium of claim 12, wherein the determination of the light change includes selection of the first plurality of the LED light sources.

14. (Original) The storage medium of claim 12, wherein the instructions include instructions that, when executed by the one or more processors, enable the one or more processors to reshape light based on the road curvature as the motor vehicle travels at least to or through the road curvature.

15. (Original) The storage medium of claim 14, wherein the reshaping of light further includes control to at least one of the first plurality of LED light sources, or a second

plurality of LED light sources, including at least one LED light source different from the LED light sources of the first plurality of LED light sources, to provide reshaped light.

16. (Original) The storage medium of claim 12, wherein the increase of light in the direction of the road curvature includes at least an increase of light emitted at a level below high-beam light and directed in the direction of the road curvature.

17. (Original) The storage medium of claim 12, wherein the instructions include instructions that, when executed by the one or more processors, enable the one or more processors to:

determine a second light change, the second change adapting the light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction of a second road curvature ahead of the motor vehicle, determined based on at least one of the first data or second data including at least second map data, and the second change shaping light based at least in part on the second road curvature; and

control at least a second plurality of the LED light sources, having at least one LED light source different from the first plurality of LED light sources, to provide light based at least in part on the determined second light change and prior to the motor vehicle reaching the second road curvature.

18. (Original) The storage medium of claim 12, wherein the increase of light in the direction of the road curvature includes at least one of expansion of the light pattern in the direction of the road curvature or an increase to intensity of light directed in the direction of the road curvature; and

wherein the determination of the light change includes determination of light changes to individual LEDs of the first plurality of LED light sources, at least one of the changes including at least one of:

a variation to at least one of intensity or color of individual LEDs of the first plurality, or

providing light directed in the direction of the road curvature from an LED not providing light directed in the direction of the road curvature prior to the change.

19. (Original) The storage medium of claim 12, wherein the instructions include instructions that, when executed by the one or more processors, enable the one or more processors to:

determine a position associated with at least one other vehicle based at least in part on second data indicating the at least one other vehicle and captured by at least one camera of the motor vehicle; and

control, based at least in part on the position, a second plurality of LED light sources providing light directed towards an area including at least a portion of the other vehicle to diminish glare to a driver of the other vehicle by a decrease to intensity of light directed towards and illuminating the area, the light that is directed towards and illuminating the area having lower intensity compared to light directed towards points laterally adjacent the area to either side.

20. (Original) The storage medium of claim 19, wherein:

the first plurality and second plurality of LED light sources include at least one common LED light source;

the control of the second plurality of LED light source is based at least in part on third data received from a non-camera sensor of the motor vehicle;

the position includes at least one of:

a distance associated with the at least one other vehicle,

at least one elevation associated with the at least one other vehicle, or

a position within image data captured by at least one of the cameras;

the first data includes data from a non-camera sensor of the motor vehicle;

either one of the control of the first plurality of LED light sources or control of the second plurality of LED light sources is subsequent to and accommodative of the other;

the control of the second plurality of LED light sources additionally includes termination of light from at least one LED providing light directed to the area prior to the termination; and

the light pattern includes at least one of an illumination pattern or an emission pattern of the headlamps.

21. (Original) The storage medium of claim 19, wherein the instructions include instructions that, when executed by the one or more processors, enable the one or more processors to utilize one or more optical control elements included in the motor vehicle to control light from at least the first plurality or second plurality of the LED light sources.

22. (Original) The storage medium of claim 21, wherein the optical control elements include at least one of one or more reflectors, refractors or lenses.

23. (Original) A computer-implemented method for adapting light from headlamps of a motor vehicle to accommodate road shape changes, the headlamps including a plurality of LED light sources, comprising:

determining an upcoming shape change of a road, ahead of the motor vehicle, based on first data, including map data, indicating the shape change;

determining a light output, the output adapting a light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction associated with the shape change ahead of the motor vehicle and shaping light based on the shape change; and

prior to reaching the road shape change, causing at least a first plurality of the LED light sources to provide light based at least in part on the determined light output.

24. (Original) The method of claim 23, wherein the determining the light includes selecting the first plurality of the LED light sources.

25. (Original) The method of claim 23, further comprising reshaping light based on the shape change as the motor vehicle travels at least to or through the shape change.

26. (Original) The method of claim 25, wherein the reshaping light further includes controlling at least one of the first plurality of LED light sources, or a second plurality of LED light sources, including at least one LED light source different from the LED light sources of the first plurality of LED light sources, to provide reshaped light.

27. (Original) The method of claim 23, wherein the increase of light in the direction associated with the shape change includes at least light output that increases light emitted at a level below high-beam light and directed in the direction associated with shape change.

28. (Original) The method of claim 23, further comprising:

determining a second light output, the second output adapting the light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction associated with a second shape change ahead of the motor vehicle, determined based on at least one of the first data or second data including at least second map data, and the second output shaping light based at least in part on the second shape change; and

controlling at least a second plurality of the LED light sources, having at least one LED light source different from the first plurality of LED light sources, to provide light based at least in part on the determined second output and prior to the motor vehicle reaching the second shape change.

29. (Original) The method of claim 23, wherein the increase of light in the direction associated with the shape change includes at least one of expansion of the light pattern in the direction associated with the shape change or an increase to intensity of light directed in the direction associated with the shape change; and

wherein the determining the light output includes determining output for individual LEDs of the first plurality of LED light sources, the output including providing light directed in the direction associated with the shape change from an LED not providing light directed in the direction associated with the shape change prior to the change.

30. (Original) The method of claim 23, further comprising:

determining a position associated with at least one other vehicle based at least in part on second data indicating the at least one other vehicle and captured by at least one camera of the motor vehicle; and

controlling, based at least in part on the position, a second plurality of LED light sources providing light directed towards an area including at least a portion of the other vehicle to diminish glare to a driver of the other vehicle by decreasing intensity of light directed towards and illuminating the area, the light directed towards and illuminating the area having lower intensity compared to light directed towards points laterally adjacent the area to either side.

31. (Original) The method of claim 30, wherein:

the first plurality and second plurality of LED light sources include at least one common LED light source;

the controlling the second plurality of LED light sources is based at least in part on third data received from a non-camera sensor of the motor vehicle;

the position includes at least one of:

a distance associated with the at least one other vehicle,

at least one elevation associated with the at least one other vehicle, or

a position within image data captured by at least one of the cameras;

the first data includes data from a non-camera sensor of the motor vehicle;

either one of the determining the light output or controlling the second plurality of LED light sources is subsequent to and accommodative of the other;

the controlling the second plurality of LED light sources additionally includes terminating light from at least one LED providing light directed to the area prior to the terminating; and

the light pattern includes at least one of an illumination pattern or an emission pattern of the headlamps.

32. (Original) The method of claim 30, further comprising utilizing one or more optical control elements included in the motor vehicle to control light from at least the first plurality or second plurality of the LED light sources.

33. (Original) The method of claim 32, wherein the optical control elements include at least one of one or more reflectors, refractors or lenses.

Remarks

For at least the reasons presented, all claims are believed to be in condition for allowance. Favorable reconsideration and allowance are respectfully requested.

Applicant spoke with the Examiner briefly on 7/13/21, to discuss the priority date of the prior art relative to the priority date of the claims. No agreement was reached, and Applicant thus responds to the action below. Applicant thanks the Examiner for the call.

Claims 1-5, 12-16 and 23-27 stand rejected under pre-AIA 35 U.S.C. § 103(a) as being unpatentable over U.S. Publication No. 2010/0286896 issued to Yamada (hereinafter "*Yamada*") in view of U.S. Publication No. 2012/0001547 issued to Nishitani et al. (hereinafter "*Nishitani*").

