UNITED STATES PATENT AND TRADEMARK OFFICE

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

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/552,303	08/23/2022	11422236	103033-P004USC4-1289479	1540

20350 7590 08/03/2022

Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Patents Stakeholder Experience (OPSE), Stakeholder Support Division (SSD) at (571)-272-4200.

INVENTOR(s) (Please see PAIR WEB site http://pair.uspto.gov for additional inventors):

Angus PACALA, San Francisco, CA;
Mark FRICHTL, San Francisco, CA;
Marvin SHU, San Francisco, CA;
Eric YOUNGE, San Francisco, CA;

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Ouster, Inc., San Francisco, CA;

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage and facilitate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.

Doc Code: MFEE.C.AD
Document Description: Maintenance Fee Address Change

PTO/AIA/47 (12-20)
Approved for use through 09/30/2021. OMB 0651-0016
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no person is required to respond to a collection of information unless it displays a valid OMB control number.

"FEE ADDRESS" INDICATION FORM

Address to:
Mail Stop Maintenance Fee
Director of the United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

-OR-

Fax to:
571-273-6500

INSTRUCTIONS: The issue fee must have been paid for the application(s) listed on this form. In addition, only an address represented by a Customer Number can be established as the fee address for maintenance fee purposes (hereafter, fee address). A fee address should be established when correspondence related to maintenance fees should be mailed to a different address than the correspondence address for the application.

When to check the first box below: If you have a Customer Number to represent the fee address.

When to check the second box below: If you have no Customer Number representing the desired fee address, in which case a completed Request for Customer Number (PTO/SB/125) must be attached to this form. For more information on Customer Numbers, see the Manual of Patent Examining Procedure (MPEP) § 403.

For the following listed application(s), please recognize as the "Fee Address" under the provisions of 37 CFR 1.363 the address associated with:

☑ Customer Number: 00197

OR

☐ The attached Request for Customer Number form (PTO/SB/125)

PATENT NUMBER (if known)	APPLICATION NUMBER
	17/552,303

Completed by (check one):

☐ Applicant/Inventor

☑ Attorney or Agent of record 37,234 (Reg. No.)

☐ Assignee of record of the entire interest. See 37 CFR 3.71. Statement under 37 CFR 3.73(c) (Form PTO/AIA/96) is enclosed or was filed on _____ (Date)

/ William L. Shaffer /
Signature

William L. Shaffer
Typed or printed name

858-350-6104
Requester's telephone number

July 15, 2022
Date

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. If the assignee is a juristic entity, this form must be signed by a patent practitioner (attorney or agent) of record. Submit multiple forms if more than one signature is required, see below*.

☑ *Total of 1 forms are submitted

This collection of information is required by 37 CFR 1.363. The information is required to obtain or retain a benefit by the public, which is to indicate (and for the USPTO to process) a fee address. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 5 minutes to complete, including gathering, preparing, and submitting the completed form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND COMPLETED FORMS TO THE PREVIOUS ADDRESS. **SEND COMPLETED FORMS TO: Mail Stop Maintenance Fee, Director of the United States Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450.**

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

Privacy Act Statement

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

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

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

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

20350 7590 04/18/2022
Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

Erica M. Rojas	(Typed or printed name)
/Erica M. Rojas/	(Signature)
July 15, 2022	(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/552,303	12/15/2021	Angus PACALA	103033-P004USC4-1289479	1540

TITLE OF INVENTION: OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$600	$0.00	$0.00	$600	07/18/2022

EXAMINER	ART UNIT	CLASS-SUBCLASS
HELLNER, MARK	3645	356-004010

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/AIA/122 or PTO/SB/122) attached.

☒ "Fee Address" indication (or "Fee Address" Indication form PTO/AIA/47 or PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Kilpatrick Townsend & Stockton LLP
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: Ouster, Inc.

(B) RESIDENCE: (CITY and STATE OR COUNTRY): San Francisco, California

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. Fees submitted: ☒ Issue Fee ☐ Publication Fee (if required) ☐ Advance Order - # of Copies _____

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

☒ Electronic Payment via EFS-Web ☐ Enclosed check ☐ Non-electronic payment by credit card (Attach form PTO-2038)

☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. 201430

5. **Change in Entity Status** (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature / William L. Shaffer / Date July 15, 2022

Typed or printed name William L. Shaffer Registration No. 37,234

UNITED STATES
PATENT AND TRADEMARK OFFICE

P.O. Box 1450
Alexandria, VA 22313 - 1450
www.uspto.gov

ELECTRONIC PAYMENT RECEIPT

APPLICATION #	RECEIPT DATE / TIME	ATTORNEY DOCKET #
17/552,303	07/15/2022 04:56:38 PM ET	103033-P004USC4-1289479

Title of Invention

OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

Application Information

APPLICATION TYPE	Utility - Nonprovisional Application under 35 USC 111(a)	PATENT #	-
CONFIRMATION #	1540	FILED BY	Erica Rojas
PATENT CENTER #	60788259	AUTHORIZED BY	Bill Shaffer
CUSTOMER #	20350	FILING DATE	12/15/2021
CORRESPONDENCE ADDRESS	-	FIRST NAMED INVENTOR	Angus PACALA

Payment Information

PAYMENT METHOD	PAYMENT TRANSACTION ID	PAYMENT AUTHORIZED BY
CARD / 8410	E20227EG57323138	Erica Rojas

PRE-AUTHORIZED ACCOUNT	PRE-AUTHORIZED CATEGORY
201430	37 CFR 1.16 (National application filing, search, and examination fees); 37 CFR 1.17 (Patent application and reexamination processing fees); 37 CFR 1.20 (Post Issuance fees); 37 CFR 1.21 (Miscellaneous fees and charges)

FEE CODE	DESCRIPTION	ITEM PRICE($)	QUANTITY	ITEM TOTAL($)
2501	UTILITY ISSUE FEE	600.00	1	600.00
			TOTAL AMOUNT:	$600.00

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

New Applications Under 35 U.S.C. 111

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

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

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

New International Application Filed with the USPTO as a Receiving Office

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

UNITED STATES
PATENT AND TRADEMARK OFFICE

P.O. Box 1450
Alexandria, VA 22313 - 1450
www.uspto.gov

ELECTRONIC ACKNOWLEDGEMENT RECEIPT

APPLICATION #	RECEIPT DATE / TIME	ATTORNEY DOCKET #
17/552,303	**07/15/2022 04:56:38 PM ET**	**103033-P004USC4-1289479**

Title of Invention

OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

Application Information

APPLICATION TYPE	Utility - Nonprovisional Application under 35 USC 111(a)	PATENT #	-
CONFIRMATION #	1540	FILED BY	Erica Rojas
PATENT CENTER #	60788259	FILING DATE	12/15/2021
CUSTOMER #	20350	FIRST NAMED INVENTOR	Angus PACALA
CORRESPONDENCE ADDRESS	-	AUTHORIZED BY	Bill Shaffer

Documents

TOTAL DOCUMENTS: 2

DOCUMENT	PAGES	DESCRIPTION	SIZE (KB)
2022-07-15_Fee_Address_Indiciation_Form_103033-P004USC4-1289479.pdf	2	Maintenance Fee Address Change	231 KB
2022-07-15_Issue_Fee_Transmittal_103033-P004USC4-1289479.pdf	1	Issue Fee Payment (PTO-85B)	1642 KB

Digest

DOCUMENT	MESSAGE DIGEST(SHA-512)

2022-07-15_Fee_Address_Indiciation_Form_103033-P004USC4-1289479.pdf	73158D0B003B4D358BBD0759379FF32DDFAA59D14ACB105DDFD270FC1AD29A520BF22AFC8AC2CB24D7513B627DC77D980C34398B54C3C152AF2B7E1686FE65DE
2022-07-15_Issue_Fee_Transmittal_103033-P004USC4-1289479.pdf	C0026C7B637CED1EC4E6FB03A7CA833517C2CE604A78EFE0BF3304DC9C8CCC9B7209C124877F80FC6241E870FDB9C26E81535D8893CA7022DD514704DF3CCD1C

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

New Applications Under 35 U.S.C. 111

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

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

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

New International Application Filed with the USPTO as a Receiving Office

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

UNITED STATES PATENT AND TRADEMARK OFFICE

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

NOTICE OF ALLOWANCE AND FEE(S) DUE

20350 7590 04/18/2022

Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

EXAMINER
HELLNER, MARK

ART UNIT	PAPER NUMBER
3645	

DATE MAILED: 04/18/2022

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/552,303	12/15/2021	Angus PACALA	103033-P004USC4-1289479	1540

TITLE OF INVENTION: OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$600	$0.00	$0.00	$600	07/18/2022

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Maintenance fees are due in utility patents issuing on applications filed on or after Dec. 12, 1980. It is patentee's responsibility to ensure timely payment of maintenance fees when due. More information is available at www.uspto.gov/PatentMaintenanceFees.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

20350 7590 04/18/2022

Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

(Typed or printed name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/552,303	12/15/2021	Angus PACALA	103033-P004USC4-1289479	1540

TITLE OF INVENTION: OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$600	$0.00	$0.00	$600	07/18/2022

EXAMINER	ART UNIT	CLASS-SUBCLASS
HELLNER, MARK	3645	356-004010

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/AIA/122 or PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/AIA/47 or PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. Fees submitted: ❑ Issue Fee ❑ Publication Fee (if required) ❑ Advance Order - # of Copies _____

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

❑ Electronic Payment via EFS-Web ❑ Enclosed check ❑ Non-electronic payment by credit card (Attach form PTO-2038)

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. _____

5. **Change in Entity Status** (from status indicated above)

❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

UNITED STATES PATENT AND TRADEMARK OFFICE

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

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/552,303	12/15/2021	Angus PACALA	103033-P004USC4-1289479	1540

20350 7590 04/18/2022

Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

EXAMINER	
HELLNER, MARK	
ART UNIT	PAPER NUMBER
3645	

DATE MAILED: 04/18/2022

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

Hesai Exhibit 1002, Page 11

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

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

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

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

Notice of Allowability	Application No. 17/552,303	Applicant(s) PACALA et al.	
	Examiner MARK HELLNER	Art Unit 3645	AIA (FITF) Status Yes

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

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to the terminal disclaimer filed 4/6/2022.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

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

3. ☑ The allowed claim(s) is/are 1-27 . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

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

   Certified copies:

   a) ☐ All b) ☐ Some* c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☑ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 4/6/2022.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☐ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/MARK HELLNER/
Primary Examiner, Art Unit 3645

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/552,303	PACALA et al.
	Examiner	Art Unit
	MARK HELLNER	3645

CPC - Searched*		
Symbol	Date	Examiner
G01S7/4816, 4817; G01S17/08, 89 - text limited	02/23/2022	/MH/
G01S7/4816, 4817; G01S17/08, 89 - text limited - updated	04/09/2022	/MH/

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner

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

Search Notes		
Search Notes	Date	Examiner
inventor and assignee search; key word search	02/23/2022	/MH/
inventor and assignee search; key word search- updated	04/09/2022	/MH/

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner
	text search of claim field	04/09/2022	/MH/

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/552,303	PACALA et al.
	Examiner	**Art Unit**
	MARK HELLNER	3645

CPC							
Symbol						**Type**	**Version**
G01S	/	7	/	4816		F	2013-01-01
G01S	/	17	/	89		I	2013-01-01
G01S	/	7	/	4817		I	2013-01-01
G01S	/	17	/	08		I	2013-01-01

CPC Combination Sets								
Symbol						**Type**	**Set**	**Ranking**	**Version**
	/		/						

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	27	
/MARK HELLNER/ Primary Examiner, Art Unit 3645	09 April 2022	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/552,303	PACALA et al.
	Examiner	**Art Unit**
	MARK HELLNER	3645

INTERNATIONAL CLASSIFICATION					
CLAIMED					
G01C	/	3	/	08	

NON-CLAIMED					
	/		/		

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**
356	4.01

CROSS REFERENCES(S)						
CLASS	**SUBCLASS (ONE SUBCLASS PER BLOCK)**					

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	27	
/MARK HELLNER/ Primary Examiner, Art Unit 3645	09 April 2022	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office

Part of Paper No.: 20220409

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/552,303	PACALA et al.
	Examiner	**Art Unit**
	MARK HELLNER	3645

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

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1	10	10	19	19										
2	2	11	11	20	20										
3	3	12	12	21	21										
4	4	13	13	22	22										
5	5	14	14	23	23										
6	6	15	15	24	24										
7	7	16	16	25	25										
8	8	17	17	26	26										
9	9	18	18	27	27										

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	27	
/MARK HELLNER/ Primary Examiner, Art Unit 3645	09 April 2022	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/552,303	PACALA et al.
	Examiner	Art Unit
	MARK HELLNER	3645

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

CLAIMS

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

CLAIM		DATE								
Final	Original	02/23/2022	04/09/2022							
1	1	✓	=							
2	2	✓	=							
3	3	O	=							
4	4	✓	=							
5	5	O	=							
6	6	✓	=							
7	7	O	=							
8	8	O	=							
9	9	✓	=							
10	10	✓	=							
11	11	O	=							
12	12	O	=							
13	13	O	=							
14	14	O	=							
15	15	✓	=							
16	16	✓	=							
17	17	✓	=							
18	18	✓	=							
19	19	O	=							
20	20	O	=							
21	21	O	=							
22	22	O	=							
23	23	✓	=							
24	24	✓	=							
25	25	O	=							
26	26	✓	=							
27	27	✓	=							

Bibliographic Data

Application No: 17/552,303

Foreign Priority claimed: ○ Yes ◉ No

35 USC 119 (a-d) conditions met: ☐ Yes ☑ No ☐ Met After Allowance

Verified and Acknowledged: /MARK HELLNER/ Examiner's Signature | Initials

Title: OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
12/15/2021	356	3645	103033-P004USC4-1289479
RULE			

APPLICANTS

Ouster, Inc., San Francisco, CA,

INVENTORS

Angus PACALA, San Francisco, CA, UNITED STATES

Mark FRICHTL, San Francisco, CA, UNITED STATES

Marvin SHU, San Francisco, CA, UNITED STATES

Eric YOUNGE, San Francisco, CA, UNITED STATES

CONTINUING DATA

This application is a CON of 17194068 03/05/2021

17194068 is a CON of 15685384 08/24/2017 PAT 10948572

15685384 has PRO of 62379130 08/24/2016

FOREIGN APPLICATIONS

IF REQUIRED, FOREIGN LICENSE GRANTED**

12/27/2021

**** SMALL ENTITY ****

STATE OR COUNTRY

UNITED STATES

ADDRESS

Kilpatrick Townsend & Stockton LLP - West Coast

Mailstop: IP Docketing - 22

1100 Peachtree Street

Suite 2800

Atlanta, GA 30309

UNITED STATES

FILING FEE RECEIVED

$3,590

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

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

Application Number	17/552,303
Filing Date	December 15, 2021
First Named Inventor	Angus Pacala
Art Unit	3645
Examiner Name	Mark Hellner
Attorney Docket Number	103033-P004USC4-1289479

U.S. PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

U.S. PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	2013114891	WO	A1	Aug 8, 2013	Panasonic Corporation		Machine Translation Attached

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	2	Application No KR10-2019-7008085, Office Action, Mailed On March 23, 2022, 8 pages.	Machine Translation Attached

EXAMINER SIGNATURE

Examiner Signature	/MARK HELLNER/	Date Considered	04/09/2022

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

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.H/

Receipt date: 04/06/2022

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

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

Application Number	17/552,303
Filing Date	December 15, 2021
First Named Inventor	Angus Pacala
Art Unit	3645
Examiner Name	Mark Hellner
Attorney Docket Number	103033-P004USC4-1289479

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

CERTIFICATION STATEMENT

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

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

OR

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

☐ See attached certification statement.

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

☐ A certification statement is not submitted herewith.

SIGNATURE

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

Signature	/ William L. Shaffer /	Date (YYYY-MM-DD)	2022-04-06
Name/Print	William L. Shaffer	Registration Number	37,234

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

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.H/

PE2E SEARCH - Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	British Equivalents	Time Stamp
L1	0	ouster.in.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:48 AM
L2	127	ouster.as.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:48 AM
L3	567	pacala.in.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:49 AM
L4	210	frichtl.in.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:49 AM
L5	654	younge.in.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:49 AM
L6	1162	L2 OR L3 OR L4 OR l5	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:49 AM
L7	14185	bulk WITH optic	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD,	OR	ON	ON	2022/02/23 11:50 AM

			DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)				
L8	121	L6 AND I7	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:50 AM
L9	520775	vertical$4 WITH offset	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:50 AM
L10	37	L8 AND I9	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:51 AM
L11	8	"10222458".pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 12:06 PM
L12	2	"9992477".pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 12:10 PM
L13	14	("2014005561" OR "20150055117").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 12:25 PM
L14	2	"9992477".pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD,	OR	ON	ON	2022/02/23 04:41 PM

			DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)				
L15	2	"20170269215".pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 04:42 PM
L16	16	("2014005561" OR "20150055117" OR "20170269215").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 04:46 PM
L17	12225	G01S7/4816.cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 05:07 PM
L18	22737	G01S7/4817.cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 05:07 PM
L19	24187	G01S17/08.cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 05:07 PM
L20	42409	G01S17/89.cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 05:07 PM
L21	82059	L17 OR L18 OR L19 OR l20	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD,	OR	ON	ON	2022/02/23 05:07 PM

			DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)				
L22	3475	pixels SAME (detect$4 OR scan$4) SAME ((unique OR individual OR distinct) WITH (path OR arcuate OR circular))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 05:10 PM
L23	86	L21 AND l22	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 05:10 PM
L24	8	"10222458".pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 05:11 PM
L25	174	("4358851" | "4634272" | "4676599" | "4702600" | "4744667" | "4851664" | "5267016" | "5288992" | "5982552" | "6014232" | "6133989" | "6255133" | "6374024" | "6414746" | "6690019" | "6721262" | "7091462" | "D531525" | "7170542" | "7295298" | "7345271" | "7421159" | "7433042" | "7808706" | "7969558" | "8013983" | "8089618" | "8130367" | "D659030" | "8319949" | "8330840" | "8374405" | "8384997" | "8494252" | "8675181" | "8717488" | "8742325" | "8743176" | "8761495" | "8767190" | "8829406" | "8836922" | "8848039" | "9041915" | "9063549" | "9071763" | "9086273" | "9111444" | "9157790" | "9164511" | "9176051" | "9229109" | "9285464" | "9285477" | "9299731" | "9368936"	(US-PGPUB; USPAT; USOCR)	OR	ON	ON	2022/02/23 05:11 PM

		| "9369689" | "9383753" | "9425654" | "9435891" | "9470520" | "9489601" | "9525863" | "9529079" | "9989406" | "9992477" | "10063849" | "20030006676" | "20030047752" | "20040061502" | "20040223071" | "20050030409" | "20060244851" | "20070007563" | "20070060806" | "20070071056" | "20070228262" | "20080121826" | "20080153189" | "20090016642" | "20090040629" | "20090179142" | "20090295910" | "20100008588" | "20100020306" | "20100110275" | "20100123893" | "20100204964" | "20110025843" | "20110032398" | "20110037849" | "20110116262" | "20110216304" | "20120044476" | "20120140109" | "20120154914" | "20120182464" | "20120287417" | "20120320164" | "20130044310" | "20130141549" | "20130206967" | "20130294089" | "20130300840" | "20140118335" | "20140118493" | "20140153001" | "20140158900" | "20140168631" | "20140176933" | "20140211194" | "20140269796" | "20140285628" | "20140291491" | "20140313519" | "20140375977" | "20140376092" | "20150002636" | "20150131080" |					

		"20150184999" | "20150192677" | "20150292948" | "20150293224" | "20150316473" | "20150355470" | "20150358601" | "20150378241" | "20150379371" | "20160003946" | "20160047895" | "20160047896" | "20160047897" | "20160047898" | "20160047899" | "20160047900" | "20160047901" | "20160047903" | "20160049765" | "20160097858" | "20160150963" | "20160161600" | "20160218727" | "20160265902" | "20160291134" | "20160306032" | "20160327779" | "20160328619" | "20170146640" | "20170219426" | "20170219695" | "20170269197" | "20170269198" | "20170269215" | "20170289524" | "20170350983" | "20180059222" | "20180152691" | "20180209841" | "20180267143").pn. OR ("10222458").urpn. AND (PGPB | USPT | USOC).dbnm.					
L26	28939	pixel SAME ((vertical OR horizontal) WITH offset)	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 05:13 PM
L27	113	L22 AND l26	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO;	OR	ON	ON	2022/02/23 05:13 PM

			JPO; DERWENT; IBM_TDB)				
L28	0	ouster.in.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L29	129	ouster.as.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L30	569	pacala.in.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L31	212	frichtl.in.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L32	661	younge.in.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L33	1169	L2 OR L3 OR L4 OR l5	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L34	14247	bulk WITH optic	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO;	OR	ON	ON	2022/04/09 12:39 PM

			JPO; DERWENT; IBM_TDB)				
L35	123	L6 AND I7	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L36	523852	vertical$4 WITH offset	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L37	38	L8 AND I9	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L38	8	"10222458".pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L39	2	"9992477".pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L40	14	("2014005561" OR "20150055117").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L41	2	"9992477".pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO;	OR	ON	ON	2022/04/09 12:39 PM

			JPO; DERWENT; IBM_TDB)				
L42	2	"20170269215".pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L43	16	("2014005561" OR "20150055117" OR "20170269215").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L44	12398	G01S7/4816.cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L45	23008	G01S7/4817.cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L46	24436	G01S17/08.cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L47	42922	G01S17/89.cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L48	82996	L17 OR L18 OR L19 OR I20	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO;	OR	ON	ON	2022/04/09 12:39 PM

			JPO; DERWENT; IBM_TDB)				
L49	3489	pixels SAME (detect$4 OR scan$4) SAME ((unique OR individual OR distinct) WITH (path OR arcuate OR circular))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L50	87	L21 AND l22	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L51	8	"10222458".pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L52	174	("4358851" | "4634272" | "4676599" | "4702600" | "4744667" | "4851664" | "5267016" | "5288992" | "5982552" | "6014232" | "6133989" | "6255133" | "6374024" | "6414746" | "6690019" | "6721262" | "7091462" | "D531525" | "7170542" | "7295298" | "7345271" | "7421159" | "7433042" | "7808706" | "7969558" | "8013983" | "8089618" | "8130367" | "D659030" | "8319949" | "8330840" | "8374405" | "8384997" | "8494252" | "8675181" | "8717488" | "8742325" | "8743176" | "8761495" | "8767190" | "8829406" | "8836922" | "8848039" | "9041915" | "9063549" | "9071763" | "9086273" | "9111444" | "9157790" | "9164511" | "9176051" | "9229109" | "9285464" | "9285477" | "9299731" | "9368936" | "9369689" | "9383753" | "9425654" | "9435891" | "9470520" | "9489601"	(US-PGPUB; USPAT; USOCR)	OR	ON	ON	2022/04/09 12:39 PM

		| "9525863" | "9529079" | "9989406" | "9992477" | "10063849" | "20030006676" | "20030047752" | "20040061502" | "20040223071" | "20050030409" | "20060244851" | "20070007563" | "20070060806" | "20070071056" | "20070228262" | "20080121826" | "20080153189" | "20090016642" | "20090040629" | "20090179142" | "20090295910" | "20100008588" | "20100020306" | "20100110275" | "20100123893" | "20100204964" | "20110025843" | "20110032398" | "20110037849" | "20110116262" | "20110216304" | "20120044476" | "20120140109" | "20120154914" | "20120182464" | "20120287417" | "20120320164" | "20130044310" | "20130141549" | "20130206967" | "20130294089" | "20130300840" | "20140118335" | "20140118493" | "20140153001" | "20140158900" | "20140168631" | "20140176933" | "20140211194" | "20140269796" | "20140285628" | "20140291491" | "20140313519" | "20140375977" | "20140376092" | "20150002636" | "20150131080" | "20150184999" | "20150192677" | "20150292948" |					

		"20150293224" | "20150316473" | "20150355470" | "20150358601" | "20150378241" | "20150379371" | "20160003946" | "20160047895" | "20160047896" | "20160047897" | "20160047898" | "20160047899" | "20160047900" | "20160047901" | "20160047903" | "20160049765" | "20160097858" | "20160150963" | "20160161600" | "20160218727" | "20160265902" | "20160291134" | "20160306032" | "20160327779" | "20160328619" | "20170146640" | "20170219426" | "20170219695" | "20170269197" | "20170269198" | "20170269215" | "20170289524" | "20170350983" | "20180059222" | "20180152691" | "20180209841" | "20180267143").pn. OR ("10222458").urpn. AND (PGPB | USPT | USOC).dbnm.					
L53	29069	pixel SAME ((vertical OR horizontal) WITH offset)	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L54	114	L22 AND I26	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:39 PM
L55	1075323	((laser OR optical)	(US-PGPUB; USPAT;	OR	ON	ON	2022/04/09

		WITH (imag$4 OR 3d OR (three ADJ dimension$3))).clm.	USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)				12:44 PM
L56	1114696	scan$3.clm.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/09 12:46 PM

PE2E SEARCH - Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	British Equivalents	Time Stamp
N1	217491	((laser OR optical) WITH (imag$4 OR 3d OR (three ADJ dimension$3))).clm.	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/09 12:44 PM
N2	7718	(pixel$1 WITH offset$3).clm.	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/09 12:45 PM
N3	986	N1 AND n2	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/09 12:45 PM
N4	267509	scan$3.clm.	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/09 12:46 PM
N5	133	N3 AND n4	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/09 12:47 PM

UNITED STATES PATENT AND TRADEMARK OFFICE

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

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
17/552,303	12/15/2021	Angus PACALA	103033-P004USC4-1289479

CONFIRMATION NO. 1540

20350
Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

PUBLICATION NOTICE

OC000000133015820

Title:OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

Publication No.US-2022-0107395-A1
Publication Date:04/07/2022

NOTICE OF PUBLICATION OF APPLICATION

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

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

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

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

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

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

Doc Code: DIST.E.FILE Document Description: Electronic Terminal Disclaimer - Filed	PTO/SB/26 U.S. Patent and Trademark Office Department of Commerce

Electronic Petition Request	**TERMINAL DISCLAIMER TO OBVIATE A DOUBLE PATENTING REJECTION OVER A "PRIOR" PATENT**
Application Number	17552303
Filing Date	15-Dec-2021
First Named Inventor	Angus PACALA
Attorney Docket Number	103033-P004USC4-1289479
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

☒ Filing of terminal disclaimer does not obviate requirement for response under 37 CFR 1.111 to outstanding Office Action

☒ This electronic Terminal Disclaimer is not being used for a Joint Research Agreement.

Owner	Percent Interest
Ouster, Inc.	100%

The owner(s) with percent interest listed above in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of prior patent number(s)

10222458

as the term of said prior patent is presently shortened by any terminal disclaimer. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and the prior patent are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the owner does not disclaim the terminal part of the term of any patent granted on the instant application that would extend to the expiration date of the full statutory term of the prior patent, "as the term of said prior patent is presently shortened by any terminal disclaimer," in the event that said prior patent later:
- expires for failure to pay a maintenance fee;
- is held unenforceable;
- is found invalid by a court of competent jurisdiction;
- is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321;
- has all claims canceled by a reexamination certificate;
- is reissued; or
- is in any manner terminated prior to the expiration of its full statutory term as presently shortened by any terminal disclaimer.

◉ Terminal disclaimer fee under 37 CFR 1.20(d) is included with Electronic Terminal Disclaimer request.

○	I certify, in accordance with 37 CFR 1.4(d)(4), that the terminal disclaimer fee under 37 CFR 1.20(d) required for this terminal disclaimer has already been paid in the above-identified application.

Applicant claims the following fee status:

◉ Small Entity

○ Micro Entity

○ Regular Undiscounted

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

THIS PORTION MUST BE COMPLETED BY THE SIGNATORY OR SIGNATORIES

I certify, in accordance with 37 CFR 1.4(d)(4) that I am:

◉ An attorney or agent registered to practice before the Patent and Trademark Office who is of record in this application

Registration Number 37234

○ A sole inventor

○ A joint inventor; I certify that I am authorized to sign this submission on behalf of all of the inventors as evidenced by the power of attorney in the application

○ A joint inventor; all of whom are signing this request

Signature	/William L. Shaffer/
Name	William L. Shaffer

*Statement under 37 CFR 3.73(b) is required if terminal disclaimer is signed by the assignee (owner).
Form PTO/SB/96 may be used for making this certification. See MPEP § 324.

Electronic Patent Application Fee Transmittal

Application Number:	17552303
Filing Date:	15-Dec-2021
Title of Invention:	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD
First Named Inventor/Applicant Name:	Angus PACALA
Filer:	William Leland Shaffer/Erica Rojas
Attorney Docket Number:	103033-P004USC4-1289479

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
STATUTORY OR TERMINAL DISCLAIMER	2814	1	170	170
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**170**

Doc Code: DISQ.E.FILE
Document Description: Electronic Terminal Disclaimer – Approved

Application No.: 17552303

Filing Date: 15-Dec-2021

Applicant/Patent under Reexamination: PACALA

Electronic Terminal Disclaimer filed on April 6, 2022

☒ APPROVED

This patent is subject to a terminal disclaimer

☐ DISAPPROVED

Approved/Disapproved by: Electronic Terminal Disclaimer automatically approved by EFS-Web

U.S. Patent and Trademark Office

Electronic Acknowledgement Receipt

EFS ID:	45409837
Application Number:	17552303
International Application Number:	
Confirmation Number:	1540
Title of Invention:	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD
First Named Inventor/Applicant Name:	Angus PACALA
Customer Number:	20350
Filer:	William Leland Shaffer/Erica Rojas
Filer Authorized By:	William Leland Shaffer
Attorney Docket Number:	103033-P004USC4-1289479
Receipt Date:	06-APR-2022
Filing Date:	15-DEC-2021
Time Stamp:	16:48:02
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$170
RAM confirmation Number	E202246G47572712
Deposit Account	201430
Authorized User	Erica Rojas

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

37 CFR 1.16 (National application filing, search, and examination fees)

37 CFR 1.17 (Patent application and reexamination processing fees)

37 CFR 1.19 (Document supply fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Terminal Disclaimer-Filed (Electronic)	eTerminal-Disclaimer.pdf	41272 5f74a533540ef4af4505fa85693d9e88cfe24df9	no	2
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	37988 42481fbf3f3f94f2db29ee70654be6f05a8004cd	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	79260		

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

New Applications Under 35 U.S.C. 111

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

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

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

New International Application Filed with the USPTO as a Receiving Office

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

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

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

Application Number	17/552,303
Filing Date	December 15, 2021
First Named Inventor	Angus Pacala
Art Unit	3645
Examiner Name	Mark Hellner
Attorney Docket Number	103033-P004USC4-1289479

U.S. PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

U.S. PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	2013114891	WO	A1	Aug 8, 2013	Panasonic Corporation		Machine Translation Attached

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	2	Application No KR10-2019-7008085, Office Action, Mailed On March 23, 2022, 8 pages.	Machine Translation Attached

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

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

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17/552,303
	Filing Date	December 15, 2021
	First Named Inventor	Angus Pacala
	Art Unit	3645
	Examiner Name	Mark Hellner
	Attorney Docket Number	103033-P004USC4-1289479

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

CERTIFICATION STATEMENT

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

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

OR

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

☐ See attached certification statement.

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

☐ A certification statement is not submitted herewith.

SIGNATURE

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

Signature	/ William L. Shaffer /	Date (YYYY-MM-DD)	2022-04-06
Name/Print	William L. Shaffer	Registration Number	37,234

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

Espacenet

Bibliographic data: WO2013114891 (A1) — 2013-08-08

IMAGING DEVICE AND IMAGING SYSTEM

Inventor(s): IMAMURA NORIHIRO; KORENAGA TSUGUHIRO; YAMAGATA MICHIHIRO ± (IMAMURA, NORIHIRO, ; KORENAGA, TSUGUHIRO, ; YAMAGATA, MICHIHIRO)

Applicant(s): PANASONIC CORP [JP] ± (PANASONIC CORPORATION)

Classification: - **international:** ***A61B1/00; G01N21/21; G01N21/27; G02B3/00; G02B3/06; G02F1/13;*** *A61B5/00*

- **cooperative:** **A61B1/00096 (EP, US); A61B1/041 (EP, US); A61B5/0077 (EP, US); A61B5/441 (EP, US); B60W40/06 (US); G01N21/21 (EP, US); G01N21/4738 (EP, US); G01S17/89 (EP, US); G01S7/499 (EP, US); G02B13/14 (US); G02B27/28 (US); G02B27/286 (EP, US); G02B3/0056 (EP, US); G02B5/201 (EP, US); G02B5/3033 (EP, US);** A61B1/04 (EP, US); G01N21/359 (EP, US)

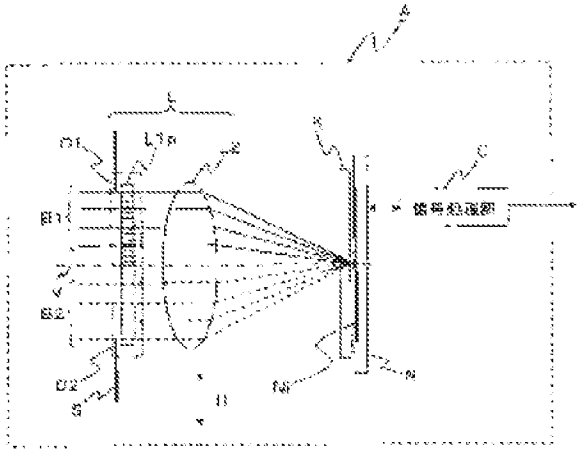
Application number: WO2013JP00566 20130201 Global Dossier

Priority number(s): JP20120021696 20120203

Also published as: CN103460024 (A) CN103460024 (B) JP6004235 (B2) JPWO2013114891 (A1) US2014055661 (A1) US9658463 (B2) less

Abstract of WO2013114891 (A1)

This imaging device is provided with a lens optical system (L), an imaging element (N) having a plurality of first and second pixels (P1, P2), and an arrayed optical element (K). The lens optical system (L) includes a first optical region (D1) that primarily transmits light oscillating in a first polarization axis direction, and a second optical region (D2) that transmits light oscillating in all directions. The arrayed optical element (K) causes the light transmitted through the first optical region (D1) to enter the plurality of first pixels (P1), and causes



C Signal processing unit

the light transmitted through the second optical region (D2) to enter the plurality of second pixels (P2).

WO2013114891A1 IMAGING DEVICE AND IMAGING SYSTEM

Data originating from sources other than the EPO may not be accurate, complete, or up to date.

The wording below is an initial machine translation of the original publication. To generate a version using the latest translation technology, go to the original language text and use Patent Translate.

Imaging apparatus and imaging system

The present application relates to an imaging device such as a camera and an imaging system.

In the field of in-vehicle cameras, an image pickup apparatus having a polarizer in which polarization axes are different for each eye in the optical path of a compound eye camera is disclosed in order to detect the state of the road surface and the lane).

Further, in cameras in medical and beauty fields such as endoscope systems and skin diagnostic systems, imaging apparatuses that acquire both non-polarized images and polarized images have been put to practical use.

These image pickup apparatuses are provided with polarized illumination for irradiating living tissue with non-polarized light and light vibrating in the direction of a predetermined polarization axis. In the case of irradiating the living tissue with light of a predetermined polarization component, the reflected light on the living body surface becomes mirror-reflected light in which the polarization component is maintained, and the reflected light in the deep part of the living body is scattered reflected light in which the polarization component is disturbed and Become. Therefore, by disposing a polarization filter that transmits light vibrating in a direction parallel to the polarization axis of polarized illumination and a polarizing filter that transmits light that vibrates in a direction perpendicular to the polarization axis of illumination, on the imaging device side, It is possible to acquire images of the surface and the deep part of the living body.

An imaging apparatus for acquiring images with different polarization characteristics is disclosed (Patent Documents 2 and 3).

However, with the above-described conventional technique, there has been a demand for an imaging apparatus capable of photographing a moving image with a simpler configuration.

One non-limiting exemplary embodiment of the present application provides an imaging apparatus capable of taking moving images with a simpler configuration.

An imaging apparatus according to one aspect of the present invention includes a lens optical system, an imaging element having at least a plurality of first pixels and a plurality of second pixels to which light having passed through the lens optical system is incident, And an array optical element disposed between the optical system and the image pickup element and including a plurality of optical elements each having a lens surface, wherein the lens optical system has a plurality of optical regions, the plurality of optical elements The region includes at least a first optical region mainly transmitting light oscillating in the direction of the first polarization axis and a second optical region transmitting light oscillating in an arbitrary direction, The plurality of optical elements of the optical element make the light passing through the first optical region incident on the plurality of first pixels and let the light passing through the second optical region be incident on the plurality of second pixels .

According to the imaging apparatus according to one embodiment of the present invention, it is possible to acquire both a polarized image and a non-polarized image at the same time using a single imaging system. In addition, when a moving image is photographed using the image pickup apparatus of the present invention, even if the position of the object changes with the lapse of time, image shift does not occur between the plurality of images.

BRIEF DESCRIPTION OF THE DRAWINGS FIG. 1 is a schematic diagram showing Embodiment 1 of an image pickup apparatus A according to the present invention. FIG. 3 is a front view of the first and second optical regions D 1, D 2 of the optical element L 1 p according to the first embodiment of the present invention

as viewed from the subject side. 1 is a perspective view of an arrayed optical element K in Embodiment 1 of the present invention. FIG. (A) is an enlarged view of the arrayed optical element K and the image pickup element N shown in FIG. 1 according to the first embodiment, and (b) shows the arrayed optical element K and the pixel As shown in FIG. FIG. 7 is a schematic diagram showing an imaging system AP 1 according to a second embodiment of the present invention. FIG. 7 is a schematic diagram showing Embodiment 3 of the imaging apparatus A according to the present invention. FIG. 7 is a front view of the first and second optical regions D 1, D 2 of the optical element L 1 s according to the third embodiment of the present invention as viewed from the subject side. FIG. 9 is a schematic diagram showing an imaging system AP 2 according to Embodiment 3 of the present invention. FIG. 5 is a schematic diagram showing Embodiment 4 of the imaging apparatus A according to the present invention. 4 is a front view of the first, second and third optical regions D 1, D 2, and D 3 of the optical element L 1 p according to Embodiment 4 of the present invention, as viewed from the subject side. FIG. (A) is an enlarged view of the arrayed optical element K and the image pickup element N shown in FIG. 8 according to Embodiment 4 of the present invention, and (b) is an enlarged view of the arrayed optical element K and the image pickup element N Of the pixel of interest. (A) is a front view of the first, second, third, and fourth optical regions D 1, D 2, D 3, and D 4 of the optical element L 1 s according to the fifth embodiment of the present invention viewed from the subject side, and b) is a front view of the first, second, third, and fourth optical regions D 1, D 2, D 3, and D 4 of the optical element L 1 p as seen from the object side. FIG. 7 is a perspective view of an arrayed optical element K according to a fifth embodiment of the present invention. (A) is an enlarged view of the arrayed optical element K and the image pickup element N in Embodiment 5, (b) shows the positional relationship between the arrayed optical element K and the pixel on the image pickup element N FIG. (A) is a front view of the first, second, third, and fourth optical regions D 1, D 2, D 3, and D 4 of the optical element L 1 s according to Embodiment 6 of the present invention as viewed from the subject side, and b) is a front view of the first, second, third, and fourth optical regions D 1, D 2, D 3, and D 4 of the optical element L 1 p as seen from the object side. (A) is a front view of the first, second, third, and fourth optical regions D 1, D 2, D 3, and D 4 of the optical element L 1 p according to another embodiment of the sixth embodiment of the present invention as seen from the subject side . (B) is a front view of the first, second, third, and fourth optical regions D 1, D 2, D 3, and D 4 of the diaphragm S as seen from the object side. (A) is a front view of the first, second, third, and fourth optical regions D 1, D 2, D 3, and D 4 of the optical element L 1 p according to the seventh embodiment of the present invention viewed from the subject side, and b) is a diagram showing the positional relationship between the arrayed optical element K and the pixels on the image pickup element N. FIG. FIG. 11 is a diagram showing a positional relationship between an arrayed optical element K and pixels on an image pickup element N according to another embodiment of the present invention. (A) and (b) are schematic diagrams showing an optical system and an imaging unit according to Embodiment 8 of the present invention. (A) is a perspective view of the optical element L 1 s according to Embodiment 8 of the present invention, and (b) is a front view of the diaphragm S as viewed from the subject side. (A) is a perspective view of another embodiment of the optical element L 1 s according to Embodiment 8 of the present invention, and (b) is a front view of the diaphragm S as seen from the object side. (A) is a perspective view of another embodiment of the optical element L 1 s according to Embodiment 8 of the present invention, and (b) is a front view of the diaphragm S as seen from the object side. FIG. 9 is a schematic diagram showing an optical system and an imaging unit according to another embodiment of the present invention. (A1) and (b1) are perspective views of the arrayed optical element K in Embodiment 9 of the present invention, (a2) and (b2) are contour lines of each optical element, (a3) and (b3) Are diagrams showing the results of the ray tracing simulation. (A) and (b) are enlarged views showing arrayed optical element K and image pickup element N in Embodiment 10 of the present invention. (A) and (b) are enlarged views showing arrayed optical element K and image pickup element N in Embodiment 11 of the present invention. (A) is an enlarged view of the arrayed optical element K and the image pickup element N shown in Embodiment 12 of the present invention, and (b) shows the pixel on the arrayed optical element K and the pixel on the image pickup element N FIG. (A 1) is a diagram showing an arrangement of a microlens array having a rotationally asymmetric shape with respect to the optical axis and contour lines thereof. (A 2) is a perspective view of the microlens array shown in (a 1). (B 1) is a diagram showing an arrangement of a microlens array having a rotationally symmetric shape with respect to the optical axis and contour lines thereof. (B 2) is a perspective view of the microlens array shown in (b 1). (C 1) are diagrams showing an arrangement in which the cylindrical microlenses are alternately shifted by a half pitch and their contour lines. (C 2) is a perspective view of the cylindrical microlens array shown in (c 1). (A) is a diagram showing the results of ray tracing simulation in the case where the microlenses shown in FIGS. 28 (a 1) and (a 2) are applied to the arrayed optical element of Embodiment 12. (B) are diagrams showing the results of a ray tracing simulation in the case where the microlenses shown in FIGS. 28 (b 1) and (b 2) are applied to the arrayed optical element of the twelfth embodiment. (C) are diagrams showing the results of ray tracing simulation when the microlenses shown in FIGS. 28 (c 1) and (c 2) are applied to the arrayed optical element of Embodiment 12. (A) and (b) are diagrams in which the pixels reaching by the light passing through the first and second regions are extracted. (A) is a front view of the microscope AP 3 according to Embodiment 13 of the

present invention, and (b) is a side view. (A) is a front view of the capsule endoscope AP 4 according to Embodiment 14 of the present invention, and (b) is a side view. (A) is a front view of the electronic mirror AP 5 in the fifteenth embodiment, and FIG. 3 (b) is a front view of the three-dimensional electron mirror AP 6. (A) and (b) are a plan view and a cross-sectional view of a diffractive optical element that can be provided on an image pickup element. (A), (b), (c), and (d) are front views of an optical element and a diaphragm according to another embodiment of the present invention.

The inventors of the present invention examined the imaging apparatuses disclosed in Patent Documents 1 to 3 in detail. According to the apparatus disclosed in Patent Document 1, since it is a compound eye configuration, in a case where the focal length is long or the object distance is close, the parallax between the acquired images largely changes depending on the subject distance. Therefore, in order to detect the state by comparing the same positions of the subject, signal processing for extracting and correcting the parallax for each minute area of the image is additionally required, and there arises a problem that the calculation processing increases. In addition, in the case of a compound eye, a lens array is formed in front of the imaging device, but in this arrangement, the effective diameter of a single optical system must be less than half of the size of the imaging area, The degree of freedom becomes small and it is difficult to construct an optical system that can obtain sufficient resolution as an object to acquire an image. It is also difficult to construct an ultra wide angle optical system like a fisheye lens.

Patent Document 2 also discloses a configuration that acquires polarized images of a plurality of wavelength bands by a plurality of polarized illuminators having different wavelength bands and a polarizing filter that transmits a polarized light component orthogonal to the polarized illumination, Respectively. However, since the image that can be photographed with such a configuration is only an image including polarized light information of which polarization axis direction is only one kind, and images of different wavelength bands need to be photographed in a time sharing manner, There is a problem that it is not suitable for imaging.

Further, Patent Document 3 discloses a configuration that obtains images with different polarization components by a polarization beam splitter. However, with such a configuration, a polarizing beam splitter and a plurality of image pickup elements are required, resulting in problems of increasing the size and increasing the cost.

