

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 of various wavelengths of light and therefore of variable chromaticity. 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 chromaticity via the differentiated powering of coincidentally 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.

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.

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 through to the homogeneous illuminance of room surfaces even after specific installation adjustment requirements have been made.

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.

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**.

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.

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.

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.

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.

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 or left the house.

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.

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.

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.

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.

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.

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.

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.

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.

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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.

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.

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.

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

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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.

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.

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.

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.

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.

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.

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.

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 FALM 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 cali-

brated 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.

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.

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 coincidentally directed light emitting diodes as is needed to obtain the desired color spectrum of the illumination as well as its luminous intensity.

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, homogeneous 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.

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.

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

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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.

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.

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

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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 then provide localized heating on an as needed basis to maintain comfort. 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.

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.

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.

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 area 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 needed for the security camera then provision is made to have IR sources aimed at the specific areas of concern.

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 coincidentally 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.

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.

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.

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.

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.

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 aimable 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.

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 ambience; 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.

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.

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.

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.

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.

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 these 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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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 conditioning 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.

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.

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.

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.

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 recommended 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.

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/cm² 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 derived even from much dimmer light.

In places where individuals with sleep disorders reside in the hours before going to sleep, it would be 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.

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, communica-

tions 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**.

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.

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.

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 WSAM) 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.

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.

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.

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.

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.

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.

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.

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.

In another embodiment example of a bedroom application (a living room or kitchen lighting application would be much the same), the FALM **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 FALM **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.

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 FALM 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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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

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 adjust-

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ability 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

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.

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.

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.

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.

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,

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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:

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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

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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;

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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 instruc-
tions 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 reflec-
tors, 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

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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 deter-
mining 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 control-
ling 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.

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