Applicant's support for claims 1-5, 12-16 and 23-27 was drawn from the original specification, U.S. Ser. No. 10/604,360, filed on July 14, 2003. See, e.g., the description of Figs. 14 and 15, such as, but not limited to:

1) [0211] in the present application and in the same form at [0179] in US 10/604,360
2) [0212] in the present application and in the same form at [0180] in US 10/604,360
3) [0215] in the present application and in the same form at [0183] in US 10/604,360
4) [0216] in the present application and in the same form at [0184] in US 10/604,360
5) [0221] in the present application and in the same form at [0189] in US 10/604,360
6) [0222] in the present application and in the same form at [0190] in US 10/604,360

As U.S. Ser. No. 10/604,360, has a filing date of July 14, 2003, and claims priority to a provisional application filed July 12, 2002, the claims are entitled to at least the 2003 priority date. Yamada was filed 9/12/06 and claims priority to a Japanese application filed on 10/12/05, and Nishitani was filed on 6/29/11 and claims priority to a Japanese application filed on 6/30/10. None of these dates precede the US priority date applicable to these particular instant claims, and withdrawal of the rejection is respectfully requested.

Please charge any fees or credit any overpayments as a result of the filing of this paper to our Deposit Account No. 02-3978.

Respectfully submitted,

YECHEZKAL EVAN SPERO

By: /Bernard P. Tomsa/
Bernard P. Tomsa
Reg. No. 60,121
Attorney/Agent for Applicant

Date: July 14, 2021

BROOKS KUSHMAN P.C.
1000 Town Center, 22nd Floor
Southfield, MI 48075-1238
Phone: 248-358-4400
Fax: 248-358-3351
\

Electronic Acknowledgement Receipt

EFS ID:	43244588
Application Number:	17152399
International Application Number:	
Confirmation Number:	6274
Title of Invention:	ADAPTIVE HEADLIGHT SYSTEM
First Named Inventor/Applicant Name:	Yechezkal Evan Spero
Customer Number:	22045
Filer:	Bernard Patrick Tomsa/Julie Oumedian
Filer Authorized By:	Bernard Patrick Tomsa
Attorney Docket Number:	TRCH0103PUSP3
Receipt Date:	14-JUL-2021
Filing Date:	19-JAN-2021
Time Stamp:	15:07:15
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		TRCH0103PUSP3_Amendment.PDF	9613610 31604d2e30a3254874d0643d202401d48ab9a22e	yes	12

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Amendment/Req. Reconsideration-After Non-Final Reject	1	1
	Claims	2	10
	Applicant Arguments/Remarks Made in an Amendment	11	12

Warnings:	
Information:	
Total Files Size (in bytes):	9613610

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 17/152,399	Filing Date 01/19/2021	☐ To be Mailed

ENTITY: ☑ LARGE ☐ SMALL ☐ MICRO

APPLICATION AS FILED - PART I

	(Column 1)	(Column 2)			
FOR	NUMBER FILED	NUMBER EXTRA		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A		N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A		N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*		x $100 =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*		x $480 =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).				
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))					
* If the difference in column 1 is less than zero, enter "0" in column 2.				TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT	07/14/2021	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 33	Minus	** 33	= 0		x $100 =	0
	Independent (37 CFR 1.16(h))	* 3	Minus	*** 3	= 0		x $480 =	0
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	0

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=		x $0 =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=		x $0 =	
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.	LIE
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".	/ANTJUAN M RIVERA/
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".	
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.	

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

22045 7590 11/08/2021

Brooks Kushman
1000 Town Center
22nd Floor
Southfield, MI 48075

EXAMINER
LE, TUNG X

ART UNIT	PAPER NUMBER
2844	

DATE MAILED: 11/08/2021

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/152,399	01/19/2021	Yechezkal Evan Spero	TRCH0103PUSP3	6274

TITLE OF INVENTION: ADAPTIVE HEADLIGHT SYSTEM

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1200	$0.00	$0.00	$1200	02/08/2022

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Maintenance fees are due in utility patents issuing on applications filed on or after Dec. 12, 1980. It is patentee's responsibility to ensure timely payment of maintenance fees when due. More information is available at www.uspto.gov/PatentMaintenanceFees.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

22045 7590 11/08/2021

Brooks Kushman
1000 Town Center
22nd Floor
Southfield, MI 48075

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

(Typed or printed name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/152,399	01/19/2021	Yechezkal Evan Spero	TRCH0103PUSP3	6274

TITLE OF INVENTION: ADAPTIVE HEADLIGHT SYSTEM

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1200	$0.00	$0.00	$1200	02/08/2022

EXAMINER	ART UNIT	CLASS-SUBCLASS
LE, TUNG X	2844	315-152000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. Fees submitted: ❑Issue Fee ❑Publication Fee (if required) ❑Advance Order - # of Copies _____

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

❑ Electronic Payment via EFS-Web ❑ Enclosed check ❑ Non-electronic payment by credit card (Attach form PTO-2038)

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. _____

5. **Change in Entity Status** (from status indicated above)

❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/152,399	01/19/2021	Yechezkal Evan Spero	TRCH0103PUSP3	6274

22045 7590 11/08/2021

Brooks Kushman
1000 Town Center
22nd Floor
Southfield, MI 48075

EXAMINER	
LE, TUNG X	
ART UNIT	PAPER NUMBER
2844	

DATE MAILED: 11/08/2021

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 17/152,399	Applicant(s) Spero, Yechezkal Evan	
	Examiner TUNG X LE	Art Unit 2844	AIA (FITF) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to 7/14/2021.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☑ The allowed claim(s) is/are 1-33 . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some* c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☑ Notice of References Cited (PTO-892)
2. ☑ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 7/8/2021.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☐ Examiner's Amendment/Comment
6. ☑ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/TUNG X LE/
Primary Examiner, Art Unit 2844

DETAILED ACTION

Notice of Pre-AIA or AIA Status

The present application is being examined under the pre-AIA first to invent provisions.

This Office Action is in response to the Applicant's amendment submitted on July 14, 2021. In virtue of this amendment, claims 1-33 are now pending in the instant application.

Information Disclosure Statement

1. The information disclosure statement (IDS) submitted on 7/8/2021 is in compliance with the provisions of 37 CFR 1.97. Accordingly, the information disclosure statement is being considered by the examiner.

Allowable Subject Matter

2. Claims **1-33** are allowed.

3. The following is an examiner's statement of reasons for allowance:

Prior art of record fails to disclose or fairly suggest the following limitations:

A system, for a motor vehicle, comprising … "*the one or more processors to receive first data, including at least map data, indicating a road curvature upcoming along a road on which the motor vehicle is traveling; determine a light change, the change adapting a light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction of the road curvature ahead of the motor vehicle and shaping light based at least in part on the road curvature; and control at least a first plurality of the LED light sources to provide light based at least in part on the determined light change and prior to the motor vehicle reaching the road curvature*", in combination with the remaining claimed limitations as claimed in independent claim 1 (claims 2-11 are allowed as being dependent on claim 1).

A non-transitory computer-readable storage medium, storing instructions that, when executed by one or more processors of a motor vehicle … "*the one or more processors to receive first data, including at least map data, indicating a road curvature upcoming along a road on which the motor vehicle is traveling; determine a light change, the change adapting a light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction of the road curvature ahead of the motor vehicle and shaping light based at least in part on the road curvature; and control at least a first plurality of the LED light sources to provide light based at least in part on the determined light change and prior to the motor vehicle reaching the road curvature*", in combination with the remaining claimed limitations as claimed in independent claim 12 (claims 13-22 are allowed as being dependent on claim 12).