In view of such a problem, the inventor of the present invention has arrived at a novel imaging apparatus capable of acquiring both an image having polarization information and a normal image by using a single imaging optical system. An outline of one embodiment of the present invention is as follows.

An imaging apparatus according to one aspect of the present invention includes a lens optical system, an imaging element having at least a plurality of first pixels and a plurality of second pixels to which light having passed through the lens optical system is incident, And an array optical element disposed between the optical system and the image pickup element and including a plurality of optical elements each having a lens surface, wherein the lens optical system has a plurality of optical regions, the plurality of optical elements The region includes at least a first optical region mainly transmitting light oscillating in the direction of the first polarization axis and a second optical region transmitting light oscillating in an arbitrary direction, The plurality of optical elements of the optical element make the light passing through the first optical region incident on the plurality of first pixels and let the light passing through the second optical region be incident on the plurality of second pixels .

The first optical region may transmit light of a first wavelength band and the second optical region may transmit light of a second wavelength band.

The first wavelength band may be a wavelength band of near-ultraviolet light.

The first wavelength band may include a predetermined band in a wavelength band from 400 nm to 600 nm.

The first wavelength band may be a wavelength band of near infrared light.

The plurality of optical regions of the lens optical system further comprises a third optical region other than the first and second optical regions and the third optical region has a direction different from the first polarization axis , The arrayed optical element mainly transmits light that vibrates in the direction of the second polarization axis of the plurality of first and second pixels except for the plurality of first and second pixels Of the third pixel.

The plurality of optical regions of the lens optical system further comprises third and fourth optical regions other than the first and second optical regions, wherein the first, second, third, and fourth Wherein the optical regions of the array optical element transmit light of first, second, third and fourth wavelength bands different from each other, and the arrayed optical element transmits light passing through the third and fourth optical regions May be incident on a plurality of third and fourth pixels other than the plurality of first and second pixels, respectively.

Wherein the plurality of optical regions of the lens optical system further comprises third and fourth optical regions other than the first and second optical regions, wherein the first and third optical regions are the same The second and fourth optical regions transmit light in wavelength bands different from wavelength bands of light passing through the first and third optical regions, The arrayed optical element causes the light passing through the third and fourth optical regions to be incident on a plurality of third and fourth pixels other than the plurality of first and second pixels May be used.

The third optical region may mainly transmit light vibrating in a direction of a second polarization axis different from the first polarization axis.

The imaging apparatus according to claim 1, further comprising a plurality of third and fourth pixels to which the light passed through the lens optical system is incident, the plurality of optical regions further including third and fourth optical regions, Wherein the third optical region transmits light oscillating in an arbitrary direction and the arrayed optical element transmits the light passing through the third and fourth optical regions to the plurality of third and fourth optical regions, 4, and the plurality of first, second, and third pixels may have filters having first, second, and third spectral transmittance characteristics, respectively.

Wherein the plurality of fourth pixels have the first spectral transmittance characteristic and the fourth optical region transmits light in a predetermined wavelength band and is different from the first polarization axis 2 may transmit light oscillating in the direction of the polarization axis.

The first, second, third, and fourth pixels of the image pickup device may be configured in a Bayer array.

An imaging apparatus according to another aspect of the present invention includes a first area that is provided with a filter that transmits light in a predetermined band and mainly transmits light oscillating in a direction of a first polarization axis, A lens optical system having a first area which is disposed at a position different from the first area and which has a second area which transmits light oscillating in an arbitrary direction, a plurality of first pixels to which light having passed through the lens optical system is incident, A plurality of second pixels including a filter having a first spectral transmittance characteristic, a plurality of third pixels including a filter having a second spectral transmittance characteristic, and a filter having a third spectral transmittance characteristic And an arrayed optical element that is disposed between the lens optical system and the image pickup element and includes a plurality of optical elements each having a lens surface, In the arrayed optical element, the first light The light passing through the region to be incident to the first pixel of the plurality, said plurality of second light passing through the second optical region, is incident third, and fourth pixel.

An imaging apparatus according to another aspect of the present invention includes: a first region that mainly transmits light oscillating in a direction of a first polarization axis; a second region that is disposed at a position different from the first region, A lens optical system having a first area that transmits light that vibrates in a direction perpendicular to the first direction and a second area that transmits light that vibrates in the direction of the first optical axis; A plurality of third pixels each including a filter having a second spectral transmittance characteristic; a plurality of pixels including a plurality of fourth pixels including a filter having a third spectral transmittance characteristic; And an arrayed optical element disposed between the lens optical system and the image pickup element and including a plurality of optical elements each having a lens surface, wherein the plurality of pixels are arranged in a first direction 1 to 1 (1 is an integer of 2 or more) A pixel group of one row in which pixels are arranged is arranged in the m rows from the 1st to the mth row in the second direction (m is an integer of 2 or more), thereby being arranged on the imaging plane, Each position of the center of the l pixels arranged in the j-th row (1 □ j □m) in the first direction corresponds to the position of the center of the l pixels arranged in the j + 1 th row in the first direction Wherein the plurality of optical elements are arranged on the surface of the arrayed optical element such that 1 to s (s is an integer equal to or greater than 2) optical elements are arranged in the second direction A row of optical element groups are arranged in t columns ranging from 1 in the first direction to the t-th column (t is an integer of 2 or more), and in the k-th column (1 □ k □t) out of the t columns The position of the center of the arranged optical element in the second direction is the position of the

optical element disposed in the (k + 1) th column in the second direction From the position of the center to the second direction.

The plurality of first pixels include first A and first B pixels, the plurality of second pixels include second A and second B pixels, and the plurality of third pixels are arranged in a 3A and a third B pixel, and the plurality of fourth pixels have a fourth A and a fourth B pixel, and the optical element in the k th row is configured to divide light passing through the first region into The first element is made incident on the first A pixel and the third A pixel, and the light passing through the second region is made incident on the second B pixel and the fourth B pixel, and the optical element in the k + 1 th row is the 1 is incident on the plurality of second A pixels and the pixel of the fourth A, and the light passing through the second area is made incident on the first B pixel and the third B pixel Good.

In the plurality of optical regions, at least two or more optical regions have mutually different optical powers, and as compared with the case where the optical powers of the plurality of optical regions are equal to each other, the light transmitted through the plurality of optical regions The in-focus positions may be close to each other.

The imaging apparatus may further include a light shielding area at a position corresponding to the boundary between the first area and the second area.

The lens optical system may be an image-side telecentric optical system.

The lens optical system may be an image side non-telecentric optical system, and the array of the arrayed optical elements may be offset with respect to the arrangement of the pixels of the imaging device outside the optical axis of the lens optical system.

The arrayed optical element may be a lenticular lens.

In the arrayed optical element, each of the lens surfaces of the plurality of optical elements is a cylindrical surface extending in a first direction, the plurality of optical elements are arranged in a second direction, and the plurality of optical elements May be arranged so as to correspond to two rows of pixels including the plurality of first pixels of one row and the plurality of second pixels of one row.

The arrayed optical element may be a microlens array.

In the arrayed optical element, each of the lens surfaces of the plurality of optical elements may have a rotationally symmetric shape.

Wherein each of the plurality of optical elements includes at least one of one of the plurality of first pixels, one of the plurality of second pixels, one of the plurality of third pixels, Or may be arranged to correspond to one of the plurality of fourth pixels.

The arrayed optical element may be formed on the imaging element.

The imaging apparatus may further include a microlens provided between the arrayed optical element and the imaging element, and the arrayed optical element may be formed on the imaging element via the microlens Good.

The microlens provided between the arrayed optical element and the image pickup element may be a binary diffractive optical element or a multilevel diffractive optical element.

The lens optical system may further include a diaphragm, and the plurality of optical regions may be disposed in the vicinity of the diaphragm.

The imaging apparatus may further include a signal processing unit that generates an image based on a signal acquired by the imaging device.

An imaging system according to one aspect of the present invention includes any one of the imaging apparatus described above and a signal processing unit that generates an image based on a signal acquired by the imaging apparatus.

An imaging system according to one aspect of the present invention includes any one of the imaging apparatus described above and polarized lighting.

The imaging system may further comprise unpolarized illumination.

An imaging system according to another aspect of the present invention includes at least one imaging device described above, a polarized light illumination device, and a display device that displays an image acquired by the imaging device.

The at least one imaging device may be two imaging devices, and the display device may display the two images acquired by the two imaging devices.

The display device is a liquid crystal display having a polarizing filter on the subject side, and the direction of the polarization axis of the polarizing filter on the liquid crystal display may be equal to the direction of the polarizing axis of the polarized illumination.

DESCRIPTION OF THE PREFERRED EMBODIMENTS Hereinafter, embodiments of an image pickup apparatus according to the present invention will be described with reference to the drawings.

First Embodiment FIG. 1 is a schematic diagram showing an image pickup apparatus A according to a first embodiment. The imaging apparatus A of the present embodiment includes a lens optical system L having V as its optical axis, an arrayed optical element K arranged near the focal point of the lens optical system L, a monochrome imaging element N, a signal processing section C .

The lens optical system L includes a diaphragm S on which light from a subject (not shown) is incident, an optical element L 1 p on which light having passed through the diaphragm S is incident, and a lens L 2 on which light having passed through the optical element L 1 p enters It is configured. The lens optical system L has first and second optical regions D 1 and D 2.

The lens L2 may be composed of a single lens or may be composed of a plurality of lenses. Further, it may have a configuration in which it is divided into a plurality of sheets before and after the diaphragm S. In FIG. 1, it is shown as a single-piece configuration.

The optical element L 1 p is disposed in the vicinity of the diaphragm S and is constituted by a part located in the first optical region D 1 and a part located in the second optical region D 2. In the first optical region D 1, a polarizing filter that transmits light oscillating in the direction of the first polarizing axis (transmission axis) is disposed, and in the second optical region D 2, light that vibrates in all directions A glass plate that transmits is arranged. For example, in the case where the vibration direction of the light from the object is biased, the attenuation of the light passing through the first optical region D 1 increases depending on the vibration direction, but vibrates in all directions in the second optical region D 2 Since it transmits light (light oscillating in an arbitrary direction), attenuation is small.

In the present embodiment, light that has passed through the two optical regions D 1 and D 2 passes through the lens L 2 and then enters the arrayed optical element K. The arrayed optical element K causes light passing through the optical region D 1 to be incident on a plurality of pixels P 1 in the image pickup element N and light passing through the optical region D 2 to be incident on a plurality of pixels P 2 in the image pickup element N. The signal processing unit C generates image information corresponding to the light vibrating in the direction of the first polarization axis from the luminance value obtained in the pixel P 1 and calculates the first polarization axis from the luminance value obtained in the pixel P 2 And generates and outputs image information corresponding to the light that vibrates in all directions including the direction.

In FIG. 1, the light flux B 1 is a light flux passing through the first optical region D 1 on the optical element L 1 p, and the light flux B 2 is a light flux passing through the second optical region D 2 on the optical element L 1 p. The light beams B 1 and B 2 pass through the diaphragm S, the optical element L 1 p, the lens L 2, and the arrayed optical element K in this order and reach the imaging surface Ni (shown in FIG. 4) on the imaging element N.

FIG. 2 is a front view of the first and second optical regions D 1 and D 2 as viewed from the object side. The first and second optical regions D 1 and D 2 in the optical element L 1 p are formed by dividing the optical axis

V in two vertically in a plane perpendicular to the optical axis V with the optical axis V as a boundary center. In FIG. 2, the broken line s indicates the opening area of the diaphragm S. An arrow H in FIGS. 1 and 2 indicates a horizontal direction in the case where the imaging apparatus is used.

FIG. 3 is a perspective view of the arrayed optical element K. FIG. The arrayed optical element K includes a plurality of optical elements M 1 each having a lens surface. In the present embodiment, the lens surface of each optical element M 1 is a cylindrical surface. On the surface of the arrayed optical element K on the side of the image pickup element N, each optical element M 1 extends in the x direction (first direction), and the plurality of optical elements M 1 are arranged in the y direction (second direction). The y direction corresponds to the horizontal direction in FIGS. A cross section perpendicular to the x direction of each optical element M 1 has a curved surface shape protruding toward the image pickup element N side. In this manner, the plurality of optical elements M constitute a lenticular lens. In the present embodiment, the x direction and the y direction are orthogonal to each other.

As shown in FIG. 1, the arrayed optical element K is disposed in the vicinity of the focal point of the lens optical system L, and is arranged at a position separated from the imaging surface Ni by a predetermined distance.

4 (a) is an enlarged view of the arrayed optical element K and the image pickup element N shown in FIG. 1, and FIG. 4 (b) is an enlarged view of the arrayed optical element K and the pixels on the image pickup element N FIG. The arrayed optical element K is arranged such that the surface on which the optical element M 1 is formed faces the imaging surface Ni side.

The imaging device N includes an imaging surface Ni and a plurality of pixels P. The plurality of pixels P are two-dimensionally arranged in the x direction and the y direction. In the case where the arrangement in the x direction and the y direction is called a row and a column, respectively, the plurality of pixels are arranged in, for example, m rows and 1 column (l, m is an integer of 2 or more) on the imaging surface Ni. That is, a pixel group of one row in which 1 to 1 pixels are arranged in the x direction is arranged in m rows from 1 to m in the y direction.

Each position of the center C'j in the x direction of the l pixels arranged in the j-th row (1 □ j □m) out of the pixel group of m rows is the position of the l pixels arranged in the j + 1-th row Of the center C 'j + 1 in the x direction.

Likewise, it can be seen that one pixel group of a plurality of pixels arranged in the y direction in a plurality of pixels is arranged in an l column from 1 to 1 in the x direction. In this case, each position of the center in the y direction of the m pixels arranged in the u th row (1 □ u □l) out of the pixel group of the l column is the m pixels arranged in the u + 1 th row Direction in the y direction.

The plurality of pixels P are arranged in the x direction, and are divided into a plurality of pixels P 1 and a plurality of pixels P 2 constituting a row. Each of the plurality of pixels P 1 and the plurality of pixels P 2 is arranged in one row in the x direction as described above. In the y direction, the rows of pixels P1 and P2 are alternately arranged. The arrayed optical element K is arranged so that one of the optical elements M 1 corresponds to pixels of two rows consisting of a pixel P 1 of one row on the imaging surface Ni and a pixel P 2 of one row. On the imaging surface Ni, microlenses Ms are provided so as to cover the surfaces of the pixels P undefined 1 and P undefined 2.

In the present embodiment, each of the plurality of first pixels P 1 and the plurality of second pixels P 2 has the same shape on the imaging surface Ni. For example, the plurality of first pixels P undefined 1 and the plurality of second pixels P undefined 2 have the same rectangular shape and have the same area.

In the arrayed optical element K, most of the light flux (the light flux B 1 indicated by the solid line in FIG. 1) having passed through the optical region D 1 (shown in FIGS. 1 and 2) on the optical element L 1 p is reflected by the pixel Most of the luminous flux (the luminous flux B 2 indicated by the broken line in FIG. 1) that has reached P 1 and passed through the optical area D 2 reaches the pixel P 2 on the imaging surface Ni. Specifically, by appropriately setting parameters such as the refractive index of the arrayed optical element K, the distance from the imaging surface Ni, and the radius of curvature of the surface of the optical element M 1, the above configuration is realized.

Further, the lens optical system L in this embodiment is an image side telecentric optical system. As a result, even if the angle of view changes, since the principal ray incident angle of the arrayed optical element K is incident at a value close to 0 degrees, the light beam that reaches the pixel P 1 and reaches the pixel P 2 over the entire imaging region Crosstalk with the light flux can be reduced.

The diaphragm S is an area through which light fluxes of all angles of view pass. Therefore, by inserting a surface having optical characteristics for controlling the polarization characteristic in the vicinity of the diaphragm S, it is possible to control the polarization characteristics of the luminous flux of all the field angles in the same manner. That is, in the present embodiment, the optical element L 1 p may be provided in the vicinity of the diaphragm S. By arranging the optical element L 1 p in the first and second optical regions D 1 and D 2 located in the vicinity of the diaphragm, it is possible to give the light flux the polarization characteristics corresponding to the number of divisions of the region.

In FIG. 1, the light having passed through the diaphragm S is provided directly at a position where it enters the optical element L 1 p (without passing through another optical member). The optical element L 1 p may be provided closer to the subject than the diaphragm S. In this case, the light having passed through the optical element L 1 p may directly enter the diaphragm S (without passing through another optical member). In the case of the image-side telecentric optical system, the angle of incidence of light rays at the focal point of the optical system is uniquely determined by the position of the ray passing through the diaphragm S. The arrayed optical element K has a function of distributing the outgoing direction according to the incident angle of the light beam. Therefore, it is possible to distribute the luminous flux to the pixels on the imaging surface Ni so as to correspond to the first and second optical regions D 1, D 2 divided near the diaphragm S.

In the case of the image side non-telecentric optical system, the incident angle of the light beam at the focal point of the optical system is uniquely determined by the position of the light beam passing through the diaphragm S and the angle of view.

With the above configuration, it is possible to generate image information having polarization information and non-polarized image information without polarization information by using the luminance information of the pixels P 1 and P 2, respectively. In addition, since the light rays passing through the area close to the diaphragm S are separated to obtain two images, it is possible to reduce the parallax as compared with a conventional imaging device of a compound eye configuration.

That is, the image capturing apparatus A acquires a plurality of pieces of image information, each of which is formed by light in a polarized state and light in a non-polarized state, with less parallax, with a single imaging optical system and with one imaging You can do.

In the configuration of this embodiment, since these images can be acquired at the same time, these images can be switched or synthesized according to image information. Such a technique can be applied, for example, to detection of a lane on a road. When detecting a lane on a wet road, unnecessary reflected light is reflected on the non-polarized image having no polarized information, so it becomes difficult to recognize the lane. On the other hand, unnecessary reflected light can be reduced in the image acquired via the polarizing filter, so that the lane can be easily recognized. By utilizing such characteristics, by estimating the condition of the road surface from image information having polarization information and non-polarized image information not having polarization information and by switching and synthesizing each image based on the estimated information, It is possible to generate an image that makes it easy to detect lanes.

In the present embodiment, the pixel value in the y direction is lost every other pixel. Therefore, the pixel value of the missing pixel may be generated complemented by the pixel value of the pixel adjacent in the y direction, or may be generated by adding the pixel value in the x direction by 2 pixels at a time.

Further, the aspect ratio in the x direction and y direction of each pixel of the image pickup element may be 2: 1. By adopting such a configuration, the supplementing process and the addition process as described above are unnecessary.

In the present embodiment, the second optical region D 2 is a glass plate, but it may be replaced by a filter that attenuates the light amount like an ND filter. Since the light transmittance of the polarizing filter is less than 50%, the brightness of the image captured via the second optical region in which the glass plate is arranged is higher than the brightness of the image through the first optical region where the polarizing filter is disposed It is more than twice the captured image. In such a configuration, since the exposure amount is adjusted so as to

match the image with the wider dynamic range of the image, the dynamic range of the image captured via the polarizing filter is half of the image captured through the glass . On the other hand, by replacing the glass plate with the ND filter with the same transmittance as that of the polarizing filter, it is possible to reduce the difference in the exposure amount of the image captured via the two regions, and effectively securing the dynamic range of any image can do.

(Embodiment 2) FIG. 5 is a schematic diagram showing an image pickup system AP 1 according to Embodiment 2. The imaging system AP 1 of the present embodiment is configured by the imaging device A of Embodiment 1, polarized illumination Qa, and a control unit CS. The polarized illumination Qa is composed of a light source LS 1 that emits visible light and a polarizing filter PL. The polarization axis of the polarization filter PL has a second polarization axis orthogonal to the polarization axis of the first optical region D 1 of the imaging device A. Further, the control unit CS controls the imaging device A and the polarized lighting Qa, and performs input / output control with the external device E, and the like. The external device E is, for example, a monitor that displays an image output from the imaging system AP 1, a personal computer that processes an image, or the like.

The light emitted from the light source LS 1 passes through the polarizing filter PL and reaches the object Ob. The polarizing filter PL mainly transmits light vibrating in a direction parallel to the second polarization axis and large light (for example, light oscillating in a direction orthogonal to the second polarization axis) that vibrates in the other direction Absorb parts. Therefore, only the light oscillating in the direction of the second polarization axis is irradiated to the subject Ob.

The object Ob is, for example, a living body such as a person's facial skin. In the present embodiment, the subject Ob is described as a facial skin of a person. The light that reaches the face (object Ob) has components to be reflected and components to be absorbed, and the imaging device A images the light of the component to be reflected. The light reflected by the facial skin includes a component that reflects on the surface of the facial skin and a component that enters the interior of the facial skin and repeats scattering and then emerges from a position different from the incident position.

Light reflected on the surface of facial skin is further divided into specularly reflecting components and diffusely reflecting components. Components specularly reflected by facial skin are in a state in which polarization is maintained. In addition, a component that diffusely reflects on facial skin and a component that enters the inside of facial skin and exits from a different position are in a non-polarized state in which the polarization state is disturbed.

Since the polarizing filter arranged in the first optical region D 1 of the image pickup apparatus A has a polarization axis orthogonal to the polarization axis of the polarizing filter PL in the polarized illumination Qa, the component of the light specularly reflected by the facial skin Cut the majority. The light diffusely reflected by the surface of the facial skin and the light entering the inside of the facial skin and exiting from different positions are nonpolarized, but the polarizing filter arranged in the first optical region D 1 of the imaging device A , And transmits the component of the light oscillating in the direction of the first polarization axis among the non-polarized light components. That is, the image information imaged by the light transmitted through the first optical region D 1 has a component of light diffusely reflected on the surface of the facial skin and a component of light entering inside the facial skin and emerging from different positions ing.

On the other hand, since the second optical region D 2 of the imaging device A transmits the light vibrating in all directions, the image information imaged by the light transmitted through the second optical region D 2 is light which specularly reflects on the facial skin , A component of light diffusely reflected by the surface of the facial skin, and a component of light entering inside the facial skin and emerging from different positions.

The above-described inside of facial skin is a skin region, and melanin is generated in a region where spots are formed in the epidermal region. Since the light entering the epidermis is attenuated by melanin, the brightness of the image of a region with a spot is lowered. However, since the image information generated by the light transmitted through the second optical region D 2 contains the specular reflection component of the facial skin, it appears as a facial appearance of the facial skin and the recognition of the decrease in brightness due to spots It becomes difficult. On the other hand, the image generated by the light transmitted through the first optical region D 1 is an image obtained by cutting most of the specular reflection component of the facial skin, that is, an image obtained by cutting a large part of the facial skin. Therefore, The state of skin stain becomes easy to see.

Further, by subtracting the image information imaged by the light transmitted through the first optical region D 1 from the image information imaged by the light transmitted through the second optical region D 2 of the imaging device A, a mirror surface It is possible to generate image information having the reflected light component. In the image information having the component of the light specularly reflected by the surface of the facial skin, since the shadow due to the irregularities of the facial skin is clear, pores, texture of the skin, fine wrinkles and the like are easy to recognize.

With the above configuration, it is possible to acquire an image that easily recognizes the state of the spot by the light transmitted through the first optical region D 1 in the imaging device A of the imaging system AP 1, and the light transmitted through the second optical region D 2 , It is possible to acquire a normal facial skin image and furthermore by using both images it is possible to acquire an image that is easily recognized by pores and texture of the facial skin.

The polarization axis of the polarizing filter PL may be a polarization axis parallel to the polarization axis of the first optical region D 1 of the imaging device A. In the case of imaging the facial skin with such a configuration, the image information captured by the light transmitted through the first optical region D undefined 1 can acquire an image that is easy to recognize pores, skin texture, fine wrinkles, and the like. Further, by subtracting the image information captured by the light transmitted through the first optical region D 1 from the image information captured by the light transmitted through the second optical region D 2 of the imaging device A, the state of the spot is recognized It is possible to acquire an easy image.

As described above, by using the imaging system AP 1 of the present embodiment, it is possible to simultaneously observe the state of the surface and the inside of the living body. The imaging system AP1 can be applied to an apparatus for confirming the diagnosis of facial skin and the state of make-up in real time, a medical camera such as an endoscope, and the like.

Embodiment 3 This Embodiment 3 is different from Embodiment 1 in that light in different wavelength bands is transmitted through the optical regions D 1 and D 2 of the image pickup apparatus A. Here, a detailed description of the same contents as those in the first embodiment in this embodiment will be omitted.

FIG. 6 is a schematic diagram showing the image pickup apparatus A according to the third embodiment. In FIG. 6, the optical element L 1 s is disposed between the diaphragm S and the optical element L 1 p. Both optical elements L1p and L1s have portions arranged in the first and second optical regions D1 and D2. A portion of the optical element L 1 s located in the optical region D 1 transmits the light of the first wavelength band and a part of the optical element L 1 s located in the optical region D 2 transmits light of the second wavelength band. The wavelength bands of the first wavelength band and the second wavelength band are different from each other.

The "wavelength band" in the "first wavelength band" and the "second wavelength band" is, for example, a continuous band occupying 50% or more of the total light quantity of light transmitted through the region, The wavelength cut by 95% or more by passing through is not included in the "wavelength band".

In addition, the two wavelength bands are different from each other means that at least one of the wavelength bands has a band not included in the other wavelength band. Therefore, some wavelength bands may be overlapped.

A configuration in which the wavelength bands to be transmitted are mutually different may be a configuration in which a filter using an organic material or a dielectric multilayer film is formed on the surface of the optical element L 1 s on the diaphragm S side, a configuration in which an absorption type filter is formed, And is realized by a configuration in which the optical element L 1 s is dyed for each region by a filter. Such a color filter may be formed on one flat plate or may be formed on a plurality of flat plates divided for each region. It should be noted that the optical elements L 1 p and L 1 s may be in contact with each other or may be separated from each other. Further, the optical elements L 1 p and L 1 s may be adhered.

In the present embodiment, the signal processing unit C of FIG. 6 generates image information corresponding to light vibrating in the direction of the first polarization axis in the first wavelength band from the luminance value obtained in the pixel P 1, From the luminance value obtained in P2, image information corresponding to unpolarized light in the second wavelength band is generated and outputted.

In FIG. 6, the light flux B 1 is a light flux passing through the optical region D 1 constituted by the upper half of the optical element L 1 s and the upper half of the optical element L 1 p, the light flux B 2 is a light flux passing through the lower half of the optical element L 1 s, And is a light flux passing through the optical region D 2 formed by the lower half of L 1 p. The light beams B 1 and B 2 pass through the diaphragm S, the optical element L 1 s, the optical element L 1 p, the lens L 2, and the arrayed optical element K in this order and reach the imaging surface Ni on the imaging element N.

FIG. 7 is a front view of the optical regions D 1 and D 2 of the optical element L 1 s viewed from the subject side. The optical regions D 1 and D 2 in the optical element L 1 s are formed by vertically dividing the optical regions D 1 and D 2 into two in a plane perpendicular to the optical axis V with the optical axis V as a boundary center. In FIG. 7, a broken line s indicates an opening area of the diaphragm S.

Further, the configuration of the optical element L 1 p, the configuration of the arrayed optical element K, and the configuration of the imaging element N are the same as those in Embodiment 1.

In the present embodiment, for example, the first wavelength band is a near ultraviolet light band and the second wavelength band is a visible light band.

By using such an image pickup apparatus A, an image pickup system as shown in FIG. 8 can be constructed. FIG. 8 is a schematic diagram showing the imaging system AP 2 according to the third embodiment. The imaging system AP 2 of the present embodiment is different from the imaging system AP 2 in that the polarized illumination irradiates the light of the first wavelength band and the unpolarized illumination that irradiates the light of the second wavelength band different from the first wavelength band is added In that it is different from the imaging system AP 1 of the second embodiment. Here, a detailed description of contents similar to those in Embodiment 2 in this embodiment will be omitted.

The polarized illumination Qa shown in FIG. 8 is composed of a light source LS 1 that irradiates near-ultraviolet light and a polarizing filter PL. Further, the non-polarized illumination Qb is constituted by a light source LS 2 that irradiates visible light. Therefore, the subject Ob is irradiated with light oscillating in the direction of the second polarization axis in the near ultraviolet light band and non-polarized light oscillating in all directions in the visible light band.

The light incident on the facial skin enters the deeper region of the skin as the wavelength is longer. Light having a short wavelength such as near ultraviolet light reaches the skin region only. Since melanin in which spots are formed is present in the epidermal area, attenuation of light due to melanin increases as the wavelength is shorter. For this reason, an image captured with light having a short wavelength such as near ultraviolet light is an image that the spot easily recognizes. Even with light having a short wavelength such as near ultraviolet light, reflected light due to specular reflection is generated on the surface of the skin, but due to the polarizing filter disposed in the first optical region of the imaging apparatus A of the present embodiment , It is possible to cut specular reflection light.

With the above configuration, an image formed by the light transmitted through the first optical region D 1 in the imaging device A of the imaging system AP 2 can acquire an image that is more likely to recognize spots as compared with the second embodiment .

The first wavelength band of the filter of the optical element L 1 s located in the first optical region D 1 of the imaging apparatus A and the wavelength band of the light source LS 1 are not necessarily the bands of the near ultraviolet light. For example, it may be a filter that transmits a predetermined band in a band of 400 nm to 600 nm such as violet, blue, green etc. in the visible light band. In such a configuration, the second wavelength band of the filter of the optical element L 1 s arranged in the second optical region D 2 of the image pickup apparatus A and the wavelength band of the light source LS 2 are set so that the optical element L 1 s arranged in the optical region D 1 The first wavelength band, and the wavelength band of the light source LS undefined 1.

The first wavelength band of the filter of the optical element L 1 s arranged in the first optical region D 1 of the imaging apparatus A and the wavelength band of the light source LS 1 may be the wavelength band of near infrared light. The wavelength of near infrared light reaches the deep part in a living body such as facial skin. Although blood vessels exist in the deep part of the living body, hemoglobin contained in the blood absorbs near infrared light, so the luminance of the image information decreases. Therefore, by using the wavelength band of near-infrared light, it is possible to acquire image information of blood vessels deep in the living body.

In FIG. 8, one polarized illumination Qa and one non-polarized illumination Qb are shown, but a plurality of them may be provided or they may be arranged alternately in an array.

In addition, the illumination of the imaging system AP 2 may be constituted by only polarized illumination. In this case, the light source is composed of a light source that emits light in the first wavelength band and light in the second wavelength band.

Further, the polarized illumination may be composed of two polarized illuminations in which the transmission polarization axes are orthogonal to each other. In this case, each light source is composed of a light source that emits light in the first wavelength band and light in the second wavelength band, and uses two polarized illuminations by switching as required.

Fourth Embodiment In the fourth embodiment, three regions are divided for the optical element L1 of FIG. 1, and a region that transmits light having a second polarization axis different from the first polarization axis is denoted by This embodiment differs from Embodiment 1 in that it is added.

FIG. 9 is a schematic diagram showing the image pickup apparatus A according to the fourth embodiment.

In FIG. 9, the luminous flux B 1 is a luminous flux passing through the optical region D 1 on the optical element L 1, the luminous flux B 2 is a luminous flux passing through the optical region D 2 on the optical element L 1, and the luminous flux B 3 is on the optical element L 1 The light flux passing through the optical area D 3 of FIG. The light beams B 1, B 2, and B 3 pass through the diaphragm S, the optical element L 1 p, the lens L 2, and the arrayed optical element K in this order and reach the imaging surface Ni (shown in FIG. 11 and the like) on the imaging element N.

In FIG. 9, in the first optical region D 1, a polarizing filter that mainly transmits light oscillating in the direction of the first polarization axis is disposed, and in the second optical region D 2, A glass plate that transmits vibrating light is disposed and a polarization filter that mainly transmits light that vibrates in the direction of the second polarization axis orthogonal to the first polarization axis is disposed in the third optical region D 3 ing.

10 is a front view of the optical element L1 viewed from the subject side, and the first, second, and third optical regions D1, D2, D3 are divided into three in the vertical direction within a plane perpendicular to the optical axis V Area.

11 (a) is an enlarged view of the arrayed optical element K and the image pickup element N shown in FIG. 9, and FIG. 11 (b) is an enlarged view of the arrayed optical element K and the pixels on the image pickup element N FIG. The arrayed optical element K is arranged such that the surface on which the optical element M 1 is formed faces the imaging surface Ni side. On the imaging surface Ni, the pixels P are arranged in a matrix. Pixel P can be distinguished as pixel P1, pixel P2 and pixel P3.

Each of the pixel P1, the pixel P2, and the pixel P3 is arranged in one row in the x direction. In the y direction, the pixels P 1, P 2, P 3 are repeatedly arranged. The arrayed optical element K is arranged so that one of its optical elements M 1 corresponds to three rows of pixels consisting of a pixel P 1 in one row on the imaging surface Ni, a pixel P 2 in one row, and a pixel P 3 in one row ing. On the imaging surface Ni, microlenses Ms are provided so as to cover the surfaces of the pixels P 1, P 2, and P 3.

In the arrayed optical element K, most of the light flux B 1 (the light flux B 1 indicated by the dotted line in FIG. 9) that has passed through the optical region D 1 (shown in FIGS. 9 and 10) on the optical element L 1 is reflected on the imaging surface Ni Most of the light flux (the light flux B 2 indicated by the solid line in FIG. 9) that has reached the pixel P 1 and passed through the optical region D 2 reaches the pixel P 2 on the imaging surface Ni, and the light flux having passed through the optical region D 3 The light flux B 3 indicated by the broken line in FIG. 3B) reaches the pixel P 3 on the imaging surface Ni. Specifically, by appropriately setting parameters such as the refractive index of the arrayed optical element K, the distance from the imaging surface Ni, and the radius of curvature of the lens surface of the optical element M 1, the above configuration is realized.

With the above configuration, the pixel P1, the pixel P2, and the pixel P3 have image information corresponding to light vibrating in the direction of the first polarization axis, non-polarized image information corresponding to light oscillating in all directions , And generates image information corresponding to the light

vibrating in the direction of the second polarization axis orthogonal to the first polarization axis. That is, the imaging apparatus A can acquire these plural pieces of image information by a single imaging optical system and by one imaging.

In Embodiments 1 and 2, since an image having polarization information is only one type of information of light that vibrates in the direction of one polarization axis, detection of a road surface condition such as an in-vehicle camera or the like and lane detection And the like. In the fourth embodiment, since there are two kinds of polarization axes, it can be applied to applications where a scene in which glass surfaces of various orientations are present between a subject and a surveillance camera, for example. For example, the glass of a building or the windshield of a car has different directions of the normal to the reflecting surface, but in the present embodiment, since there are two kinds of polarizing axes, it is difficult for a person on the other side of the building's glass or a car It becomes easy to recognize the person of the windshield.

In this embodiment, as in the third embodiment, an optical element L 1 s having a region through which light having wavelength bands different from each other in each optical region can be transmitted may be added. In this case, the direction of the polarization axis may be one kind.

Fifth Embodiment A fifth embodiment is different from the third embodiment in that the area division of the optical element L undefined 1 of FIG. 1 is changed to four and the arrayed optical element is replaced with a microlens from a lenticular lens It is different. Here, a detailed description of the same contents as those in Embodiment 1 will be omitted.

FIG. 12 (a) is a front view of the optical element L 1 s as viewed from the subject side. The optical element L 1 s is arranged in the first, second, third and fourth optical regions D 1, D 2, D 3, and D 4. The first, second, third, and fourth optical regions D 1, D 2, D 3, and D 4 are regions divided into four vertically and horizontally in a plane perpendicular to the optical axis V with the optical axis V as a boundary center . The spectral transmittance characteristics of the portions located in the first, second, third, and fourth optical regions D 1, D 2, D 3, and D 4 of the optical element L 1 s are different from each other. The optical element L 1 s is arranged between the diaphragm S and the optical element L 1 p. In regions corresponding to the first, second, third, and fourth optical regions D 1, D 2, D 3, and D 4 of the optical element L 1 s, regions respectively transmitting light in the first wavelength band, A region that transmits light of the band, a region that transmits light of the third wavelength band, and a region that transmits light of the fourth wavelength band are arranged. The wavelength bands of the first wavelength band, the second wavelength band, the third wavelength band, and the fourth wavelength band are different from each other.

FIG. 12 (b) is a front view of the optical element L 1 p as viewed from the subject side. The first, second, third and fourth optical regions D 1, D 2, D 3, and D 4 are regions divided into four vertically and horizontally in a plane perpendicular to the optical axis V with the optical axis V as a boundary center. A polarizing filter that transmits light oscillating in the direction of the first polarization axis is disposed only in a portion of the optical element L 1 p that is located in the first optical region D 1 and in the portion located in the other region, A glass plate that transmits light vibrating in the direction is arranged.

FIG. 13 is a perspective view of the arrayed optical element K. FIG. On the surface of the arrayed optical element K on the image pickup element N side, optical elements M 2 are arranged in a lattice pattern. The cross section (each section perpendicular to the x direction and the y direction) of each optical element M 2 is a curved surface shape, and each optical element M 2 protrudes toward the image pickup element N side. In this manner, the lens surface of the optical element M 2 is a microlens, and the arrayed optical element K is a microlens array.

14 (a) is an enlarged view of the arrayed optical element K and the image pickup element N. FIG. 14 (b) shows the positional relationship between the arrayed optical element K and the pixel on the image pickup element N as FIG. The arrayed optical element K is arranged such that the surface on which the optical element M 2 is formed faces the imaging surface Ni side. On the imaging surface Ni, the pixels P are arranged in a matrix. Pixel P can be distinguished as pixel P1, pixel P2, pixel P3 and pixel P4.

Like the first embodiment, the arrayed optical element K is disposed in the vicinity of the focal point of the lens optical system L, and is arranged at a position separated from the imaging surface Ni by a predetermined distance. On the imaging surface Ni, microlenses Ms are provided so as to cover the surfaces of the pixels P 1, P 2, P 3, and P 4.

The arrayed optical element K is arranged so that the surface on which the optical element M 2 is formed faces the imaging surface Ni side. The arrayed optical element K is arranged such that one of the optical elements M 2 corresponds to four pixels of the pixels P 1 to P 4 of 2 rows and 2 columns on the imaging surface Ni.

In the arrayed optical element K, most of the light flux having passed through the first, second, third, and fourth optical regions D 1, D 2, D 3, and D 4 constituted by the optical elements L 1 s and L 1 p are incident on the imaging surface And is designed to reach pixels P1, P2, P3, and P4 on Ni. Specifically, by appropriately setting parameters such as the refractive index of the arrayed optical element K, the distance from the imaging surface Ni, and the radius of curvature of the surface of the optical element M 1, the above configuration is realized.

With the above configuration, in the present embodiment, image information corresponding to light vibrating in the direction of the first polarization axis in the first wavelength band is generated from the luminance value obtained in the pixel P1, and the image information obtained in the pixel P2 Image information corresponding to unpolarized light in the second wavelength band is generated from the luminance value and image information corresponding to unpolarized light in the third wavelength band is generated from the luminance value obtained in the pixel P 3 , Generates and outputs image information corresponding to nonpolarized light in the fourth wavelength band from the luminance value obtained in the pixel P 4.

In the present embodiment, for example, the first wavelength band in the optical region D 1 is the near ultraviolet light band, the second wavelength band in the optical region D 2 is the blue light band, and the third wavelength region in the optical region D 3 Is the band of green light, and the fourth wavelength band in the optical region D 4 is the band of red light.

By using such an imaging device A, it is possible to configure an imaging system similar to that shown in FIG. 8 described in Embodiment 3. With such a configuration, in the present embodiment, it is possible to acquire a near-ultraviolet image having polarization information and a non-polarized color image composed of three primary colors of blue, green, and red.

With nonpolarized color images, it is difficult to recognize spots due to the facial skin, but since near-ultraviolet images having polarization information are more likely to recognize spots, by combining these images, It is possible to generate a color image that is easy to recognize.

In the present embodiment, the first wavelength band is a band of near-ultraviolet light, but for example, a predetermined band in the 400 to 600 nm band of purple, blue, green, etc. in the visible light band May be used.

Sixth Embodiment The sixth embodiment is different from the fifth embodiment in that the first and third optical regions transmit light in the same wavelength band. Here, a detailed description of the same contents as those in the fifth embodiment will be omitted.

FIG. 15 (a) is a front view of the optical element L 1 s seen from the subject side. In the fifth embodiment, in regions corresponding to the first, second, third, and fourth optical regions D 1, D 2, D 3, and D 4 of the optical element L 1 s, the regions through which light of all different wavelength bands is transmitted However, in the present embodiment, the first and third optical regions D 1 and D 3 transmit light in the same wavelength band. The second and fourth optical regions D 2 and D 4 transmit light in wavelength bands different from the optical regions D 1 and D 3, respectively.

FIG. 15 (b) is a front view of the optical element L 1 p viewed from the subject side, which is the same as the configuration of FIG. 12 (b) in the fifth embodiment.

In the present embodiment, for example, the first wavelength band (optical regions D 1 and D 3) is a band of blue light, the second wavelength band (optical region D 2) is the band of green light, and the third wavelength band (Optical region D 4) is a band of red light.

By using such an imaging device A, it is possible to configure an imaging system similar to that shown in FIG. 8 described in Embodiment 3. In the present embodiment, however, the polarized light Qa in FIG. 8 is composed of a light source LS 1 for emitting blue light and a polarizing filter PL. In addition, the non-polarized illumination Qb is constituted by a light source LS 2 which irradiates green and red light. With such a

configuration, in the present embodiment, it is possible to obtain a blue image having polarized information and a non-polarized color image composed of three primary colors of blue, green, and red.

In non-polarized color images, it is difficult to recognize spots due to the appearance of facial skin, but blue images with polarized information are more likely to recognize spots, so by synthesizing these images, recognition of spots It is possible to generate a color image which is easy to be changed.

In the present embodiment, it is assumed that the first wavelength band (optical regions D 1 and D 3) is green, the second wavelength band (optical region D 2) is blue, the third wavelength band (optical region D 4) is red band May be used.

Further, in the present embodiment, as shown in FIG. 16 (a), a configuration in which a polarizing filter orthogonal to the polarization axis of the polarizing filter arranged in the optical region D 1 is arranged in the optical region D 3 may be adopted. Since light that has passed through the optical region D 1 cuts specular reflection components, it is possible to acquire image information that is easy to recognize spots. Further, by the light transmitted through the optical region D 3, image information of specular reflection components can be acquired. As described in the second embodiment, the light specularly reflected by the surface of the facial skin is shaded by the irregularities of the facial skin, so that it is possible to acquire image information that pores and the like are easy to recognize. By combining these image information and the image information of the light transmitted through the optical regions D 2 and D 4, it is possible to acquire both a color image that is easy to recognize spots and a color image that is easy to recognize pores and the like .

Further, as shown in FIG. 16 (b), the area of the optical regions D 2 and D 4 may be relatively reduced with respect to the optical regions D 1 and D 3 by the stop S. By adopting such a configuration, it is possible to reduce the difference in the exposure amount of the image captured through each region, and it is possible to effectively secure the dynamic range of any image. In addition, the area of the optical area D 3 may be relatively reduced with respect to the optical area D 1 by the diaphragm S. When photographing a living body such as skin, specular reflection component may be larger than scattered reflected light in some cases. Therefore, it is possible to reduce the difference in exposure amount between the image of the specular reflection component obtained by the light transmitted through the optical region D 3 and the image of the scattered reflection light component obtained by the light transmitted through the optical region D 1, Can also effectively secure the dynamic range.

Further, in the present embodiment, since the optical regions D 1 and D 3 transmit light in the same wavelength band, it is necessary to generate image information of non-polarization by adding images by light transmitted through the optical regions D 1 and D 3 You can do. By combining these image information and the image information by the light transmitted through the optical regions D 2 and D 4, it is also possible to obtain a non-polarized color image.

Seventh Embodiment The seventh embodiment is different from the fifth embodiment in that there is no optical element L 1 s and that the imaging element N is a color imaging element. Here, a detailed description of the same contents as those in Embodiments 5 and 6 will be omitted.

FIG. 17 (a) is a front view of the optical element L 1 p viewed from the subject side, and is the same as the configuration of FIGS. 12 (b) and 15 (b) shown in Embodiments 5 and 6.