A computer-implemented method for adapting light from headlamps of a motor vehicle … comprising "*determining an upcoming shape change of a road, ahead of the motor vehicle, based on first data, including map data, indicating the shape change; determining a light output, the output adapting a light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction associated with the shape change ahead of the motor vehicle and shaping light based on the shape change; and prior to reaching the road shape change, causing at least a first plurality of the LED light sources to provide light based at least in part on the determined light output*", in combination with the remaining claimed limitations as claimed in independent claim 23 (claims 24-33 are allowed as being dependent on claim 23).

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Conclusion

4. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

Prior art Stam et al. – US 6,049,171

Prior art Schofield et al. – US 5,796,094

5. Any inquiry concerning this communication or earlier communications from the examiner should be directed to TUNG X LE whose telephone number is (571)272-6010. The examiner can normally be reached Monday to Friday from 10am to 6pm.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Amy C Johnson can be reached on 571-272-2238. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of published or unpublished applications may be obtained from Patent Center. Unpublished application information in Patent Center is available to registered users. To file and manage patent submissions in Patent Center, visit: https://patentcenter.uspto.gov. Visit https://www.uspto.gov/patents/apply/patent-center for more information about Patent Center and https://www.uspto.gov/patents/docx for information about filing in DOCX format. For additional questions, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/TUNG X LE/
Primary Examiner, Art Unit 2844
October 22, 2021

Notice of References Cited	Application/Control No. 17/152,399	Applicant(s)/Patent Under Reexamination Spero, Yechezkal Evan	
	Examiner TUNG X LE	Art Unit 2844	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-6049171-A	04-2000	Stam; Joseph S.	B60Q1/1423	315/82
*	B	US-5796094-A	08-1998	Schofield; Kenneth	B60N2/002	250/208.1
	C					
	D					
	E					
	F					
	G					
	H					
	I					
	J					
	K					
	L					
	M					

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/152,399	Spero, Yechezkal Evan
	Examiner	Art Unit
	TUNG X LE	2844

CPC - Searched*		
Symbol	Date	Examiner
B60Q: 1/04, 1/085, 1/1423, 2300/112, 2300/134	07/01/2021	TXL
updated above	10/22/2021	TXL

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	Date	Examiner
EAST (see search history printout)	07/01/2021	TXL
CPC Searches	07/01/2021	TXL
Inventor and Assignee Searches	07/01/2021	TXL
Citations: Forward and Backward	07/01/2021	TXL
Updated EAST (see search history printout)	10/22/2021	TXL

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner
B60Q	1/085, 1/1423	10/22/2021	TXL

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/152,399	Spero, Yechezkal Evan
	Examiner	**Art Unit**
	TUNG X LE	2844

CPC						
Symbol					**Type**	**Version**
B60Q	/	1	/	04	F	2013-01-01
F21K	/	9	/	23	I	2016-08-01
F21K	/	9	/	232	I	2016-08-01
B60Q	/	1	/	085	I	2013-01-01
B60Q	/	1	/	1423	I	2013-01-01
F21V	/	19	/	02	I	2013-01-01
F21V	/	23	/	0471	I	2013-01-01
F21V	/	23	/	0464	I	2013-01-01
F21V	/	23	/	0478	I	2013-01-01
F21S	/	4	/	28	I	2016-01-01
F21S	/	41	/	143	I	2018-01-01
F21S	/	41	/	147	I	2018-01-01
F21S	/	41	/	65	I	2018-01-01
H05B	/	47	/	105	I	2020-01-01
H05B	/	45	/	20	I	2020-01-01
H05B	/	47	/	10	I	2020-01-01
H05B	/	47	/	11	I	2020-01-01
F21S	/	41	/	153	I	2018-01-01
H05B	/	47	/	115	I	2020-01-01
H05B	/	45	/	395	I	2020-01-01
H05B	/	3	/	008	I	2013-01-01
F21V	/	29	/	74	A	2015-01-15
F21Y	/	2115	/	10	A	2016-08-01
B60Q	/	2300	/	054	A	2013-01-01
B60Q	/	2300	/	112	A	2013-01-01
B60Q	/	2300	/	116	A	2013-01-01
B60Q	/	2300	/	122	A	2013-01-01
B60Q	/	2300	/	134	A	2013-01-01
B60Q	/	2300	/	142	A	2013-01-01
B60Q	/	2300	/	21	A	2013-01-01
B60Q	/	2300	/	23	A	2013-01-01

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	33	
/TUNG X LE/ Primary Examiner, Art Unit 2844	22 October 2021	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	22

U.S. Patent and Trademark Office

Part of Paper No.: 20211022

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/152,399	Spero, Yechezkal Evan
	Examiner	**Art Unit**
	TUNG X LE	2844

CPC						
Symbol					**Type**	**Version**
B60Q	/	2300	/	312	A	2013-01-01
B60Q	/	2300	/	314	A	2013-01-01
B60Q	/	2300	/	322	A	2013-01-01
B60Q	/	2300	/	41	A	2013-01-01
B60Q	/	2300	/	42	A	2013-01-01
F21V	/	21	/	02	A	2013-01-01
F21V	/	21	/	30	A	2013-01-01
F21W	/	2111	/	023	A	2013-01-01
F21W	/	2111	/	027	A	2013-01-01
F21W	/	2111	/	08	A	2013-01-01
F21W	/	2131	/	103	A	2013-01-01
F21W	/	2131	/	40	A	2013-01-01
F21Y	/	2113	/	00	A	2013-01-01
F21W	/	2102	/	00	A	2018-01-01
Y02B	/	20	/	30	A	2013-01-01
Y02B	/	20	/	40	A	2013-01-01

CPC Combination Sets							
Symbol					**Type**	**Set**	**Ranking**	**Version**
	/		/					

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	33	
/TUNG X LE/ Primary Examiner, Art Unit 2844	22 October 2021	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	22

U.S. Patent and Trademark Office — Part of Paper No.: 20211022

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/152,399	Spero, Yechezkal Evan
	Examiner	**Art Unit**
	TUNG X LE	2844

INTERNATIONAL CLASSIFICATION				
CLAIMED				
B60Q	/	1	/	04

NON-CLAIMED				
	/		/	

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**

CROSS REFERENCES(S)						
CLASS	**SUBCLASS (ONE SUBCLASS PER BLOCK)**					

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	33	
/TUNG X LE/ Primary Examiner, Art Unit 2844	22 October 2021	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	22

U.S. Patent and Trademark Office — Part of Paper No.: 20211022

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/152,399	Spero, Yechezkal Evan
	Examiner	**Art Unit**
	TUNG X LE	2844

☑ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
	1		10		19		28								
	2		11		20		29								
	3		12		21		30								
	4		13		22		31								
	5		14		23		32								
	6		15		24		33								
	7		16		25										
	8		17		26										
	9		18		27										

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	33	
/TUNG X LE/ Primary Examiner, Art Unit 2844	22 October 2021	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	22

U.S. Patent and Trademark Office Part of Paper No.: 20211022

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	17	"10604360"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/10/22 09:16
L10	2	"10894503".pn.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/10/22 09:28
L11	61	("20010014019" | "20020022774" | "20020022927" | "20020039238" | "20020046100" | "20020047628" | "20020047646" | "20020057340" | "20020130326" | "20040052076" | "20040061605" | "20040105264" | "20040138726" | "20040230358" | "20060222213" | "20080136356" | "20090315485" | "20100052550" | "20100302779" | "20110211110" | "20120001566" | "20120091897" | "20120262575" |	US-PGPUB; USPAT; USOCR	OR	ON	2021/10/22 09:28

		"20120283908" | "20130258688" | "4597033" | "5018290" | "5033099" | "5130909" | "5546475" | "5561346" | "5577832" | "5749646" | "5785243" | "5803579" | "5921660" | "5969754" | "5983161" | "5994844" | "6046549" | "6149283" | "6166496" | "6281632" | "6340868" | "6346777" | "6379022" | "6385352" | "6394614" | "6406172" | "6483439" | "6498440" | "6499860" | "6528954" | "6601982" | "6676282" | "6820998" | "7524097" | "8045760" | "8115394" | "8665079" | "9398270").PN. OR ("10894503").URPN.				
L19	765	("20020003571" | "20020113873" | "20020159270" | "20020188392" | "20030025597" | "20030052773" | "20030137586" | "20030156015" | "20030169522" | "20030222982" | "20030236622" | "20040149504" | "20040200948" | "20050073853" | "20050219852" | "20050232469" | "20050237385" | "20060018511" | "20060018512" | "20060050018" | "20060091813" |	US-PGPUB; USPAT; USOCR	OR	ON	2021/10/22 09:30

"20060103727" |
"20060125919" |
"20060164230" |
"20060171704" |
"20060250501" |
"20070104476" |
"20070109406" |
"20070120657" |
"20070242339" |
"20080147321" |
"20090052003" |
"20090113509" |
"20090190015" |
"20090201137" |
"20090243824" |
"20090256938" |
"20120045112" |
"2598420" | "2632040" |
"2827594" | "2959709" |
"3751711" | "3985424" |
"4037134" | "4200361" |
"4214266" | "4218698" |
"4236099" | "4247870" |
"4249160" | "4257703" |
"4258979" | "4266856" |
"4277804" | "4281898" |
"4288814" | "4355271" |
"4357558" | "4381888" |
"4420238" | "4431896" |
"4443057" | "4460831" |
"4481450" | "4491390" |
"4512637" | "4529275" |
"4529873" | "4546551" |
"4549208" | "4571082" |
"4572619" | "4580875" |
"4599544" | "4600913" |
"4603946" | "4614415" |
"4620141" | "4623222" |
"4626850" | "4629941" |
"4630109" | "4632509" |
"4638287" | "4647161" |
"4653316" | "4665321" |
"4669825" | "4671615" |
"4672457" | "4676601" |

"4690508" | "4692798" |
"4697883" | "4701022" |
"4713685" | "4717830" |
"4727290" | "4731669" |
"4741603" | "4768135" |
"4772942" | "4789904" |
"4793690" | "4817948" |
"4820933" | "4825232" |
"4838650" | "4847772" |
"4855822" |
"4859031").PN. OR
("4862037" | "4867561" |
"4871917" | "4872051" |
"4881019" | "4882466" |
"4882565" | "4886960" |
"4891559" | "4892345" |
"4895790" | "4896030" |
"4900133" | "4907870" |
"4910591" | "4916374" |
"4917477" | "4931937" |
"4937796" | "4942533" |
"4953305" | "4956591" |
"4961625" | "4967319" |
"4970653" | "4971430" |
"4974078" | "4975703" |
"4987357" | "4987410" |
"4991054" | "5001558" |
"5003288" | "5008946" |
"5012082" | "5016977" |
"5027001" | "5027200" |
"5036437" | "5044706" |
"5050966" | "5055668" |
"5059877" | "5063603" |
"5064274" | "5072154" |
"5086253" | "5086510" |
"5096287" | "5097362" |
"5100093" | "5121200" |
"5124549" | "5128874" |
"5130709" | "5144685" |
"5148014" | "5166681" |
"5168378" | "5170374" |
"5172235" | "5177685" |
"5182502" | "5184956" |
"5187383" | "5189561" |

"5193000" | "5193029" |
"5204778" | "5208701" |
"5214408" | "5225827" |
"5235178" | "5245422" |
"5246193" | "5253109" |
"5276389" | "5285060" |
"5289182" | "5289321" |
"5298732" | "5304980" |
"5305012" | "5307136" |
"5309137" | "5313072" |
"5325096" | "5325386" |
"5329206" | "5331312" |
"5336980" | "5341437" |
"5351044" | "5355118" |
"5365603" | "5369590" |
"5371535" | "5374852" |
"5379196" | "5386285" |
"5394333" | "5406395" |
"5408346" | "5410346" |
"5414257" | "5414461" |
"5416313" | "5416318" |
"5416478" | "5424952" |
"5426294" | "5430431" |
"5434407" | "5434927" |
"5440428" | "5444478" |
"5448484" | "5451822" |
"5457493" | "5461357" |
"5461361" | "5467284" |
"5469298" | "5471515" |
"5475494").PN. OR
("5483060" | "5487116" |
"5488496" | "5493392" |
"5498866" | "5500766" |
"5508592" | "5510983" |
"5515448" | "5521633" |
"5528698" | "5529138" |
"5530240" | "5530420" |
"5530771" | "5535144" |
"5535314" | "5537003" |
"5539397" | "5541590" |
"5550677" | "5555136" |
"5555312" | "5555555" |
"5568027" | "5568316" |
"5574443" | "5581464" |

"5582383" | "5594222" |
"5612883" | "5614788" |
"5617085" | "5619370" |
"5627586" | "5634709" |
"5638116" | "5642093" |
"5642299" | "5646612" |
"5648835" | "5650944" |
"5660454" | "5661303" |
"5666028" | "5668663" |
"5670935" | "5673019" |
"5675489" | "5676484" |
"5677851" | "5680263" |
"5699044" | "5699057" |
"5715093" | "5724187" |
"5724316" | "5737226" |
"5745310" | "5757949" |
"5760826" | "5760828" |
"5760931" | "5760962" |
"5761094" | "5764139" |
"5765116" | "5765940" |
"5781437" | "5786772" |
"5790403" | "5790973" |
"5793308" | "5793420" |
"5796094" | "5798575" |
"5808589" | "5811888" |
"5835255" | "5835613" |
"5837994" | "5841126" |
"5844505" | "5844682" |
"5845000" | "5848802" |
"5850176" | "5850254" |
"5867591" | "5877707" |
"5877897" | "5878370" |
"5883739" | "5884212" |
"5890021" | "5890083" |
"5892855" | "5896085" |
"5899956" | "5912534" |
"5914815" | "5923027" |
"5929784" | "5929786" |
"5938320" | "5940120" |
"5942853" | "5949331" |
"5956181" | "5959367" |
"5959555" | "5963247" |
"5964822" | "5971552" |
"5986796" | "5990469" |

"5990649" | "6001486" |
"6005492" | "6009336" |
"6009377" | "6020704" |
"6031484" | "6037860" |
"6037975").PN. OR
("6044321" | "6049171" |
"6049619" | "6057754" |
"6066933" | "6084519" |
"6087953" | "6097023" |
"6097024" | "6104552" |
"6107939" | "6116743" |
"6124647" | "6124886" |
"6139172" | "6144022" |
"6144158" | "6150014" |
"6166628" | "6169940" |
"6172613" | "6173222" |
"6175164" | "6175300" |
"6198409" | "6201236" |
"6201642" | "6218960" |
"6222447" | "6222460" |
"6226389" | "6226592" |
"6229319" | "6243003" |
"6246961" | "6249214" |
"6250148" | "6259412" |
"6266082" | "6266442" |
"6269308" | "6278377" |
"6282483" | "6285393" |
"6291906" | "6292111" |
"6292752" | "6294989" |
"6297781" | "6302545" |
"6310611" | "6311119" |
"6313454" | "6315421" |
"6317057" | "6318870" |
"6320176" | "6320282" |
"6324450" | "6326613" |
"6329925" | "6330511" |
"6333759" | "6341523" |
"6353392" | "6362729" |
"6366213" | "6366236" |
"6370329" | "6388565" |
"6388580" | "6396397" |
"6411204" | "6411328" |
"6420975" | "6424273" |
"6428172" | "6429594" |