FIG. 17 (b) is a diagram showing the positional relationship between the arrayed optical element K and the pixels on the color imaging element Nc. The arrayed optical element K is arranged such that the surface on which the optical element M 2 is formed faces the imaging surface Ni side. On the imaging surface Ni, the pixels P are arranged in a matrix. Pixel P can be distinguished as pixel P1, pixel P2, pixel P3 and pixel P4. The pixel P 1 is provided with a filter having a first spectral transmittance characteristic, and mainly passes light rays in the purple band and absorbs or reflects light rays in other bands. In addition, the pixel P 2 is provided with a filter having a second spectral transmittance characteristic, mainly passing light rays in the blue band and absorbing or reflecting light rays in other bands. In addition, the pixel P 3 is provided with a filter having a third spectral transmittance characteristic, and mainly passes light rays in the green band, and absorbs or reflects light in other bands. In addition, the pixel P 4 is provided with a filter having a fourth spectral transmittance characteristic, and mainly passes light rays in the red band, and absorbs or reflects light in other bands.

Since the polarizing filter is provided only in the optical region D 1 of the optical element L 1 p, polarized light parallel to the first polarization axis is incident on the pixel P 1 and unpolarized light is incident on the

other pixels P 2 to P 4. Therefore, in the present embodiment, it is possible to acquire a violet image having polarization information and a non-polarized color image composed of three primary colors of blue, green, and red.

In the present embodiment, the spectral function of the optical element L 1 s of the fifth embodiment is replaced by the color filter of each pixel on the color imaging element Nc. With such a configuration, it is possible to obtain the same effect as in the fifth embodiment.

In addition, as shown in FIG. 18, the pixels P 1 and P 3 may be filters of Bayer arrangement having the same spectral transmittance characteristics. In the case of such a configuration, the optical element L 1 p can be combined with the configuration of FIG. 12 (b) or FIG. 16. With such a configuration, it is possible to obtain the same effect as in the sixth embodiment.

Further, in the present embodiment, the pixel P1 is provided with the filter having the first spectral transmittance characteristic. However, the filter P1 is not provided with the filter P1, and the filter having the desired spectral transmission characteristic in the optical region D1 And the optical regions D 2 to D 3 may further include an optical element L 1 s not provided with a filter. In this case, since the pixel P1 can detect white light, that is, light of an arbitrary wavelength, by changing the characteristics of the filter provided in the optical region D1 of the optical element L1s, the wavelength band of the polarized light detected by the pixel P1 Can be changed. Generally, changing the spectral characteristic of the filter provided on the pixel P1 of the color image pickup element Nc makes it difficult to manufacture the color image pickup element Nc of another specification. On the other hand, it is easy to change the characteristics of the filter provided in the optical region D 1 of the optical element L 1 s. Therefore, adopting such a structure makes it possible to easily change the color of the image having the polarization information at low cost.

Eighth Embodiment In the eighth embodiment, as in the third to seventh embodiments, in the plurality of optical regions, the optical element L1s that transmits light in different wavelength bands between the optical regions is provided, Further, it is assumed that the lens L2 is a lens having axial chromatic aberration. In such a configuration, in order to make the in-focus positions of the light beams transmitted through the plurality of optical regions substantially equal, in the plane perpendicular to the optical axis in the vicinity of the diaphragm, the plurality of optical regions are made of optical Having power. This point is different from Embodiments 3 to 7. Here, a detailed description of the same contents as those in the third to seventh embodiments will be omitted.

FIG. 19 (a) is a diagram schematically showing a ray diagram in the case where the lens L2 is a lens having axial chromatic aberration due to wavelength dispersion characteristics of the refractive index like the single lens in Embodiment 8. In FIG. 19 (a), a filter that transmits light in the first wavelength band is formed in the first optical region D 1, a filter that transmits light in the second optical region D 2 relatively A filter that transmits light in the second long wavelength band is formed. Since the lens L2 is a lens having on-axis chromatic aberration due to the chromatic dispersion characteristic of the refractive index like a single lens, for example, light having a longer wavelength is focused toward the side farther from the lens. Therefore, as shown in FIG. 19 (a), if the light ray passing through the optical region D 1 is set so as to be focused on the imaging surface Ni, the light ray having passed through the optical region D 2 is focused on the imaging surface Ni It becomes a state where it can not be done.

FIG. 19 (b) is a diagram schematically showing a ray diagram of the image pickup apparatus according to the eighth embodiment. In FIG. 19 (b), the light beam having passed through the second optical region D 2 having the second spectral transmittance characteristic forms a lens surface of optical power such that the light beam is focused on the imaging surface Ni. Specifically, the surface on the diaphragm side of the portion of the optical element L 1 s located in the second optical region D 2 has curvature, whereas in the optical element L 1 s, it is located in the first optical region D 1 The surface on the side of the diaphragm of the part is a flat surface. Note that the optical element L 1 s is composed of a substrate formed of a translucent member such as glass or resin and an optical filter provided on the surface of the substrate. For example, a shape (curved surface or diffractive lens) for making optical characteristics different is provided on a part of the surface on the diaphragm side of the base. Therefore, both the light ray passing through the first optical region D 1 and the light ray passing through the second optical region D 2 are focused on the imaging surface Ni. As described above, according to the present embodiment, since the first optical region D 1 and the second optical region D 2 have different optical powers, the first optical region D 1 and the second optical region D 2 have equal optical powers The in-focus position of the light transmitted through the first optical area D 1 and the in-focus position of the light transmitted through the second optical area D 2 are closer to each other as compared with the case where the focus position is included.

It is to be noted that since the substrate itself in the optical element L 1 s is colored, it may have the function of an optical filter. In this case, the portion of the base that is located in the first optical region D 1 transmits the light of the first wavelength band, and the portion of the base located in the second optical region D 2 transmits the light of the second wavelength band It is not necessary to separately provide an optical filter.

In the present embodiment, a structure for making the optical power different may be provided in a portion other than the surface on the stop side of the optical element L 1 s. For example, the optical power may be varied depending on the shape (curved surface, diffractive lens) for making the optical characteristics different on part of the surface of the optical element L 1 s on the image pickup element side.

FIG. 20 (a) is a perspective view of the optical element L 1 s shown in FIG. 19 (b). The optical element L 1 s is composed of a substrate and a filter formed on the surface thereof. The surface on the diaphragm side of the portion of the base body located in the first optical region D 1 is a flat surface (radius of curvature R 1 = ∞), and a filter having a first spectral transmittance characteristic is formed on the flat surface There. The surface on the diaphragm side of the substrate located in the second optical region D 2 is a lens surface (radius of curvature R 2), and a filter having a second spectral transmittance characteristic is formed on the lens surface . Therefore, a step is formed at the boundary portion between the first optical region D 1 and the second optical region D 2 on the diaphragm side surface of the base. Since the light ray that has passed through such a step becomes unnecessary light, it is preferable that the stop S is provided with a light shielding region as shown in FIG. 20 (b). Apart from the diaphragm S, a light shielding member covering the boundary between the first optical region D 1 and the second optical region D 2 on the base may be provided.

Although the above configuration is an embodiment using two optical regions, even three optical regions can be configured similarly.

FIG. 21 (a) is a perspective view of the optical element L 1 s when the optical region is divided into three. The surface of the base of the optical element L 1 s located on the first optical region D 1 on the diaphragm side is a flat surface (radius of curvature R 1 = ∞), and on the flat surface thereof has a first spectral transmittance characteristic A filter is formed. The surface of the base of the optical element L 1 s located in the second optical region D 2 on the diaphragm side is a lens surface (curvature radius R 2), and on the lens surface, a filter having a second spectral transmittance characteristic Are formed. The surface of the base of the optical element L 1 s located in the third optical region D 3 on the diaphragm side is a lens surface (radius of curvature R 3), and on the lens surface, a filter having a third spectral transmittance characteristic Are formed. With such a configuration, a step is formed in the portion of the base body located at the boundary of each optical area. Since the light ray passing through such a step becomes unnecessary light, it is preferable that the stop S has a light shielding region as shown in FIG. 21 (b).

Also in the case where the lens optical system has four optical regions, a light shielding region can be similarly provided.

FIG. 22 (a) is a perspective view of the optical element L 1 s when the optical region is divided into four. The surface on the diaphragm side of the base of the optical element L 1 s located in the first optical region D 1 is a plane (radius of curvature R 1 = ∞), on which the first spectral transmittance characteristic is Is formed on the filter. The surface of the base of the optical element L 1 s located in the second optical region D 2 on the diaphragm side is a lens surface (curvature radius R 2), and on the lens surface, a filter having a second spectral transmittance characteristic Are formed. The surface of the base of the optical element L 1 s located in the third optical region D 3 on the diaphragm side is a lens surface (radius of curvature R 3), and on the lens surface, a filter having a third spectral transmittance characteristic Are formed. On the base of the optical element L 1 s, the surface on the diaphragm side of the part located in the fourth optical region D 4 is the lens surface (radius of curvature R 4), and the filter having the fourth spectral transmittance characteristic is disposed on the lens surface And is formed. With such a configuration, a step is formed in the portion of the base body located at the boundary of each optical area. Since light rays that have passed through such a step become unnecessary light, it is preferable that the stop S is provided with a light shielding region as shown in FIG. 22 (b).

FIG. 23 shows an example in which, apart from the optical element L 1 s, a lens for varying the optical power is provided for each optical region. In FIG. 23, the optical element L 1 a, the optical element L 1 s, and the optical element L 1 p are arranged in this order in the direction from the diaphragm to the imaging element. The optical element L 1 a, the optical element L 1 s, and the optical element L 1 p are arranged in the vicinity of the diaphragm. Each of the optical elements L1a, L1s, and L1p has a portion located in a plurality of optical regions.

In this way, the element having the filter and the element having the lens provided with the lens surface may be separate bodies. Further, the optical elements L 1 a, L 1 s, and L 1 p may be arranged in a reversed order of arrangement, or may be arranged on the object side near the diaphragm. Further, it may be divided and arranged on the image pickup element side near the diaphragm and the object side near the diaphragm.

In addition, although FIG. 23 has a configuration having two divided optical regions, it may have a configuration having three divided regions and four divided optical regions.

As described above, in the eighth embodiment, even in the case of using the lens in which the axial chromatic aberration is not corrected like the single lens, such as the single lens, it is possible to obtain the two lenses having different optical powers in the plane perpendicular to the optical axis By providing one region, axial chromatic aberration can be reduced.

Ninth Embodiment In the ninth embodiment, the microlenses are rotationally symmetric with respect to the optical axis within each microlens region, and in this respect, this embodiment is similar to the fifth embodiment, 6, and 7, respectively.

As a method for manufacturing a microlens, there is a method of patterning a resist into a rectangle and forming a lens curved surface by heat treatment, a perspective view of such a microlens is as shown in FIG. 24 (a 1). Since the contour lines of the microlens in FIG. 24 (a 1) are as shown in FIG. 24 (a 2), the radius of curvature in the oblique direction is different from that in the x and y directions. FIG. 24 (a 3) shows the result of ray tracing simulation when the microlenses shown in FIGS. 24 (a 1) and (a 2) are applied to the arrayed optical element of the present invention. In FIG. 24 (a 3), only the light flux passing through one optical region among the light passing through the arrayed optical element K is shown, but in the case of the rotationally asymmetric micro lens, light Leaks and crosstalk occurs. On the other hand, a perspective view of a microlens having a rotationally symmetric shape in the square region of each microlens is as shown in FIG. 24 (b 1). The contour line of the microlens in FIG. 24 (b 1) is as shown in FIG. 24 (b 2), and the curvature radii in the oblique direction are equal to those in the x and y directions. Such microlenses can be formed by thermal imprinting or UV imprinting process. FIG. 24 (b 3) shows the result of ray tracing simulation when the microlenses shown in FIGS. 24 (b 1) and (b 2) are applied to the arrayed optical element of the present invention. In FIG. 24 (b 3), only the light flux passing through one optical region among the light that passes through the arrayed optical element K is shown, but the crosstalk as shown in FIG. 24 (a 3) does not occur . In this way, since the lens surfaces of the respective optical elements of the microlens have a rotationally symmetrical shape, it is possible to reduce crosstalk, so that it is possible to suppress crosstalk of color information and crosstalk of polarization information .

Tenth Embodiment The tenth embodiment is different from the first to ninth embodiments in that lenticular lenses or microlens arrays which are arrayed optical elements are formed on the imaging surface. Here, a detailed description of the same contents as those in the first to ninth embodiments in this embodiment will be omitted.

25A and 25B are enlarged views of the arrayed optical element K and the image pickup element N, and only light rays that have passed through one optical region are shown. In the present embodiment, a lenticular lens (or microlens array) Md that is the arrayed optical element K is formed on the imaging surface Ni of the imaging element N. On the imaging surface Ni, the pixels P are arranged in a matrix like the first embodiment and the like. An optical element of one lenticular lens or one microlens corresponds to the plurality of pixels P. In the present embodiment as well, like the first to seventh embodiments, it is possible to guide light beams passing through different optical regions to different pixels. Further, FIG. 25 (b) is a diagram showing a modified example of the present embodiment. In the configuration shown in FIG. 25 (b), a microlens Ms is formed on the imaging surface Ni so as to cover the pixel P, and the arrayed optical element is laminated on the surface of the microlens Ms via the low refractive index layer W Has been done. In the configuration shown in FIG. 25 (b), the light collection efficiency can be improved as compared with the configuration in FIG. 25 (a).

When the arrayed optical element is separated from the imaging element as in Embodiments 1 to 9, it becomes difficult to align the arrayed optical element and the imaging element. However, as in the present embodiment, the arrayed optical element Since K is formed on the image pickup element, alignment can be performed by the wafer process, so that alignment is facilitated and alignment accuracy can be increased.

Eleventh Embodiment The eleventh embodiment is different from the first to tenth embodiments in that the lens optical system L is an image side non-telecentric optical system. Most of lenses used for image pickup

devices such as cameras are non-telecentric optical systems on the image side. When the image side non-telecentric optical system is applied to the lens optical system L of the embodiment of the present invention, when the angle of view changes, the chief ray obliquely enters the arrayed optical element K. FIG. 26 (a) is an enlarged view showing the vicinity of the imaging unit outside the optical axis. In FIG. 26 (a), only the light flux passing through one optical region among the light passing through the arrayed optical element K is shown. As shown in FIG. 26 (a), when the lens optical system L is an image-side non-telecentric optical system, light leaks to adjacent pixels and crosstalk is likely to occur. However, as shown in FIG. 26 (b) Since the crosstalk can be reduced by offsetting the arrayed optical element by Δ with respect to the pixel arrangement, degradation of color purity can be suppressed. Since the incident angle depends on the image height, the offset amount Δ may be set according to the incident angle of the light beam on the imaging surface.

By using an image side non-telecentric optical system, the optical length can be made shorter than that of the image side telecentric optical system, so that the image pickup apparatus A can be downsized.

Twelfth Embodiment The twelfth embodiment is different from the twelfth embodiment in that the optical element L1p has two optical regions, that a color imaging element having a Bayer array filter is used, and that the optical element of the arrayed optical element is 1 Direction by a half pitch in the first embodiment. Thereby, the image pickup apparatus of this embodiment can acquire a color image by nonpolarized light and a color image by polarized light all at once.

As shown in FIG. 1, the imaging apparatus of the present embodiment includes a lens optical system L, an arrayed optical element K, and an imaging element N. As shown in FIGS. 1 and 2, the lens optical system L includes an optical element L 1 p having a first optical region D 1 and a second optical region D 2. In the first optical region D 1, a polarizing filter that transmits light oscillating in the direction of the first polarizing axis (transmission axis) is disposed, and in the second optical region D 2, light that vibrates in all directions A transparent glass plate is placed. Therefore, the light beam B1 transmitted through the first optical region D1 is polarized light that vibrates in the direction of the first polarization axis (transmission axis). The light beam B 2 transmitted through the second optical region D 2 is unpolarized light.

FIG. 27 (a) is an enlarged view of the arrayed optical element K and the image pickup element N of the present embodiment. The arrayed optical element K includes a plurality of optical elements M 1 and a plurality of optical elements M 2 and is arranged so that the surface on which the plurality of optical elements M 1 and M 2 are formed faces the imaging surface Ni side.

27 (b) is a diagram showing the positional relationship between the plurality of optical elements M 1, M 2 of the arrayed optical element K and the pixels on the image pickup element N. FIG. As in the first embodiment, the imaging element N includes a plurality of pixels arranged on the imaging surface Ni. As shown in FIG. 27 (b), the plurality of pixels are two-dimensionally arranged in the x direction (the first direction) and the y direction (the second direction). In the case where the arrangement in the x direction and the y direction is called a row and a column, respectively, the plurality of pixels are arranged in, for example, m rows and 1 column (l, m is an integer of 2 or more) on the imaging surface Ni. That is, a pixel group of one row in which 1 to l pixels are arranged in the x direction is arranged in m rows from 1 to m in the y direction.

Each position of the center C'j in the x direction of the l pixels arranged in the j-th row (1 □ j □m) out of the pixel group of m rows is the position of the l pixels arranged in the j + 1 th row is approximately the same as each position of the center C'j + 1 in the x direction.

Likewise, it can be seen that one pixel group of a plurality of pixels arranged in the y direction in a plurality of pixels is arranged in an l column from 1 to 1 in the x direction. In this case, each position of the center in the y direction of the m pixels arranged in the u th row (1 □ u □l) out of the pixel group of the l column is the m pixels arranged in the u + 1 th row Direction in the y direction.

Further, in the present embodiment, in this embodiment, each of the plurality of pixels has the same shape on the imaging surface Ni. For example, a plurality of pixels have the same rectangular shape and areas are equal to each other. Further, in the present embodiment, the plurality of pixels are arranged at the same pitch in the x direction and the y direction.

For the sake of explanation, a plurality of pixels are respectively distinguished into a plurality of pixels P1A, P2A, P3A, P4A, P1B, P2B, P3B, and P4B. One of the plurality of pixels P1A, one of the plurality of pixels P2B, one of the plurality of P3A, and one of the plurality of P4B are arranged in two rows and two columns As

shown in FIG. The pixels P1A, P2B, P3A, P4B arranged in two rows and two columns are referred to as "first pixel group Pg1". One of the plurality of pixels P 1 B, one of the plurality of pixels P 2 A, one of the plurality of pixels P 3 B, and one of the plurality of pixels P 4 A are arranged in two rows They are arranged in two rows. Pixels P1B, P2A, P3B, P4A arranged in two rows and two columns are referred to as "second pixel group Pg2".

Here, it is assumed that the pixel P 3 A belonging to the first pixel group Pg 1 is arranged at the position (p, q). p and q are integers satisfying 1 □ p □1 and 1 □ q □m, respectively. In this case, the remaining pixels P 1 A, P 2 B, P 4 B of the first pixel group Pg 1 are arranged at positions (p + 1, q), (p, q + 1), (p + 1, q + 1), respectively. Further, the pixels 2 A, P 1 B, P 3 B, and P 4 A in the second pixel group Pg 2 are disposed at positions of (p + 2, q + 1), (p + 3, q + 2), (p + 2, q + 2), (p + 3, q + 1) There.

On the surface of the arrayed optical element K facing the imaging surface Ni, the optical element M 1 is a microlens provided at positions corresponding to the four pixels of the first pixel group Pg 1. Light from the optical element M 1 in the arrayed optical element K is incident on the first pixel group Pg 1. The optical element M 1 makes most of the light passing through the region D 1 incident on the pixels P 1 A and P 3 A in the image pickup element N and most of the light passing through the region D 2 on the pixels P 2 B and P 4 B in the image pickup element N.

On the surface of the arrayed optical element K facing the imaging surface Ni, the optical element M 2 is a microlens provided at a position corresponding to the four pixels of the second pixel group Pg 2. Light from the optical element M 2 in the arrayed optical element K is incident on the second pixel group Pg 2. The optical element M 2 makes most of the light passing through the region D 1 incident on the pixels P 2 A and P 4 A in the image pickup element N and most of the light passing through the region D 2 to the pixels P 1 B and P 3 B in the image pickup element N.

Filters having a first spectral transmittance characteristic are provided for the pixels P1A, P2A, P1B, and P2B. The filter having the first spectral transmittance characteristic mainly passes light rays in the green band and absorbs light rays in other bands. The pixels P 3 A and P 3 B are provided with filters having second spectral transmittance characteristics. The filter having the second spectral transmittance characteristic mainly passes light rays in the red band and absorbs light rays in other bands. Further, the pixels P 4 A and P 4 B are provided with a filter having a third spectral transmittance characteristic. The filter having the third spectral transmittance characteristic mainly passes light rays in the blue band and absorbs light rays in other bands.

The pixels P1A and P3A, the pixels P1B and P3B, the pixels P2A and P4A, and the pixels P2B and P4B are alternately arranged in the x direction. In addition, the pixels P1A and P4A, the pixels P1B and P4B, the pixels P2A and P3A, and the pixels P2B and P3B are alternately arranged in the y direction. The pixels P 1 A, P 3 A, P 1 B, and P 3 B are arranged in the same row (arranged in the x direction), the pixels P 2 A, P 4 A, P 2 B, and P 4 B are arranged in the same row (arranged in the y direction) , P1B, and P3B rows and the rows of pixels P2A, P4A, P2B, and P4B are alternately arranged in the y direction. In this manner, each of the plurality of pixels forms a Bayer array. In the case where pixels are arranged in the Bayer arrangement, the pixels P 1 A and P 2 B, the pixels P 1 B and P 2 A, which have filters that pass light in the green band, are disposed at oblique positions in the respective pixel groups Pg 1 and Pg 2 Are arranged.

The arrayed optical element K has a function of distributing the outgoing direction according to the incident angle of the light beam. Therefore, light can be made incident on pixels on the imaging surface Ni so as to correspond to the first optical region D 1 and the second optical region D 2. In order to realize the incidence of light to such a pixel, by appropriately setting parameters such as the refractive index of the arrayed optical element K, the distance from the imaging surface Ni, and the radius of curvature of the surface of the optical element M 1, The configuration is realized.

Next, the specific configuration of the arrayed optical element will be described.

27 (a), (a 2), (b 1), (b 2), (c 1) and (c 2) show the shapes and arrangements of the optical elements M 1 and M 2 shown in FIGS. FIG. 28 (a 1) is a diagram showing the arrangement and contour lines of optical elements (microlenses) having a rotationally asymmetric shape with respect to the optical axis, and FIG. 28 (a 2) is a perspective view thereof. Such a microlens array can be formed by forming a quadrangular prism shaped resist on a glass plate and performing heat treatment.

As shown in FIG. 28 (a 1), the optical elements M 1 and M 2 are s (number of) arranged in the y direction on the surface of the arrayed optical element K (for example, a plane perpendicular to the optical axis of the lens

optical system L) s is an integer of 2 or more), and the columns of the optical element M 1 and the columns of the optical element M 2 are alternately arranged in the x direction. For example, these columns are arranged in t columns ranging from 1 in the x direction to the t th column (n is an integer of 2 or more). If an arbitrary integer greater than or equal to 1 and smaller than t is k (1 □ k □n), the position Yk of the center Ck in the y direction of the optical element arranged in the k-th column is arranged in the k + 1 th column Is shifted in the y direction from the position Yk + 1 of the center Ck + 1 in the column direction of the optical element. That is, the positions of the centers of the optical element M1 and the optical element M2 are shifted from each other in the y direction.

Here, on the surface of the arrayed optical element K, the distance between the centers of the two optical elements M 1 and M 2 adjacent in the y column direction in the column direction is Y. The pitch in the y direction of the optical elements M 1 and M 2 is Y at all. In this case, the shift in the column direction between the position Yk and the position Yk + 1 in the y direction is, for example, 0.5 Y (half pitch). However, in consideration of manufacturing tolerance of the arrayed optical element K and the like, this shift may be 0.45 Y or more and 0.55 Y or less. If the deviation is 0.45 Y or more and 0.55 Y or less, the light incident on the first optical region D 1 and the second optical region D 2 can be distributed to desired pixels by the arrayed optical element K.

The "center in the column direction of the optical element" is, for example, a vertex of a solid constituting each optical element. Or the middle point of the line segment connecting the two end portions in the column direction of each optical element.

28 (b 1) is a diagram showing the arrangement and contour lines of microlenses having a rotationally symmetric shape with respect to the optical axis, and FIG. 28 (b 2) is a perspective view thereof. The microlenses in FIG. 28 (b 1) are each separated by a hexagon. However, since each microlens is formed so as to cover four pixels arranged in a square array, it is not typically a regular hexagon. Although the boundary between the micro lenses shown in FIGS. 28 (b 1) and (b 2) is partitioned by a hexagon, the upper part than the boundary part of the microlenses may be a spherical surface or an aspheric surface. Such rotationally symmetric microlenses can be formed on a glass plate or the like by thermal imprinting or UV imprinting process.

28 (c 1) is a diagram showing the arrangement and contour lines of a microlens array having a shape obtained by alternately shifting the cylindrical microlenses by half a pitch every two pixels, and FIG. 28 (c 2) is a perspective view thereof. The microlens array in FIG. 28 (c 1) can also be formed on a glass plate or the like by thermal imprinting or UV imprinting process.

29 (a) is a diagram showing the results of a three-dimensional ray tracing simulation when the microlenses shown in (a 1) and (a 2) of FIG. 28 are applied to the arrayed optical element of this embodiment. In FIG. 29 (a), only light rays passing through the region D 1 among the light passing through the arrayed optical element K are shown, but in the case of the rotationally asymmetric microlens, And the diagonal direction (the diagonal direction of the bottom surface of the microlens) are different from each other, light leaks to the adjacent pixels, and crosstalk occurs.

FIG. 29 (b) is a diagram showing the results of a three-dimensional ray tracing simulation in the case where the microlenses shown in FIGS. 28 (b 1) and (b 2) are applied to the arrayed optical element of this embodiment. In FIG. 29 (b), only the light flux passing through one region of the light passing through the arrayed optical element K is shown, but it is found that crosstalk as shown in FIG. 29 (a) does not occur . In this way, by making each optical element of the arrayed optical element rotationally symmetrical, crosstalk between the first color image and the second color image described below can be reduced.

Although the microlenses shown in FIGS. 28 (b 1) and (b 2) are hexagonal, they are not necessarily hexagonal as long as they are rotationally symmetrical.

FIG. 29 (c) is a diagram showing the results of a three-dimensional ray tracing simulation when the cylindrical microlenses shown in FIGS. 28 (c 1) and (c 2) are applied to the arrayed optical element of the present embodiment. In FIG. 29 (c), only the light flux passing through one region of the light passing through the arrayed optical element K is shown, but it is found that crosstalk as shown in FIG. 29 (a) does not occur . In this way, by making each optical element of the arrayed optical element into a cylindrical shape, crosstalk between the first color image and the second color image can be reduced.

Next, a method of generating a color image by polarized light and a color image by non-polarized light will be described.

FIGS. 30 (a) and 30 (b) are diagrams in which only pixels on which light having passed through the first optical region D 1 and the second optical region D 2 are incident are extracted. As shown in FIG. 28, since the optical element M 2 is displaced by a half pitch in the y direction with respect to the optical element M 1, in the pixel where the light passing through the first optical region D 1 and the second optical region D 2 enters , Color information of red (P3A or P3B), green (P1A, P2A or P1B, P2B), blue (P4A or P4B) becomes included.

However, the light passing through the first optical region D 1 is polarized light parallel to the first optical axis. Therefore, as shown in FIG. 30 (a), the pixels P 3 A (red), the pixels P 1 A and P 2 A (green) and the pixel P 4 A (blue) detect the polarized light parallel to the first optical axis. On the other hand, as shown in FIG. 30 (b), the pixels P 3 B (red), the pixels P 1 B and P 2 B (green), and the pixel P 4 B (blue) detect unpolarized light. Therefore, a color image formed by the polarized light parallel to the first optical axis and a color image by the non-polarized light are generated by the pixels on which the light having passed through the first optical region D 1 and the second optical region D 2 is incident be able to. Hereinafter, a color image by polarized light parallel to the first optical axis and a color image by non-polarized light are referred to as a first color image and a second color image.

The first color image and the second color image are generated by the signal processing unit C (shown in FIG. 1). The first color image and the second color image are generated by color information obtained from the pixels shown in FIGS. 30 (a) and 30 (b), specifically, luminance information. As shown in FIGS. 30 (a) and 30 (b), since both the first and second pixel groups corresponding to color pixels have only one color information for one pixel, The color information of two colors is generated by complementing from the luminance value of surrounding pixels.

For example, in the case of the first color image, as shown in FIG. 30 (a), there is only green (G 2) information at the position of the pixel P 2 A of the second pixel group Pg 2. For this reason, information of red (R) and blue (B) is supplemented from surrounding pixels, and information of blue, green and red is obtained at the position of pixel P2A of the second pixel group Pg2. Specifically, the red and blue luminance information in P2A of the second pixel group Pg2 is interpolated from the red and blue luminance information obtained by the pixels P3A and P4A positioned in the y direction, the x direction, or the oblique direction. Likewise, the green and red luminance information in the pixel P 4 A of the second pixel group Pg 2 is interpolated using the pixel P 2 A positioned in the y direction, the x direction, or the oblique direction and the green and red luminance information obtained by the pixel P 3 A . Red and blue luminance information in the pixel P1A of the first pixel group Pg1 and green and blue luminance information in the pixel P3A of the first pixel group Pg1 are also obtained by the same interpolation. Thus, a first color image can be obtained.

Likewise for the second color image, as shown in FIG. 30 (b), red and green luminance information in the pixel P 4 B of the first pixel group Pg 1, red and blue luminance information in the pixel P 2 B, The luminance information of red and blue at the pixel P1B of the second pixel group Pg2 and the luminance information of green and blue at the pixel P3B are obtained by interpolation. In this way, a second color image can be obtained.

In each of the first and second color images, the color information in the y direction is partially missing. For example, in the four pixels of the first pixel group Pg 1 of the first color image, the pixel P 4 B and the pixel P 2 B are missing. Even if the luminance information of these missing pixels is generated by interpolation using the luminance value of the color detected in the pixel adjacent in the y direction and the luminance value of the color obtained by interpolation after completing the aforementioned color Good. Specifically, the luminance information of red, blue and green in the pixels P 4 B and P 2 B of the first pixel group Pg 1 is calculated from the luminance information of red, blue and green in the pixel P 3 A and the pixel P 1 A adjacent in the y direction You may ask for it.

By the complementary processing as described above, it is possible to generate a color image by polarized light parallel to the first optical axis and a color image by non-polarized light.

According to the present embodiment, as shown in FIGS. 30 (a) and 30 (b), in each of the color image by the polarized light parallel to the first optical axis and the color image of the color image by the nonpolarized light, The groups (the first pixel group Pg 1, the second pixel group Pg 2, the first pixel group Pg 1 and the second pixel group Pg 2) each constitute a color pixel. Therefore, the pitch of pixels constituting the two color images is not lengthened, and an image with high resolution can be obtained.

Further, according to the present embodiment, it is possible to use a conventional Bayer array type image pickup element, so initial investment of a photomask or the like for a color filter having a dedicated filter arrangement becomes unnecessary and suppression of initial investment You can do.

It should be noted that the optical system of the image pickup apparatus of this embodiment may be an image side telecentric optical system. Even if the angle of view is changed, the principal ray incidence angle with respect to the arrayed optical element K is incident at a value close to 0 degrees, so that the pixels P1A, P1B, P2A, P2B, P3A, P3B, Crosstalk between the light beams reaching P 4 A and P 4 B can be reduced.

(Thirteenth Embodiment) In a thirteenth embodiment, the imaging system AP2 of the third embodiment is applied to a microscope. As the imaging device A of the imaging system AP 2 applied to the microscope of the present embodiment, any one of the imaging devices A of Embodiments 1, 3 to 11 can be used.

31 (a) and 31 (b) are a front view and a side view of the microscope AP 3 of Embodiment 13, respectively. The microscope AP 3 is composed of a head portion E 1, a lens barrel E 2 on which the imaging device A, polarized lighting Qa, nonpolarized lighting Qb are mounted, and a cable E 3.

As shown in FIG. 31 (a), the polarized illumination Qa and the non-polarized illumination Qb are alternately arranged concentrically around the imaging device A. The tip of the head portion E 1 is set so as to be in the in-focus position of the imaging device A, and the resolution becomes the highest when the head portion E 1 is brought into close contact with the subject Ob such as the face skin.

The light from the polarized light illumination Qa and the light from the non-polarized illumination Qb are irradiated on the subject Ob such as facial skin, so that the image capturing apparatus A captures image information having polarization information from reflected light from the subject Ob and image information It is possible to acquire both of the image information at the same time. The image information acquired by the imaging apparatus A is connected to a monitor, a personal computer, or the like via the cable E 3.

By using such a microscope AP 3, it is possible to simultaneously acquire a normal enlarged image, an enlarged image easy to recognize the state of the spot, and an enlarged image easily recognizable by pores and texture of the facial skin.

It should be noted that the imaging system AP 1 of the second embodiment may be used for the microscope of the thirteenth embodiment. As the imaging device A of the imaging system AP 1 used for the microscope, any one of the imaging devices A of Embodiments 1 and 3 to 12 may be used.

(Embodiment 14) In Embodiment 14, the imaging system AP 2 of Embodiment 3 is applied to a capsule endoscope. As the imaging device A of the imaging system AP 2 applied to the capsule endoscope, the imaging devices A of Embodiments 1 and 3 to 12 can be used.

32 (a) and (b) are a front view and a side view of the capsule endoscope AP 4 according to Embodiment 14, respectively. The capsule endoscope AP 4 is constituted by a lens barrel E 5 on which the dome portion E 4, the imaging device A, the polarized illumination Qa, and the non-polarized illumination Qb are mounted. Inside the lens barrel E 5, a battery, an IC for transmission and reception, an antenna for transmission and reception, and the like may be incorporated.

As shown in FIG. 32 (a), the polarized illumination Qa and the non-polarized illumination Qb are alternately arranged concentrically around the imaging device A.

The light from the polarized light illumination Qa and the light from the non-polarized illumination Qb are irradiated on the subject, which is a digestive organ in the living body, so that the imaging device A captures image information having polarization information from reflected light from the subject, Of the image information at the same time. The image information acquired by the imaging apparatus A is wirelessly transmitted to an external terminal via a transmission / reception IC and a transmission / reception antenna.

By using such a capsule endoscope AP 4, it is possible to simultaneously acquire a polarized image that can easily recognize the condition of digestive organs and a normal image.

Note that the imaging system AP 1 of the second embodiment may be used for the capsule endoscope of the fourteenth embodiment. As the imaging device A of the imaging system AP 1 used for the capsule endoscope, any one of the imaging devices A of Embodiments 1 and 3 to 12 may be used.

Fifteenth Embodiment A fifteenth embodiment is a configuration in which the imaging system AP 2 of the third embodiment is applied to an electronic mirror. As the imaging device A in the imaging system AP 2, the imaging devices A of Embodiments 1 and 3 to 12 can be used.

FIG. 33 (a) is a front view of the electronic mirror AP 5. The electronic mirror AP 5 is composed of a frame T 1 on which a display J 1, an imaging device A, a polarized illumination Qa, and a non-polarized illumination Qb are mounted. As shown in FIG. 33 (a), polarized light illumination Qa and non-polarized illumination Qb are arranged alternately in the vertical direction in the left and right regions of the display J 1.

The light from the polarized light illumination Qa and the light from the non-polarized illumination Qb are irradiated on the face of a person as a subject, so that the image capturing apparatus A captures image information having polarization information from reflected light of a person as a subject, Of the image information at the same time. The image information acquired by the imaging apparatus A is displayed on the display J 1 in real time in a state that the left and right are inverted.

By using such an electronic mirror AP 5, it is possible to simultaneously acquire a normal image, an image easy to recognize the state of spots, and an image easy to recognize the pores and texture of the facial skin, and the user himself Can see the mirror image of the user himself like a usual mirror. A normal image, an image that easily recognizes the spotted state, and an image that is easy to recognize pores and texture of the facial skin may be switched as appropriate by the user.

It is to be noted that such an electronic mirror may be configured using two imaging devices A and an autostereoscopic display.

FIG. 33 (b) is a front view of the three-dimensional electron mirror AP 6. The stereoscopic electronic mirror AP 6 is composed of a frame T 2 in which an autostereoscopic display J 2, two imaging devices A 1 and A 2, a polarized illumination Qa, and a nonpolarized illumination Qb are mounted. The autostereoscopic display is a parallax barrier autostereoscopic display or a lenticular type autostereoscopic display.

The light from the polarized illumination Qa and the light from the non-polarized illumination Qb are irradiated on the face of the person as the subject, so that the two image pickup apparatuses A1 and A2 acquire image information having polarization information of a person as a subject, Acquire both normal image information at the same time. The image information acquired by the two image capturing apparatuses A is displayed on the naked-eye stereoscopic display J 2 in real time in a state where the images having parallax are horizontally inverted from each other.

By using such an electronic mirror AP 6, it is possible to confirm the mirror image of the user himself more realistically than the electronic mirror AP 4.

In addition, the fifteenth embodiment may be a combination of any one of the imaging apparatus A described in the first embodiment, the third to the twelfth, and the imaging system AP 1 described in the second embodiment.

Further, when the display J 1 and the stereoscopic display J 2 are constituted by a liquid crystal display, light from the liquid crystal display itself is also irradiated on the subject, so that the polarizing axis of the polarizing filter on the front side of the liquid crystal display is the same as the polarizing axis of the polarized illumination Qa May be used. This makes it possible to make the polarization direction of the light irradiated on the subject from the liquid crystal display the same as the polarization direction of the light from the polarized illumination.

Further, in the present embodiment, it is constituted by polarized illumination and non-polarized illumination, but it may be constituted only by polarized illumination.

Further, in the case of only polarized illumination, two polarized illuminations in which the transmission polarization axes are mutually orthogonal may be used.

In addition, as a light source of polarized illumination, it may be constituted by only a white light source, or in order to compensate for the attenuation of light by the polarizing filter in the optical region of the image pickup apparatus, a configuration in which a blue light source is added to the white light source, It may be polarized illumination with a configuration to which a light source is added.

(Other Embodiments) Although the first to tenth and twelfth embodiments are provided with the signal processing unit C, the signal processing unit C may not be provided. In that case, processing performed by the signal processing unit C may be performed using a personal computer or the like outside the imaging apparatus. That is, the present invention can also be realized by a system including an imaging apparatus including a lens optical system L, an arrayed optical element K, and an imaging element N, and an external signal processing apparatus.

In the first to fifteenth embodiments, the microlens provided on each pixel of the image pickup device has a lens surface having a curved surface shape, but micro lenses of other shapes may be provided in the image pickup element. For example, a diffractive optical element for condensing light by distribution of materials having different refractive indexes as disclosed in Japanese Patent Laid-Open No. 2008-10773 may be used. 34 (a) and (b) are a plan view and a cross-sectional view showing an example of the diffractive optical element Ms'. In FIGS. 34 (a) and (b), the hatched optical member portion and the surrounding portion are composed of materials and media having different refractive indices. As shown in FIGS. 34 (a) and 34 (b), for example, the diffractive optical element Ms' has a ring shape in a plane horizontal to the plane on which pixels are formed and has a plurality of cylinders extending in a direction perpendicular to the plane Of the optical members are concentrically arranged. The refractive index of the diffractive optical element Ms' can be adjusted by the difference in refractive index between the optical member and the surrounding portion, the size of the cylinder, the spacing of cylinders concentrically arranged, and the like. The shape of the optical member is not limited to a cylindrical shape and may be non-rotationally symmetrical with respect to the optical axis. In FIGS. 34 (a) and (b), the binary diffractive optical element of two levels is used, but a multi-level diffractive optical element of three levels or more may be used.

The diffractive optical element Ms' having such a structure can be manufactured using, for example, a semiconductor photolithography technique. For example, since a microlens having a conventional lens surface is manufactured by thermally deforming a resin, it is difficult to make a curved surface of a lens surface different between a plurality of microlenses provided on a plurality of pixels of an image pickup element there were. On the other hand, in the case of using the diffractive optical element Ms', it is possible to change the optical characteristics by making the dimensions of the above-mentioned optical members different among the plurality of pixels of the imaging element. Therefore, even when light rays obliquely enter the pixels of the image pickup element N by the optical system L and the arrayed optical element K, it is possible to efficiently condense the light to the pixels.

Further, the focal length of the diffractive optical element Ms 'can be shortened by increasing the difference in the refractive index of the diffractive optical element Ms'. Therefore, for example, as described in the tenth embodiment, when arranging the arrayed optical element K on the imaging surface Ni of the imaging element, the total thickness of the arrayed optical element K and the diffractive optical element Ms' is reduced And hence the height of the image pickup element can be reduced. Therefore, an image pickup apparatus having a small thickness can be realized.

Further, a configuration in which the area of each optical region is limited by the aperture S or a configuration in which the optical elements L 1 s and L 1 p are arranged on the same plane may be adopted. For example, as shown in FIG. 35 (a), the first optical region D 1 mainly transmits light oscillating in the direction of the first polarization axis, and the second optical region D 2 mainly transmits light oscillating in an arbitrary direction , The third optical region D 3 transmits light oscillating in an arbitrary direction in the visible light band, the fourth optical region D 4 transmits light in the visible light band , And the area of the fourth optical region is smaller than the area of the third optical region D 3. Such a configuration is useful as an in-vehicle imaging device. According to such a configuration, it is easy to detect a lane of a wet road as described in the first embodiment by the light transmitted through the first optical region D undefined 1. By using a near-infrared light projector at nighttime driving, it is easier to detect the state of a person, an obstacle, and a road which is difficult to detect with the naked eye by the light transmitted through the second optical region D 2. Since the image formed by the light passing through the third optical region D 3 and the image formed by the light transmitted through the fourth optical region D 4 are images with different amounts of exposure, by combining these images, the dynamic range A wide image can be generated. With an image with a wide dynamic range, at the exit of the tunnel, it is possible to acquire an image with little whiteout or blackout in the inside and the

outside of the tunnel. With such a configuration, it is possible to detect the situation in front of one imaging device under any environment. In addition, in such a configuration, by setting the areas of the third optical region D 3 and the fourth optical region D 4 to be the same, and by placing the ND filter in the fourth region, it is possible to generate an image with a wide dynamic range.

Further, as shown in FIG. 35 (b), the amount of light transmitting through the fourth optical region D 4 and the amount of light passing through the third optical region D 3 may be the same. In such a configuration, an image obtained by adding the image formed by the light passing through the third optical region D 3 and the image by the light transmitted through the fourth optical region D 4, and the image obtained by the light transmitted through the first optical region D 1 Are images having different exposure amounts, respectively. Therefore, by combining these images, it is possible to generate an image with a wide dynamic range.

Further, in order to increase the exposure amount ratio as compared with the configuration of FIG. 35 (b), as shown in FIG. 35 (c), the area of the first optical region D 1 may be reduced.

The optical regions D 3 and D 4 in FIGS. 35 (a), (b), and (c) may be transparent glasses or hollow states.

Further, as shown in FIG. 35 (d), the second optical region may have the same structure as the third and fourth optical regions. Further, the area of the first optical region D undefined 1 may be smaller than that of FIG. 35 (d).

The imaging apparatus disclosed in the present application is useful as an imaging apparatus such as a digital still camera, a digital video camera, an in-vehicle camera, a surveillance camera, a skin diagnosis camera, and an endoscope camera. It can also be applied to imaging systems such as microscopes and electronic mirrors.

A image pickup device L lens optical system L 1 s, L 1 p optical element L 2 lens D 1, D 2, D 3, D 4 optical area S diaphragm K arrayed optical element N imaging element Ni imaging surface M 1, M 2, Md optical element in arrayed optical element Ms imaging Micro lenses P1 to P4 on the element Pixel C signal processing section on the image pickup element

WO2013114891A1 IMAGING DEVICE AND IMAGING SYSTEM

Data originating from sources other than the EPO may not be accurate, complete, or up to date.

The wording below is an initial machine translation of the original publication. To generate a version using the latest translation technology, go to the original language text and use Patent Translate.

An image pickup element having at least a lens optical system, at least a plurality of first pixels to which light passing through the lens optical system is incident, and a plurality of second pixels; and a lens disposed between the lens optical system and the image pickup element And an arrayed optical element including a plurality of optical elements each having a lens surface, wherein the lens optical system has a plurality of optical regions, the plurality of optical regions are arranged in a direction of a first polarization axis At least the first optical region mainly transmitting the vibrating light and the second optical region transmitting the light vibrating in an arbitrary direction, wherein the plurality of optical elements of the arrayed optical element satisfy the condition The light passing through the first optical region is made incident on the plurality of first pixels, and the light passing through the second optical region is made incident on the plurality of second pixels.

The imaging apparatus according to claim 1, wherein the first optical region transmits light in a first wavelength band, and the second optical region transmits light in a second wavelength band.

The imaging apparatus according to claim 2, wherein the first wavelength band is a wavelength band of near-ultraviolet light.

The imaging apparatus according to claim 2, wherein the first wavelength band includes a predetermined band in a wavelength band from 400 nm to 600 nm.

The imaging apparatus according to claim 2, wherein the first wavelength band is a wavelength band of near infrared light.

The plurality of optical regions of the lens optical system further comprises a third optical region other than the first and second optical regions and the third optical region has a direction different from the first polarization axis , The arrayed optical element mainly transmits light that vibrates in the direction of the second polarization axis of the plurality of first and second pixels except for the plurality of first and second pixels The second pixel of the image pickup device is caused to enter the third pixel of the first pixel.

The plurality of optical regions of the lens optical system further comprises third and fourth optical regions other than the first and second optical regions, wherein the first, second, third, and fourth Wherein the optical regions of the array optical element transmit light of first, second, third and fourth wavelength bands different from each other, and the arrayed optical element transmits light passing through the third and fourth optical regions To the plurality of third and fourth pixels other than the plurality of first and second pixels, respectively.

Wherein the plurality of optical regions of the lens optical system further comprises third and fourth optical regions other than the first and second optical regions, wherein the first and third optical regions are the same The second and fourth optical regions transmit light in wavelength bands different from wavelength bands of light passing through the first and third optical regions, And the arrayed optical element causes light having passed through the third and fourth optical regions to be incident on a plurality of third and fourth pixels other than the plurality of first and second pixels, respectively , The image pickup apparatus according to any one of claims 1 to 5.

The imaging apparatus according to claim 8, wherein the third optical region mainly transmits light vibrating in a direction of a second polarization axis different from the first polarization axis.

The imaging apparatus according to claim 1, further comprising a plurality of third and fourth pixels to which the light passed through the lens optical system is incident, the plurality of optical regions further including third and fourth optical regions, Wherein the third optical region transmits light oscillating in an arbitrary direction and the arrayed optical element transmits the light passing through the third and fourth optical regions to the plurality of third and fourth optical regions, 4, respectively, and the plurality of first, second, and third pixels each have a filter having first, second and third spectral transmittance characteristics, respectively. .

Wherein the plurality of fourth pixels have the first spectral transmittance characteristic and the fourth optical region transmits light in a predetermined wavelength band and is different from the first polarization axis And transmits light that vibrates in the direction of the polarization axis of the image pickup device.

The imaging device according to claim 11, wherein the first, second, third, and fourth pixels of the imaging device are configured in a Bayer array.

A first region that is provided with a filter that transmits light in a predetermined band and that mainly transmits light that vibrates in the direction of the first polarization axis and a second region that is disposed at a position different from the first region, A plurality of first pixels to which light having passed through the lens optical system is incident, and a plurality of second pixels each including a filter having a first spectral transmittance characteristic , A plurality of third pixels each including a filter having a second spectral transmittance characteristic, and a plurality of fourth pixels each having a filter having a third spectral transmittance characteristic And an arrayed optical element disposed between the lens optical system and the image pickup element and including a plurality of optical elements each having a lens surface, wherein the arrayed optical element has a first optical region And transmits the passed light to the plurality of And makes the light incident on the first pixel, and causes light passing through the second optical region to enter the plurality of second, third, and fourth pixels.

A first region mainly transmitting light oscillating in a direction of a first polarization axis and a second region arranged at a position different from the first region and transmitting light oscillating in an arbitrary direction A plurality of first and second pixels each including a filter having a first spectral transmittance characteristic with which light having passed through the lens optical system enters, a filter having a second spectral transmittance characteristic, An image pickup element having a plurality of pixels including a plurality of fourth pixels each having a filter having a third spectral transmittance characteristic and an image pickup surface; And an arrayed optical element disposed between the optical element and the element and including a plurality of optical elements each having a lens surface, wherein the plurality of pixels are arranged in 1 to 1 (1 is an integer of 2 or more) in a first direction, One pixel row in which pixels of (M is an integer of 2 or more) in the first direction from the first direction to the m-th row in the second direction (m is an integer of 2 or more), and is arranged on the image pickup surface, the jth row (1 □ j □m) In the first direction is substantially the same as each position of the center of the l pixels arranged in the j + 1-th row in the first direction, Wherein the plurality of optical elements are arranged such that one row of optical element groups in which 1 to s (s is an integer of 2 or more) optical elements are arranged in the second direction on the surface of the arrayed optical element, Of the optical elements arranged in the t-th column from the 1st to the t-th column (t is an integer of 2 or more) in the direction of the second element (1 □ k □t) The position of the center in the direction from the center position in the second direction of the optical element arranged in the (k + 1) It is offset in two directions, the image pickup device.

The plurality of first pixels include first A and first B pixels, the plurality of second pixels include second A and second B pixels, and the plurality of third pixels are arranged in a 3A and a third B pixel, and the plurality of fourth pixels have a fourth A and a fourth B pixel, and the optical element in the k th row is configured to divide light passing through the first region into The first element is made incident on the first A pixel and the third A pixel, and the light passing through the second region is made incident on the second B pixel and the fourth B pixel, and the optical element in the k + 1 th row is the 1 is incident on the plurality of second A pixels and the pixel of the fourth A, and the light passing through the second area is made incident on the first B pixel and the third B pixel The imaging apparatus according to any one of items 1 to 3.

In the plurality of optical regions, at least two or more optical regions have mutually different optical powers, and as compared with the case where the optical powers of the plurality of optical regions are equal to each other, the light transmitted through the plurality of optical regions 16. The imaging apparatus according to claim 1, wherein focusing positions are close to each other.

17. The imaging device according to claim 1, further comprising a light shielding region at a position corresponding to a boundary between the first region and the second region.

18. The imaging apparatus according to claim 1, wherein the lens optical system is an image side telecentric optical system.

The lens optical system is an image side non-telecentric optical system, and the array of the arrayed optical elements is offset with respect to the arrangement of the pixels of the imaging device outside the optical axis of the lens optical system. To (17) above.

The imaging apparatus according to claim 1, wherein the arrayed optical element is a lenticular lens.

In the arrayed optical element, each of the lens surfaces of the plurality of optical elements is a cylindrical surface extending in the first direction, the plurality of optical elements are arranged in a second direction, and the plurality of optical elements Are arranged so as to correspond to two rows of pixels including the plurality of first pixels of one row and the plurality of second pixels of one row.

16. The imaging apparatus according to claim 7, wherein the arrayed optical element is a microlens array.

23. The imaging device according to claim 22, wherein in the arrayed optical element, the lens surfaces of the plurality of optical elements each have a rotationally symmetric shape.

Wherein each of the plurality of optical elements includes at least one of one of the plurality of first pixels, one of the plurality of second pixels, one of the plurality of third pixels, And the second pixel is arranged to correspond to one of the plurality of fourth pixels.

25. The imaging apparatus according to claim 1, wherein the arrayed optical element is formed on the imaging element.

The imaging apparatus according to claim 25, further comprising a microlens provided between the arrayed optical element and the imaging element, wherein the arrayed optical element is formed on the imaging element via the microlens. .

27. The image pickup apparatus according to claim 26, wherein the microlens provided between the arrayed optical element and the image pickup element is a binary diffractive optical element or a multilevel diffractive optical element.

28. The imaging apparatus according to claim 1, wherein the lens optical system further comprises a diaphragm, and the plurality of optical regions are disposed in the vicinity of the diaphragm.

28. The optical system according to claim 28, wherein at least one of the first, second, third, and fourth optical regions has an area different from that of the other optical region by the stop. .

30. The imaging apparatus according to claim 1, further comprising a signal processing unit that generates an image based on a signal acquired by the imaging device.

An imaging system, further comprising: the imaging device according to claim 1; and a signal processing unit for generating an image based on a signal acquired by the imaging device.

An imaging system comprising: the imaging device according to claim 1; and polarization illumination.

33. The imaging system of claim 32, further comprising unpolarized illumination.

30. An imaging system comprising at least one imaging device according to any of claims 1 to 29, polarized lighting, and a display device for displaying the images acquired in the imaging device.

35. The imaging system according to claim 34, wherein the at least one imaging device is two imaging devices, and the display device displays the two images acquired in the two imaging devices.

35. The display device according to claim 34 or 35, wherein the display device is a liquid crystal display including a polarizing filter on the subject side, and the direction of the polarization axis of the polarizing filter in the liquid crystal display is equal to the direction of the polarization axis of the polarized illumination Imaging system.

(12) 特許協力条約に基づいて公開された国際出願

(19) 世界知的所有権機関
国際事務局

(43) 国際公開日
2013 年 8 月 8 日(08.08.2013)

WIPO | PCT

(10) 国際公開番号
WO 2013/114891 A1

(51) 国際特許分類:
G01N 21/27 (2006.01) *G02B 3/06* (2006.01)
A61B 1/00 (2006.01) *G02F 1/13* (2006.01)
G01N 21/21 (2006.01) *A61B 5/00* (2006.01)
G02B 3/00 (2006.01)

(21) 国際出願番号: PCT/JP2013/000566

(22) 国際出願日: 2013 年 2 月 1 日(01.02.2013)

(25) 国際出願の言語: 日本語

(26) 国際公開の言語: 日本語

(30) 優先権データ:
特願 2012-021696 2012 年 2 月 3 日(03.02.2012) JP

(71) 出願人: パナソニック株式会社 (PANASONIC CORPORATION) [JP/JP]; 〒5718501 大阪府門真市大字門真１００６番地 Osaka (JP).

(72) 発明者: 今村　典広 (IMAMURA, Norihiro). 是永　継博 (KORENAGA, Tsuguhiro). 山形　道弘 (YAMAGATA, Michihiro).

(74) 代理人: 奥田　誠司 (OKUDA, Seiji); 〒5410041 大阪府大阪市中央区北浜一丁目８番１６号　大阪証券取引所ビル１０階　奥田国際特許事務所 Osaka (JP).

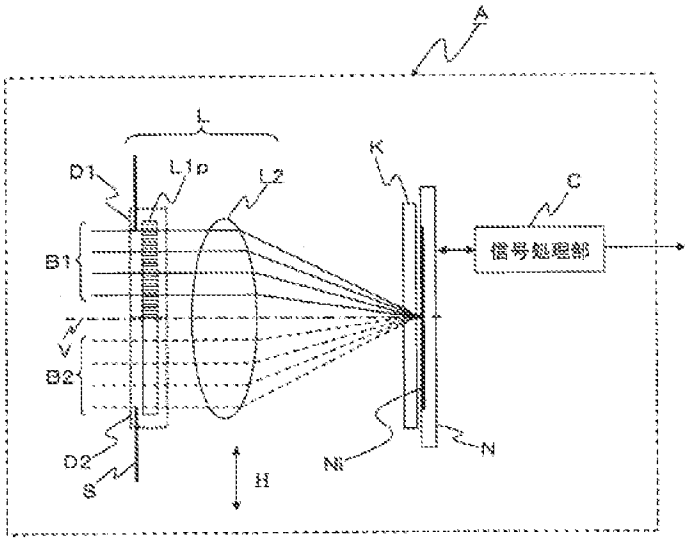
(81) 指定国 (表示のない限り、全ての種類の国内保護が可能): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) 指定国 (表示のない限り、全ての種類の広域保護が可能): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), ユーラシア (AM, AZ, BY, KG, KZ, RU, TJ, TM), ヨーロッパ (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

添付公開書類:
— 国際調査報告（条約第 21 条(3)）

(54) Title: IMAGING DEVICE AND IMAGING SYSTEM

(54) 発明の名称 : 撮像装置および撮像システム



C Signal processing unit

(57) **Abstract**: This imaging device is provided with a lens optical system (L), an imaging element (N) having a plurality of first and second pixels (P1, P2), and an arrayed optical element (K). The lens optical system (L) includes a first optical region (D1) that primarily transmits light oscillating in a first polarization axis direction, and a second optical region (D2) that transmits light oscillating in all directions. The arrayed optical element (K) causes the light transmitted through the first optical region (D1) to enter the plurality of first pixels (P1), and causes the light transmitted through the second optical region (D2) to enter the plurality of second pixels (P2).

(57) 要約: 本願に開示された撮像装置は、レンズ光学系Ｌと、複数の第１、第２の画素Ｐ１、Ｐ２を有する撮像素子Ｎと、アレイ状光学素子Ｋとを備え、レンズ光学系Ｌは、第１の偏光軸の方向に振動する光を主に透過する第１の光学領域Ｄ１と、全ての方向に振動する光を透過する第２の光学領域Ｄ２とを含み、アレイ状光学素子Ｋは、第１の光学領域Ｄ１を通過した光を複数の第１の画素Ｐ１に入射させ、第２の光学領域Ｄ２を通過した光を複数の第２の画素Ｐ２に入射させる。

WO 2013/114891 A1

明　細　書

発明の名称 ： 撮像装置および撮像システム

技術分野

[0001] 本願はカメラ等の撮像装置および撮像システムに関する。

背景技術

[0002] 車載カメラの分野において、路面の状態や車線を検知するため、複眼カメラの光路中に、個眼毎に偏光軸を互いに異ならせた偏光子を設けた撮像装置が開示されている（特許文献１）。

[0003] また、内視鏡システムや肌診断システム等、医療・美容分野のカメラにおいて、無偏光画像と偏光画像の両方を取得する撮像装置が実用化されている。

[0004] これらの撮像装置には、無偏光の光と所定の偏光軸の方向に振動する光とを生体組織に照射する偏光照明が備えられている。所定の偏光成分の光を生体組織に照射する場合、生体表面での反射光は、偏光成分が維持された鏡面反射光となり、生体深部での反射光は、偏光成分が乱れた散乱反射光となる。したがって、撮像装置側に偏光照明の偏光軸と平行な方向に振動する光を透過する偏光フィルタと、照明の偏光軸と垂直な方向に振動する光を透過する偏光フィルタを配置することで、生体表面と生体深部の画像を取得することが可能となる。

[0005] このような偏光特性の異なる画像を取得するための撮像装置が開示されている（特許文献２、３）。

先行技術文献

特許文献

[0006] 特許文献1：特開２０１０－２５９１５号公報

特許文献2：特開２００８－２３７２４３号公報

特許文献3：特開２０１１－９７９８７号公報

発明の概要

発明が解決しようとする課題

[0007] しかしながら、上述した従来の技術では、より簡単な構成で動画を撮影可能な撮像装置が求められていた。

[0008] 本願の、限定的ではない例示的なある実施の形態は、より簡単な構成で動画を撮影可能な撮像装置を提供する。

課題を解決するための手段

[0009] 本発明の一態様にかかる撮像装置は、レンズ光学系と、前記レンズ光学系を通過した光が入射する複数の第１の画素と複数の第２の画素とを少なくとも有する撮像素子と、前記レンズ光学系と前記撮像素子との間に配置され、レンズ面をそれぞれ有する複数の光学要素を含むアレイ状光学素子とを備え、前記レンズ光学系は、複数の光学領域を有し、前記複数の光学領域は、第１の偏光軸の方向に振動する光を主に透過する第１の光学領域と、任意の方向に振動する光を透過する第２の光学領域と、を少なくとも含み、前記アレイ状光学素子の前記複数の光学要素は、前記第１の光学領域を通過した光を前記複数の第１の画素に入射させ、前記第２の光学領域を通過した光を前記複数の第２の画素に入射させる。

発明の効果

[0010] 本発明の一態様にかかる撮像装置によれば、単一の撮像系を用いて偏光画像と無偏光画像の両方を同時に取得することができる。また、本発明の撮像装置を用いて動画を撮影した場合、時間の経過によって被写体の位置に変化が生じても、複数の画像間で像のずれが生じることがない。

図面の簡単な説明

[0011] [図1]本発明による撮像装置Ａの実施の形態１を示す模式図である。

[図2]本発明の実施の形態１における光学素子Ｌ１ｐの第１および第２の光学領域Ｄ１、Ｄ２を被写体側から見た正面図である。

[図3]本発明の実施の形態１におけるアレイ状光学素子Ｋの斜視図である。

[図4]（ａ）は、本実施の形態１における図１に示すアレイ状光学素子Ｋおよ

び撮像素子Ｎを拡大して示す図であり、（ｂ）は、アレイ状光学素子Ｋと撮像素子Ｎ上の画素との位置関係を示す図である。

[図5]本発明の実施の形態２における撮像システムＡＰ１を示す模式図である。

[図6]本発明による撮像装置Ａの実施の形態３を示す模式図である。

[図7]本発明の実施の形態３における光学素子Ｌ１ｓの第１および第２の光学領域Ｄ１、Ｄ２を被写体側から見た正面図である。

[図8]本発明の実施の形態３における撮像システムＡＰ２を示す模式図である。

[図9]本発明による撮像装置Ａの実施の形態４を示す模式図である。

[図10]本発明の実施の形態４における光学素子Ｌ１ｐの第１、第２および第３の光学領域Ｄ１、Ｄ２、およびＤ３を被写体側から見た正面図である。

[図11]（ａ）は、本発明の実施の形態４における図８に示すアレイ状光学素子Ｋおよび撮像素子Ｎを拡大して示す図であり、（ｂ）は、アレイ状光学素子Ｋと撮像素子Ｎ上の画素との位置関係を示す図である。

[図12]（ａ）は、本発明の実施の形態５における光学素子Ｌ１ｓの第１、第２、第３および第４の光学領域Ｄ１、Ｄ２、Ｄ３およびＤ４を被写体側から見た正面図であり、（ｂ）は、光学素子Ｌ１ｐの第１、第２、第３および第４の光学領域Ｄ１、Ｄ２、Ｄ３およびＤ４を被写体側から見た正面図である。

[図13]本発明の実施の形態５におけるアレイ状光学素子Ｋの斜視図である。

[図14]（ａ）は、本実施の形態５におけるアレイ状光学素子Ｋおよび撮像素子Ｎを拡大して示す図であり、（ｂ）は、アレイ状光学素子Ｋと撮像素子Ｎ上の画素との位置関係を示す図である。

[図15]（ａ）は、本発明の実施の形態６における光学素子Ｌ１ｓの第１、第２、第３および第４の光学領域Ｄ１、Ｄ２、Ｄ３およびＤ４を被写体側から見た正面図であり、（ｂ）は、光学素子Ｌ１ｐの第１、第２、第３および第４の光学領域Ｄ１、Ｄ２、Ｄ３およびＤ４を被写体側から見た正面図である

。

[図16]（ａ）は、本発明の実施の形態６の別の形態における光学素子Ｌ１ｐの第１、第２、第３および第４の光学領域Ｄ１、Ｄ２、Ｄ３およびＤ４を被写体側から見た正面図である。（ｂ）は、絞りＳの第１、第２、第３および第４の光学領域Ｄ１、Ｄ２、Ｄ３およびＤ４を被写体側から見た正面図である。

[図17]（ａ）は、本発明の実施の形態７における光学素子Ｌ１ｐの第１、第２、第３および第４の光学領域Ｄ１、Ｄ２、Ｄ３およびＤ４を被写体側から見た正面図であり、（ｂ）は、アレイ状光学素子Ｋと撮像素子Ｎ上の画素との位置関係を示す図である。

[図18]本発明の実施の形態７の別の形態における、アレイ状光学素子Ｋと撮像素子Ｎ上の画素との位置関係を示す図である。

[図19]（ａ）および（ｂ）は、本発明の実施の形態８における光学系と撮像部を示す模式図である。

[図20]（ａ）は、本発明の実施の形態８における光学素子Ｌ１ｓの斜視図であり、（ｂ）は、絞りＳを被写体側から見た正面図である。

[図21]（ａ）は、本発明の実施の形態８における別の形態の光学素子Ｌ１ｓの斜視図であり、（ｂ）は、絞りＳを被写体側から見た正面図である。

[図22]（ａ）は、本発明の実施の形態８における別の形態の光学素子Ｌ１ｓの斜視図であり、（ｂ）は、絞りＳを被写体側から見た正面図である。

[図23]本発明の実施の形態８における別の形態の光学系と撮像部を示す模式図である。

[図24]（ａ１）および（ｂ１）は、本発明の実施の形態９におけるアレイ状光学素子Ｋの斜視図、（ａ２）および（ｂ２）は、各光学要素の等高線を示す図、（ａ３）および（ｂ３）は、光線追跡シミュレーションの結果を示す図である。

[図25]（ａ）および（ｂ）は、本発明の実施の形態１０におけるアレイ状光学素子Ｋおよび撮像素子Ｎを拡大して示す図である。

[図26]（ａ）および（ｂ）は、本発明の実施の形態１１におけるアレイ状光学素子Ｋおよび撮像素子Ｎを拡大して示す図である。

[図27]（ａ）は、本発明の実施の形態１２における示すアレイ状光学素子Ｋおよび撮像素子Ｎを拡大して示す図であり、（ｂ）は、アレイ状光学素子Ｋと撮像素子Ｎ上の画素との位置関係を示す図である。

[図28]（ａ１）は、光軸に対して回転非対称な形状を有するマイクロレンズアレイの配置と、その等高線を示す図である。（ａ２）は、（ａ１）に示すマイクロレンズアレイの斜視図である。（ｂ１）は、光軸に対して回転対称な形状を有するマイクロレンズアレイの配置と、その等高線を示す図である。（ｂ２）は、（ｂ１）に示すマイクロレンズアレイの斜視図である。（ｃ１）は、シリンドリカルマイクロレンズを交互に半ピッチずらした配置と、その等高線を示す図である。（ｃ２）は、（ｃ１）に示すシリンドリカルマイクロレンズアレイの斜視図である。

[図29]（ａ）は、図２８（ａ１）、（ａ２）、に示すマイクロレンズを実施の形態１２のアレイ状光学素子に適用した場合の、光線追跡シミュレーションの結果を示す図である。（ｂ）は、図２８（ｂ１）、（ｂ２）に示すマイクロレンズを実施の形態１２のアレイ状光学素子に適用した場合の、光線追跡シミュレーションの結果を示す図である。（ｃ）は、図２８（ｃ１）、（ｃ２）に示すマイクロレンズを実施の形態１２のアレイ状光学素子に適用した場合の、光線追跡シミュレーションの結果を示す図である。

[図30]（ａ）および（ｂ）は、それぞれ第１および第２の領域を通過した光が到達する画素を抽出した図である。

[図31]（ａ）は、本発明の実施の形態１３におけるマイクロスコープＡＰ３の正面図であり、（ｂ）は側面図である。

[図32]（ａ）は、本発明の実施の形態１４におけるカプセル内視鏡ＡＰ４の正面図であり、（ｂ）は、側面図である。

[図33]（ａ）は、本実施の形態１５における電子ミラーＡＰ５の正面図であり、（ｂ）は、立体電子ミラーＡＰ６の正面図である。

[図34]（ａ）および（ｂ）は、撮像素子上に設けることが可能な回折光学素子の平面図および断面図である。

[図35]（ａ）、（ｂ）、（ｃ）および（ｄ）は、本発明のその他の形態における光学素子と絞りの正面図である。

発明を実施するための形態

[0012] 本願発明者が特許文献１から３に開示された撮像装置を詳細に検討した。特許文献１に開示された装置によれば、複眼構成であるため、焦点距離が長い場合や、被写体距離が近い用途では、取得した画像間の視差が被写体距離によって大きく変化する。したがって、被写体の同じ位置同士を比較して状態を検知するには、画像の微小領域毎に視差を抽出して補正するための信号処理が別途必要となり、演算処理が増大するという課題が生じる。また、複眼の場合、撮像素子前方にレンズアレイを構成しているが、この配置では、単一の光学系の有効径は、撮像領域の大きさの半分未満でなければならず、光学設計の自由度が小さくなり、画像を取得する目的としては、十分な解像度が得られる光学系を構成するのは困難である。また、魚眼レンズのような超広角な光学系を構成するのも困難である。

[0013] また、特許文献２は、波長帯域の異なる複数の偏光照明と、偏光照明と直交した偏光成分の光を透過する偏光フィルタが配置されたカメラによって、複数の波長帯域の偏光画像を取得する構成を開示している。しかし、このような構成で撮影できる画像は、偏光軸の方向が１種類のみの偏光情報を含む画像のみであり、かつ異なる波長帯域の画像は、時分割で撮影する必要があるため、動画の撮像には適さないという課題がある。

[0014] また、特許文献３は、偏光ビームスプリッタによって偏光成分の異なる画像を取得する構成を開示している。しかし、このような構成では、偏光ビームスプリッタや複数の撮像素子が必要となり、大型化、高コスト化するという課題が生じる。

[0015] このような課題に鑑み、本願発明者は、単一の撮像光学系を用いて、偏光情報を有する画像と通常画像の両方を取得することが可能な新規な撮像装置

を想到した。本発明の一態様の概要は以下のとおりである。

[0016] 本発明の一態様にかかる撮像装置は、レンズ光学系と、前記レンズ光学系を通過した光が入射する複数の第１の画素と複数の第２の画素とを少なくとも有する撮像素子と、前記レンズ光学系と前記撮像素子との間に配置され、レンズ面をそれぞれ有する複数の光学要素を含むアレイ状光学素子とを備え、前記レンズ光学系は、複数の光学領域を有し、前記複数の光学領域は、第１の偏光軸の方向に振動する光を主に透過する第１の光学領域と、任意の方向に振動する光を透過する第２の光学領域と、を少なくとも含み、前記アレイ状光学素子の前記複数の光学要素は、前記第１の光学領域を通過した光を前記複数の第１の画素に入射させ、前記第２の光学領域を通過した光を前記複数の第２の画素に入射させる。

[0017] 前記第１の光学領域は第１の波長帯域の光を透過し、前記第２の光学領域は第２の波長帯域の光を透過してもよい。

[0018] 前記第１の波長帯域は、近紫外光の波長帯域であってもよい。

[0019] 前記第１の波長帯域は、４００ｎｍから６００ｎｍの波長帯域の中の所定の帯域を含んでいてもよい。

[0020] 前記第１の波長帯域は、近赤外光の波長帯域であてもよい。

[0021] 前記レンズ光学系の前記複数の光学領域は、前記第１、第２の光学領域以外の第３の光学領域をさらに備え、前記第３の光学領域は、前記第１の偏光軸とは異なる方向の第２の偏光軸の方向に振動する光を主に透過し、前記アレイ状光学素子は、前記第３の光学領域を通過した光を、前記複数の第１、第２の画素以外の複数の第３の画素に入射させてもよい。

[0022] 前記レンズ光学系の前記複数の光学領域は、前記第１、および第２の光学領域以外の第３、および第４の光学領域をさらに備え、前記第１、第２、第３、および第４の光学領域は、それぞれ互いに異なる第１、第２、第３、および第４の波長帯域の光を透過し、前記アレイ状光学素子は、前記第３、および第４の光学領域を通過した光を、前記複数の第１、および第２画素以外の複数の第３、および第４の画素にそれぞれ入射させてもよい。

[0023] 前記レンズ光学系の前記複数の光学領域は、前記第１、および第２の光学領域以外の第３、および第４の光学領域をさらに備え、前記第１、および第３の光学領域は、同じ波長帯域の光を透過し、第２、および第４の光学領域は、それぞれ前記第１、および前記第３の光学領域を透過する光の波長帯域とはそれぞれ異なる波長帯域の光を透過し、前記アレイ状光学素子は、前記第３、および第４の光学領域を通過した光を、前記複数の第１、および第２の画素以外の複数の第３、および第４の画素にそれぞれ入射させてもよい。

[0024] 前記第３の光学領域は、前記第１の偏光軸と異なる第２の偏光軸の方向に振動する光を主に透過してもよい。

[0025] 前記撮像素子は、前記レンズ光学系が通過した光が入射する複数の第３、および第４の画素をさらに有し、前記複数の光学領域は、第３、第４の光学領域をさらに含み、前記第３の光学領域は、任意の方向に振動する光を透過し、前記アレイ状光学素子は、前記第３、および第４の光学領域を通過した光を、前記複数の第３、および第４の画素にそれぞれ入射させ、前記複数の第１、第２、および第３の画素は、第１、第２および第３の分光透過率特性を有するフィルタをそれぞれ有していてもよい。

[0026] 前記複数の第４の画素は、前記第１の分光透過率特性を有し、前記第４の光学領域は、所定の波長帯域の光を透過し、かつ前記第１の偏光軸とは異なる第２の偏光軸の方向に振動する光を透過してもよい。

[0027] 前記撮像素子の前記第１、第２、第３および第４の画素がベイヤー配列で構成されていてもよい。

[0028] 本発明の他の一態様にかかる撮像装置は、所定帯域の光を透過するフィルタを備え、かつ第１の偏光軸の方向に振動する光を主に透過する第１の領域と、前記第１の領域とは異なる位置に配置され、任意の方向に振動する光を透過する第２の領域を有するレンズ光学系と、前記レンズ光学系を通過した光が入射する複数の第１の画素と、第１の分光透過率特性を有するフィルタを備える複数の第２の画素と、第２の分光透過率特性を有するフィルタを備える複数の第３の画素と、第３の分光透過率特性を有するフィルタを備える

複数の第４の画素とを有する撮像素子と、前記レンズ光学系と前記撮像素子との間に配置され、レンズ面をそれぞれ有する複数の光学要素を含むアレイ状光学素子とを備え、前記アレイ状光学素子は、前記第１の光学領域を通過した光を前記複数の第１の画素に入射させ、前記第２の光学領域を通過した光を前記複数の第２、第３、及び第４の画素に入射させる。

[0029] 本発明の他の一態様にかかる撮像装置は、第１の偏光軸の方向に振動する光を主に透過する第１の領域と、前記第１の領域とは異なる位置に配置され、任意の方向に振動する光を透過する第２の領域を有するレンズ光学系と、前記レンズ光学系を通過した光が入射する第１の分光透過率特性を有するフィルタを備える複数の第１および第２の画素と、第２の分光透過率特性を有するフィルタを備える複数の第３の画素と、第３の分光透過率特性を有するフィルタを備える複数の第４の画素とを含む複数の画素および撮像面を有する撮像素子と、前記レンズ光学系と前記撮像素子との間に配置され、レンズ面をそれぞれ有する複数の光学要素を含むアレイ状光学素子とを備え、前記複数の画素は、第１の方向に１からｉ個（ｉは２以上の整数）の画素が配列した一行の画素群が、第２の方向に１からｍ行目（ｍは２以上の整数）までのｍ行に配列されることによって、前記撮像面に配置され、前記ｍ行のうちｊ行目（１≦ｊ<ｍ）に配列されたｉ個の画素の前記第１の方向における中心の各位置は、ｊ＋１行目に配列されたｉ個の画素の前記第１の方向における中心の各位置と略同一であり、前記複数の光学要素は、前記アレイ状光学素子の表面において、前記第２の方向に１からｓ個（ｓは２以上の整数）の光学要素が配列した一列の光学要素群が、前記第１の方向に１からｔ列目（ｔは２以上の整数）までのｔ列に配列され、前記ｔ列のうちｋ列目（１≦ｋ<ｔ）に配置される光学要素の前記第２の方向における中心の位置は、ｋ＋１列目に配置される光学要素の前記第２の方向における中心の位置から、前記第２の方向にずれている。

[0030] 前記複数の第１の画素は、第１Ａおよび第１Ｂの画素を有し、前記複数の第２の画素は、第２Ａおよび第２Ｂの画素を有し、前記複数の第３の画素は

、第３Ａおよび第３Ｂの画素を有し、前記複数の第４の画素は、第４Ａおよび第４Ｂの画素を有し、前記ｋ行目における光学要素は、前記第１の領域を通過した光を前記第１Ａの画素と前記第３Ａの画素に入射させ、前記第２の領域を通過した光を前記第２Ｂの画素と前記第４Ｂの画素に入射させ、前記ｋ＋１行目における光学要素は、前記第１の領域を通過した光を複数の第２Ａの画素と前記第４Ａの画素に入射させ、前記第２の領域を通過した光を前記第１Ｂの画素と前記第３Ｂの画素に入射させてもよい。

[0031] 前記複数の光学領域において、少なくとも２つ以上の光学領域は互いに異なる光学パワーを有し、前記複数の光学領域の光学パワーが互いに等しい場合と比較して、前記複数の光学領域を透過した光の合焦位置が互いに近くてもよい。

[0032] 前記撮像装置は、前記第１の領域および前記第２の領域の境界部に対応する位置に遮光領域をさらに備えていてもよい。

[0033] 前記レンズ光学系が像側テレセントリック光学系であってもよい。

[0034] 前記レンズ光学系は像側非テレセントリック光学系であって、前記レンズ光学系の光軸外において前記アレイ状光学素子の配列を前記撮像素子の画素の配列に対してオフセットさせていてもよい。

[0035] 前記アレイ状光学素子はレンチキュラレンズであってもよい。

[0036] 前記アレイ状光学素子において、前記複数の光学要素の前記レンズ面はそれぞれシ第１の方向に伸びるシリンドリカル面であり、前記複数の光学要素は、第２の方向に配置され、前記複数の光学要素のそれぞれは、１行の前記複数の第１の画素と１行の前記複数の第２の画素からなる２行の画素に対応するように配置されていてもよい。

[0037] 前記アレイ状光学素子はマイクロレンズアレイであってもよい。

[0038] 前記アレイ状光学素子において、前記複数の光学要素の前記レンズ面はそれぞれ回転対称形状を有していてもよい。

[0039] 前記複数の光学要素のそれぞれは、前記複数の第１の画素のうちの１つ、前記複数の第２の画素のうちの１つ、前記複数の第３の画素のうちの１つ、

および前記複数の第４の画素のうちの１つ、に対応するように配置されていてもよい。

[0040] 前記アレイ状光学素子は前記撮像素子上に形成されていてもよい。

[0041] 前記撮像装置は、前記アレイ状光学素子と前記撮像素子との間に設けられたマイクロレンズをさらに備え、前記アレイ状光学素子は、前記マイクロレンズを介して前記撮像素子上に形成されていてもよい。

[0042] 前記アレイ状光学素子と前記撮像素子との間に設けられたマイクロレンズは、バイナリー回折光学素子もしくはマルチレベル回折光学素子であってもよい。

[0043] 前記レンズ光学系は絞りをさらに備え、前記複数の光学領域は、前記絞り近傍に配置されていてもよい。

[0044] 前記撮像装置は、前記撮像素子において取得された信号に基づいて画像を生成する信号処理部をさらに備えていてもよい。

[0045] 本発明の一態様にかかる撮像システムは上記いずれかに記載の撮像装置と、前記撮像装置において取得された信号に基づいて画像を生成する信号処理部とを備える。

[0046] 本発明の一態様にかかる撮像システムは上記いずれかに記載の撮像装置と、偏光照明とを備える。

[0047] 前記撮像システムは無偏光照明をさらに備えていてもよい。

[0048] 本発明の他の一態様にかかる撮像システムは、上記いずれかに記載の少なくとも１つの撮像装置と、偏光照明と、前記撮像装置において取得された画像を表示する表示装置とを備える。

[0049] 前記少なくとも１つの撮像装置は２つの撮像装置であって、前記表示装置は、前記２つの撮像装置において取得された２つの画像を表示してもよい。

[0050] 前記表示装置は、被写体側に偏光フィルタを備える液晶ディスプレイであって、前記液晶ディスプレイにおける前記偏光フィルタの偏光軸の方向が前記偏光照明の偏光軸の方向と等しくてもよい。

[0051] 以下、本発明による撮像装置の実施形態を、図面を参照しながら説明する

。

[0052] （実施の形態１）

図１は、実施の形態１の撮像装置Ａを示す模式図である。本実施形態の撮像装置Ａは、Ｖを光軸とするレンズ光学系Ｌと、レンズ光学系Ｌの焦点近傍に配置されたアレイ状光学素子Ｋと、モノクロの撮像素子Ｎと、信号処理部Ｃとを備える。

[0053] レンズ光学系Ｌは、被写体（図示せず）からの光が入射する絞りＳと、絞りＳを通過した光が入射する光学素子Ｌ１ｐと、光学素子Ｌ１ｐを通過した光が入射するレンズＬ２とから構成されている。レンズ光学系Ｌは、第１、第２の光学領域Ｄ１、Ｄ２を有する。

[0054] レンズＬ２は、一枚のレンズで構成されていてもよいし、複数枚のレンズで構成されていてもよい。また、絞りＳの前後に複数枚に分かれて配置された構成であってもよい。図１では、一枚構成として図示している。

[0055] 光学素子Ｌ１ｐは、絞りＳの近傍に配置され、第１の光学領域Ｄ１に位置する部分と第２の光学領域Ｄ２に位置する部分によって構成される。第１の光学領域Ｄ１には、第１の偏光軸（透過軸）の方向に振動する光を透過する偏光フィルタが配置され、第２の光学領域Ｄ２には、全ての方向に振動する光を透過するガラス板が配置されている。例えば、被写体からの光の振動方向に偏りのある場合など、振動方向によっては第１の光学領域Ｄ１を通過する光の減衰が大きくなるが、第２の光学領域Ｄ２では全ての方向に振動する光（任意の方向に振動する光）を透過するため、減衰は少ない。

[0056] 本実施形態では、２つの光学領域Ｄ１、Ｄ２を通過した光は、レンズＬ２を通過した後、アレイ状光学素子Ｋに入射する。アレイ状光学素子Ｋは、光学領域Ｄ１を通過した光を撮像素子Ｎにおける複数の画素Ｐ１に、光学領域Ｄ２を通過した光を撮像素子Ｎにおける複数の画素Ｐ２に入射させる。信号処理部Ｃは、画素Ｐ１において得られる輝度値から、第１の偏光軸の方向に振動する光に対応する画像情報を生成し、画素Ｐ２において得られる輝度値から、第１の偏光軸を含む全ての方向に振動する光に対応する画像情報を生

成し、出力する。

[0057] 図１において、光束Ｂ１は、光学素子Ｌ１ｐ上の第１の光学領域Ｄ１を通過する光束であり、光束Ｂ２は、光学素子Ｌ１ｐ上の第２の光学領域Ｄ２を通過する光束である。光束Ｂ１、Ｂ２は、絞りＳ、光学素子Ｌ１ｐ、レンズＬ２、アレイ状光学素子Ｋをこの順に通過し、撮像素子Ｎ上の撮像面Ｎｉ（図４に示す）に到達する。

[0058] 図２は、第１および第２の光学領域Ｄ１とＤ２を被写体側から見た正面図である。光学素子Ｌ１ｐにおける第１および第２の光学領域Ｄ１とＤ２は、光軸Ｖを境界中心として光軸Ｖに垂直な面内で上下に２分割することで形成される。図２において、破線ｓは、絞りＳの開口領域を示している。また、図１および図２における矢印Ｈが、撮像装置が使用される場合における水平方向を示す。

[0059] 図３は、アレイ状光学素子Ｋの斜視図である。アレイ状光学素子Ｋは、レンズ面をそれぞれ有する複数の光学要素Ｍ１を含む。本実施の形態においては、各光学要素Ｍ１のレンズ面はシリンドリカル面である。アレイ状光学素子Ｋの撮像素子Ｎ側の面において、各光学要素Ｍ１はｘ方向（第１の方向）に伸び、複数の光学要素Ｍ１がｙ方向（第２の方向）に配列されている。ｙ方向は図１、２における水平方向に対応する。それぞれの光学要素Ｍ１のｘ方向に垂直な断面は、撮像素子Ｎ側に突出した曲面の形状を有する。このように、複数の光学要素Ｍは、レンチキュラレンズを構成している。本実施形態では、ｘ方向およびｙ方向は互いに直交している。

[0060] 図１に示すように、アレイ状光学素子Ｋは、レンズ光学系Ｌの焦点近傍に配置されており、撮像面Ｎｉから所定の距離だけ離れた位置に配置されている。

[0061] 図４（ａ）は、図１に示すアレイ状光学素子Ｋおよび撮像素子Ｎを拡大して示す図であり、図４（ｂ）は、アレイ状光学素子Ｋと撮像素子Ｎ上の画素との位置関係を示す図である。アレイ状光学素子Ｋは、光学要素Ｍ１が形成された面が撮像面Ｎｉ側に向かうように配置されている。

[0062] 撮像素子Ｎは、撮像面Ｎｉと複数の画素Ｐとを含む。複数の画素Ｐは、ｘ方向およびｙ方向に２次元に配列されている。ｘ方向およびｙ方向への配列をそれぞれ行および列と呼ぶ場合、複数の画素は、撮像面Ｎｉ上において、例えば、ｍ行ｌ列（ｌ、ｍは２以上の整数）に配置されている。つまり、ｘ方向に１からｌ個の画素が配列した一行の画素群が、ｙ方向に１からｍ行目までのｍ行に配列されている。

[0063] ｍ行の画素群のうち、ｊ行目（１≦ｊ＜ｍ）に配列されたｌ個の画素のｘ方向における中心Ｃ’ｊの各位置は、ｊ＋１行目に配列されたｌ個の画素のｘ方向における中心Ｃ’ｊ＋１の各位置と略同一である。

[0064] 同様に、複数の画素をｙ方向に配列された複数画素群による１列の画素群がｘ方向に１からｌ列までのｌ列に配列されていると見ることもできる。この場合、ｌ列の画素群のうちｕ列行目（１≦ｕ＜ｌ）に配列されたｍ個の画素のｙ方向における中心の各位置は、ｕ＋１行目に配列されたｍ個の画素のｙ方向における中心の各位置と略同一である。

[0065] 複数の画素Ｐは、それぞれｘ方向に配列され、行を構成する複数の画素Ｐ１および複数の画素Ｐ２に分けられる。複数の画素Ｐ１および複数の画素Ｐ２のそれぞれは、上述したようにｘ方向に１行に並んで配置されている。ｙ方向において、画素Ｐ１の行と画素Ｐ２の行とは交互に配置されている。アレイ状光学素子Ｋは、その光学要素Ｍ１の１つが、撮像面Ｎｉ上における１行の画素Ｐ１および１行の画素Ｐ２からなる２行の画素に対応するように配置されている。撮像面Ｎｉ上には、画素Ｐ１、Ｐ２の表面を覆うようにマイクロレンズＭｓが設けられている。

[0066] 本実施の形態において、複数の第１の画素Ｐ１および複数の第２の画素Ｐ２ははいずれも撮像面Ｎｉにおいて同じ形状を有している。例えば、複数の第１の画素Ｐ１および複数の第２の画素Ｐ２は同じ矩形形状を有しており、面積も互いに等しい。

[0067] アレイ状光学素子Ｋは、光学素子Ｌ１ｐ上の光学領域Ｄ１（図１、図２に示す）を通過した光束（図１において実線で示される光束Ｂ１）の大部分が

、撮像面Ｎｉ上の画素Ｐ１に到達し、光学領域Ｄ２を通過した光束（図１において破線で示される光束Ｂ２）の大部分が、撮像面Ｎｉ上の画素Ｐ２に到達するように設計されている。具体的には、アレイ状光学素子Ｋの屈折率、撮像面Ｎｉからの距離及び光学要素Ｍ１表面の曲率半径等のパラメータを適切に設定することで、上記構成が実現する。

[0068] また、本実施形態におけるレンズ光学系Ｌは、像側テレセントリック光学系としている。これにより、画角が変化しても、アレイ状光学素子Ｋの主光線入射角は、０度に近い値で入射するため、撮像領域全域にわたって、画素Ｐ１に到達する光束と画素Ｐ２に到達する光束とのクロストークを低減することができる。

[0069] 絞りＳは全ての画角の光束が通過する領域である。従って、絞りＳの近傍に偏光特性を制御する光学特性を有する面を挿入することにより、全ての画角の光束の偏光特性を同様に制御することができる。すなわち、本実施形態では、光学素子Ｌ１ｐは、絞りＳの近傍に設けられていてもよい。絞り近傍に位置する第１および第２の光学領域Ｄ１、Ｄ２に光学素子Ｌ１ｐを配置することによって、領域の分割数に応じた偏光特性を光束に与えることができる。

[0070] 図１においては、絞りＳを通過した光が直接（他の光学部材を介することなく）、光学素子Ｌ１ｐに入射する位置に設けられている。光学素子Ｌ１ｐは、絞りＳよりも被写体側に設けられていてもよい。この場合、光学素子Ｌ１ｐを通過した光が、直接（他の光学部材を介することなく）、絞りＳに入射してもよい。像側テレセントリック光学系の場合、光学系の焦点における光線の入射角は、絞りＳを通過する光線の位置によって一義的に決定される。また、アレイ状光学素子Ｋは、光線の入射角に応じて出射方向を振り分ける機能を有する。そのため、絞りＳの近傍で分割された第１及び第２の光学領域Ｄ１、Ｄ２に対応するように、撮像面Ｎｉ上の画素に光束を振り分けることができる。

[0071] なお、像側非テレセントリック光学系の場合、光学系の焦点における光線

の入射角は、絞りＳを通過する光線の位置と画角によって一義的に決定される。

[0072] 以上の構成により、画素Ｐ１とＰ２の輝度情報を用いて、偏光情報を有する画像情報と偏光情報を有しない無偏光の画像情報をそれぞれ生成することができる。また、絞りＳに近接した領域を通過する光線を分離して２つの画像を取得するため、従来の複眼構成の撮像装置と比べて視差を小さくすることができる。