"6430303" | "6433676" |
"6433817" | "6441748" |
"6442465" | "6469739" |
"6472979" | "6477464" |
"6485155" | "6497503" |
"6498620" | "6513252" |
"6516272" | "6516664" |
"6523964" | "6534884" |
"6539306" | "6540193" |
"6547133" | "6553130" |
"6559435" | "6574033" |
"6578017" | "6580996" |
"6587573" | "6589625" |
"6590719" | "6593565" |
"6594583" | "6611202" |
"6611610" | "6627918" |
"6631994" | "6636258" |
"6648477" | "6650233" |
"6650455" | "6671607" |
"6672731" | "6674562" |
"6678056" | "6678614" |
"6680792" | "6690268" |
"6691008" | "6700605" |
"6703925").PN. OR
("6704621" | "6708100" |
"6710908" | "6711474" |
"6714331" | "6717610" |
"6728393" | "6728623" |
"6735506" | "6741377" |
"6744353" | "6748312" |
"6757109" | "6762867" |
"6764210" | "6765480" |
"6784828" | "6794119" |
"6795221" | "6801127" |
"6801244" | "6802617" |
"6806452" | "6812463" |
"6819231" | "6822563" |
"6823241" | "6823261" |
"6824281" | "6831261" |
"6838980" | "6842189" |
"6847487" | "6859148" |
"6861809" | "6873253" |
"6882287" | "6888447" |
"6889161" | "6891563" |

"6898518" | "6906620" |
"6906639" | "6909753" |
"6914521" | "6932669" |
"6933837" | "6940423" |
"6941216" | "6946978" |
"6950035" | "6953253" |
"6959994" | "6961178" |
"6961661" | "6967569" |
"6968266" | "6968736" |
"6975775" | "6989736" |
"6995687" | "7004593" |
"7004606" | "7005974" |
"7012727" | "7023331" |
"7030738" | "7030778" |
"7038577" | "7046448" |
"7057505" | "7057681" |
"7062300" | "7065432" |
"7068289" | "7085633" |
"7085637" | "7092548" |
"7095432" | "7106213" |
"7110021" | "7110156" |
"7116246" | "7121028" |
"7123168" | "7133661" |
"7149613" | "7151844" |
"7167796" | "7187498" |
"7195381" | "7202776" |
"7202987" | "7205904" |
"7221363" | "7224324" |
"7227459" | "7227611" |
"7235918" | "7248287" |
"7249860" | "7253723" |
"7255451" | "7271951" |
"7295682" | "7304661" |
"7311406" | "7325934" |
"7325935" | "7337055" |
"7338177" | "7339149" |
"7344261" | "7355524" |
"7360932" | "7370983" |
"7375803" | "7380948" |
"7388182" | "7402786" |
"7420756" | "7423248" |
"7423821" | "7425076" |
"7429998").PN. OR
("7432967" | "7446924" |

		"7459664" | "7460007" | "7463138" | "7474963" | "7489374" | "7495719" | "7525604" | "7526103" | "7541743" | "7543946" | "7545429" | "7548291" | "7551103" | "7561181" | "7565006" | "7567291" | "7613327" | "7616781" | "7619508" | "7629996" | "7633383" | "7639149" | "7653215" | "7655894" | "7663798" | "7676087" | "7679498" | "7720580" | "7724434" | "7731403" | "7742864" | "7791694" | "7792329" | "7842154" | "7843451" | "7854514" | "7855755" | "7855778" | "7859565" | "7881496" | "7903324" | "7903335" | "7914187" | "7930160" | "7949152" | "7965357" | "7994462" | "8017898" | "8027691" | "8090153" | "8095310" | "8098142" | "8120652" | "8184159" | "8203440" | "8222588" | "8224031" | "8289142" | "8289430" | "8305471" | "8308325" | "8314689" | "8324552" | "8339526" | "8405726" | "D351370" | "RE30835").PN. OR ("8665079").URPN.				
L20	234	("20010014019" | "20020022774" | "20020022927" | "20020039238" | "20020046100" | "20020047628" | "20020047646" | "20020057340" |	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/10/22 09:35

		"20020130326" | "20040052076" | "20040061605" | "20040105264" | "20040138726" | "20040230358" | "20060222213" | "20080136356" | "20090315485" | "20100052550" | "20100302779" | "20110211110" | "20120001566" | "20120091897" | "20120262575" | "20120283908" | "20120287493" | "20130258688" | "3316442" | "4597033" | "5018290" | "5033099" | "5130909" | "5546475" | "5561346" | "5577832" | "5749646" | "5785243" | "5803579" | "5921660" | "5969754" | "5983161" | "5994844" | "6046549" | "6149283" | "6166496" | "6227679" | "6281632" | "6340868" | "6346777" | "6379022" | "6385352" | "6394614" | "6406172" | "6483439" | "6498440" | "6499860" | "6528954" | "6587573" | "6601982" | "6676282" | "6820998" | "6861809" | "7524097" | "8045760" | "8115394" | "8665079" | "9398270").PN.				
L21	22,639	vehicle with (headlamp or headlight or lamp or (light near2 source)) and	US-PGPUB; USPAT; USOCR; FPRS; EPO;	OR	ON	2021/10/22 09:57

		(memory with (data or instruction))	JPO; DERWENT; IBM_TDB			
L22	18	(yechezkal near3 evan near3 spero).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/10/22 09:58
L23	16,896	(B60Q1/04 or B60Q1/085 or B60Q1/1423 or B60Q2300/112 or B60Q2300/134).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/10/22 09:58
L24	38,900	21 or 23	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/10/22 09:59
L25	513	24 and ((adjust$4 or chang$3 or shap$3) near2 light) and ((headlight or headlamp) with LED.u/c.)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/10/22 09:59
L26	31	25 and (map with data) and (road with (curvature or curv$3))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/10/22 10:00
L27	249	("20020040962" | "2131888" | "2632040" | "2827594" | "3179845" | "3581276" | "3663819" |	US-PGPUB; USPAT; USOCR	OR	ON	2021/10/22 10:03

"4139801"	"4151526"
"4236099"	"4258979"
"4286308"	"4357558"
"4376909"	"4479173"
"4599544"	"4645975"
"4665321"	"4692798"
"4716298"	"4727290"
"4768135"	"4862037"
"4891559"	"4930742"
"4934273"	"4967319"
"5008946"	"5036437"
"5072154"	"5086253"
"5096287"	"5124549"
"5166681"	"5182502"
"5187383"	"5235178"
"5329206"	"5347261"
"5347459"	"5355146"
"5379104"	"5396054"
"5402170"	"5416318"
"5426294"	"5428464"
"5430450"	"5434407"
"5451822"	"5452004"
"5471515"	"5475441"
"5481268"	"5483346"
"5485155"	"5508592"
"5537003"	"5541724"
"5550677"	"5554912"
"5574463"	"5587929"
"5592146"	"5614788"
"5621460"	"5660454"
"5666028"	"5684473"
"5707129"	"5710565"
"5714751"	"5715093"
"5736816"	"5751832"
"5781105"	"5786787"
"5796094"	"5798727"
"5811888"	"5812321"
"5835613"	"5837994"
"5841126"	"5845000"
"5867214"	"5877897"
"5905457"	"5912534"
"5923027"	"5942853"
"5990469"	"6008486"
"6018308"	"6049171"