[0073] つまり、撮像装置Ａは、偏光状態の光と無偏光状態の光によってそれぞれ形成される互いに視差の少ない複数の画像情報を、単一の撮像光学系で、かつ、１回の撮像で取得することができる。

[0074] 本実施形態の構成では、これらの画像を同時に取得することができるため、画像情報に応じてこれらの画像の切替えや合成をすることができる。このような手法は、例えば、道路の車線の検出に応用することができる。濡れた道路の車線を検出する場合、偏光情報を有しない無偏光の画像には、不要な反射光が写りこむため、車線の認識が困難となる。一方、偏光フィルタを介して取得した画像においては、不要な反射光を低減できるため、車線の認識がしやすくなる。このような特性を利用し、偏光情報を有する画像情報と偏光情報を有しない無偏光の画像情報から路面の状況を推定し、推定情報に基づいて、各画像の切替えや合成をすることにより、車線の検出がしやすい画像を生成することができる。

[0075] なお、本実施の形態では、ｙ方向の画素値が１画素おきに欠落する。このため、欠落している画素の画素値をｙ方向に隣接する画素の画素値によって補完して生成してもよいし、ｘ方向の画素値を２画素ずつ加算して生成してもよい。

[0076] また、撮像素子の各画素のｘ方向とｙ方向のアスペクト比が２：１である構成であってもよい。このような構成にすることにより、前述のような補完処理や加算処理が不要となる。

[0077] また、本実施形態では、第２の光学領域Ｄ２はガラス板であるが、ＮＤフ

ィルタのように光量を減衰させるフィルタに置き換えてもよい。偏光フィルタの光の透過率は、５０％未満であるため、ガラス板を配置した第２の光学領域を介して撮像した画像の明るさは、偏光フィルタを配置した第１の光学領域を介して撮像した画像の２倍以上となる。このような構成においては、画像のダイナミックレンジが広い方の画像に適合するように露光量を調整するため、偏光フィルタを介して撮像した画像のダイナミックレンジは、ガラスを介して撮像した画像の半分未満となる。一方、ガラス板を偏光フィルタと等しい透過率のＮＤフィルタに置き換えることにより、２つの領域を介して撮像した画像の露光量の差を小さくすることができ、いずれの画像もダイナミックレンジを有効に確保することができる。

[0078] （実施の形態２）

図５は、実施の形態２の撮像システムＡＰ１を示す模式図である。本実施の形態の撮像システムＡＰ１は、実施の形態１の撮像装置Ａと、偏光照明Ｑａと、制御部ＣＳによって構成されている。偏光照明Ｑａは、可視光を発する光源ＬＳ１と、偏光フィルタＰＬとによって構成されている。偏光フィルタＰＬの偏光軸は、撮像装置Ａの第１の光学領域Ｄ１の偏光軸と直交する第２の偏光軸を有している。また、制御部ＣＳは、撮像装置Ａおよび偏光照明Ｑａの制御や、外部装置Ｅとの入出力制御等を行う。外部装置Ｅは、例えば、撮像システムＡＰ１から出力された画像を表示するモニターや、画像を処理するパーソナルコンピュータ等である。

[0079] 光源ＬＳ１から出射した光は、偏光フィルタＰＬを通過して被写体Ｏｂに到達する。偏光フィルタＰＬは、第２の偏光軸と平行な方向に振動する光を主に透過し、それ以外の方向に振動する光（例えば第２の偏光軸と直交する方向に振動する光）の大部分を吸収する。したがって、被写体Ｏｂには、第２の偏光軸の方向に振動する光のみが照射される。

[0080] 被写体Ｏｂは、例えば、人の顔肌等の生体である。本実施形態では、被写体Ｏｂは人の顔肌として説明する。顔肌（被写体Ｏｂ）に到達した光には、反射される成分と吸収される成分があり、撮像装置Ａは反射される成分の光

を撮像する。顔肌で反射される光には、顔肌の表面で反射する成分と、顔肌の内部に入り込んで散乱を繰り返した後、入射した位置とは異なる位置から出射する成分がある。

[0081] 顔肌の表面で反射する光は、さらに鏡面反射する成分と拡散反射する成分に分けられる。顔肌で鏡面反射する成分は、偏光が維持された状態となる。また、顔肌で拡散反射する成分と、顔肌の内部に入り込んで異なる位置から出射する成分は、偏光状態が乱れた無偏光の状態となる。

[0082] 撮像装置Ａの第１の光学領域Ｄ１に配置された偏光フィルタは、偏光照明Ｑａにおける偏光フィルタＰＬの偏光軸と直交する偏光軸を有しているため、顔肌で鏡面反射する光の成分の大部分をカットする。また、顔肌の表面で拡散反射した光と、顔肌の内部に入り込んで異なる位置から出射する光は無偏光であるが、撮像装置Ａの第１の光学領域Ｄ１に配置された偏光フィルタは、前述の無偏光の光の成分の中で、第１の偏光軸の方向に振動する光の成分を透過する。つまり、第１の光学領域Ｄ１を透過した光によって撮像した画像情報は、顔肌の表面で拡散反射した光の成分と、顔肌の内部に入り込んで異なる位置から出射する光の成分を有している。

[0083] 一方、撮像装置Ａの第２の光学領域Ｄ２は、全ての方向に振動する光を透過するので、第２の光学領域Ｄ２を透過した光によって撮像した画像情報は、顔肌で鏡面反射する光の成分、顔肌の表面で拡散反射した光の成分、および顔肌の内部に入り込んで異なる位置から出射する光の成分を有している。

[0084] 前述した顔肌の内部とは、表皮領域であり、表皮領域の中でシミが発生している領域にはメラニンが生成されている。表皮に入り込んだ光は、メラニンによって減衰されるため、シミのある領域の画像の輝度は低下する。但し、第２の光学領域Ｄ２を透過した光によって生成した画像情報には、顔肌の鏡面反射成分が含まれているため、顔肌のテカリとなって現れ、シミによる輝度の低下の認識が困難となる。一方、第１の光学領域Ｄ１を透過した光によって生成した画像は、顔肌の鏡面反射成分の大部分をカットした画像、つまり、顔肌のテカリの大部分をカットした画像となるため、顔肌のシミの状

態が見やすくなる。

[0085] また、撮像装置Ａの第２の光学領域Ｄ２を透過した光によって撮像した画像情報から、第１の光学領域Ｄ１を透過した光によって撮像した画像情報を減算することによって、顔肌の表面で鏡面反射した光の成分を有する画像情報を生成することもできる。顔肌の表面で鏡面反射した光の成分を有する画像情報においては、顔肌の凹凸による陰影がはっきりするため、毛穴や肌のキメ、小ジワ等が認識しやすい画像となる。

[0086] 以上の構成により、撮像システムＡＰ１の撮像装置Ａにおける第１の光学領域Ｄ１を透過した光によって、シミの状態を認識しやすい画像を取得することができ、第２の光学領域Ｄ２を透過した光によって、通常の顔肌の画像を取得することができ、さらには、両者の画像を用いることによって、顔肌の毛穴やキメが認識しやすい画像を取得することができる。

[0087] なお、偏光フィルタＰＬの偏光軸は、撮像装置Ａの第１の光学領域Ｄ１の偏光軸と平行な偏光軸としてもよい。このような構成で顔肌を撮像した場合、第１の光学領域Ｄ１を透過した光によって撮像した画像情報は、毛穴や肌のキメ、小ジワ等が認識しやすい画像を取得することができる。また、撮像装置Ａの第２の光学領域Ｄ２を透過した光によって撮像した画像情報から、第１の光学領域Ｄ１を透過した光によって撮像した画像情報を減算することによって、シミの状態を認識しやすい画像を取得することができる。

[0088] このように本実施の形態の撮像システムＡＰ１を用いることにより、生体の表面と内部の状態を同時に観察できる。撮像システムＡＰ１は、顔肌の診断や化粧の状態をリアルタイムで確認するための装置や、内視鏡等の医療用カメラ等に応用することができる。

[0089] （実施の形態３）

本実施の形態３は、撮像装置Ａの光学領域Ｄ１とＤ２に異なる波長帯域の光が透過するという点で実施の形態１と異なっている。ここでは、本実施形態において実施の形態１と同様の内容についての詳細な説明は省略する。

[0090] 図６は、実施の形態３の撮像装置Ａを示す模式図である。図６において、

光学素子Ｌ１ｓが、絞りＳと光学素子Ｌ１ｐとの間に配置されている。光学素子Ｌ１ｐ、Ｌ１ｓは、共に、第１および第２の光学領域Ｄ１、Ｄ２に配置された部分を有する。光学素子Ｌ１ｓのうち光学領域Ｄ１に位置する部分は、第１の波長帯域の光を透過し、光学素子Ｌ１ｓのうち光学領域Ｄ２に位置する部分は、第２の波長帯域の光を透過する。第１の波長帯域と、第２の波長帯域とでは、波長帯域が互いに異なる。

[0091] 「第１の波長帯域」及び「第２の波長帯域」における「波長帯域」とは、例えば、領域を透過する光の全光量のうち５０％以上の光量を占める連続する帯域であり、領域を通過することにより９５％以上カットされる波長は「波長帯域」に含まれない。

[0092] また、２つの波長帯域が互いに異なるとは、少なくとも一方の波長帯域に、他方の波長帯域には含まれない帯域が存在することを言う。したがって、一部の波長帯域が重複していてもよい。

[0093] 透過する波長帯域が互いに異なる構成は、光学素子Ｌ１ｓの絞りＳ側の表面上に有機材料や誘電多層膜を用いたフィルタを形成する構成や、吸収型のフィルタを形成する構成や、染色系のフィルタによって光学素子Ｌ１ｓを領域毎に染色する構成によって実現する。このようなカラーフィルタは、１つの平板上に形成されていても良いし、領域毎に分割した複数の平板上に形成されていてもよい。なお、光学素子Ｌ１ｐ、Ｌ１ｓは接触していてもよいし、離間していてもよい。また、光学素子Ｌ１ｐ、Ｌ１ｓは接着されていてもよい。

[0094] 本実施形態では、図６の信号処理部Ｃは、画素Ｐ１において得られる輝度値から、第１の波長帯域において第１の偏光軸の方向に振動する光に対応する画像情報を生成し、画素Ｐ２において得られる輝度値から、第２の波長帯域において無偏光の光に対応する画像情報を生成し、出力する。

[0095] 図６において、光束Ｂ１は、光学素子Ｌ１ｓの上半分、および光学素子Ｌ１ｐの上半分で構成される光学領域Ｄ１を通過する光束であり、光束Ｂ２は、光学素子Ｌ１ｓの下半分、および光学素子Ｌ１ｐの下半分で構成される光

学領域Ｄ２を通過する光束である。光束Ｂ１、Ｂ２は、絞りＳ、光学素子Ｌ１ｓ、光学素子Ｌ１ｐ、レンズＬ２、アレイ状光学素子Ｋをこの順に通過し、撮像素子Ｎ上の撮像面Ｎｉに到達する。

[0096] 図７は、光学素子Ｌ１ｓの光学領域Ｄ１とＤ２を被写体側から見た正面図である。光学素子Ｌ１ｓにおける光学領域Ｄ１とＤ２は、光軸Ｖを境界中心として光軸Ｖに垂直な面内で上下に２分割することで形成される。図７において、破線ｓは、絞りＳの開口領域を示している。

[0097] また、光学素子Ｌ１ｐの構成、アレイ状光学素子Ｋの構成、および撮像素子Ｎの構成は、実施の形態１と同じである。

[0098] 本実施の形態では、例えば、第１の波長帯域は近紫外光の帯域であり、第２の波長帯域は可視光の帯域である。

[0099] このような撮像装置Ａを用いることにより、図８に示すような撮像システムを構成することができる。図８は、実施の形態３の撮像システムＡＰ２を示す模式図である。本実施の形態の撮像システムＡＰ２は、偏光照明が第１の波長帯域の光を照射するという点と、第１の波長帯域とは異なる第２の波長帯域の光を照射する無偏光照明が追加されたという点で、実施の形態２の撮像システムＡＰ１と異なる。ここでは、本実施形態において実施の形態２と同様の内容についての詳細な説明は省略する。

[0100] 図８に示す偏光照明Ｑａは、近紫外光を照射する光源ＬＳ１と、偏光フィルタＰＬによって構成されている。また、無偏光照明Ｑｂは、可視光を照射する光源ＬＳ２によって構成されている。したがって、被写体Ｏｂには、近紫外線光の帯域において、第２の偏光軸の方向に振動する光と、可視光の帯域において、全ての方向に振動する無偏光の光が照射される。

[0101] 顔肌に入射した光は、波長が長いほど肌の深い領域に入り込む。近紫外線のように波長の短い光は、表皮領域までしか到達しない。表皮領域にはシミが発生しているメラニンが存在しているため、波長が短い光ほどメラニンによる光の減衰が大きくなる。このため、近紫外光のように波長の短い光で撮像した画像は、シミが認識しやすい画像となる。また、近紫外線のように波

長の短い光であっても、肌の表面では鏡面反射による反射光が発生するが、本実施形態の撮像装置Ａの第１の光学領域に配置された偏光フィルタによって、鏡面反射光をカットすることができる。

[0102] 以上の構成により、撮像システムＡＰ２の撮像装置Ａにおける第１の光学領域Ｄ１を透過した光によって形成される画像は、実施の形態２に比べてさらにシミを認識しやすい画像を取得することができる。

[0103] なお、撮像装置Ａの第１の光学領域Ｄ１に位置する光学素子Ｌ１ｓのフィルタの第１の波長帯域と、光源ＬＳ１の波長帯域は、必ずしも近紫外線の光の帯域でなくてもよい。例えば、可視光帯域における紫色、青色、緑色等の４００ｎｍから６００ｎｍの帯域の中の所定の帯域を透過するフィルタであってもよい。このような構成の場合、撮像装置Ａの第２の光学領域Ｄ２に配置する光学素子Ｌ１ｓのフィルタの第２の波長帯域、および光源ＬＳ２の波長帯域は、光学領域Ｄ１に配置する光学素子Ｌ１ｓの第１の波長帯域、および光源ＬＳ１の波長帯域と重複しないように構成されていてもよい。

[0104] また、撮像装置Ａの第１の光学領域Ｄ１に配置する光学素子Ｌ１ｓのフィルタの第１の波長帯域と、光源ＬＳ１の波長帯域は、近赤外光の波長帯域であってもよい。近赤外光の波長は顔肌等の生体において深部まで到達する。生体深部には血管が存在しているが、血液に含まれるヘモグロビンは近赤外光を吸収するため、画像情報の輝度が小さくなる。従って、近赤外光の波長帯域を利用することによって、生体の深部の血管の画像情報を取得することができる。

[0105] また、図８において、偏光照明Ｑａと無偏光照明Ｑｂは、それぞれ１つずつとして図示しているが、複数備えられていてもよいし、アレイ状に交互に配置されていてもよい。

[0106] また、撮像システムＡＰ２の照明は偏光照明のみで構成してもよい。この場合、光源は第１の波長帯域の光と第２の波長帯域の光を発光する光源で構成される。

[0107] また、偏光照明は、透過偏光軸が互いに直交した２つの偏光照明で構成され

ていてもよい。この場合、それぞれの光源は第１の波長帯域の光と第２の波長帯域の光を発光する光源で構成され、必要に応じて２つの偏光照明を切り替えて使用する。

[0108] （実施の形態４）

本実施の形態４は、図１の光学素子Ｌ１の領域分割を３つにした点と、第１の偏光軸と異なる第２の偏光軸を有する光を透過する領域を追加した点において、実施の形態１と異なる。

[0109] 図９は、実施の形態４の撮像装置Ａを示す模式図である。

[0110] 図９において、光束Ｂ１は、光学素子Ｌ１上の光学領域Ｄ１を通過する光束であり、光束Ｂ２は、光学素子Ｌ１上の光学領域Ｄ２を通過する光束であり、光束Ｂ３は、光学素子Ｌ１上の光学領域Ｄ３を通過する光束である。光束Ｂ１、Ｂ２、およびＢ３は、絞りＳ、光学素子Ｌ１ｐ、レンズＬ２、アレイ状光学素子Ｋをこの順に通過し、撮像素子Ｎ上の撮像面Ｎｉ（図１１等に示す）に到達する。

[0111] また、図９において、第１の光学領域Ｄ１には、第１の偏光軸の方向に振動する光を主に透過する偏光フィルタが配置され、第２の光学領域Ｄ２には、全ての方向に振動する光を透過するガラス板が配置され、第３の光学領域Ｄ３には、第１の偏光軸と直交する第２の偏光軸の方向に振動する光を主に透過する偏光フィルタが配置されている。

[0112] 図１０は、光学素子Ｌ１を被写体側から見た正面図であり、第１、第２および第３の光学領域Ｄ１、Ｄ２、Ｄ３は、光軸Ｖに垂直な面内で上下方向に３分割された領域である。

[0113] 図１１（ａ）は、図９に示すアレイ状光学素子Ｋおよび撮像素子Ｎを拡大して示す図であり、図１１（ｂ）は、アレイ状光学素子Ｋと撮像素子Ｎ上の画素との位置関係を示す図である。アレイ状光学素子Ｋは、光学要素Ｍ１が形成された面が撮像面Ｎｉ側に向かうように配置されている。撮像面Ｎｉには、画素Ｐが行列状に配置されている。画素Ｐは、画素Ｐ１、画素Ｐ２および画素Ｐ３に区別できる。

[0114] 画素Ｐ１、画素Ｐ２および画素Ｐ３のそれぞれは、ｘ方向に１行に並んで配置されている。ｙ方向においては、画素Ｐ１、Ｐ２、Ｐ３が繰り返し配置されている。アレイ状光学素子Ｋは、その光学要素Ｍ１の１つが、撮像面Ｎｉ上における１行の画素Ｐ１、１行の画素Ｐ２および１行の画素Ｐ３からなる３行の画素に対応するように配置されている。撮像面Ｎｉ上には、画素Ｐ１、Ｐ２、Ｐ３の表面を覆うようにマイクロレンズＭｓが設けられている。

[0115] アレイ状光学素子Ｋは、光学素子Ｌ１上の光学領域Ｄ１（図９、図１０に示す）を通過した光束Ｂ１（図９において点線で示される光束Ｂ１）の大部分が、撮像面Ｎｉ上の画素Ｐ１に到達し、光学領域Ｄ２を通過した光束（図９において実線で示される光束Ｂ２）の大部分が、撮像面Ｎｉ上の画素Ｐ２に到達し、光学領域Ｄ３を通過した光束（図９において破線で示される光束Ｂ３）の大部分が、撮像面Ｎｉ上の画素Ｐ３に到達するように設計されている。具体的にはアレイ状光学素子Ｋの屈折率、撮像面Ｎｉからの距離及び光学要素Ｍ１のレンズ面の曲率半径等のパラメータを適切に設定することで、上記構成が実現する。

[0116] 以上の構成により、画素Ｐ１、画素Ｐ２、および画素Ｐ３は、第１の偏光軸の方向に振動する光に対応する画像情報と、全ての方向に振動する光に対応する無偏光の画像情報と、第１の偏光軸と直交する第２の偏光軸の方向に振動する光に対応する画像情報をそれぞれ生成する。つまり、撮像装置Ａは、これらの複数の画像情報を、単一の撮像光学系で、かつ、１回の撮像で取得することができる。

[0117] 実施の形態１、および２では、偏光情報を有する画像については、１つの偏光軸の方向に振動する光の情報のみの１種類であるため、例えば、車載カメラ等の路面状態の検出や車線検出の用途等に限定される。本実施の形態４では、偏光軸が２種類であるため、例えば、監視カメラ等、被写体との間に様々な向きのガラス面が存在するシーンが想定される用途に応用することができる。例えば、建物のガラスや車のフロントガラスは、互いに反射面の法線の方向が異なるが、本実施の形態では、偏光軸が２種類であるため、建物

のガラスの向こうの人物や、車のフロントガラスの人物を認識しやすくなる。

[0118] なお、本実施の形態は、実施の形態３のように光学領域毎に異なる波長帯域の光が透過する領域を有する光学素子Ｌ１ｓを追加した構成であってもよい。この場合、偏光軸の方向は１種類であってもよい。

[0119] （実施の形態５）

本実施の形態５は、図１の光学素子Ｌ１の領域分割を４つにした点と、アレイ状光学素子をレンチキュラレンズからマイクロレンズに置き換えた点で実施の形態３と異なっている。ここでは、実施の形態１と同様の内容についての詳細な説明は省略する。

[0120] 図１２（ａ）は、光学素子Ｌ１ｓを被写体側から見た正面図である。光学素子Ｌ１ｓは、第１、第２、第３および第４の光学領域Ｄ１、Ｄ２、Ｄ３、およびＤ４に配置されている。第１、第２、第３および第４の光学領域Ｄ１、Ｄ２、Ｄ３、およびＤ４は、光軸Ｖを境界中心として光軸Ｖに垂直な面内で上下左右に４分割された領域である。光学素子Ｌ１ｓのうち第１、第２、第３および第４の光学領域Ｄ１、Ｄ２、Ｄ３、およびＤ４に位置する部分の分光透過率特性は互いに異なる。光学素子Ｌ１ｓは、絞りＳと光学素子Ｌ１ｐの間に配置されている。光学素子Ｌ１ｓの第１、第２、第３および第４の光学領域Ｄ１、Ｄ２、Ｄ３、およびＤ４に対応する領域には、それぞれ第１の波長帯域の光を透過する領域、第２の波長帯域の光を透過する領域、第３の波長帯域の光を透過する領域、および第４の波長帯域の光を透過する領域が配置されている。第１の波長帯域と、第２の波長帯域と、第３の波長帯域と、第４の波長帯域とは、波長帯域が互いに異なる。

[0121] 図１２（ｂ）は、光学素子Ｌ１ｐを被写体側から見た正面図である。第１、第２、第３および第４の光学領域Ｄ１、Ｄ２、Ｄ３、およびＤ４は光軸Ｖを境界中心として光軸Ｖに垂直な面内で上下左右に４分割された領域である。光学素子Ｌ１ｐのうち第１の光学領域Ｄ１に位置する部分のみに、第１の偏光軸の方向に振動する光を透過する偏光フィルタが配置され、その他の領

域に位置する部分には、全ての方向に振動する光を透過するガラス板が配置されている。

[0122] 図１３は、アレイ状光学素子Ｋの斜視図である。アレイ状光学素子Ｋにおける撮像素子Ｎ側の面には、光学要素Ｍ２が格子状に配置されている。それぞれの光学要素Ｍ２の断面（ｘ方向およびｙ方向に垂直なそれぞれの断面）は曲面形状であり、それぞれの光学要素Ｍ２は、撮像素子Ｎ側に突出している。このように、光学要素Ｍ２のレンズ面はマイクロレンズであり、アレイ状光学素子Ｋは、マイクロレンズアレイとなっている。

[0123] 図１４（ａ）は、アレイ状光学素子Ｋと撮像素子Ｎとを拡大して示す図であり、図１４（ｂ）は、アレイ状光学素子Ｋと撮像素子Ｎ上の画素との位置関係を示す図である。アレイ状光学素子Ｋは、光学要素Ｍ２が形成された面が撮像面Ｎｉ側に向かうように配置されている。撮像面Ｎｉには、画素Ｐが行列状に配置されている。画素Ｐは、画素Ｐ１、画素Ｐ２、画素Ｐ３および画素Ｐ４に区別できる。

[0124] アレイ状光学素子Ｋは、実施の形態１と同様に、レンズ光学系Ｌの焦点近傍に配置されており、かつ撮像面Ｎｉから所定の距離だけ離れた位置に配置されている。また、撮像面Ｎｉ上には、画素Ｐ１、Ｐ２、Ｐ３、Ｐ４の表面を覆うようにマイクロレンズＭｓが設けられている。

[0125] また、アレイ状光学素子Ｋは、光学要素Ｍ２が形成された面が撮像面Ｎｉ側に向うように配置されている。アレイ状光学素子Ｋは、その光学要素Ｍ２の１つが、撮像面Ｎｉにおける２行２列の画素Ｐ１～Ｐ４の４つの画素に対応するように配置されている。

[0126] アレイ状光学素子Ｋは、光学素子Ｌ１ｓ、およびＬ１ｐで構成される第１、第２、第３および第４の光学領域Ｄ１、Ｄ２、Ｄ３、およびＤ４を通過した光束の大部分がそれぞれ撮像面Ｎｉ上の画素Ｐ１、画素Ｐ２、画素Ｐ３、および画素Ｐ４に到達するように設計されている。具体的にはアレイ状光学素子Ｋの屈折率、撮像面Ｎｉからの距離及び光学要素Ｍ１表面の曲率半径等のパラメータを適切に設定することで、上記構成が実現する。

[0127] 以上の構成により、本実施形態では、画素Ｐ１において得られる輝度値から、第１の波長帯域において第１の偏光軸の方向に振動する光に対応する画像情報を生成し、画素Ｐ２において得られる輝度値から、第２の波長帯域において無偏光の光に対応する画像情報を生成し、画素Ｐ３において得られる輝度値から、第３の波長帯域において無偏光の光に対応する画像情報を生成し、画素Ｐ４において得られる輝度値から、第４の波長帯域において無偏光の光に対応する画像情報を生成し、出力する。

[0128] 本実施の形態では、例えば、光学領域Ｄ１における第１の波長帯域は近紫外光の帯域であり、光学領域Ｄ２における第２の波長帯域は青色の光の帯域であり、光学領域Ｄ３における第３の波長帯域は、緑色の光の帯域であり、光学領域Ｄ４における第４の波長帯域は、赤色の光の帯域である。

[0129] このような撮像装置Ａを用いることにより、実施の形態３で示した図８と同様な撮像システムを構成することができる。このような構成によって、本実施形態では、偏光情報を有する近紫外線の画像と、青色、緑色、および赤色の３原色で構成された無偏光のカラー画像を取得することができる。

[0130] 無偏光のカラー画像では、顔肌のテカリによってシミの認識が困難となるが、偏光情報を有する近紫外線の画像はシミの認識がしやすくなるため、これらの画像を合成することによって、シミの認識がしやすいカラー画像を生成することができる。

[0131] なお、本実施の形態では、第１の波長帯域は、近紫外光の帯域としているが、例えば、可視光帯域における紫色、青色、緑色等の４００から６００ｎｍの帯域の中の所定の帯域を透過するフィルタであってもよい。

[0132] （実施の形態６）

本実施の形態６は、第１および第３の光学領域が同じ波長帯域の光を透過する点で実施の形態５と異なっている。ここでは、実施の形態５と同様の内容についての詳細な説明は省略する。

[0133] 図１５（ａ）は、光学素子Ｌ１ｓを被写体側から見た正面図である。実施の形態５では、光学素子Ｌ１ｓの第１、第２、第３および第４の光学領域Ｄ

１、Ｄ２、Ｄ３、およびＤ４に対応する領域には、全て異なる波長帯域の光を透過する領域が設けられていたが、本実施形態では、第１および第３の光学領域Ｄ１とＤ３は、同じ波長帯域の光を透過する。第２および第４の光学領域Ｄ２とＤ４は、それぞれ光学領域Ｄ１およびＤ３とは異なる波長帯域の光を透過する。

[0134] 図１５（ｂ）は、光学素子Ｌ１ｐを被写体側から見た正面図であり、実施の形態５における図１２（ｂ）の構成と同じである。

[0135] 本実施の形態では、例えば、第１の波長帯域（光学領域Ｄ１とＤ３）は青色の光の帯域であり、第２の波長帯域（光学領域Ｄ２）は緑色の光の帯域であり、第３の波長帯域（光学領域Ｄ４）は赤色の光の帯域である。

[0136] このような撮像装置Ａを用いることにより、実施の形態３で示した図８と同様な撮像システムを構成することができる。但し、本実施形態では、図８の偏光Ｑａは、青色の光を照射する光源ＬＳ１と、偏光フィルタＰＬによって構成されている。また、無偏光照明Ｑｂは、緑色と赤色の光を照射する光源ＬＳ２によって構成されている。このような構成によって、本実施形態では、偏光情報を有する青色の画像と、青色、緑色、および赤色の３原色で構成された無偏光のカラー画像を取得することができる。

[0137] 無偏光のカラー画像では、顔肌のテカリによってシミの認識が困難となるが、偏光情報を有する青色の画像はシミの認識がしやすくなるため、これらの画像を合成することによって、シミの認識がしやすいカラー画像を生成することができる。

[0138] なお、本実施の形態では、第１の波長帯域（光学領域Ｄ１とＤ３）を緑色、第２の波長帯域（光学領域Ｄ２）を青色、第３の波長帯域（光学領域Ｄ４）を赤色の帯域としてもよい。

[0139] また、本実施の形態では、図１６（ａ）に示すように光学領域Ｄ３に、光学領域Ｄ１に配置した偏光フィルタの偏光軸と直交した偏光フィルタを配置した構成であってもよい。光学領域Ｄ１を透過した光は鏡面反射成分をカットするため、シミの認識がしやすい画像情報を取得することができる。また

、光学領域Ｄ３を透過した光によって、鏡面反射の成分の画像情報を取得することができる。実施の形態２で説明した通り、顔肌の表面で鏡面反射した光は、顔肌の凹凸による陰影がはっきりするため、毛穴等が認識しやすい画像情報を取得することができる。これらの画像情報と光学領域Ｄ２およびＤ４を透過した光による画像情報とを合成することにより、シミの認識がしやすいカラー画像と毛穴等の認識がしやすいカラー画像の両方を取得することができる。

[0140] また、図１６（ｂ）に示すように、絞りＳによって光学領域Ｄ２、Ｄ４の面積を光学領域Ｄ１、Ｄ３に対して相対的に小さくした構成であってもよい。このような構成にすることにより、各領域を介して撮像した画像の露光量の差を小さくすることができ、いずれの画像もダイナミックレンジを有効に確保することができる。また、絞りＳによって光学領域Ｄ３の面積を光学領域Ｄ１に対して相対的に小さくした構成であってもよい。肌等の生体を撮影する場合、鏡面反射成分の方が散乱反射光よりも大きくなる場合がある。従って、光学領域Ｄ３を透過した光によって得られる鏡面反射成分の画像と光学領域Ｄ１を透過した光によって得られる散乱反射光成分の画像との露光量の差を小さくすることができ、いずれの画像もダイナミックレンジを有効に確保することができる。

[0141] また、本実施形態では、光学領域Ｄ１とＤ３は、同じ波長帯域の光を透過するため、光学領域Ｄ１とＤ３を透過した光による画像を加算することによって、無偏光の画像情報を生成することができる。これらの画像情報と光学領域Ｄ２およびＤ４を透過した光による画像情報とを合成することにより、無偏光のカラー画像を取得することもできる。

[0142] （実施の形態７）

本実施の形態７は、光学素子Ｌ１ｓが存在しない点と、撮像素子Ｎがカラー撮像素子であるという点で実施の形態５と異なっている。ここでは、実施の形態５、６と同様の内容についての詳細な説明は省略する。

[0143] 図１７（ａ）は、光学素子Ｌ１ｐを被写体側から見た正面図であり、実施

の形態５および６で示した図１２（ｂ）および図１５（ｂ）の構成と同じである。

[0144] 図１７（ｂ）は、アレイ状光学素子Ｋとカラー撮像素子Ｎｃ上の画素との位置関係を示す図である。アレイ状光学素子Ｋは、光学要素Ｍ２が形成された面が撮像面Ｎｉ側に向かうように配置されている。撮像面Ｎｉには、画素Ｐが行列状に配置されている。画素Ｐは、画素Ｐ１、画素Ｐ２、画素Ｐ３および画素Ｐ４に区別できる。画素Ｐ１には第１の分光透過率特性を有するフィルタが備えられており、紫色帯域の光線を主に通過し、他の帯域の光線を吸収または反射する。また、画素Ｐ２には、第２の分光透過率特性を有するフィルタが備えられており、青色帯域の光線を主に通過し、他の帯域の光線を吸収または反射する。また、画素Ｐ３には、第３の分光透過率特性を有するフィルタが備えられており、緑色帯域の光線を主に通過し、他の帯域の光線を吸収または反射する。また、画素Ｐ４には、第４の分光透過率特性を有するフィルタが備えられており、赤色帯域の光線を主に通過し、他の帯域の光線を吸収または反射する。

[0145] 光学素子Ｌ１ｐの光学領域Ｄ１にのみ偏光フィルタが設けられているため、画素Ｐ１は第１の偏光軸に平行な偏光光が入射し、他の画素Ｐ２～Ｐ４には無偏光光が入射する。したがって、本実施の形態では、偏光情報を有する紫色の画像と、青色、緑色、および赤色の３原色で構成された無偏光のカラー画像を取得することができる。

[0146] 本実施の形態では、実施の形態５の光学素子Ｌ１ｓの分光機能がカラー撮像素子Ｎｃ上の各画素のカラーフィルタによって置き換えられている。このような構成によって、実施の形態５と同様の効果を得ることができる。

[0147] また、図１８に示すように画素Ｐ１とＰ３が同じ分光透過率特性を有するベイヤー配列のフィルタであってもよい。このような構成の場合、光学素子Ｌ１ｐは、図１２（ｂ）、もしくは図１６の構成と組み合わせることができる。このような構成によって、実施の形態６と同様の効果を得ることができる。

[0148] また、本実施形態では、画素Ｐ１には第１の分光透過率特性を有するフィルタが備えられていたが、画素Ｐ１にはフィルタが設けられず、光学領域Ｄ１に所望の分光透過特性を有するフィルタが設けられ、光学領域Ｄ２からＤ３には、フィルタが設けられていない光学素子Ｌ１ｓをさらに備えていてもよい。この場合、画素Ｐ１は白色光つまり、任意の波長の光を検出することができるため、光学素子Ｌ１ｓの光学領域Ｄ１に設けるフィルタの特性を変えることによって、画素Ｐ１が検出する偏光光の波長帯域を変えることができる。一般に、カラー撮像素子Ｎｃの画素Ｐ１上に設けるフィルタの分光特性を変更することは、別の仕様のカラー撮像素子Ｎｃを製造することになり、容易ではない。これに対し、光学素子Ｌ１ｓの光学領域Ｄ１に設けるフィルタの特性を変更することは容易である。したがって、このような構造を採用すれば、偏光情報を有する画像の色を容易にかつ低コストで変更することが可能となる。

[0149] （実施の形態８）

本実施の形態８は、実施の形態３から７のように複数の光学領域において、光学領域間で異なる波長帯域の光を透過する光学素子Ｌ１ｓを有する構成であって、さらにレンズＬ２が軸上色収差を有するレンズであることを前提とする。このような構成の場合に、複数の光学領域を透過した光線の合焦位置が実質的に等しくなるように、絞り近傍の光軸と垂直な面内において、複数の光学領域が、互いに異なる光学パワーを有する。この点で実施の形態３から７と異なっている。ここでは、実施の形態３から７と同様の内容についての詳細な説明は省略する。

[0150] 図１９（ａ）は、実施の形態８において、レンズＬ２が単レンズのように屈折率の波長分散特性により軸上色収差を有するレンズである場合の光線図を模式的に示す図である。図１９（ａ）において、第１の光学領域Ｄ１には、第１の波長帯域の光を透過するフィルタが形成され、第２の光学領域Ｄ２には、第１の波長帯域よりも相対的に長い第２の波長帯域の光を透過するフィルタが形成されている。レンズＬ２は、例えば、単レンズのように屈折率

の波長分散特性により軸上色収差を有するレンズであるため、波長が長い光ほどレンズから遠い方に合焦する。従って、図１９（ａ）に示すように、光学領域Ｄ１を通過した光線が撮像面Ｎｉ上に合焦するように設定すると、光学領域Ｄ２を通過した光線は、撮像面Ｎｉ上では合焦しきれない状態となる。

[0151] 図１９（ｂ）は、実施の形態８の撮像装置の光線図を模式的に示す図である。図１９（ｂ）では、第２の分光透過率特性を有する第２の光学領域Ｄ２を透過した光線が、撮像面Ｎｉで合焦するような光学パワーのレンズ面を形成している。具体的には、光学素子Ｌ１ｓのうち第２の光学領域Ｄ２に位置する部分の絞り側の面が曲率を有しているのに対し、光学素子Ｌ１ｓのうち第１の光学領域Ｄ１に位置する部分の絞り側の面は平面である。なお、光学素子Ｌ１ｓは、例えばガラスや樹脂といった透光性部材から形成されている基体と、基体の表面に設けられた光学フィルタとから構成されている。例えば、基体の絞り側の表面の一部に、光学特性を異ならせるための形状（曲面や回折レンズ）が設けられている。このため、第１の光学領域Ｄ１を通過した光線と第２の光学領域Ｄ２を通過した光線は、共に撮像面Ｎｉ上で合焦する。このように、本実施形態によると、第１の光学領域Ｄ１および第２の光学領域Ｄ２が異なる光学パワーを有することにより、第１の光学領域Ｄ１および第２の光学領域Ｄ２が等しい光学パワーを有する場合と比較して、第１の光学領域Ｄ１を透過した光の合焦位置と第２の光学領域Ｄ２を透過した光の合焦位置とが近づいている。

[0152] なお、光学素子Ｌ１ｓにおける基体自体が着色されていることにより、光学フィルタの機能を有していてもよい。この場合、基体のうち第１の光学領域Ｄ１に位置する部分が第１の波長帯域の光を透過し、基体のうち第２の光学領域Ｄ２に位置する部分が第２の波長帯域の光を透過するため、光学フィルタを別途設けなくてもよい。

[0153] 本実施の形態では、光学素子Ｌ１ｓにおける絞り側の面以外の部分に光学パワーを異ならせるための構造を設けてもよい。例えば、光学素子Ｌ１ｓに

おける撮像素子側の表面の一部において光学特性を異ならせるための形状（曲面、回折レンズ）により、光学パワーを異ならせてもよい。

[0154] 図２０（ａ）は、図１９（ｂ）で示した光学素子Ｌ１ｓの斜視図である。光学素子Ｌ１ｓは、基体と、その表面に形成されたフィルタとから構成されている。基体のうち第１の光学領域Ｄ１に位置する部分の絞り側の面は、平面（曲率半径Ｒ１＝∞）であり、その平面上には第１の分光透過率特性を有するフィルタが形成されている。基体のうち第２の光学領域Ｄ２に位置する部分の絞り側の面はレンズ面（曲率半径Ｒ２）であり、そのレンズ面上には第２の分光透過率特性を有するフィルタが形成されている。このため、基体の絞り側の面において第１の光学領域Ｄ１と第２の光学領域Ｄ２との境界部分には段差が生じている。このような段差を通過した光線は不要光となるため、絞りＳは、図２０（ｂ）のような遮光領域を設けた構成であることが望ましい。なお、絞りＳとは別に、基体における第１の光学領域Ｄ１と第２の光学領域Ｄ２との境界を覆う遮光部材を設けてもよい。

[0155] 以上の構成は、２つの光学領域による実施例であるが、３つの光学領域であっても同様に構成することができる。

[0156] 図２１（ａ）は、光学領域を３分割にした場合の光学素子Ｌ１ｓの斜視図である。光学素子Ｌ１ｓの基体のうち第１の光学領域Ｄ１に位置する部分の絞り側の面は平面（曲率半径Ｒ１＝∞）であり、その平面の上には、第１の分光透過率特性を有するフィルタが形成されている。光学素子Ｌ１ｓの基体のうち第２の光学領域Ｄ２に位置する部分の絞り側の面はレンズ面（曲率半径Ｒ２）であり、そのレンズ面の上に、第２の分光透過率特性を有するフィルタが形成されている。光学素子Ｌ１ｓの基体のうち第３の光学領域Ｄ３に位置する部分の絞り側の面はレンズ面（曲率半径Ｒ３）であり、そのレンズ面の上に、第３の分光透過率特性を有するフィルタが形成されている。このような構成によって、基体のうち各光学領域の境界に位置する部分には段差が生じている。このような段差を通過した光線は不要光となるため、絞りＳは、図２１（ｂ）のような遮光領域を設けた構成であることが望ましい。

[0157] また、レンズ光学系が４つの光学領域を有する場合にも同様に、遮光領域を設けることができる。

[0158] 図２２（ａ）は、光学領域を４分割にした場合の光学素子Ｌ１ｓの斜視図である。光学素子Ｌ１ｓの基体のうち第１の光学領域Ｄ１に位置する部分の絞り側の面は、平面（曲率半径Ｒ１＝∞）であり、その平面の上には、第１の分光透過率特性を有するフィルタが形成されている。光学素子Ｌ１ｓの基体のうち第２の光学領域Ｄ２に位置する部分の絞り側の面はレンズ面（曲率半径Ｒ２）であり、そのレンズ面の上に、第２の分光透過率特性を有するフィルタが形成されている。光学素子Ｌ１ｓの基体のうち第３の光学領域Ｄ３に位置する部分の絞り側の面はレンズ面（曲率半径Ｒ３）であり、そのレンズ面の上に、第３の分光透過率特性を有するフィルタが形成されている。光学素子Ｌ１ｓの基体のうち第４の光学領域Ｄ４に位置する部分の絞り側の面はレンズ面（曲率半径Ｒ４）であり、そのレンズ面の上に第４の分光透過率特性を有するフィルタが形成されている。このような構成によって、基体のうち各光学領域の境界に位置する部分には段差が生じている。このような段差を通過した光線は不要光となるため、絞りＳは、図２２（ｂ）のような遮光領域を設けた構成であることが望ましい。

[0159] 図２３は、光学素子Ｌ１ｓとは別に、光学領域ごとに光学パワーを異ならせるレンズを設けた例を示す。図２３においては、絞りから撮像素子に向かう方向に、光学素子Ｌ１ａ、光学素子Ｌ１ｓ、光学素子Ｌ１ｐがこの順で配置されている。光学素子Ｌ１ａ、光学素子Ｌ１ｓ、光学素子Ｌ１ｐは絞り近傍に配置されている。光学素子Ｌ１ａ、Ｌ１ｓ、およびＬ１ｐは、それぞれ複数の光学領域に位置する部分を有する。このように、フィルタを有する素子と、レンズ面が設けられるレンズを有する素子とが別体であってもよい。また、光学素子Ｌ１ａ、Ｌ１ｓ、およびＬ１ｐは、配置の順序が入れ替わった構成であってもよいし、絞り近傍の被写体側に配置されていてもよい。また、絞り近傍の撮像素子側と絞り近傍の被写体側に分割して配置されていてもよい。

[0160] また、図２３は２分割の光学領域を有する構成であるが、３分割および４分割の光学領域を有する構成であってもよい。

[0161] このように、本実施の形態８では、レンズＬ２が単レンズのように軸上色収差が補正されていないレンズを用いた場合でも、光軸と垂直な面内に、互いに異なる光学パワーを有する２つの領域を設けることにより、軸上色収差を低減させることができる。

[0162] （実施の形態９）

本実施の形態９においては、それぞれのマイクロレンズの領域内において、マイクロレンズが光軸に対して回転対称な形状であり、この点で本実施形態は実施の形態５、６、および７と異なっている。

[0163] マイクロレンズの製法として、レジストを矩形にパターーニングし、熱処理によってレンズ曲面を形成する手法があるが、このようなマイクロレンズの斜視図は、図２４（ａ１）のようになる。図２４（ａ１）のマイクロレンズの等高線は、図２４（ａ２）のようになるため、ｘ、ｙ方向と斜め方向の曲率半径が異なる。図２４（ａ３）は、図２４（ａ１）、（ａ２）に示すマイクロレンズを本発明のアレイ状光学素子に適用した場合の、光線追跡シミュレーションの結果である。図２４（ａ３）では、アレイ状光学素子Ｋを通過する光のうち１つの光学領域を通過する光束のみを示しているが、このように回転非対称形状のマイクロレンズの場合、隣接の画素に光が漏れてクロストークが発生する。一方、それぞれのマイクロレンズの正方形の領域内において回転対称形状のマイクロレンズの斜視図は、図２４（ｂ１）のようになる。図２４（ｂ１）のマイクロレンズの等高線は、図２４（ｂ２）のようになり、ｘ、ｙ方向と斜め方向の曲率半径は等しい。このようなマイクロレンズは、熱インプリントやＵＶインプリント製法により形成することができる。図２４（ｂ３）は、図２４（ｂ１）、（ｂ２）に示すマイクロレンズを本発明のアレイ状光学素子に適用した場合の、光線追跡シミュレーションの結果である。図２４（ｂ３）では、アレイ状光学素子Ｋを通過する光のうち１つの光学領域を通過する光束のみを示しているが、図２４（ａ３）のよう

なクロストークは、発生していないことがわかる。このように、マイクロレンズの各光学要素のレンズ面は、回転対称形状を有することにより、クロストークを低減させることができるため、色情報のクロストークや偏光情報のクロストークを抑制することができる。

[0164] （実施の形態１０）

本実施の形態１０は、アレイ状光学素子であるレンチキュラレンズやマイクロレンズアレイを撮像面上に形成したという点で、実施の形態１から９と異なる。ここでは、本実施形態において実施の形態１から９と同様の内容についての詳細な説明は省略する。

[0165] 図２５（ａ）および（ｂ）は、アレイ状光学素子Ｋおよび撮像素子Ｎを拡大して示す図であり、１つの光学領域を通過した光線のみ図示している。本実施形態では、アレイ状光学素子Ｋであるレンチキュラレンズ（またはマイクロレンズアレイ）Ｍｄが、撮像素子Ｎの撮像面Ｎｉ上に形成されている。撮像面Ｎｉには、実施の形態１等と同様に、画素Ｐが行列状に配置されている。これら複数の画素Ｐに対して、１つのレンチキュラレンズの光学要素あるいは、１つのマイクロレンズが対応している。本実施の形態においても、実施の形態１～７と同様に、異なる光学領域を通過した光束を、それぞれ異なる画素に導くことができる。また、図２５（ｂ）は、本実施形態の変形例を示す図である。図２５（ｂ）に示す構成では、撮像面Ｎｉ上に、画素Ｐを覆うようにマイクロレンズＭｓが形成され、マイクロレンズＭｓの表面上に低屈折率層Ｗを介してアレイ状光学素子が積層されている。図２５（ｂ）に示す構成では、図２５（ａ）の構成よりも集光効率を高めることができる。

[0166] 実施の形態１～９のようにアレイ状光学素子が撮像素子と分離していると、アレイ状光学素子と撮像素子との位置合せが難しくなるが、本実施形態のように、アレイ状光学素子Ｋを撮像素子上に形成する構成にすることにより、ウエハプロセスによって位置合せが可能になるため、位置合せが容易となり、位置合せ精度も増すことができる。

[0167] （実施の形態１１）

本実施の形態１１は、レンズ光学系Ｌが像側非テレセントリック光学系であるという点で、実施の形態１から１０と異なっている。カメラ等の撮像素子に用いられるレンズの多くは、像側が非テレセントリック光学系である。本発明の形態のレンズ光学系Ｌに像側非テレセントリック光学系を適用した場合、画角が変化すると、主光線はアレイ状光学素子Ｋに対して斜めに入射する。図２６（ａ）は、光軸外の撮像部近傍を拡大して示す図である。図２６（ａ）では、アレイ状光学素子Ｋを通過する光のうち１つの光学領域を通過する光束のみを示している。図２６（ａ）に示すように、レンズ光学系Ｌが像側非テレセントリック光学系の場合には、隣接画素に光が漏れてクロストークが発生しやすくなるが、図２６（ｂ）のようにアレイ状光学素子を画素配列に対してΔだけオフセットさせることにより、クロストークを低減させることができるため、色純度の劣化を抑制することができる。前記入射角は、像高によって異なるため、前記オフセット量Δは、撮像面への光束の入射角に応じて設定すればよい。

[0168] 像側非テレセントリック光学系にすることにより、像側テレセントリック光学系に比べて光学長を短くすることができるため、撮像装置Ａを小型化することができる。

[0169] （実施の形態１２）

実施の形態１２は、光学素子Ｌ１ｐの光学領域が２つである点、ベイヤー配列のフィルタを備えたカラー撮像素子を用いる点、および、アレイ状光学素子の光学要素が１方向に半ピッチシフトしている点で実施の形態１と異なる。これにより、本実施の形態の撮像装置は、無偏光光によるカラー画像と偏光光によるカラー画像とを一度に取得することができる。

[0170] 本実施の形態の撮像装置は、図１に示すように、レンズ光学系Ｌ、アレイ状光学素子Ｋおよび撮像素子Ｎを備える。また、図１、図２に示すように、レンズ光学系Ｌは、第１の光学領域Ｄ１および第２の光学領域Ｄ２を有する光学素子Ｌ１ｐを含む。第１の光学領域Ｄ１には、第１の偏光軸（透過軸）の方向に振動する光を透過する偏光フィルタが配置され、第２の光学領域Ｄ

２には、全ての方向に振動する光を透過するガラス板が配置されている。このため、第１の光学領域Ｄ１を透過した光束Ｂ１は第１の偏光軸（透過軸）の方向に振動する偏光光である。第２の光学領域Ｄ２を透過した光束Ｂ２は非偏光光である。

[0171] 図２７（ａ）は、本実施の形態のアレイ状光学素子Ｋおよび撮像素子Ｎを拡大して示す図である。アレイ状光学素子Ｋは複数の光学要素Ｍ１および複数の光学要素Ｍ２を含み、複数の光学要素Ｍ１、Ｍ２が形成された面が撮像面Ｎｉ側に向かうように配置されている。

[0172] 図２７（ｂ）は、アレイ状光学素子Ｋの複数の光学要素Ｍ１、Ｍ２と撮像素子Ｎ上の画素との位置関係を示す図である。実施の形態１と同様、撮像素子Ｎは、撮像面Ｎｉに配列された複数の画素を含む。図２７（ｂ）に示すように、複数の画素は、ｘ方向（第１の方向）およびｙ方向（第２の方向）に２次元に配列されている。ｘ方向およびｙ方向への配列をそれぞれ行および列と呼ぶ場合、複数の画素は、撮像面Ｎｉ上において、例えば、ｍ行ｌ列（ｌ、ｍは２以上の整数）に配置されている。つまり、ｘ方向に１からｌ個の画素が配列した一行の画素群が、ｙ方向に１からｍ行目までのｍ行に配列されている。

[0173] ｍ行の画素群のうちｊ行目（１≦ｊ＜ｍ）に配列されたｌ個の画素のｘ方向における中心Ｃ’ｊの各位置は、ｊ＋１行目に配列されたｌ個の画素のｘ方向における中心Ｃ’ｊ＋１の各位置と略同一である。

[0174] 同様に、複数の画素をｙ方向に配列された複数画素群による１列の画素群がｘ方向に１からｌ列までのｌ列に配列されていると見ることもできる。この場合、ｌ列の画素群のうちｕ列行目（１≦ｕ＜ｌ）に配列されたｍ個の画素のｙ方向における中心の各位置は、ｕ＋１行目に配列されたｍ個の画素のｙ方向における中心の各位置と略同一である。

[0175] また、本実施の形態において、複数の画素は本実施の形態ではいずれも撮像面Ｎｉにおいて同じ形状を有している。例えば、複数の画素は同じ矩形形状を有しており、面積も互いに等しい。また、本実施の形態では、複数の画

素はｘ方向およびｙ方向に同じピッチで配置されている。

[0176] 説明のため、複数の画素を、それぞれ複数の画素Ｐ１Ａ、Ｐ２Ａ、Ｐ３Ａ、Ｐ４Ａ、Ｐ１Ｂ、Ｐ２Ｂ、Ｐ３Ｂ、およびＰ４Ｂに区別する。複数の画素Ｐ１Ａのうちの１つ、複数の画素Ｐ２Ｂのうちの１つ、複数のＰ３Ａのうちの１つ、および、複数のＰ４Ｂのうちの１つは、撮像面Ｎｉにおいて、２行２列に配置されている。これら２行２列に配列されている画素Ｐ１Ａ、Ｐ２Ｂ、Ｐ３Ａ、Ｐ４Ｂを、「第１の画素群Ｐｇ１」と称する。複数の画素Ｐ１Ｂのうちの１つ、複数の画素Ｐ２Ａのうちの１つ、複数の画素Ｐ３Ｂのうちの１つ、および、複数の画素Ｐ４Ａのうちの１つは、撮像面Ｎｉにおいて、２行２列に配列されている。これら２行２列に配列されている画素Ｐ１Ｂ、Ｐ２Ａ、Ｐ３Ｂ、Ｐ４Ａを、「第２の画素群Ｐｇ２」と称する。

[0177] ここで、第１の画素群Ｐｇ１に属する画素Ｐ３Ａが、（ｐ、ｑ）の位置に配置されているとする。ｐ、ｑは、それぞれ、$1 \leqq p < l$、$1 \leqq q < m$を満たす整数である。この場合、第１の画素群Ｐｇ１のうちの残りの画素Ｐ１Ａ、Ｐ２Ｂ、Ｐ４Ｂは、それぞれ、（ｐ＋１、ｑ）、（ｐ、ｑ＋１）、（ｐ＋１、ｑ＋１）の位置に配置されている。また、第２の画素群Ｐｇ２における画素２Ａ、Ｐ１Ｂ、Ｐ３Ｂ、Ｐ４Ａは、それぞれ、（ｐ＋２、ｑ＋１）、（ｐ＋３、ｑ＋２）、（ｐ＋２、ｑ＋２）、（ｐ＋３、ｑ＋１）の位置に配置されている。

[0178] アレイ状光学素子Ｋのうち撮像面Ｎｉに対向する表面において、光学要素Ｍ１は、第１の画素群Ｐｇ１の４つの画素に対応する位置に設けられたマイクロレンズである。第１の画素群Ｐｇ１には、アレイ状光学素子Ｋにおける光学要素Ｍ１からの光が入射する。光学要素Ｍ１は、領域Ｄ１を通過した光の大部分を、撮像素子Ｎにおける画素Ｐ１Ａ、Ｐ３Ａに、領域Ｄ２を通過した光の大部分を撮像素子Ｎにおける画素Ｐ２Ｂ、Ｐ４Ｂに入射させる。

[0179] アレイ状光学素子Ｋのうち撮像面Ｎｉに対向する表面において、光学要素Ｍ２は、第２の画素群Ｐｇ２の４つの画素に対応する位置に設けられたマイクロレンズである。第２の画素群Ｐｇ２には、アレイ状光学素子Ｋにおける

光学要素Ｍ２からの光が入射する。光学要素Ｍ２は、領域Ｄ１を通過した光の大部分を撮像素子Ｎにおける画素Ｐ２Ａ、Ｐ４Ａに、領域Ｄ２を通過した光の大部分を撮像素子Ｎにおける画素Ｐ１Ｂ、Ｐ３Ｂに入射させる。

[0180] 画素Ｐ１Ａ、Ｐ２Ａ、Ｐ１Ｂ、およびＰ２Ｂには第１の分光透過率特性を有するフィルタが設けられている。第１の分光透過率特性を有するフィルタは、緑色帯域の光線を主に通過し、他の帯域の光線を吸収する。画素Ｐ３ＡおよびＰ３Ｂには、第２の分光透過率特性を有するフィルタが設けられている。第２の分光透過率特性を有するフィルタは、赤色帯域の光線を主に通過し、他の帯域の光線を吸収する。また、画素Ｐ４ＡおよびＰ４Ｂには、第３の分光透過率特性を有するフィルタが設けられている。第３の分光透過率特性を有するフィルタは、青色帯域の光線を主に通過し、他の帯域の光線を吸収する。

[0181] 画素Ｐ１ＡとＰ３Ａ、画素Ｐ１ＢとＰ３Ｂ、画素Ｐ２ＡとＰ４Ａ、および画素Ｐ２ＢとＰ４Ｂとは、いずれもｘ方向に交互に配置されている。また、画素Ｐ１ＡとＰ４Ａ、画素Ｐ１ＢとＰ４Ｂ、画素Ｐ２ＡとＰ３Ａ、および画素Ｐ２ＢとＰ３Ｂは、いずれもｙ方向に交互に配置されている。また、画素Ｐ１Ａ、Ｐ３Ａ、Ｐ１Ｂ、およびＰ３Ｂは同じ行に配列（ｘ方向に配列）され、画素Ｐ２Ａ、Ｐ４Ａ、Ｐ２Ｂ、およびＰ４Ｂは同じ行に配列（ｙ方向に配列）され、画素Ｐ１Ａ、Ｐ３Ａ、Ｐ１Ｂ、およびＰ３Ｂの行と画素Ｐ２Ａ、Ｐ４Ａ、Ｐ２Ｂ、およびＰ４Ｂの行はｙ方向に交互に配置されている。このように、それぞれの複数の画素は、ベイヤー配列を成している。ベイヤー配列で画素が配置されている場合には、共に緑色帯域の光を透過するフィルタを有する画素Ｐ１Ａおよび画素Ｐ２Ｂ、画素Ｐ１Ｂおよび画素Ｐ２Ａは、それぞれの画素群Ｐｇ１、Ｐｇ２において、斜めの位置に配置されている。

[0182] アレイ状光学素子Ｋは、光線の入射角に応じて出射方向を振り分ける機能を有する。そのため、第１の光学領域Ｄ１および第２の光学領域Ｄ２に対応するように、撮像面Ｎｉ上の画素に光を入射させることができる。このような画素への光の入射を実現するには、アレイ状光学素子Ｋの屈折率、撮像面

Ｎｉからの距離及び光学要素Ｍ１表面の曲率半径等のパラメータを適切に設定することで、上記構成が実現する。

[0183] 次に、アレイ状光学素子の具体的な構成について説明する。

[0184] 図２８（ａ１）、（ａ２）、（ｂ１）、（ｂ２）、（ｃ１）、および（ｃ２）は、図２７（ａ）、（ｂ）で示した光学要素Ｍ１、Ｍ２の形状および配置を示す図である。図２８（ａ１）は、光軸に対して回転非対称な形状を有する光学要素（マイクロレンズ）の配置と等高線を示す図であり、図２８（ａ２）は、その斜視図である。このようなマイクロレンズアレイは、ガラス板の上に四角柱状のレジストを形成して熱処理を行うことにより形成することができる。

[0185] 図２８（ａ１）に示すように、光学要素Ｍ１、Ｍ２は、アレイ状光学素子Ｋの表面（例えばレンズ光学系Ｌの光軸と垂直な面）において、それぞれｙ方向に並べられたｓ個（ｓは２以上の整数）の列を構成し、光学要素Ｍ１の列および光学要素Ｍ２の列がｘ方向に交互に配列されている。例えば、これらの列は、ｘ方向に１からｔ列目（ｎは２以上の整数）までのｔ列に配列されている。１以上であってｔより小さい任意の整数をｋ（１≦ｋ＜ｎ）とすると、ｋ列目に配置される光学要素のｙ方向における中心Ｃｋの位置Ｙｋは、ｋ＋１列目に配置される光学要素の列方向の中心Ｃｋ＋１の位置Ｙｋ＋１から、ｙ方向にずれている。つまり、光学要素Ｍ１および光学要素Ｍ２の中心の位置は、互いにｙ方向にずれている。

[0186] ここで、アレイ状光学素子Ｋの表面において、ｙ列方向に隣接する２つの光学要素Ｍ１、Ｍ２の列方向における中心間の距離をＹとする。光学要素Ｍ１、Ｍ２のｙ方向のピッチはいずれもＹである。この場合、ｙ方向において、位置Ｙｋと位置Ｙｋ＋１の列方向のずれは、例えば、０．５Ｙ（半ピッチ）である。ただし、アレイ状光学素子Ｋの製造誤差などを考慮すると、このずれは、０．４５Ｙ以上０．５５Ｙ以下であってもよい。ずれが０．４５Ｙ以上０．５５Ｙ以下であれば、第１の光学領域Ｄ１および第２の光学領域Ｄ２に入射した光を、アレイ状光学素子Ｋによって、所望の画素に振り分ける

ことができる。

[0187] なお、「光学要素の列方向における中心」は、例えば、各光学要素を構成する立体の頂点である。または、各光学要素の列方向における２つの端部を結ぶ線分の中点である。

[0188] 図２８（ｂ１）は、光軸に対して回転対称な形状を有するマイクロレンズの配置と等高線を示す図であり、図２８（ｂ２）は、その斜視図である。図２８（ｂ１）のマイクロレンズは、それぞれ六角形で区切られている。ただし、それぞれのマイクロレンズは、それぞれ正方配列された４つの画素を覆うように形成されるため、典型的には、正六角形ではない。図２８（ｂ１）、（ｂ２）に示されるマイクロレンズ同士の境界は六角形で区切られているが、マイクロレンズのうち境界部分よりも上部は、球面や非球面であってもよい。このような回転対称形状のマイクロレンズは、熱インプリントやＵＶインプリント製法により、ガラス板等の上に形成することができる。

[0189] 図２８（ｃ１）は、シリンドリカルマイクロレンズを２画素毎に交互に半ピッチずらした形状を有するマイクロレンズアレイの配置と等高線を示す図であり、図２８（ｃ２）は、その斜視図である。図２８（ｃ１）のマイクロレンズアレイも熱インプリントやＵＶインプリント製法により、ガラス板等の上に形成することができる。

[0190] 図２９（ａ）は、図２８（ａ１）、（ａ２）に示すマイクロレンズを本実施の形態のアレイ状光学素子に適用した場合の、三次元光線追跡シミュレーションの結果を示す図である。図２９（ａ）では、アレイ状光学素子Ｋを通過する光のうち領域Ｄ１を通過する光線のみを示しているが、このように回転非対称形状のマイクロレンズの場合、縦横方向（マイクロレンズの底面の四辺と平行な方向）と斜め方向（マイクロレンズの底面の対角線方向）との曲率半径が異なることにより、隣接の画素に光が漏れてクロストークが発生する。

[0191] 図２９（ｂ）は、図２８（ｂ１）、（ｂ２）に示すマイクロレンズを本実施の形態のアレイ状光学素子に適用した場合の、三次元光線追跡シミュレー

ションの結果を示す図である。図２９（ｂ）では、アレイ状光学素子Ｋを通過する光のうち１つの領域を通過する光束のみを示しているが、図２９（ａ）のようなクロストークは発生していないことがわかる。このように、アレイ状光学素子の各光学要素を回転対称形状にすることにより、以下で説明する第１のカラー画像と第２のカラー画像間のクロストークを低減させることができる。

[0192] なお、図２８（ｂ１）、（ｂ２）で示したマイクロレンズは、六角形であるが、回転対称であれば、必ず六角形である必要はない。

[0193] 図２９（ｃ）は、図２８（ｃ１）、（ｃ２）に示すシリンドリカルマイクロレンズを本実施の形態のアレイ状光学素子に適用した場合の、三次元光線追跡シミュレーションの結果を示す図である。図２９（ｃ）では、アレイ状光学素子Ｋを通過する光のうち１つの領域を通過する光束のみを示しているが、図２９（ａ）のようなクロストークは発生していないことがわかる。このように、アレイ状光学素子の各光学要素をシリンドリカル形状にすることにより、第１のカラー画像と第２のカラー画像間のクロストークを低減させることができる。

[0194] 次に偏光光によるカラー画像および無偏光光によるカラー画像を生成する方法を説明する。

[0195] 図３０（ａ）、（ｂ）は、それぞれ第１の光学領域Ｄ１および第２の光学領域Ｄ２を通過した光が入射する画素のみを抽出した図である。図２８に示すように、光学要素Ｍ２は、光学要素Ｍ１に対してｙ方向に半ピッチずれているため、第１の光学領域Ｄ１および第２の光学領域Ｄ２を通過した光が入射する画素には、いずれも赤（Ｐ３Ａ、もしくはＰ３Ｂ）、緑（Ｐ１Ａ、Ｐ２Ａ、もしくはＰ１Ｂ、Ｐ２Ｂ）、青（Ｐ４Ａ、もしくはＰ４Ｂ）の色情報が含まれるようになる。

[0196] ただし、第１の光学領域Ｄ１を通過した光は第１の光軸に平行な偏光光である。このため、図３０（ａ）に示すように、画素Ｐ３Ａ（赤）、画素Ｐ１ＡおよびＰ２Ａ（緑）、画素Ｐ４Ａ（青）は、第１の光軸に平行な偏光光を

検出する。一方、図３０（ｂ）に示すように、画素Ｐ３Ｂ（赤）、画素Ｐ１ＢおよびＰ２Ｂ（緑）、画素Ｐ４Ｂ（青）は、無偏光光を検出する。よって、第１の光学領域Ｄ１および第２の光学領域Ｄ２を通過した光が入射する画素によってそれぞれ、第１の光軸平行な偏光光によるカラー画像と、無偏光光によるカラー画像とを生成することができる。以下、第１の光軸平行な偏光光によるカラー画像および無偏光光によるカラー画像を第１のカラー画像および第２のカラー画像と呼ぶ。

[0197] 第１のカラー画像および第２のカラー画像は、信号処理部Ｃ（図１に示す）にて生成される。第１のカラー画像および第２のカラー画像は、それぞれ図３０（ａ）、（ｂ）に示す画素から得られる色情報、具体的には輝度情報によって生成される。図３０（ａ）、（ｂ）に示すように、カラー画素に対応する第１および第２の画素群は、いずれも１つの画素に対して１つの色情報しか有していないため、他の２色の色情報は周辺の画素の輝度値から補完して生成する。

[0198] 例えば、第１のカラー画像の場合、図３０（ａ）に示すように、第２の画素群Ｐｇ２の画素Ｐ２Ａの位置には緑色（Ｇ２）の情報しかない。このため、周辺の画素から赤色（Ｒ）および青色（Ｂ）の情報を補完し、第２の画素群Ｐｇ２の画素Ｐ２Ａの位置において、青色、緑色、赤色の情報を得る。具体的には第２の画素群Ｐｇ２のＰ２Ａにおける赤色および青色の輝度情報を、ｙ方向、ｘ方向あるいは斜め方向に位置する画素Ｐ３Ａおよび画素Ｐ４Ａによって得られる赤色および青色の輝度情報から補間する。同様に、第２の画素群Ｐｇ２の画素Ｐ４Ａにおける緑色および赤色の輝度情報を、ｙ方向、ｘ方向あるいは斜め方向に位置する画素Ｐ２Ａおよび画素Ｐ３Ａによって得られる緑色および赤色の輝度情報を用いた補間によって求める。第１の画素群Ｐｇ１の画素Ｐ１Ａにおける赤色および青色の輝度情報、ならびに、第１の画素群Ｐｇ１の画素Ｐ３Ａにおける緑色および青色の輝度情報も同様の補間によって求める。これにより第１のカラー画像を得ることができる。

[0199] 図３０（ｂ）に示すように、第２のカラー画像についても、同様に、第１

の画素群Ｐｇ１の画素Ｐ４Ｂにおける赤色および緑色の輝度情報、画素Ｐ２Ｂにおける赤色および青色の輝度情報、ならびに、第２の画素群Ｐｇ２の画素Ｐ１Ｂにおける赤色および青色の輝度情報、画素Ｐ３Ｂにおける緑色および青色の輝度情報を補間によって求める。これにより、第２のカラー画像を得ることができる。

[0200] なお、第１、第２のカラー画像のそれぞれでは、ｙ方向の色情報は、部分的に欠落している。例えば、第１のカラー画像の第１の画素群Ｐｇ１の４つの画素において、画素Ｐ４Ｂおよび画素Ｐ２Ｂは欠落している。これらの欠落している画素の輝度情報は、前述の色の補完後に、ｙ方向に隣接する画素において検出した色の輝度値および補間によって求めた色の輝度値を用いた補完によって生成してもよい。具体的には、第１の画素群Ｐｇ１の画素Ｐ４Ｂおよび画素Ｐ２Ｂにおける赤色、青色および緑色の輝度情報を、ｙ方向に隣接する画素Ｐ３Ａおよび画素Ｐ１Ａにおける赤色、青色および緑色の輝度情報からそれぞれ求めてもよい。

[0201] 以上のような補完処理によって、第１の光軸に平行な偏光光によるカラー画像および無偏光光によるカラー画像を生成することができる。

[0202] 本実施の形態によると、図３０（ａ）および（ｂ）に示すように第１の光軸に平行な偏光光によるカラー画像および無偏光光によるカラー画像のカラー画像のそれぞれにおいて、隣接する画素群（第１の画素群Ｐｇ１どうし、第２の画素群Ｐｇ２どうし、または、第１の画素群Ｐｇ１と第２の画素群Ｐｇ２）がそれぞれカラーの画素を構成している。このため、２つのカラー画像を構成する画素のピッチが長くなることがなく、解像度の高い画像を得ることができる。

[0203] また、本実施の形態によれば、従来のベイヤー配列型の撮像素子を利用することができるため、専用のフィルタ配列のカラーフィルタ用のフォトマスク等の初期投資が不要となり、初期投資を抑えることができる。

[0204] なお、本実施の形態の撮像装置の光学系は、像側テレセントリック光学系であってもよい。これにより画角が変化しても、アレイ状光学素子Ｋに対す

る主光線入射角は、０度に近い値で入射するため、撮像領域全域にわたって、画素Ｐ１Ａ、Ｐ１Ｂ、Ｐ２Ａ、Ｐ２Ｂ、Ｐ３Ａ、Ｐ３Ｂ、Ｐ４Ａ、およびＰ４Ｂに到達する光束間のクロストークを低減することができる。

[0205] （実施の形態１３）

本実施の形態１３は、実施の形態３の撮像システムＡＰ２をマイクロスコープに応用した構成である。なお、本実施形態のマイクロスコープに応用する撮像システムＡＰ２の撮像装置Ａとしては、実施の形態１、３から１１の撮像装置Ａのいずれかを用いることができる。

[0206] 図３１（ａ）と（ｂ）は、それぞれ実施の形態１３のマイクロスコープＡＰ３の正面図と側面図である。マイクロスコープＡＰ３は、ヘッド部Ｅ１、撮像装置Ａと、偏光照明Ｑａと、無偏光照明Ｑｂとが実装された鏡筒Ｅ２、およびケーブルＥ３によって構成されている。

[0207] 図３１（ａ）に示すように、偏光照明Ｑａと、無偏光照明Ｑｂは、撮像装置Ａの周りに同心円状に交互に配置されている。ヘッド部Ｅ１の先端が撮像装置Ａの合焦位置になるように設定されており、ヘッド部Ｅ１を顔肌等の被写体Ｏｂに密着させたときに解像度が最も高くなる。

[0208] 偏光照明Ｑａからの光と無偏光照明Ｑｂからの光が顔肌等の被写体Ｏｂに照射されることにより、撮像装置Ａは、被写体Ｏｂからの反射光から偏光情報を有する画像情報と、通常の画像情報の両方を同時に取得することができる。撮像装置Ａで取得した画像情報は、ケーブルＥ３を介してモニターやパーソナルコンピュータ等に接続される。

[0209] このようなマイクロスコープＡＰ３を用いることによって、通常の拡大画像、シミの状態を認識しやすい拡大画像、および顔肌の毛穴やキメが認識しやすい拡大画像を同時に取得することができる。

[0210] なお、本実施の形態１３のマイクロスコープに、実施の形態２の撮像システムＡＰ１を用いてもよい。マイクロスコープに用いられる撮像システムＡＰ１の撮像装置Ａとしては、実施の形態１、および３から１２の撮像装置Ａのいずれかを用いてもよい。

[0211] （実施の形態１４）

本実施の形態１４は、実施の形態３の撮像システムＡＰ２をカプセル内視鏡に応用した構成である。なお、カプセル内視鏡に応用される撮像システムＡＰ２の撮像装置Ａとしては、実施の形態１、および３から１２の撮像装置Ａを用いることができる。

[0212] 図３２（ａ）と（ｂ）は、それぞれ実施の形態１４のカプセル内視鏡ＡＰ４の正面図と側面図である。カプセル内視鏡ＡＰ４は、ドーム部Ｅ４と、撮像装置Ａと、偏光照明Ｑａと、無偏光照明Ｑｂとが実装された鏡筒Ｅ５によって構成されている。鏡筒Ｅ５の内部には、他に電池、送受信用のＩＣ、送受信用のアンテナ等が組み込まれていてもよい。

[0213] 図３２（ａ）に示すように、偏光照明Ｑａと、無偏光照明Ｑｂは、撮像装置Ａの周りに同心円状に交互に配置されている。

[0214] 偏光照明Ｑａからの光と無偏光照明Ｑｂからの光が生体内の消化器官である被写体に照射されることにより、撮像装置Ａは、被写体からの反射光から偏光情報を有する画像情報と、通常の画像情報の両方を同時に取得することができる。撮像装置Ａで取得した画像情報は、送受信用のＩＣ、送受信用のアンテナを介して外部の端末に無線で送信される。

[0215] このようなカプセル内視鏡ＡＰ４を用いることによって、消化器官の状態を認識しやすい偏光画像と、通常の画像を同時に取得することができる。

[0216] なお、本実施の形態１４のカプセル内視鏡に、実施の形態２の撮像システムＡＰ１を用いてもよい。カプセル内視鏡に用いられる撮像システムＡＰ１の撮像装置Ａとしては、実施の形態１、および３から１２の撮像装置Ａのいずれかを用いてもよい。

[0217] （実施の形態１５）

本実施の形態１５は、実施の形態３の撮像システムＡＰ２を電子ミラーに応用した構成である。なお、撮像システムＡＰ２における撮像装置Ａとしては、実施の形態１、および３から１２の撮像装置Ａを用いることができる。

[0218] 図３３（ａ）は、電子ミラーＡＰ５の正面図である。電子ミラーＡＰ５は

、ディスプレイＪ１と、撮像装置Ａと、偏光照明Ｑａと、無偏光照明Ｑｂとが実装されたフレームＴ１によって構成されている。図３３（ａ）に示すように、ディスプレイＪ１の左右の領域に、偏光照明Ｑａと無偏光照明Ｑｂが上下方向に交互に配列されている。

[0219] 偏光照明Ｑａからの光と無偏光照明Ｑｂからの光が被写体である人物の顔に照射されることにより、撮像装置Ａは、被写体である人物の反射光から偏光情報を有する画像情報と、通常の画像情報の両方を同時に取得することができる。撮像装置Ａで取得した画像情報は、左右が反転された状態でディスプレイＪ１にリアルタイムに表示される。

[0220] このような電子ミラーＡＰ５を用いることによって、通常の画像、シミの状態を認識しやすい画像、および顔肌の毛穴やキメが認識しやすい画像を同時に取得することができ、被写体である利用者自身が通常の鏡のような感覚で利用者自身の鏡像を確認することができる。通常の画像、シミの状態を認識しやすい画像、および顔肌の毛穴やキメが認識しやすい画像は、利用者によって適宜切替えることができる構成にしてもよい。

[0221] なお、このような電子ミラーは、２つの撮像装置Ａと裸眼立体ディスプレイを用いた構成でもよい。

[0222] 図３３（ｂ）は、立体電子ミラーＡＰ６の正面図である。立体電子ミラーＡＰ６は、裸眼立体ディスプレイＪ２と、２つの撮像装置Ａ１、およびＡ２と、偏光照明Ｑａと、無偏光照明Ｑｂとが実装されたフレームＴ２によって構成されている。裸眼立体ディスプレイは、パララックスバリア方式の裸眼立体ディスプレイや、レンチキュラ方式の裸眼立体ディスプレイである。

[0223] 偏光照明Ｑａからの光と無偏光照明Ｑｂからの光が被写体である人物の顔に照射されることにより、２つの撮像装置Ａ１およびＡ２は、被写体である人物の偏光情報を有する画像情報と、通常の画像情報の両方を同時に取得する。２つの撮像装置Ａで取得した画像情報は、互いに視差のある画像を左右反転した状態で、裸眼立体ディスプレイＪ２にリアルタイムに表示される。

[0224] このような電子ミラーＡＰ６を用いることによって、電子ミラーＡＰ４よ

りもリアルに利用者自身の鏡像を確認することができる。

[0225] また、本実施の形態１５は、実施の形態１、および３から１２で説明した撮像装置Ａのいずれかと、実施の形態２で説明した撮像システムＡＰ１の組み合わせた構成であってもよい。

[0226] また、ディスプレイＪ１および立体ディスプレイＪ２を液晶ディスプレイで構成する場合、液晶ディスプレイ自体からの光も被写体に照射されるため、液晶ディスプレイの前面側の偏光フィルタの偏光軸は偏光照明Ｑａの偏光軸と同じであってもよい。これにより、液晶ディスプレイから被写体に照射される光の偏光方向を偏光照明からの光の偏光方向と同じにすることができる。

[0227] また、本実施の形態では偏光照明と無偏光照明によって構成されているが、偏光照明だけで構成されていていてもよい。

[0228] また、偏光照明のみで構成する場合、透過偏光軸が互いに直交した２つの偏光照明で構成されていてもよい。

[0229] また、偏光照明の光源としては白色光源のみで構成してもよいし、撮像装置の光学領域における偏光フィルタによる光の減衰を補うため、白色光源に青色光源を付加した構成、或いは白色光源に緑色光源を付加した構成の偏光照明であってもよい。

[0230] （その他の実施の形態）

実施の形態１から１０および１２は、信号処理部Ｃを備えた構成であるが、信号処理部Ｃを備えていなくてもよい。その場合、撮像装置の外部のパーソナルコンピュータ等を用いて、信号処理部Ｃが行う処理を行えばよい。すなわち、本発明は、レンズ光学系Ｌ、アレイ状光学素子Ｋおよび撮像素子Ｎを備える撮像装置と、外部の信号処理装置とを備えるシステムによっても実現することができる。

[0231] また、実施の形態１から１５において、撮像素子の各画素上に設けられるマイクロレンズは、曲面形状を有するレンズ面を備えているが、他の形状のマイクロレンズを撮像素子に設けてもよい。例えば、特開２００８－１０７

７３号公報に開示されているような、屈折率の異なる材料の分布によって光を集光させる回折光学素子を用いてもよい。図３４（ａ）および（ｂ）は、回折光学素子Ｍｓ’の一例を示す平面図および断面図である。図３４（ａ）および（ｂ）において、斜線で示す光学部材分とその周囲の部分は互いに異なる屈折率の材料や媒質で構成される。図３４（ａ）および（ｂ）に示すように、回折光学素子Ｍｓ’は、例えば、画素が形成される平面と水平な平面においてリング形状を有し、平面に垂直な方向に伸びる円筒の複数の光学部材が同心状に配置されることによって構成される。光学部材とその周囲の部分との屈折率差や、円筒のサイズ、同心に配置される円筒の間隔などによって、回折光学素子Ｍｓ’の屈折率を調整し得る。光学部材の形状は円筒に限られず、光軸に対して非回転対称であってもよい。また、図３４（ａ）および（ｂ）では、２レベルのバイナリー回折光学素子としているが、３レベル以上のマルチレベル回折光学素子であってもよい。

[0232] このような構造を有する回折光学素子Ｍｓ’は、例えば半導体フォトリソグラフ技術を用いて製造することができる。従来のレンズ面を有するマイクロレンズは、例えば、樹脂を熱変形させて製造するため、撮像素子の複数の画素上に設けられる複数のマイクロレンズ間で、レンズ面の曲面を異ならせることは困難であった。これに対し、回折光学素子Ｍｓ’を用いる場合、撮像素子の複数の画素間で、上述の光学部材の寸法を異ならせることにより、光学特性を変えることができる。よって、光学系Ｌやアレイ状光学素子Ｋによって、斜めから光線が撮像素子Ｎの画素に入射する場合でも、効率よく画素に光を集光させることができる。

[0233] また、回折光学素子Ｍｓ’における上述の屈折率差を大きくすることによって、回折光学素子Ｍｓ’の焦点距離を短くすることできる。よって、例えば、実施の形態１０で説明したように、アレイ状光学素子Ｋを撮像素子の撮像面Ｎｉ上に設ける場合、アレイ状光学素子Ｋおよび回折光学素子Ｍｓ’を合わせた厚さを小さくすることができ、撮像素子の高さを小さくすることができる。よって、厚さの小さい撮像装置を実現し得る。

[0234] また、それぞれの光学領域の面積を絞りＳによって制限した構成や光学素子Ｌ１ｓとＬ１ｐを同一平面に配列した構成であってもよい。例えば、図３５（ａ）に示すように、第１の光学領域Ｄ１は第１の偏光軸の方向に振動する光を主に透過し、第２の光学領域Ｄ２は任意の方向に振動する光を透過し、かつ近赤外光の波長帯域の光を透過し、第３の光学領域Ｄ３は可視光帯域において任意の方向に振動する光を透過し、第４の光学領域Ｄ４は可視光帯域において任意の方向に振動する光を透過し、かつ第４の光学領域の面積は、第３の光学領域Ｄ３の面積よりも小さい。このような構成は、車載用の撮像装置として有用である。このような構成によれば、第１の光学領域Ｄ１を透過した光によって、実施の形態１で示したように濡れた道路の車線を検出しやすくなる。夜間走行時において近赤外光の投光器を用いることにより、第２の光学領域Ｄ２を透過した光によって、肉眼では検知しにくい人物、障害物、道路の状態を検知しやすくなる。また第３の光学領域Ｄ３を通過した光による画像と、第４の光学領域Ｄ４を透過した光による画像は、それぞれ露光量が異なる画像であるため、これらの画像を合成することにより、ダイナミックレンジの広い画像を生成することができる。ダイナミックレンジの広い画像では、トンネルの出口において、トンネルの内部と外部において白飛びや黒つぶれの少ない画像の取得することができる。このような構成により、１つの撮像装置であらゆる環境下において前方の状況を検知することができる。また、このような構成において、第３の光学領域Ｄ３と第４の光学領域Ｄ４の面積を同じとし、第４の領域にＮＤフィルタを入れることによってダイナミックレンジの広い画像を生成することができる。

[0235] また、図３５（ｂ）のように、第４の光学領域Ｄ４を透過する光の量と、第３の光学領域Ｄ３を透過する光の量を同じにした構成としてもよい。このような構成では、第３の光学領域Ｄ３を通過した光による画像と第４の光学領域Ｄ４を透過した光による画像とを加算した画像と、第１の光学領域Ｄ１を透過した光による画像とは、それぞれ露光量が異なる画像となる。従ってこれらの画像を合成することにより、ダイナミックレンジの広い画像を生成

することができる。

[0236] また、図３５（ｂ）の構成よりも露光量比を大きくするため、図３５（ｃ）のように、第１の光学領域Ｄ１の面積を小さくした構成であってもよい。

[0237] なお、図３５（ａ）、（ｂ）、および（ｃ）における光学領域Ｄ３、およびＤ４は、透明ガラスであってもよいし、中空状態であってもよい。

[0238] また、図３５（ｄ）ように、第２の光学領域を第３および第４の光学領域と同じ構成としてもよい。また、図３５（ｄ）に対して第１の光学領域Ｄ１の面積を小さくした構成であってもよい。

産業上の利用可能性

[0239] 本願に開示された撮像装置は、デジタルスチルカメラ、デジタルビデオカメラ、車載カメラ、監視カメラ、肌診断カメラ、および内視鏡カメラ等の撮像装置として有用である。また、マイクロスコープや電子ミラーなどの撮像システムに応用することができる。

符号の説明

[0240]

Ａ	撮像装置
Ｌ	レンズ光学系
Ｌ１ｓ、Ｌ１ｐ	光学素子
Ｌ２	レンズ
Ｄ１、Ｄ２、Ｄ３、Ｄ４	光学領域
Ｓ	絞り
Ｋ	アレイ状光学素子
Ｎ	撮像素子
Ｎｉ	撮像面
Ｍ１、Ｍ２、Ｍｄ	アレイ状光学素子における光学要素
Ｍｓ	撮像素子上のマイクロレンズ
Ｐ１～Ｐ４	撮像素子上の画素
Ｃ	信号処理部

請求の範囲

[請求項1] レンズ光学系と、

前記レンズ光学系を通過した光が入射する複数の第１の画素と複数の第２の画素とを少なくとも有する撮像素子と、

前記レンズ光学系と前記撮像素子との間に配置され、レンズ面をそれぞれ有する複数の光学要素を含むアレイ状光学素子と

を備え、

前記レンズ光学系は、複数の光学領域を有し、前記複数の光学領域は、第１の偏光軸の方向に振動する光を主に透過する第１の光学領域と、任意の方向に振動する光を透過する第２の光学領域と、を少なくとも含み、

前記アレイ状光学素子の前記複数の光学要素は、前記第１の光学領域を通過した光を前記複数の第１の画素に入射させ、前記第２の光学領域を通過した光を前記複数の第２の画素に入射させる、撮像装置。

[請求項2] 前記第１の光学領域は第１の波長帯域の光を透過し、前記第２の光学領域は第２の波長帯域の光を透過する、請求項１に記載の撮像装置。

[請求項3] 前記第１の波長帯域は、近紫外光の波長帯域である、請求項２に記載の撮像装置。

[請求項4] 前記第１の波長帯域は、４００ｎｍから６００ｎｍの波長帯域の中の所定の帯域を含んでいる、請求項２に記載の撮像装置。

[請求項5] 前記第１の波長帯域は、近赤外光の波長帯域である、請求項２に記載の撮像装置。

[請求項6] 前記レンズ光学系の前記複数の光学領域は、前記第１、第２の光学領域以外の第３の光学領域をさらに備え、

前記第３の光学領域は、前記第１の偏光軸とは異なる方向の第２の偏光軸の方向に振動する光を主に透過し、

前記アレイ状光学素子は、前記第３の光学領域を通過した光を、前

記複数の第１、第２の画素以外の複数の第３の画素に入射させる、請求項１から５のいずれかに記載の撮像装置。

[請求項7] 前記レンズ光学系の前記複数の光学領域は、前記第１、および第２の光学領域以外の第３、および第４の光学領域をさらに備え、

前記第１、第２、第３、および第４の光学領域は、それぞれ互いに異なる第１、第２、第３、および第４の波長帯域の光を透過し、

前記アレイ状光学素子は、前記第３、および第４の光学領域を通過した光を、前記複数の第１、および第２画素以外の複数の第３、および第４の画素にそれぞれ入射させる、請求項１から５のいずれかに記載の撮像装置。

[請求項8] 前記レンズ光学系の前記複数の光学領域は、前記第１、および第２の光学領域以外の第３、および第４の光学領域をさらに備え、

前記第１、および第３の光学領域は、同じ波長帯域の光を透過し、第２、および第４の光学領域は、それぞれ前記第１、および前記第３の光学領域を透過する光の波長帯域とはそれぞれ異なる波長帯域の光を透過し、

前記アレイ状光学素子は、前記第３、および第４の光学領域を通過した光を、前記複数の第１、および第２の画素以外の複数の第３、および第４の画素にそれぞれ入射させる、請求項１から５のいずれかに記載の撮像装置。

[請求項9] 前記第３の光学領域は、前記第１の偏光軸と異なる第２の偏光軸の方向に振動する光を主に透過する、請求項８に記載の撮像装置。

[請求項10] 前記撮像素子は、前記レンズ光学系が通過した光が入射する複数の第３、および第４の画素をさらに有し、

前記複数の光学領域は、第３、第４の光学領域をさらに含み、

前記第３の光学領域は、任意の方向に振動する光を透過し、

前記アレイ状光学素子は、前記第３、および第４の光学領域を通過した光を、前記複数の第３、および第４の画素にそれぞれ入射させ、

前記複数の第１、第２、および第３の画素は、第１、第２および第３の分光透過率特性を有するフィルタをそれぞれ有する、請求項１に記載の撮像装置。

[請求項11] 前記複数の第４の画素は、前記第１の分光透過率特性を有し、

前記第４の光学領域は、所定の波長帯域の光を透過し、かつ前記第１の偏光軸とは異なる第２の偏光軸の方向に振動する光を透過する、請求項１０に記載の撮像装置。

[請求項12] 前記撮像素子の前記第１、第２、第３および第４の画素がベイヤー配列で構成されている、請求項１１に記載の撮像装置。

[請求項13] 所定帯域の光を透過するフィルタを備え、かつ第１の偏光軸の方向に振動する光を主に透過する第１の領域と、前記第１の領域とは異なる位置に配置され、任意の方向に振動する光を透過する第２の領域を有するレンズ光学系と、

前記レンズ光学系を通過した光が入射する複数の第１の画素と、第１の分光透過率特性を有するフィルタを備える複数の第２の画素と、第２の分光透過率特性を有するフィルタを備える複数の第３の画素と、第３の分光透過率特性を有するフィルタを備える複数の第４の画素とを有する撮像素子と、

前記レンズ光学系と前記撮像素子との間に配置され、レンズ面をそれぞれ有する複数の光学要素を含むアレイ状光学素子と

を備え、

前記アレイ状光学素子は、前記第１の光学領域を通過した光を前記複数の第１の画素に入射させ、前記第２の光学領域を通過した光を前記複数の第２、第３、及び第４の画素に入射させる、撮像装置。

[請求項14] 第１の偏光軸の方向に振動する光を主に透過する第１の領域と、前記第１の領域とは異なる位置に配置され、任意の方向に振動する光を透過する第２の領域を有するレンズ光学系と、