		"6097023" | "6102546" | "6130421" | "6140933" | "6144158" | "6166698" | "6184781" | "6255639" | "6281632" | "6329925" | "6349782" | "6356376" | "6379013" | "6396040" | "6396397" | "6403942" | "6442465" | "6443602" | "6465962" | "6469739" | "6483438" | "6507779" | "6617564").PN. OR ("6861809").URPN.				
L28	8	("20020036901" | "20100188864" | "20160039286" | "20170136939" | "20170158112" | "20180099605" | "6220735" | "6861809").PN. OR ("10953790").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2021/10/22 10:05
L29	457	25 not 26	US-PGPUB; USPAT; USOCR	OR	ON	2021/10/22 10:12
L30	145	("20020040962" | "2131888" | "2632040" | "2827594" | "3179845" | "3581276" | "4139801" | "4236099" | "4357558" | "4376909" | "4599544" | "4665321" | "4692798" | "4727290" | "4768135" | "4862037" | "4891559" | "4930742" | "4967319" | "5036437" | "5072154" | "5086253" | "5124549" | "5166681" | "5182502" | "5187383" | "5235178" | "5329206" | "5416318" | "5426294" | "5434407" | "5451822" | "5471515" | "5508592" | "5537003" |	US-PGPUB; USPAT; USOCR	OR	ON	2021/10/22 10:18

		"5550677" | "5614788" | "5660454" | "5666028" | "5707129" | "5715093" | "5796094" | "5811888" | "5812321" | "5835613" | "5837994" | "5841126" | "5877897" | "5912534" | "5923027" | "5942853" | "5990469" | "6008486" | "6049171" | "6097023" | "6130421" | "6144158" | "6166698" | "6329925" | "6349782" | "6356376" | "6396397" | "6465962" | "6507779").PN. OR ("6728393").URPN.				
L31	1	(vehicle and headlamp and LED.u/c. and processor and memory and (data with map with road with curvature) and (light with pattern with color with shap$3)).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/10/22 10:24
L32	233	("2449338" | "3348095" | "3385998" | "3414763" | "3430100" | "3764816" | "3993914" | "4667129" | "4684819" | "4686423" | "4831310" | "4841199" | "4862036" | "4899083" | "4956562" | "5136209" | "5185558" | "5614788" | "5666028").PN. OR ("5912534").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2021/10/22 11:33

10/22/2021 11:34:11 AM
C:\Users\tle16\Documents\EAST\Workspaces\17152399.wsp

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

BIB DATA SHEET

CONFIRMATION NO. 6274

SERIAL NUMBER	FILING or 371(c) DATE RULE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
17/152,399	01/19/2021	315	2844	TRCH0103PUSP3

APPLICANTS

INVENTORS

Yechezkal Evan Spero, Tifrach, ISRAEL;

**** CONTINUING DATA ***************************

This application is a CON of 15/961,861 04/24/2018 PAT 10894503
which is a CON of 13/357,549 01/24/2012 PAT 9955551
which is a CIP of 10/604,360 07/14/2003 PAT 8100552
which claims benefit of 60/395,308 07/12/2002
and said 13/357,549 01/24/2012
claims benefit of 61/535,981 09/17/2011

**** FOREIGN APPLICATIONS ***************************

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ****

02/23/2021

Foreign Priority claimed	35 USC 119(a-d) conditions met	Verified and Acknowledged	Met after Allowance	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
❑ Yes ☑ No	❑ Yes ☑ No	/TUNG X LE/ Examiner's Signature	❑ TXL Initials	ISRAEL	24	33	3

ADDRESS

Brooks Kushman
1000 Town Center
22nd Floor
Southfield, MI 48075
UNITED STATES

TITLE

ADAPTIVE HEADLIGHT SYSTEM

FILING FEE RECEIVED		
3540	FEES: Authority has been given in Paper No._____ to charge/credit DEPOSIT ACCOUNT No._____ for following:	❑ All Fees ❑ 1.16 Fees (Filing) ❑ 1.17 Fees (Processing Ext. of time) ❑ 1.18 Fees (Issue) ❑ Other _____ ❑ Credit

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (02-18)
Approved for use through 11/30/2020. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	17152399
Filing Date	2021-01-19
First Named Inventor	YECHEZKAL EVAN SPERO
Art Unit	2844
Examiner Name	LE, TUNG X
Attorney Docket Number	TRCH0103PUSP3

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	3,316,442	A	1967-04-25	Konrad	
	2	4,597,033	A	1986-06-24	Meggs et al.	
	3	5,018,290	A	1991-05-28	Kozek et al.	
	4	5,033,099	A	1991-07-16	Yamada et al.	
	5	5,130,909	A	1992-07-14	Gross	
	6	5,546,475	A	1996-08-13	Bolle et al.	
	7	5,561,346	A	1996-10-01	Byrne	
	8	5,577,832	A	1996-11-26	Lodhie	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /T.X.L/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17152399
	Filing Date	2021-01-19
	First Named Inventor	YECHEZKAL EVAN SPERO
	Art Unit	2844
	Examiner Name	LE, TUNG X
	Attorney Docket Number	TRCH0103PUSP3

	9	5,749,646	A	1998-05-12	Brittell	
	10	5,785,243	A	1998-07-28	Cross	
	11	5,803,579	A	1998-09-08	Turnbull	
	12	5,921,660	A	1999-07-13	Yu	
	13	5,969,754	A	1999-10-19	Zeman	
	14	5,983,161	A	1999-11-09	Lemelson et al.	
	15	5,994,844	A	1999-11-30	Crawford et al.	
	16	6,046,549	A	2000-04-04	James	
	17	6,149,283	A	2000-11-21	Conway et al.	
	18	6,166,496	A	2000-12-26	Lys et al.	
	19	6,227,679	B1	2001-05-08	Zhang et al.	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /T.X.L/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17152399
	Filing Date	2021-01-19
	First Named Inventor	YECHEZKAL EVAN SPERO
	Art Unit	2844
	Examiner Name	LE, TUNG X
	Attorney Docket Number	TRCH0103PUSP3

	20	6,281,632	B1	2001-08-28	Stam et al.	
	21	6,340,868	B1	2002-01-22	Lys et al.	
	22	6,346,777	B1	2002-02-12	Kim	
	23	6,379,022	B1	2002-04-30	Amerson et al.	
	24	6,385,352	B1	2002-05-07	Roustaei	
	25	6,394,614	B1	2002-05-28	Chang	
	26	6,406,172	B1	2002-06-18	Harbers et al.	
	27	6,483,439	B1	2002-11-19	Vukosic	
	28	6,498,440	B2	2002-12-24	Stam et al.	
	29	6,499,860	B2	2002-12-31	Begemann	
	30	6,528,954	B1	2003-03-04	Lys et al.	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /T.X.L/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17152399
	Filing Date	2021-01-19
	First Named Inventor	YECHEZKAL EVAN SPERO
	Art Unit	2844
	Examiner Name	LE, TUNG X
	Attorney Docket Number	TRCH0103PUSP3

	31	6,601,982	B1	2003-08-05	Begemann et al.	
	32	6,676,282	B2	2004-01-13	Begemann et al.	
	33	6,820,998	B2	2004-11-23	Chen	
	34	7,524,097	B2	2009-04-28	Turnbull et al.	
	35	8,045,760	B2	2011-10-25	Stam et al.	
	36	8,115,394	B2	2012-02-14	Kobayashi	
	37	8,665,079	B2	2014-03-14	Pawlicki et al.	
	38	9,398,270	B2	2016-07-19	Liken et al.	
	39	6,587,573	B1	2003-07-01	Stam et al.	
	40	6,861,809	B2	2005-03-01	Stam	

If you wish to add additional U.S. Patent citation information please click the Add button. Add

U.S.PATENT APPLICATION PUBLICATIONS Remove

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /T.X.L/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	17152399
Filing Date	2021-01-19
First Named Inventor	YECHEZKAL EVAN SPERO
Art Unit	2844
Examiner Name	LE, TUNG X
Attorney Docket Number	TRCH0103PUSP3

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20010014019	A1	2001-08-16	Begemann	
	2	20020022774	A1	2002-02-21	Kamieli	
	3	20020022927	A1	2002-02-21	Lemelson et al.	
	4	20020039238	A1	2002-04-04	Chang	
	5	20020046100	A1	2002-04-18	Kinjo	
	6	20020047646	A1	2002-04-25	Lys et al.	
	7	20020047628	A1	2002-04-25	Morgan et al.	
	8	20020057340	A1	2002-05-16	Fernandez et al.	
	9	20020130326	A1	2002-09-19	Tamura et al.	
	10	20040052076	A1	2004-03-18	Mueller	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /T.X.L/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17152399
	Filing Date	2021-01-19
	First Named Inventor	YECHEZKAL EVAN SPERO
	Art Unit	2844
	Examiner Name	LE, TUNG X
	Attorney Docket Number	TRCH0103PUSP3

	11	20040061605	A1	2004-04-01	Howard	
	12	20040105264	A1	2004-06-03	Spero	
	13	20040138726	A1	2004-07-15	Savage et al.	
	14	20040230358	A1	2004-11-18	Stam et al.	
	15	20060222213	A1	2006-10-05	Kiyohara et al.	
	16	20080136356	A1	2008-06-12	Zampini et al.	
	17	20090315485	A1	2009-12-24	Verfuerth et al.	
	18	20100302779	A1	2010-12-02	Chemel	
	19	20100052550	A1	2010-03-04	Kobayashi	
	20	20110211110	A1	2011-09-01	Doublet	
	21	20120001566	A1	2012-01-05	Josefowicz	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /T.X.L/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17152399
	Filing Date	2021-01-19
	First Named Inventor	YECHEZKAL EVAN SPERO
	Art Unit	2844
	Examiner Name	LE, TUNG X
	Attorney Docket Number	TRCH0103PUSP3

	22	20120091897	A1	2012-04-19	O et al.	
	23	20120262575	A1	2012-10-18	Champagne	
	24	20120283908	A1	2012-11-08	Schofield et al.	
	25	20120287493	A1	2012-11-15	Kuhlman et al.	
	26	20130258688	A1	2013-10-13	Kalapodas	

If you wish to add additional U.S. Published Application citation information please click the Add button. Add

FOREIGN PATENT DOCUMENTS Remove

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	2001070538	WO	A2	2001-09-27	Stam et al.		

If you wish to add additional Foreign Patent Document citation information please click the Add button Add

NON-PATENT LITERATURE DOCUMENTS Remove

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1		

If you wish to add additional non-patent literature document citation information please click the Add button Add

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /T.X.L/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17152399
	Filing Date	2021-01-19
	First Named Inventor	YECHEZKAL EVAN SPERO
	Art Unit	2844
	Examiner Name	LE, TUNG X
	Attorney Docket Number	TRCH0103PUSP3

EXAMINER SIGNATURE			
Examiner Signature	/TUNG X LE/	Date Considered	10/22/2021

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /T.X.L/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	17152399
Filing Date	2021-01-19
First Named Inventor	YECHEZKAL EVAN SPERO
Art Unit	2844
Examiner Name	LE, TUNG X
Attorney Docket Number	TRCH0103PUSP3

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

See attached certification statement.

☒ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Bernard P. Tomsa/	Date (YYYY-MM-DD)	2021-07-07
Name/Print	Bernard P. Tomsa	Registration Number	60,121

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /T.X.L/

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /T.X.L/

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

YECHEZKAL EVAN SPERO

Group Art Unit: 2844

Examiner: LE, TUNG X.

Serial No.: 17/152,399

Filed: January 19, 2021

For: ADAPTIVE HEADLIGHT SYSTEM

Attorney Docket No.: TRCH0103PUSP3

AMENDMENT AFTER ALLOWANCE
UNDER 37 C.F.R. § 1.312

Mail Stop Issue Fee
Commissioner for Patents
U.S. Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

Please amend the above-identified application as follows:

Amendments to the Specification:

Please amend numbered paragraph [0001], as shown below:

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a Continuation of pending U.S. patent application Ser. No. 15/961,861 filed Apr. 24, 2018, now U.S. Patent No. 10,894,503 which issued January 19, 2021 which is a Continuation of U.S. patent application Ser. No. 13/357,549 filed Jan. 24, 2012, now U.S. Patent No. 9,955,551 which issued Apr. 24, 2018, which is a Continuation-in-Part of U.S. patent application Ser. No. 10/604,360, entitled "Multiple Light-Source Illuminating System" filed on Jul. 14, 2003, now U.S. Patent No. 8,100,552 which issued on Jan. 24, 2012, which claims benefit under 35 U.S.C., § 119(e) of U.S. Provisional Application No. 60/395,308 filed Jul. 12, 2002, entitled "Multiple Light Source Illumination System". U.S. patent application Ser. No. ~~13,357,549~~ 13/357,549 filed Jan. 24, 2012, also claims benefit of U.S. Provisional Application No. 61/535,981 filed Sept. 17, 2011 entitled "Adjustable Light Fixture". The entire content of the disclosures are all expressly incorporated herein by reference.

Remarks

In this amendment, Applicant has amended paragraph [0001] Cross-Reference to Related Applications to correct a typographical error. No new matter has been added. Please charge any fees or credit any overpayments as a result of the filing of this paper to our Deposit Account No. 02-3978.

Respectfully submitted,

YECHEZKAL EVAN SPERO

By: /Bernard P. Tomsa/
Bernard P. Tomsa
Reg. No. 60,121
Attorney for Applicant

Date: November 10, 2021

BROOKS KUSHMAN P.C.
1000 Town Center, 22nd Floor
Southfield, MI 48075-1238
Phone: 248-358-4400
Fax: 248-358-3351

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any changes of address)

22845 7590 11/08/2021

Brooks Kushman
1000 Town Center
22nd Floor
Southfield, MI 48075

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

Bernard P. Tomsa	(Typed or printed name)
/Bernard P. Tomsa/	(Signature)
November 10, 2021	(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/152,399	01/19/2021	Yechezkal Evan Spero	TRCH0103PUSP3	6274

TITLE OF INVENTION: ADAPTIVE HEADLIGHT SYSTEM

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1200	$0.00	$0.00	$1200	02/08/2022

EXAMINER	ART UNIT	CLASS-SUBCLASS
LE, TUNG X	2844	315-152000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Brooks Kushman P.C.
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. Fees submitted: ☒ Issue Fee ☐ Publication Fee (if required) ☐ Advance Order - # of Copies _____

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

☒ Electronic Payment via EFS-Web ☐ Enclosed check ☐ Non-electronic payment by credit card (Attach form PTO-2038)

☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. 02-3978

5. **Change in Entity Status** (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /Bernard P. Tomsa/ Date November 10, 2021

Typed or printed name Bernard P. Tomsa Registration No. 60,121

Electronic Patent Application Fee Transmittal

Application Number:	17152399
Filing Date:	19-Jan-2021
Title of Invention:	ADAPTIVE HEADLIGHT SYSTEM
First Named Inventor/Applicant Name:	Yechezkal Evan Spero
Filer:	Bernard Patrick Tomsa/Claire Flood
Attorney Docket Number:	TRCH0103PUSP3

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
UTILITY APPL ISSUE FEE	1501	1	1200	1200