前記レンズ光学系を通過した光が入射する第１の分光透過率特性を

有するフィルタを備える複数の第１および第２の画素と、第２の分光透過率特性を有するフィルタを備える複数の第３の画素と、第３の分光透過率特性を有するフィルタを備える複数の第４の画素とを含む複数の画素および撮像面を有する撮像素子と、

前記レンズ光学系と前記撮像素子との間に配置され、レンズ面をそれぞれ有する複数の光学要素を含むアレイ状光学素子とを備え、

前記複数の画素は、第１の方向に１からｌ個（ｌは２以上の整数）の画素が配列した一行の画素群が、第２の方向に１からｍ行目（ｍは２以上の整数）までのｍ行に配列されることによって、前記撮像面に配置され、

前記ｍ行のうちｊ行目（１≦ｊ<ｍ）に配列されたｌ個の画素の前記第１の方向における中心の各位置は、ｊ＋１行目に配列されたｌ個の画素の前記第１の方向における中心の各位置と略同一であり、

前記複数の光学要素は、前記アレイ状光学素子の表面において、前記第２の方向に１からｓ個（ｓは２以上の整数）の光学要素を配列した一列の光学要素群が、前記第１の方向に１からｔ列目（ｔは２以上の整数）までのｔ列に配列され、前記ｔ列のうちｋ列目（１≦ｋ<ｔ）に配置される光学要素の前記第２の方向における中心の位置は、ｋ＋１列目に配置される光学要素の前記第２の方向における中心の位置から、前記第２の方向にずれている、撮像装置。

[請求項15] 前記複数の第１の画素は、第１Ａおよび第１Ｂの画素を有し、前記複数の第２の画素は、第２Ａおよび第２Ｂの画素を有し、前記複数の第３の画素は、第３Ａおよび第３Ｂの画素を有し、前記複数の第４の画素は、第４Ａおよび第４Ｂの画素を有し、

前記ｋ行目における光学要素は、前記第１の領域を通過した光を前記第１Ａの画素と前記第３Ａの画素に入射させ、前記第２の領域を通過した光を前記第２Ｂの画素と前記第４Ｂの画素に入射させ、

前記ｋ＋１行目における光学要素は、前記第１の領域を通過した光

を複数の第２Ａの画素と前記第４Ａの画素に入射させ、前記第２の領域を通過した光を前記第１Ｂの画素と前記第３Ｂの画素に入射させる、請求項１から３のいずれかに記載の撮像装置。

[請求項16] 前記複数の光学領域において、少なくとも２つ以上の光学領域は互いに異なる光学パワーを有し、

前記複数の光学領域の光学パワーが互いに等しい場合と比較して、

前記複数の光学領域を透過した光の合焦位置が互いに近い、請求項１から１５のいずれかに記載の撮像装置。

[請求項17] 前記第１の領域および前記第２の領域の境界部に対応する位置に遮光領域をさらに備える、請求項１から１６のいずれかに記載の撮像装置。

[請求項18] 前記レンズ光学系が像側テレセントリック光学系である、請求項１から１７のいずれかに記載の撮像装置。

[請求項19] 前記レンズ光学系は像側非テレセントリック光学系であって、

前記レンズ光学系の光軸外において前記アレイ状光学素子の配列を前記撮像素子の画素の配列に対してオフセットさせている、請求項１から１７のいずれかに記載の撮像装置。

[請求項20] 前記アレイ状光学素子はレンチキュラレンズである、請求項１から６のいずれかに記載の撮像装置。

[請求項21] 前記アレイ状光学素子において、前記複数の光学要素の前記レンズ面はそれぞれシ第１の方向に伸びるシリンドリカル面であり、前記複数の光学要素は、第２の方向に配置され、

前記複数の光学要素のそれぞれは、１行の前記複数の第１の画素と１行の前記複数の第２の画素からなる２行の画素に対応するように配置されている、請求項２０に記載の撮像装置。

[請求項22] 前記アレイ状光学素子はマイクロレンズアレイである、請求項７から１５のいずれかに記載の撮像装置。

[請求項23] 前記アレイ状光学素子において、前記複数の光学要素の前記レンズ

面はそれぞれ回転対称形状を有する、請求項２２に記載の撮像装置。

[請求項24] 前記複数の光学要素のそれぞれは、前記複数の第１の画素のうちの１つ、前記複数の第２の画素のうちの１つ、前記複数の第３の画素のうちの１つ、および前記複数の第４の画素のうちの１つ、に対応するように配置されている、請求項２３に記載の撮像装置。

[請求項25] 前記アレイ状光学素子は前記撮像素子上に形成されている、請求項１から２４のいずれかに記載の撮像装置。

[請求項26] 前記アレイ状光学素子と前記撮像素子との間に設けられたマイクロレンズをさらに備え、

前記アレイ状光学素子は、前記マイクロレンズを介して前記撮像素子上に形成されている、請求項２５に記載の撮像装置。

[請求項27] 前記アレイ状光学素子と前記撮像素子との間に設けられたマイクロレンズは、バイナリー回折光学素子、もしくはマルチレベル回折光学素子である、請求項２６に記載の撮像装置。

[請求項28] 前記レンズ光学系は絞りをさらに備え、

前記複数の光学領域は、前記絞り近傍に配置されている、請求項１から２７のいずれかに記載の撮像装置。

[請求項29] 前記第１、第２、第３、および第４の光学領域のうち少なくとも１つの光学領域は、前記絞りによって光学領域の面積を他の光学領域の面積に対して異ならせている、請求項２８に記載の撮像装置。

[請求項30] 前記撮像素子において取得された信号に基づいて画像を生成する信号処理部をさらに備える、請求項１から２９のいずれかに記載の撮像装置。

[請求項31] 請求項１から２９のいずれかに記載の撮像装置と、

前記撮像装置において取得された信号に基づいて画像を生成する信号処理部とをさらに備える、撮像システム。

[請求項32] 請求項１から２９のいずれかに記載の撮像装置と、

偏光照明とを備える撮像システム。

[請求項33] 無偏光照明をさらに備える、請求項３２に記載の撮像システム。

[請求項34] 請求項１から２９のいずれかに記載の少なくとも１つの撮像装置と、

偏光照明と、

前記撮像装置において取得された画像を表示する表示装置とを備える、撮像システム。

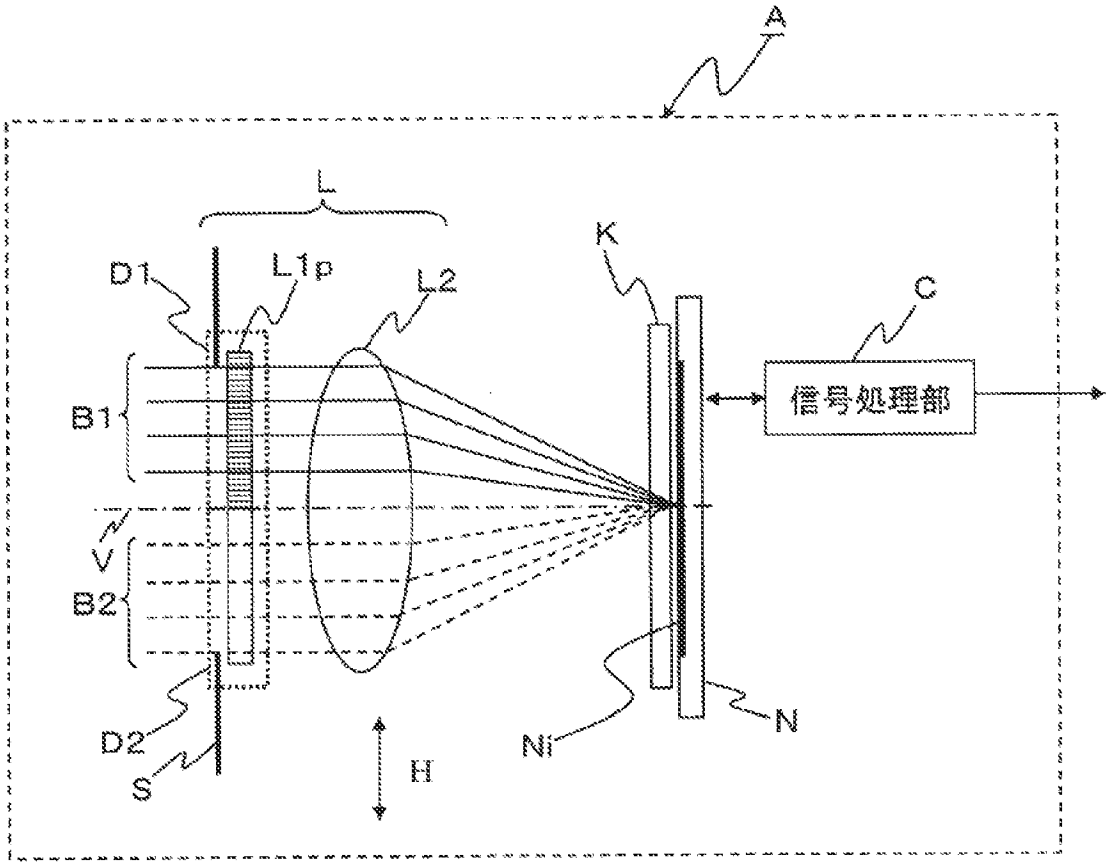
[請求項35] 前記少なくとも１つの撮像装置は２つの撮像装置であって、

前記表示装置は、前記２つの撮像装置において取得された２つの画像を表示する、請求項３４に記載の撮像システム。

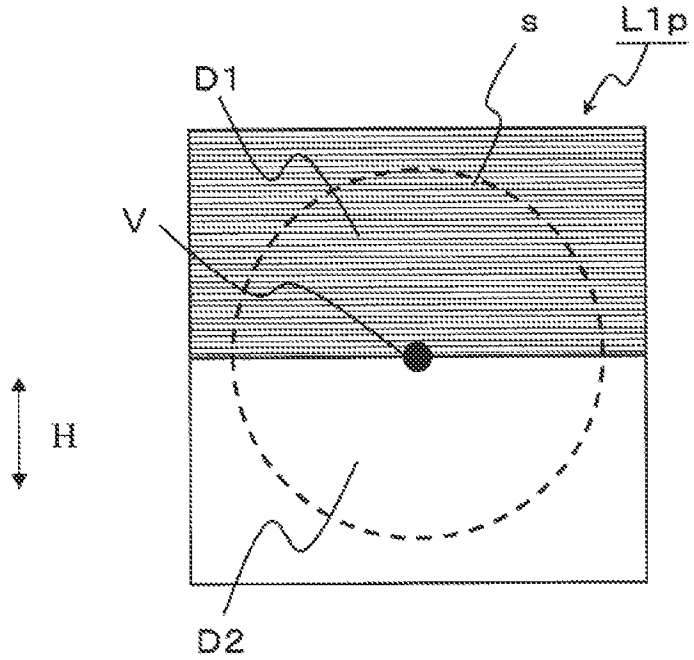
[請求項36] 前記表示装置は、被写体側に偏光フィルタを備える液晶ディスプレイであって、

前記液晶ディスプレイにおける前記偏光フィルタの偏光軸の方向が前記偏光照明の偏光軸の方向と等しい、請求項３４または３５に記載の撮像システム。

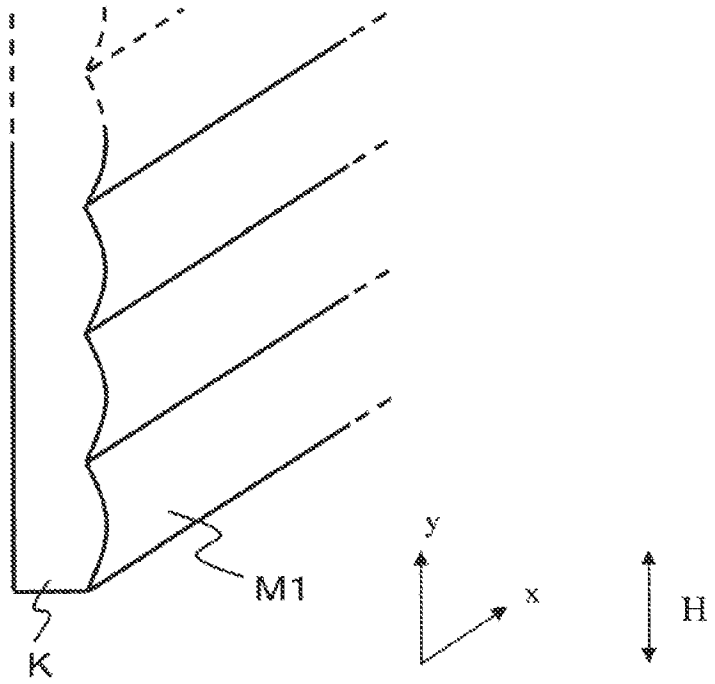
[図1]



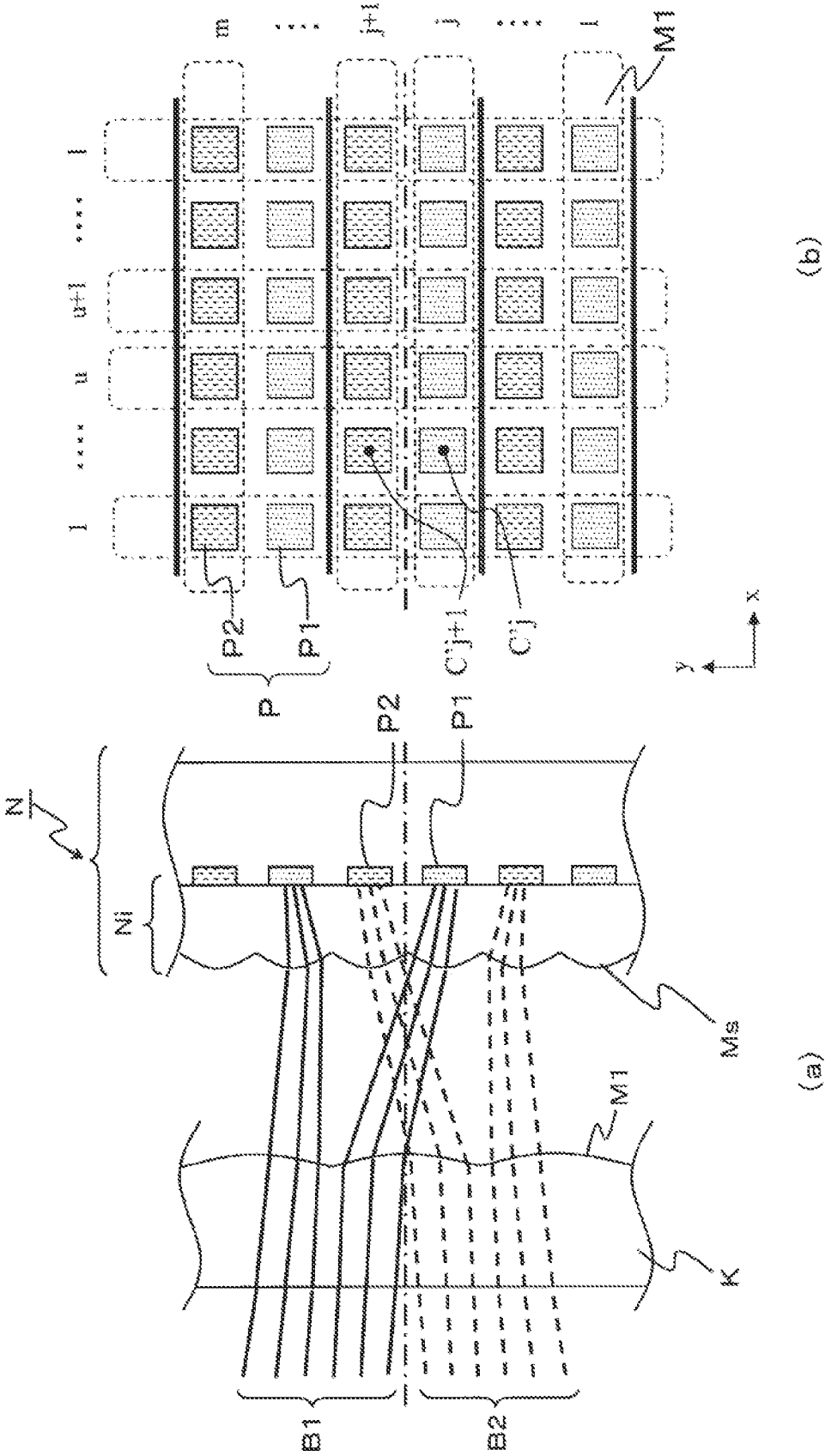
[図2]



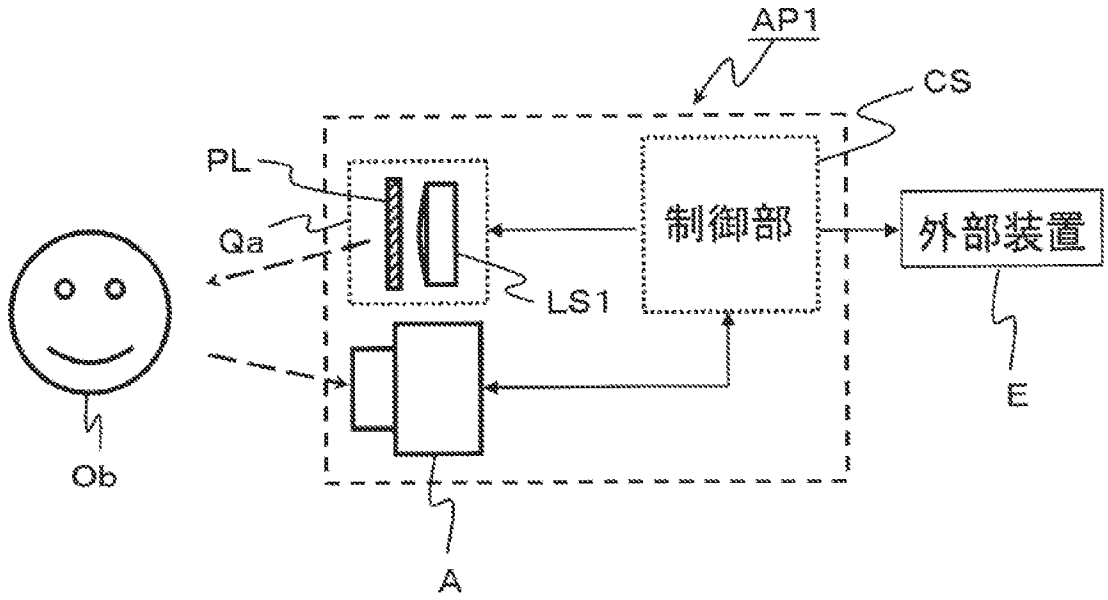
[図3]



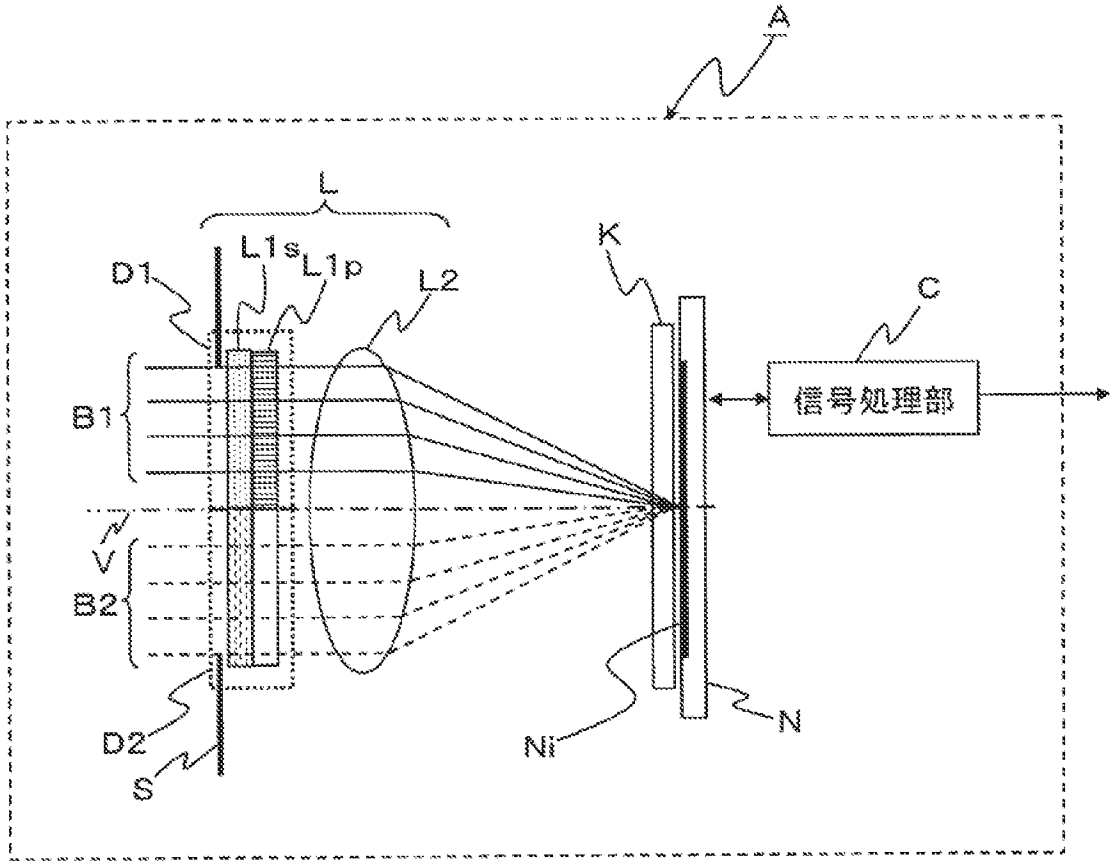
[図4]



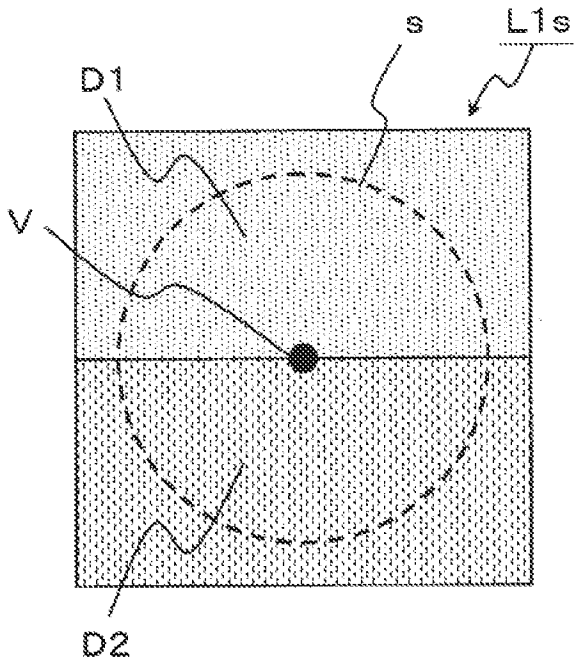
[図5]


AP1
CS
PL
Qa
制御部
外部装置
LS1
Ob
E
A

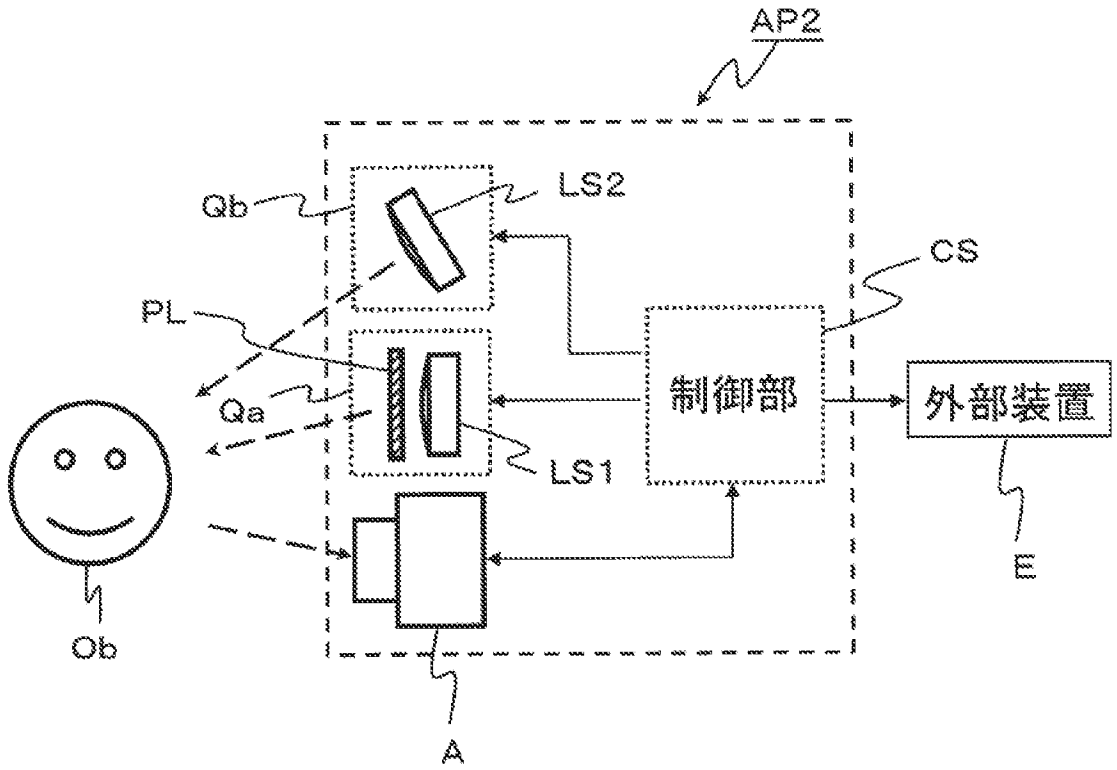
[図6]


A
L
L1s
L1p
D1
L2
K
C
信号処理部
B1
B2
D2
S
Ni
N

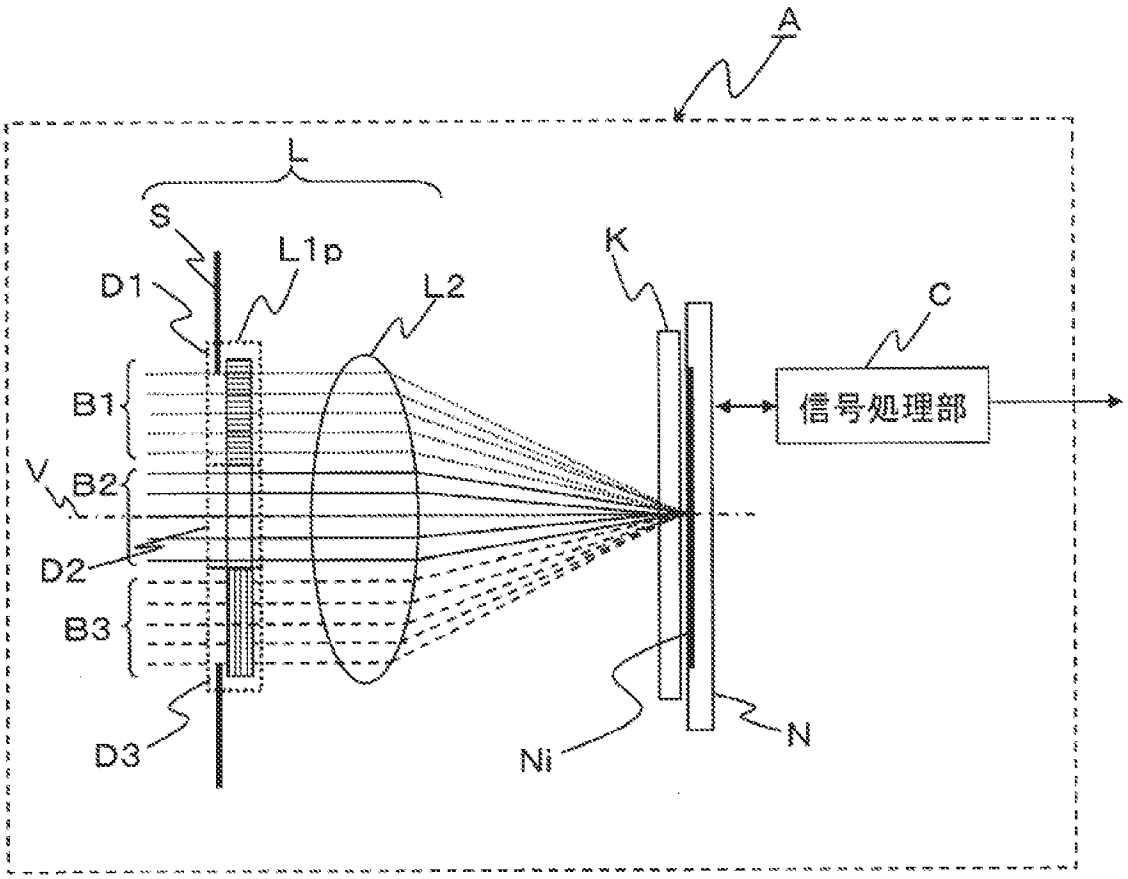
[図7]



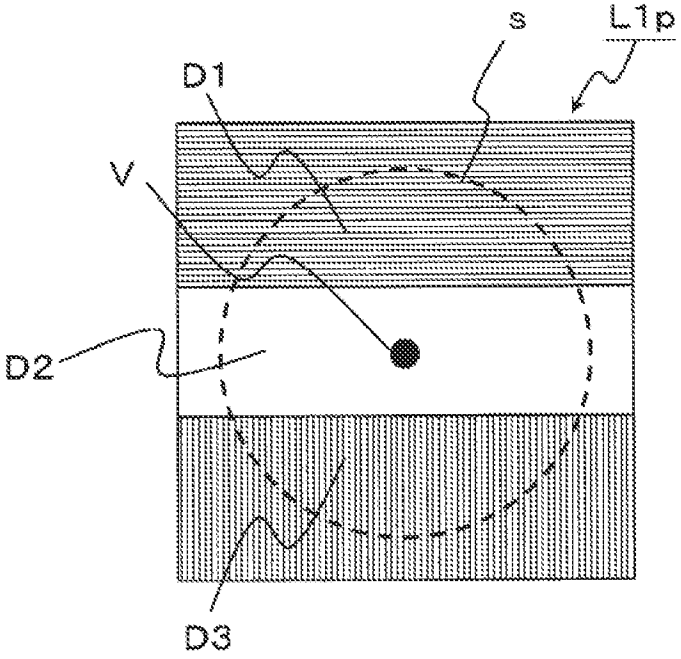
[図8]



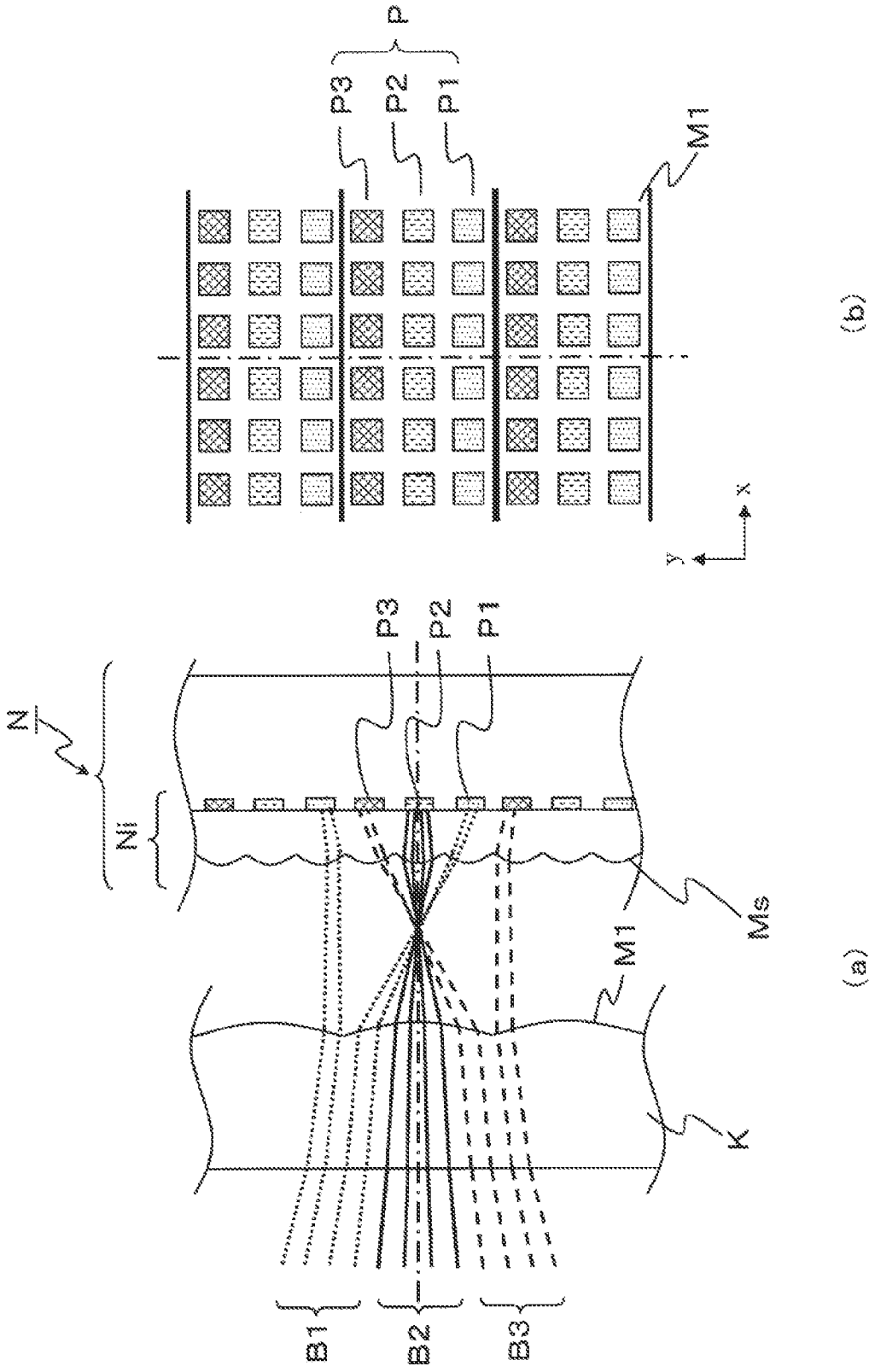
[図9]



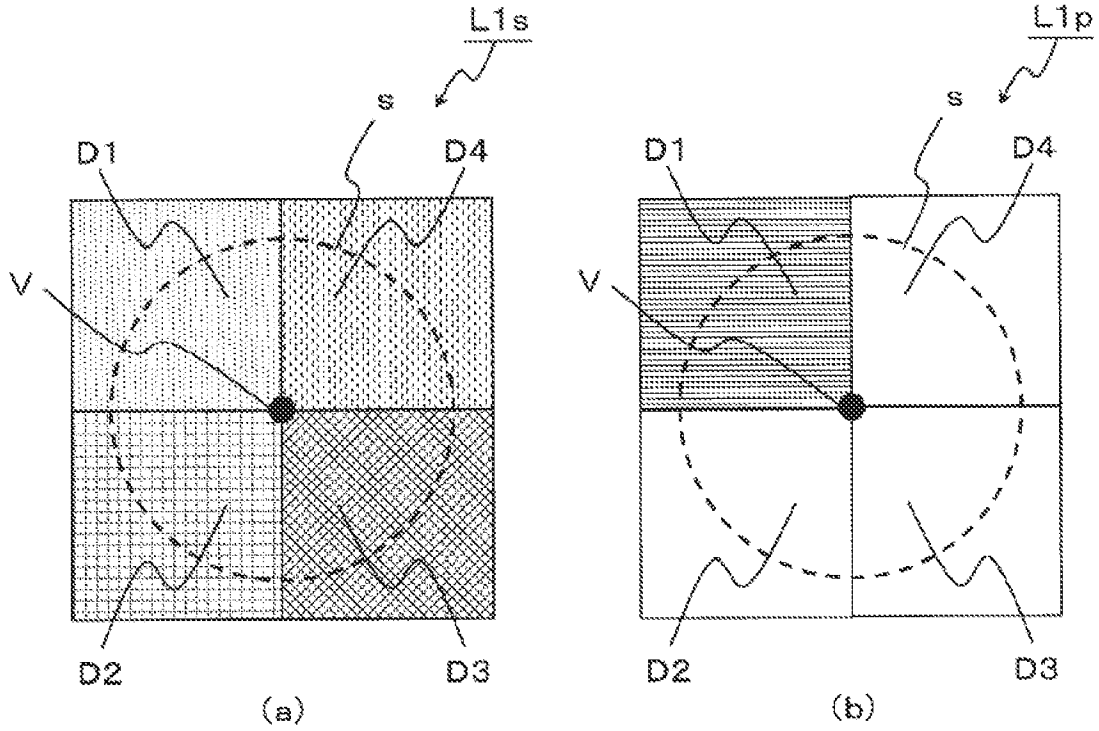
[図10]



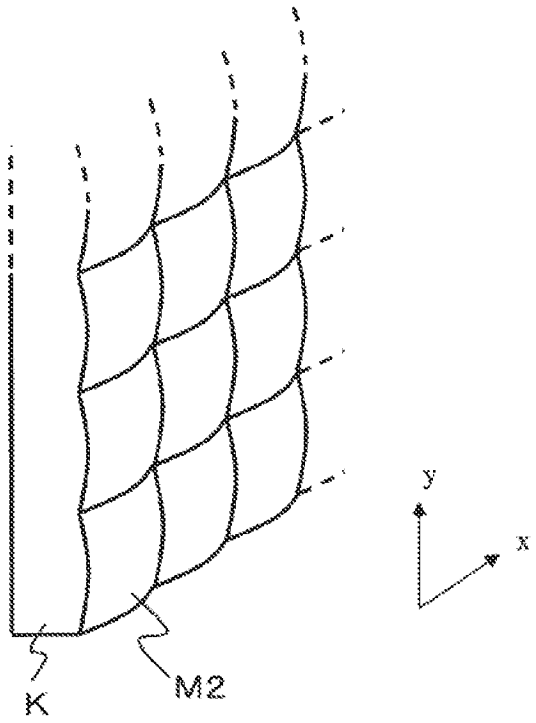
[図11]



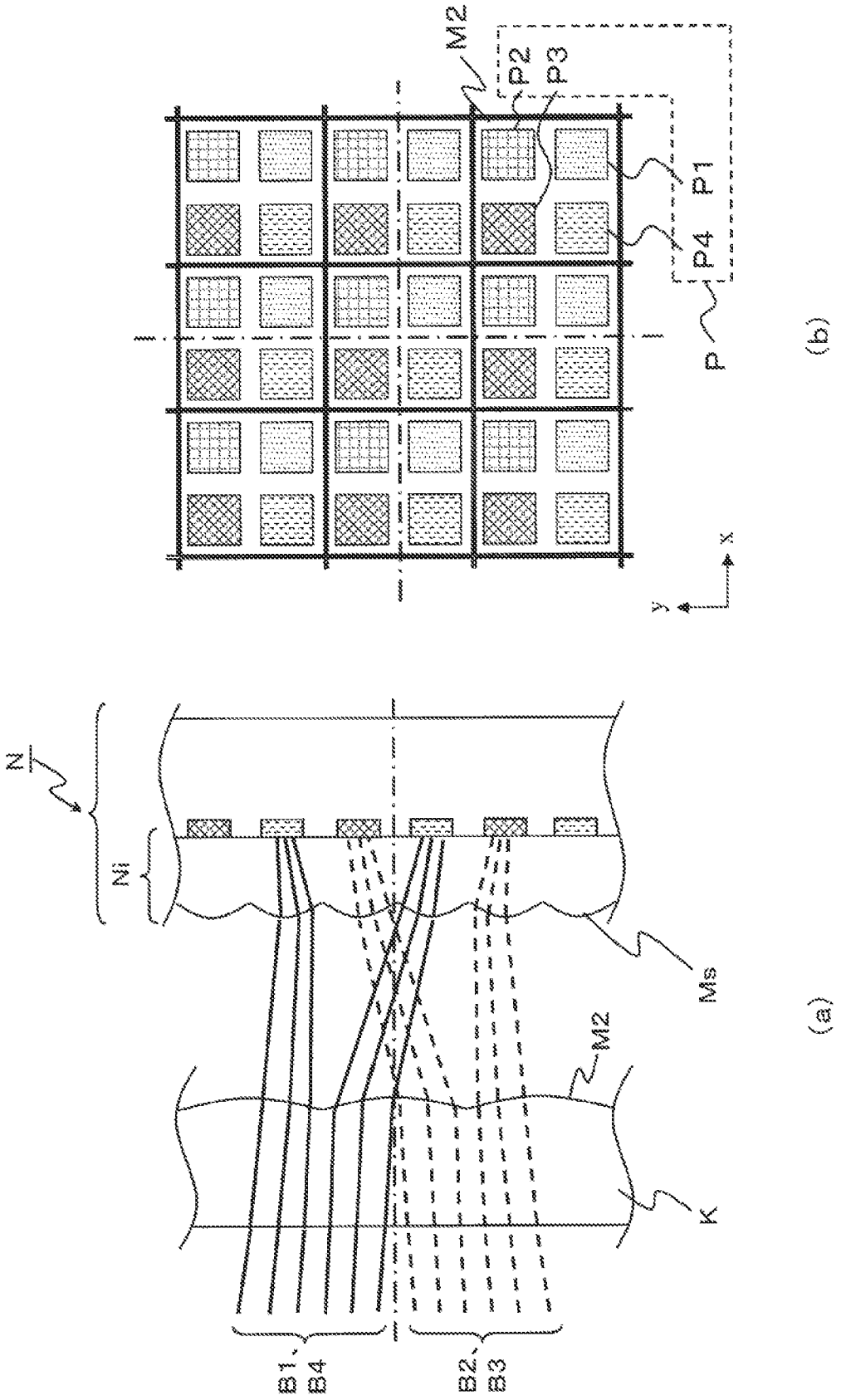
[図12]



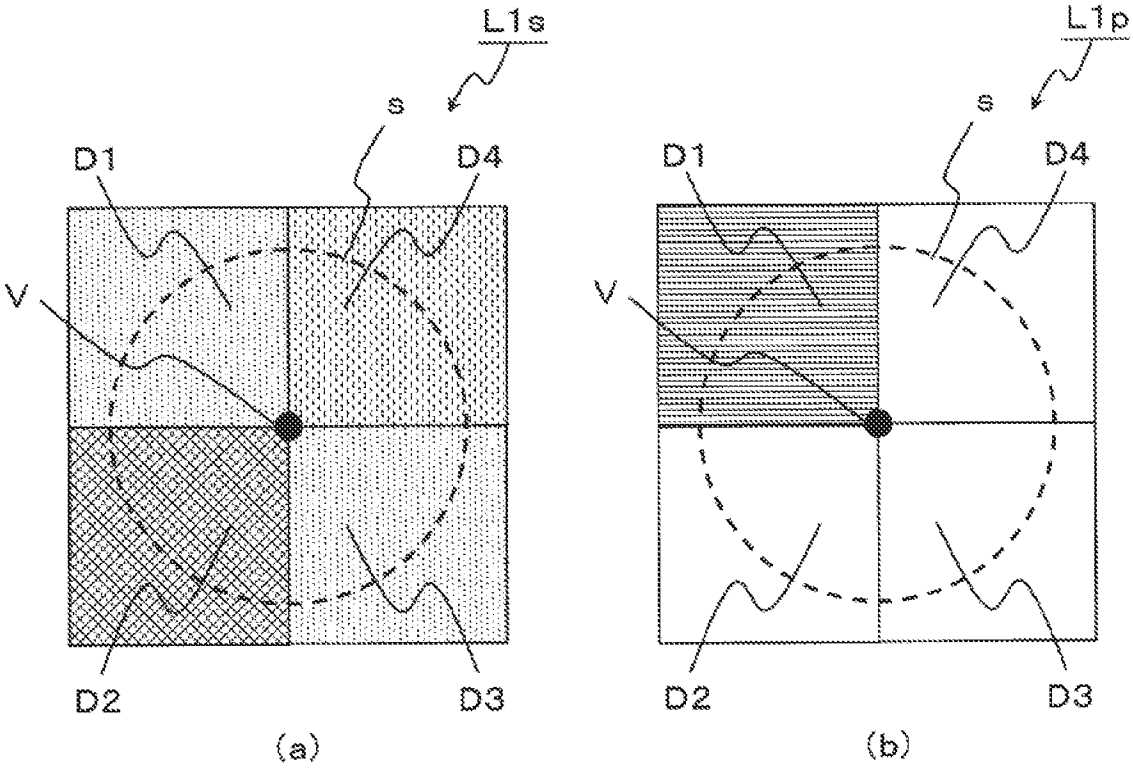
[図13]