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**1200**

Electronic Acknowledgement Receipt

EFS ID:	44251972
Application Number:	17152399
International Application Number:	
Confirmation Number:	6274
Title of Invention:	ADAPTIVE HEADLIGHT SYSTEM
First Named Inventor/Applicant Name:	Yechezkal Evan Spero
Customer Number:	22045
Filer:	Bernard Patrick Tomsa/Claire Flood
Filer Authorized By:	Bernard Patrick Tomsa
Attorney Docket Number:	TRCH0103PUSP3
Receipt Date:	10-NOV-2021
Filing Date:	19-JAN-2021
Time Stamp:	16:51:06
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$1200
RAM confirmation Number	E2021A0G53074522
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Miscellaneous Incoming Letter	TRCH0103PUSP3_Comments_on_Reasons_for_Allowance.PDF	81388 2cd98ac4910d23c021de9b3658203d4bcade5a73	no	2
Warnings:					
Information:					
2		TRCH0103PUSP3_Amendment_After_Allowance.pdf	124330 f404448c52ec5d7932e9b815b746d42a2df9cbc4	yes	3

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Amendment after Notice of Allowance (Rule 312)	1	1
	Specification	2	2
	Applicant Arguments/Remarks Made in an Amendment	3	3

Warnings:					
Information:					
3	Issue Fee Payment (PTO-85B)	TRCH0103PUSP3_Issue_Fee_Transmittal.PDF	626735 a8b3d04d9ead03b987f1336e5ef22f7f0d009d1f	no	1
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	37785 a65d4f8db13dc3184061a9cf506c7a1e239c0339	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	870238		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

YECHEZKAL EVAN SPERO

Group Art Unit: 2844

Examiner: LE, TUNG X

Serial No.: 17/152,399

Filed: January 19, 2021

For: ADAPTIVE HEADLIGHT SYSTEM

Attorney Docket No.: TRCH0103PUSP3

COMMENTS ON STATEMENT OF REASONS FOR ALLOWANCE

Mail Stop Issue Fee
Commissioner for Patents
U.S. Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

In response to the Examiner's Statement of Reasons for Allowance contained in the Notice of Allowance mailed November 8, 2021, Applicant submits the following comments:

Remarks

Applicant thanks the Examiner for the allowance of the indicated claims, and while Applicant agrees that the claims are allowable over the prior art, Applicant notes that the reasons listed for allowance are not necessarily the exclusive reasons for allowance, and instead represent sufficient reasons for allowance. Accordingly, Applicant reserves all future rights to take any position that the claims are allowable for a variety of additional and/or alternative reasons if any of the claims should come under scrutiny for any reason, if anyone questions the present reasons for allowance, and/or for any other reasonable and necessary purpose as determined by Applicant.

Respectfully submitted,

YECHEZKAL EVAN SPERO

By: /Bernard P. Tomsa/
Bernard P. Tomsa
Reg. No. 60,121
Attorney for Applicant

Date: November 10, 2021

BROOKS KUSHMAN P.C.
1000 Town Center, 22nd Floor
Southfield, MI 48075-1238
Phone: 248-358-4400
Fax: 248-358-3351

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/152,399	01/19/2021	Yechezkal Evan Spero	TRCH0103PUSP3	6274

22045 7590 11/26/2021

Brooks Kushman
1000 Town Center
22nd Floor
Southfield, MI 48075

EXAMINER	
LE, TUNG X	

ART UNIT	PAPER NUMBER
2844	

NOTIFICATION DATE	DELIVERY MODE
11/26/2021	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

docketing@brookskushman.com
kdilucia@brookskushman.com

Response to Rule 312 Communication	Application No.	Applicant(s)	
	17/152,399	Spero, Yechezkal Evan	
	Examiner	Art Unit	AIA (FITF) Status
	TUNG X LE	2844	No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

1. ☑ The amendment filed on 10 November 2021 under 37 CFR 1.312 has been considered, and has been:

a) ☑ entered.

b) ☐ entered as directed to matters of form not affecting the scope of the invention.

c) ☐ disapproved because the amendment was filed after the payment of the issue fee.

Any amendment filed after the date the issue fee is paid must be accompanied by a petition under 37 CFR 1.313(c)(1) and the required fee to withdraw the application from issue.

d) ☐ disapproved. See explanation below.

e) ☐ entered in part. See explanation below.

Applicant's amendment to specification in paragraph [0001] has been entered.

/TUNG X LE/
Primary Examiner, Art Unit 2844

OK TO ENTER: /T.X.L/ 11/17/2021

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

YECHEZKAL EVAN SPERO

Group Art Unit: 2844

Examiner: LE, TUNG X.

Serial No.: 17/152,399

Filed: January 19, 2021

For: ADAPTIVE HEADLIGHT SYSTEM

Attorney Docket No.: TRCH0103PUSP3

AMENDMENT AFTER ALLOWANCE
UNDER 37 C.F.R. § 1.312

Mail Stop Issue Fee
Commissioner for Patents
U.S. Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

Please amend the above-identified application as follows:

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/152,399	12/28/2021	11208029	TRCH0103PUSP3	6274

22045 7590 12/08/2021

Brooks Kushman
1000 Town Center
22nd Floor
Southfield, MI 48075

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

INVENTOR(s) (Please see PAIR WEB site http://pair.uspto.gov for additional inventors):

Yechezkal Evan Spero, Tifrach, ISRAEL;

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage and facilitate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.

AO 120 (Rev. 08/10)

TO:	REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT OR TRADEMARK
Mail Stop 8 Director of the U.S. Patent and Trademark Office P.O. Box 1450 Alexandria, VA 22313-1450	

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court for the District of Delaware on the following

☐ Trademarks or ☑ Patents. (☐ the patent action involves 35 U.S.C. § 292.):

DOCKET NO.	DATE FILED	U.S. DISTRICT COURT
	6/7/2022	for the District of Delaware

PLAINTIFF	DEFENDANT
Torchlight Technologies LLC	Daimler AG, et al

	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1	9,955,551	4/24/2018	Yechezkal Evan Spero
2	10,894,503	1/19/2021	Yechezkal Evan Spero
3	11,208,029	12/28/2021	Yechezkal Evan Spero
4			
5			

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

DATE INCLUDED	INCLUDED BY ☐ Amendment ☐ Answer ☐ Cross Bill ☐ Other Pleading		
	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1			
2			
3			
4			
5			

In the above—entitled case, the following decision has been rendered or judgement issued:

DECISION/JUDGEMENT

CLERK	(BY) DEPUTY CLERK	DATE

Copy 1—Upon initiation of action, mail this copy to Director Copy 3—Upon termination of action, mail this copy to Director
Copy 2—Upon filing document adding patent(s), mail this copy to Director Copy 4—Case file copy

AO 120 (Rev. 08/10)

TO:	REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT OR TRADEMARK
Mail Stop 8 Director of the U.S. Patent and Trademark Office P.O. Box 1450 Alexandria, VA 22313-1450	

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court for the District of Delaware on the following

☐ Trademarks or ☑ Patents. (☐ the patent action involves 35 U.S.C. § 292.):

DOCKET NO.	DATE FILED	U.S. DISTRICT COURT for the District of Delaware
PLAINTIFF Torchlight Technologies LLC		DEFENDANT General Motors LLC, General Motors Holdings LLC, and General Motors Company

	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1	9,955,551	4/24/2018	Yechezkal Evan Spero
2	10,894,503	1/19/2021	Yechezkal Evan Spero
3	11,208,029	12/28/2021	Yechezkal Evan Spero
4			
5			

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

DATE INCLUDED	INCLUDED BY ☐ Amendment ☐ Answer ☐ Cross Bill ☐ Other Pleading	
PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1		
2		
3		
4		
5		

In the above—entitled case, the following decision has been rendered or judgement issued:

DECISION/JUDGEMENT

CLERK	(BY) DEPUTY CLERK	DATE

Copy 1—Upon initiation of action, mail this copy to Director Copy 3—Upon termination of action, mail this copy to Director
Copy 2—Upon filing document adding patent(s), mail this copy to Director Copy 4—Case file copy