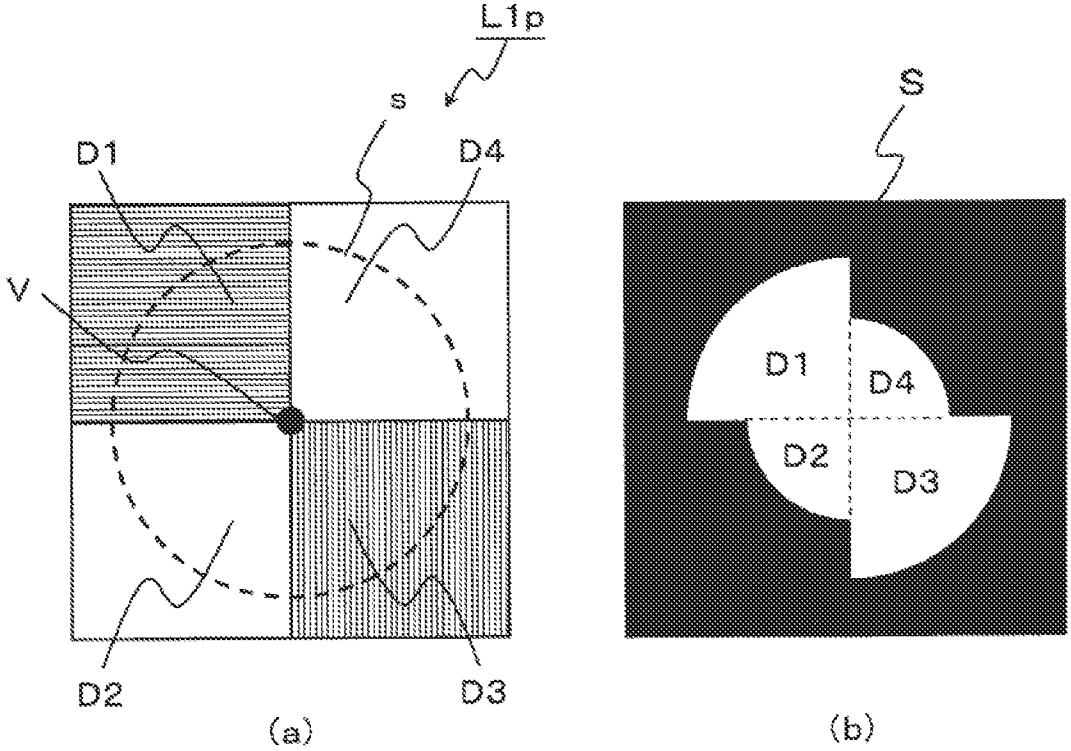
[図14]



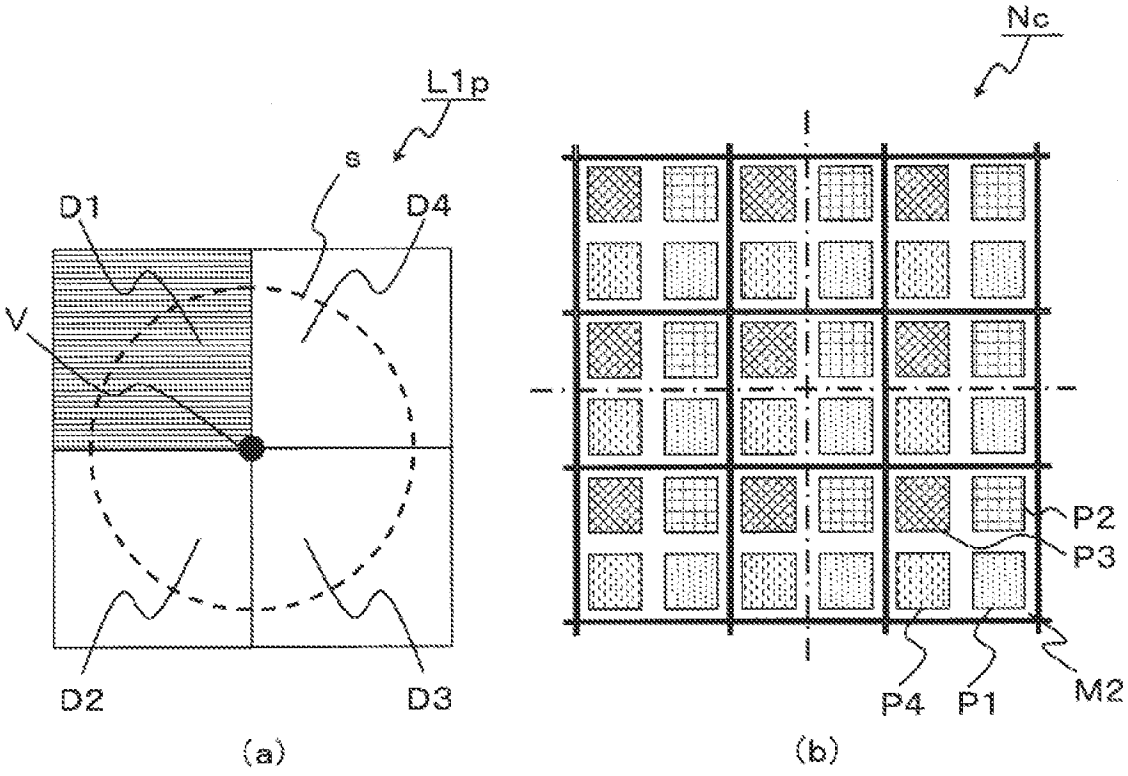
[図15]


L1s
s
D1
D4
V
D2
D3
(a)
L1p
s
D1
D4
V
D2
D3
(b)

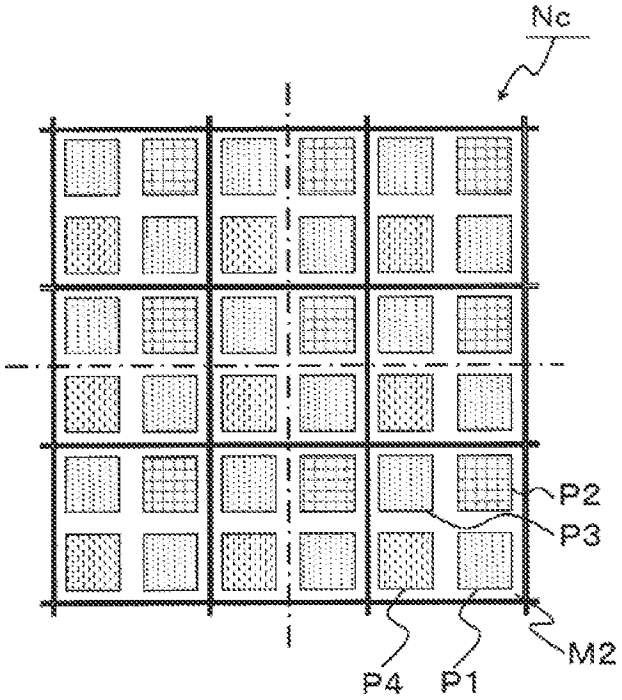
[図16]


L1p
s
D1
D4
V
D2
D3
(a)
S
D1
D4
D2
D3
(b)

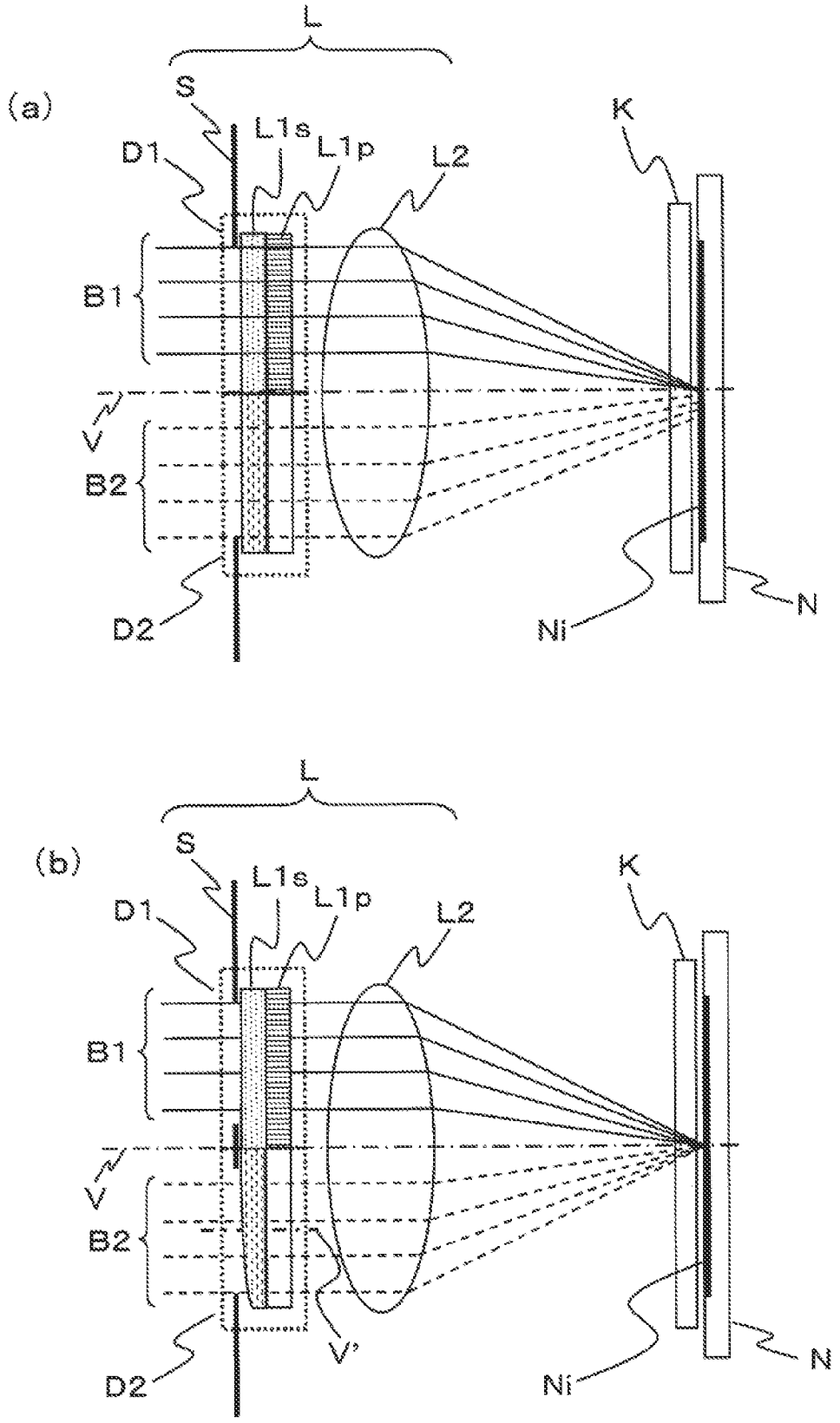
[図17]



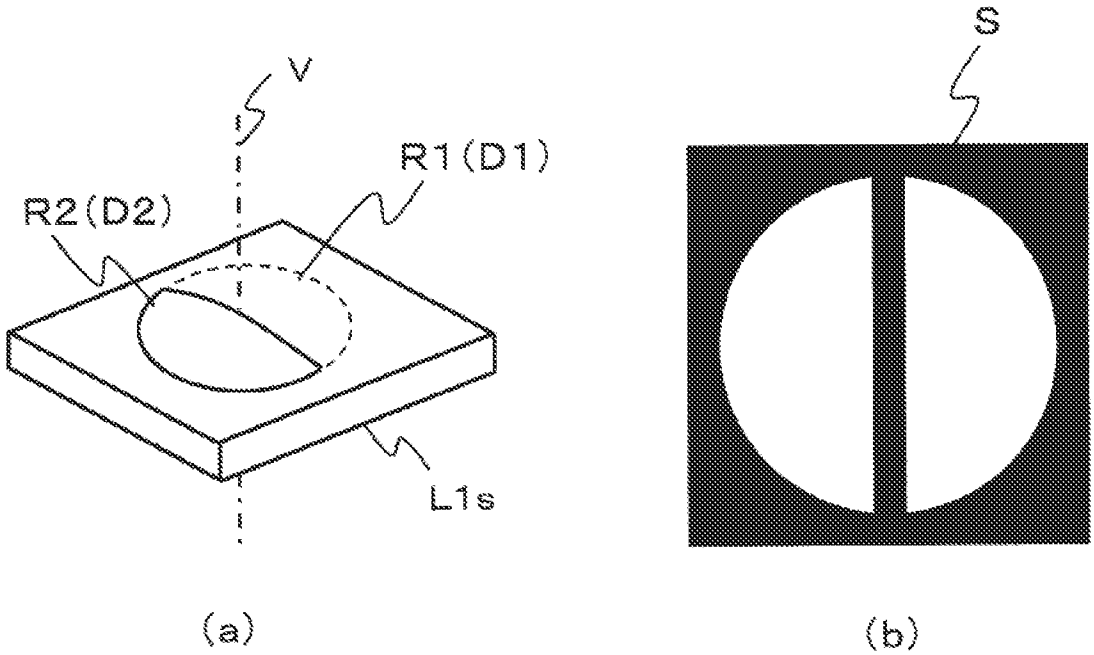
[図18]



[図19]

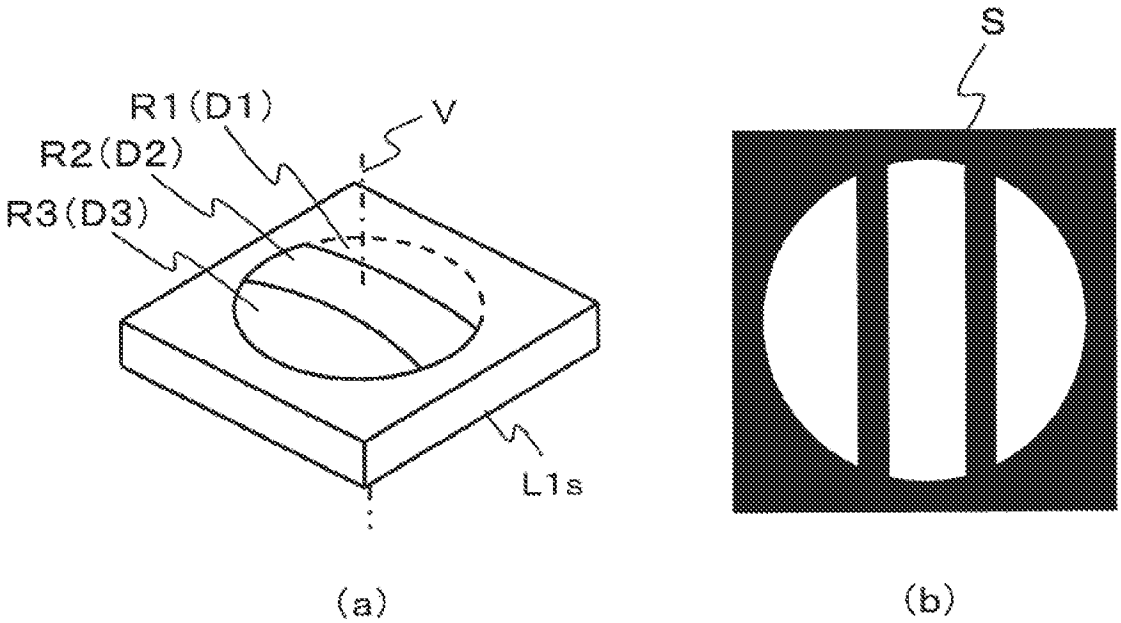


[図20]



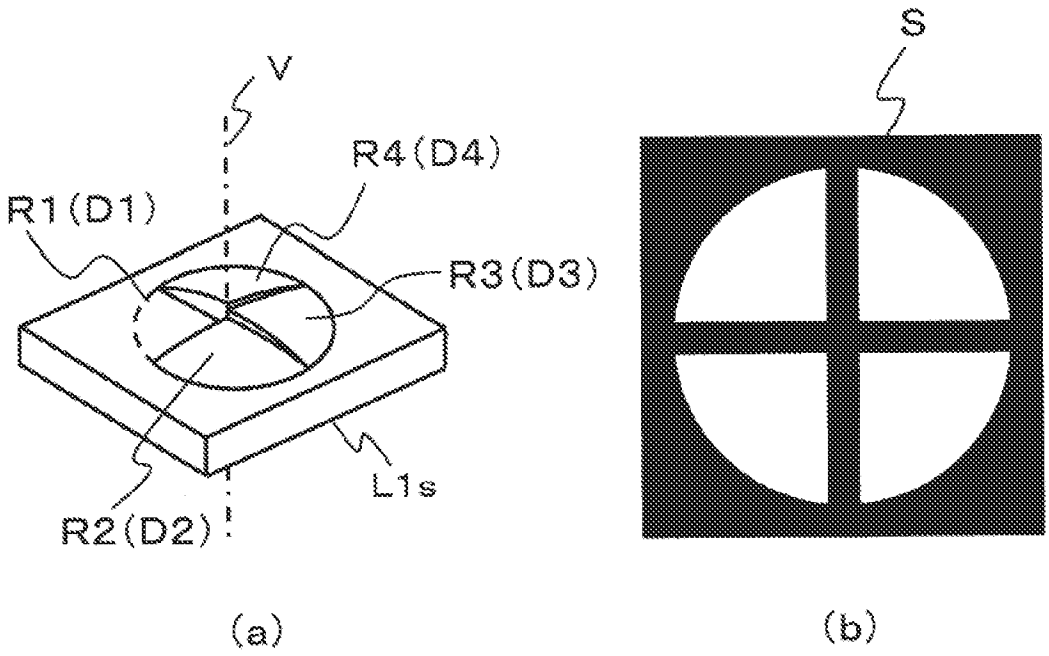
(a) (b)

[図21]

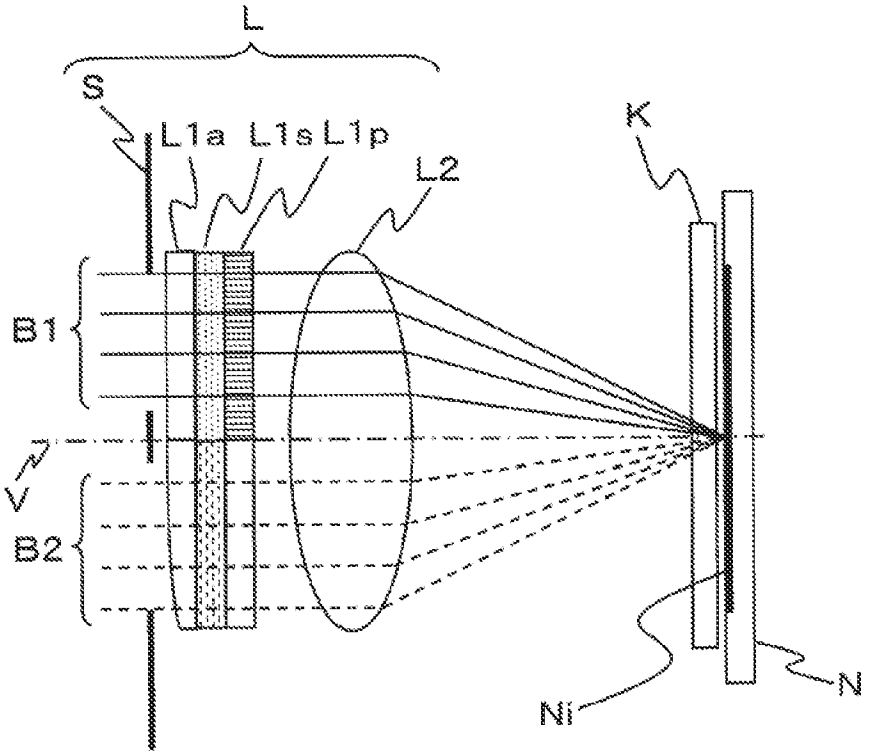


(a) (b)

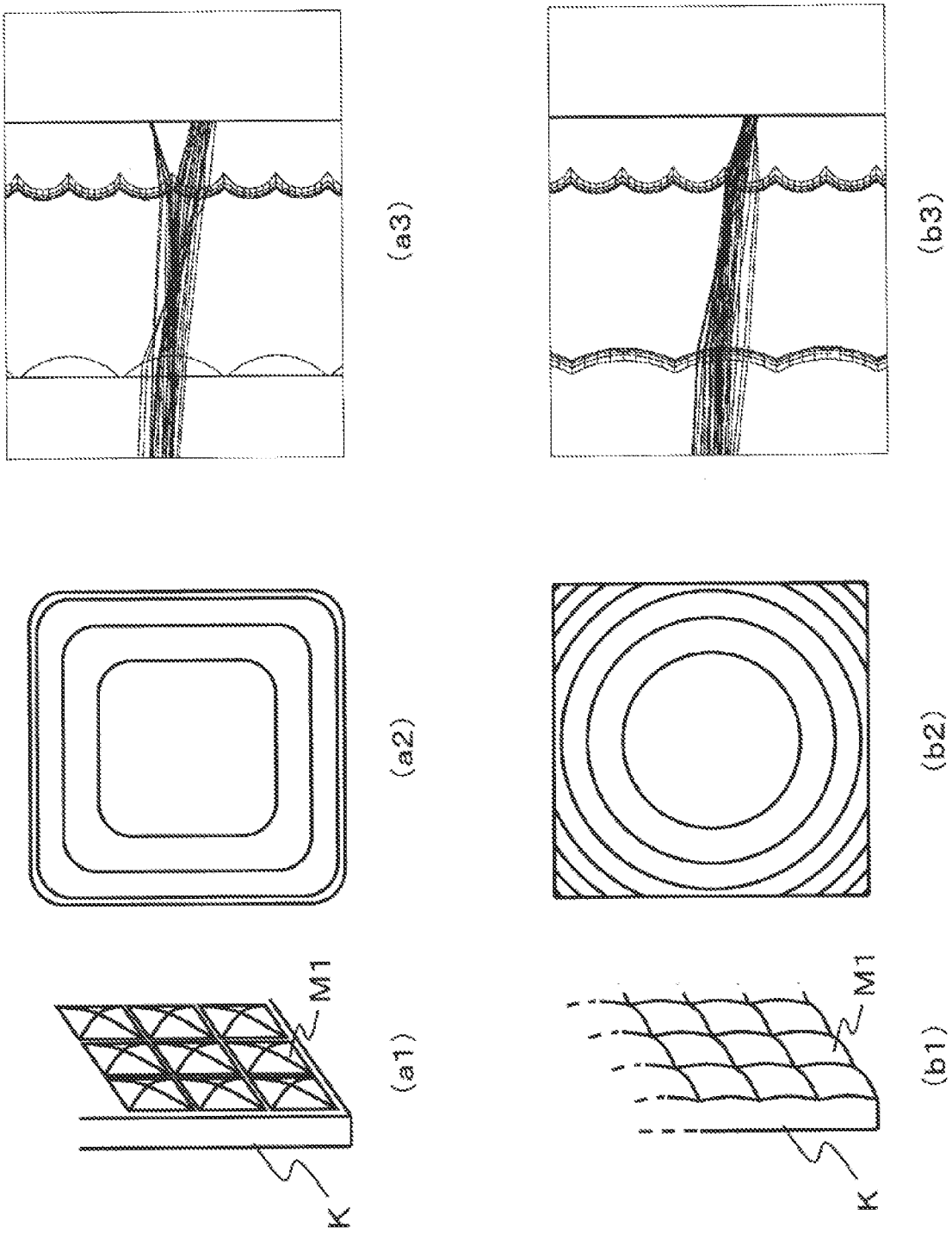
[図22]



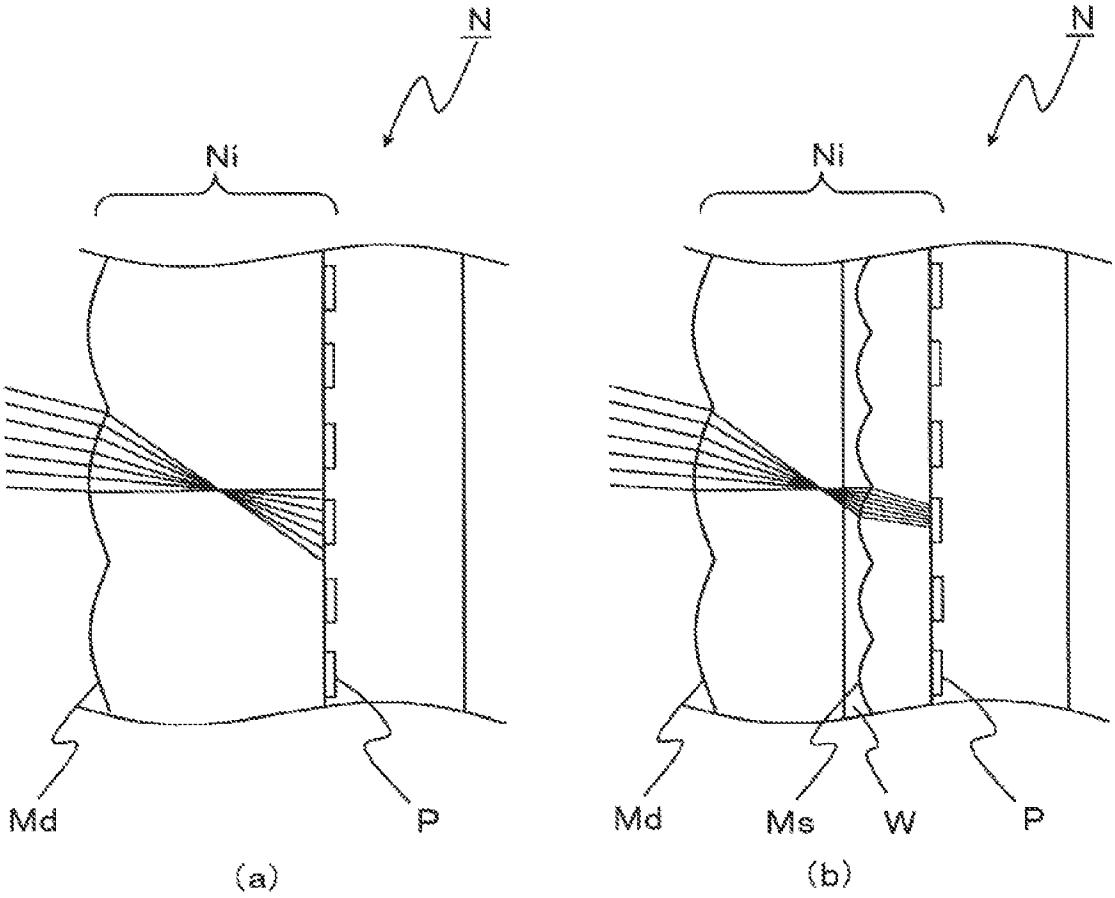
[図23]



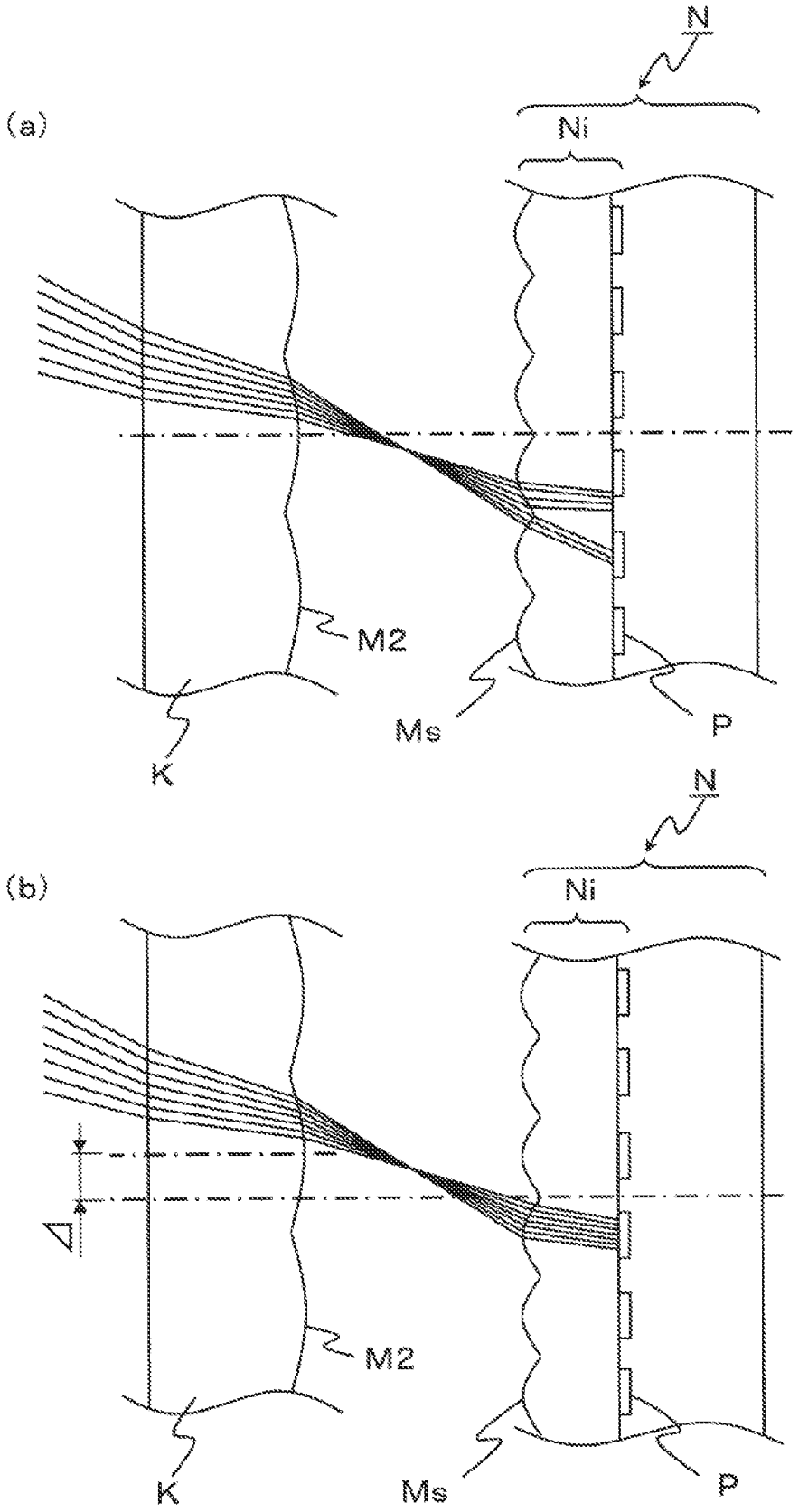
[図24]



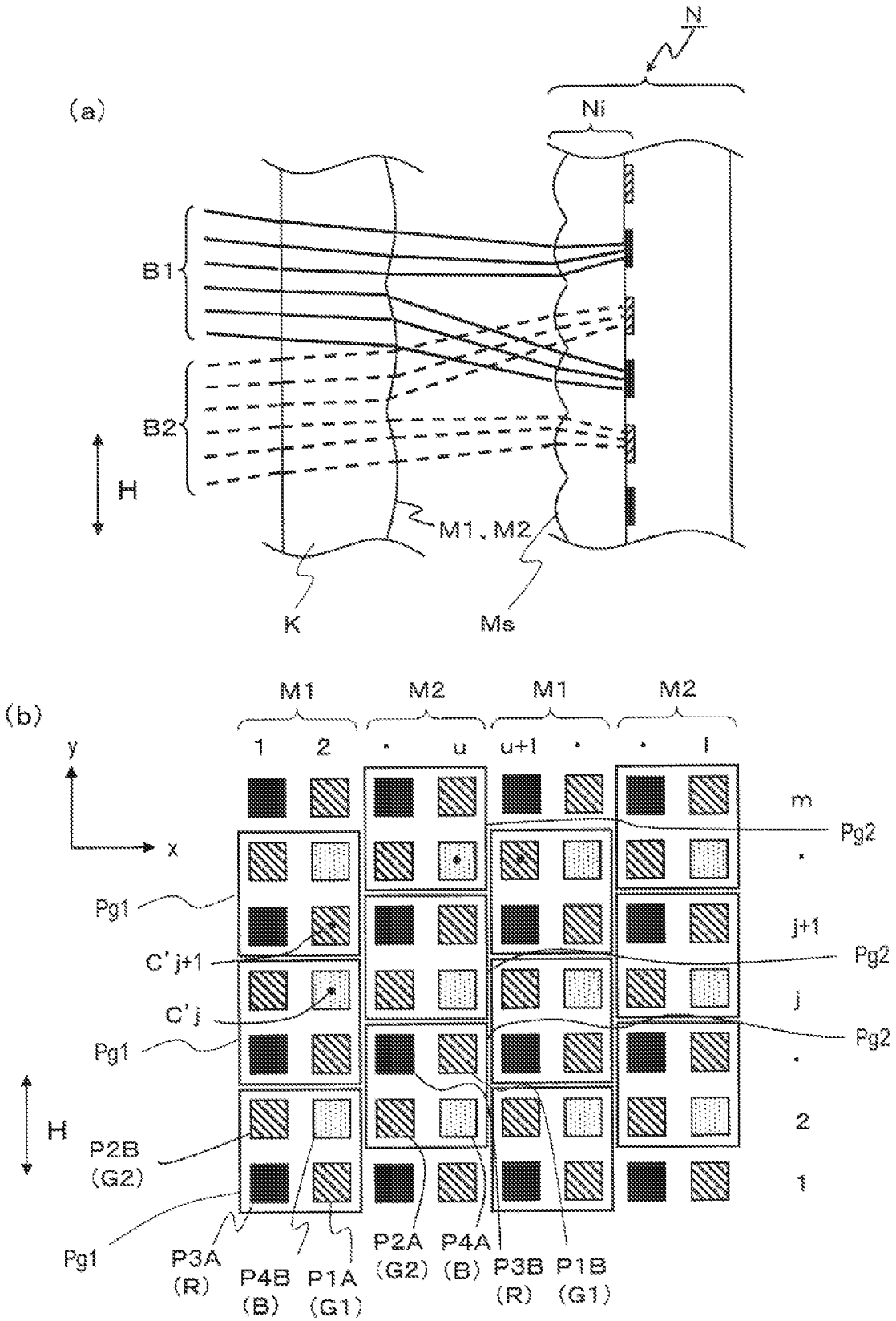
[図25]



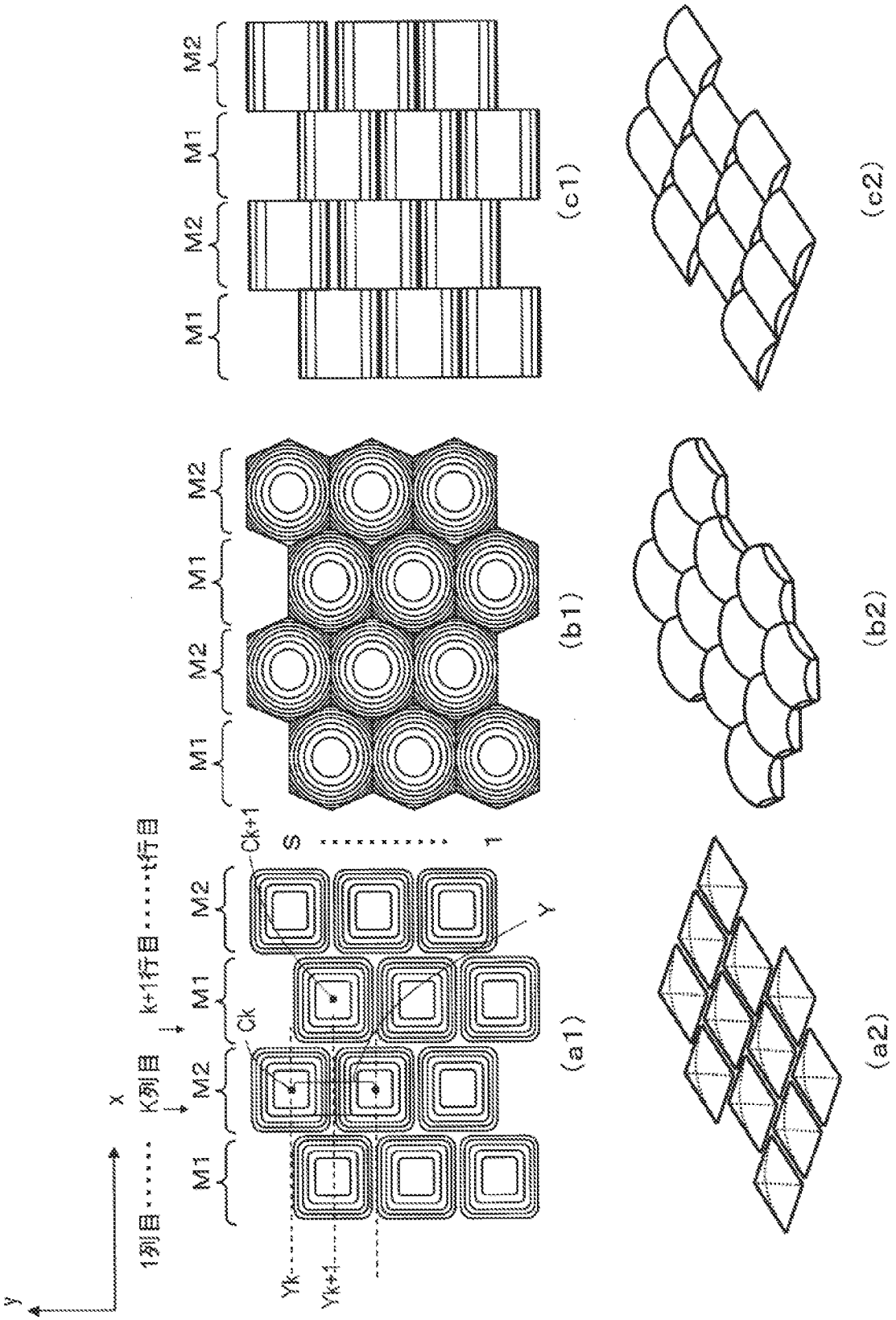
[図26]



[図27]

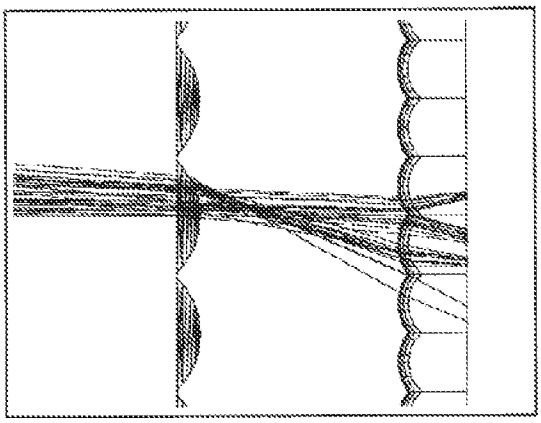

(a)
N
Ni
B1
B2
H
M1、M2
K
Ms
(b)
M1
M2
M1
M2
1
2
u
u+1
l
m
j+1
j
2
1
y
x
Pg1
Pg2
C'j+1
C'j
H
P2B
(G2)
P3A
(R)
P4B
(B)
P1A
(G1)
P2A
(G2)
P4A
(B)
P3B
(R)
P1B
(G1)

[図28]

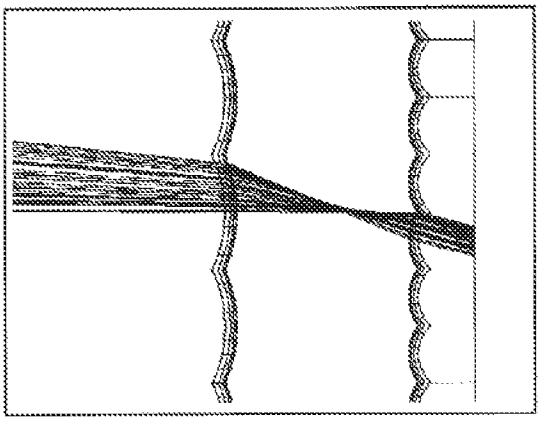

M2
M1
M2
M1
(c1)
(c2)
M2
M1
M2
M1
(b1)
(b2)
Ck+1
S
T
Y
k+1行目……t行目
K列目
Ck
X
1列目……
M2
M1
M2
M1
(a1)
(a2)
Yk
Yk+1
y

[図29]

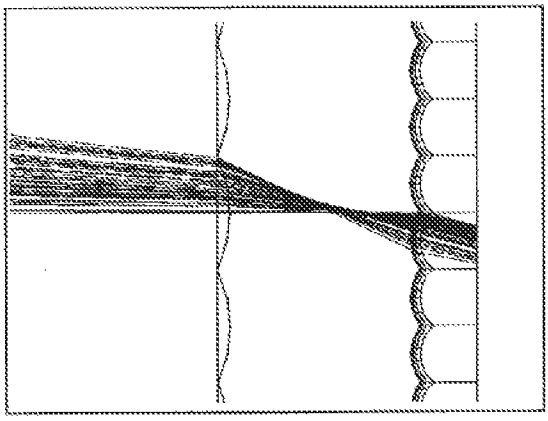
(a)



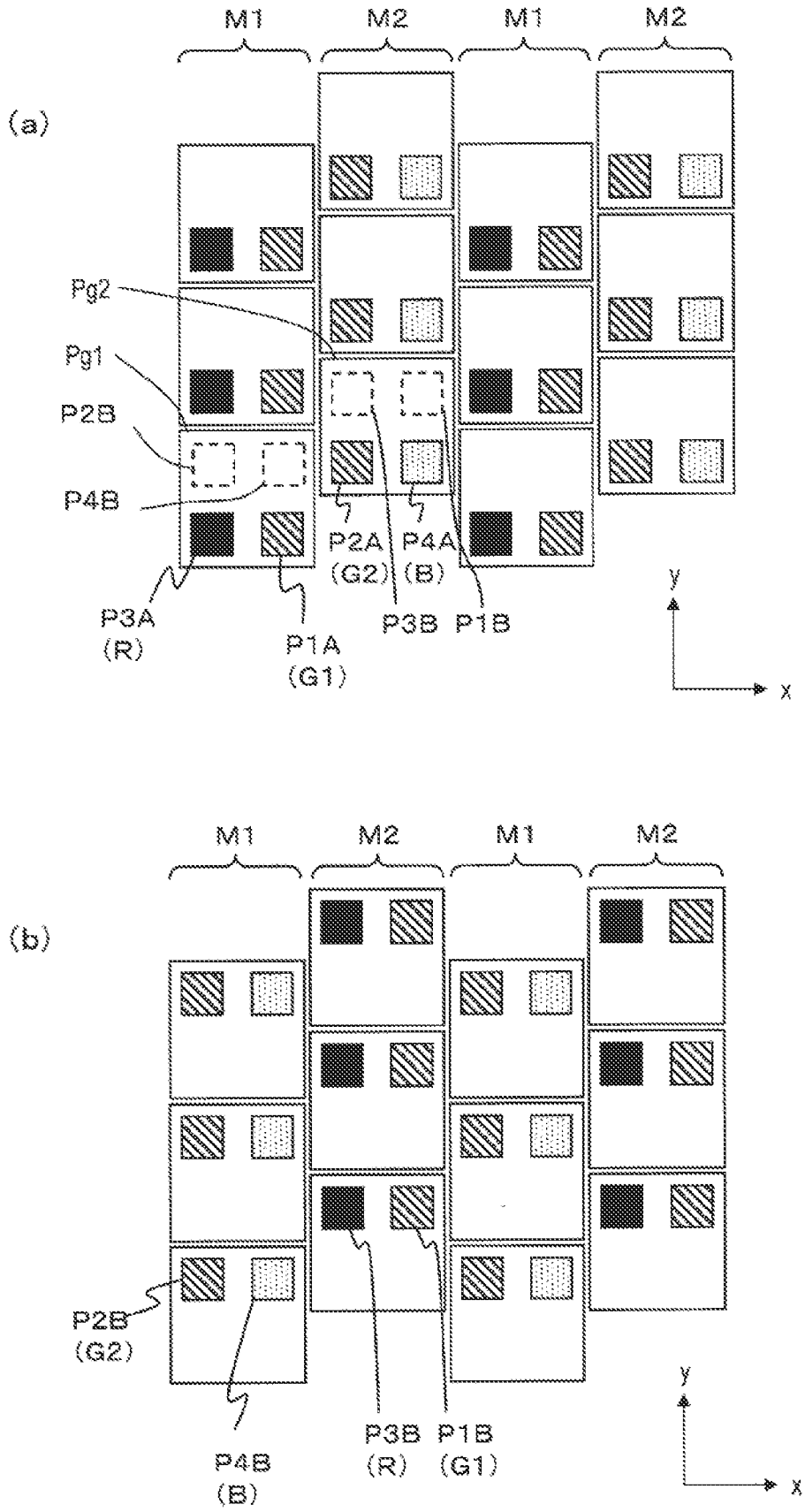
(b)



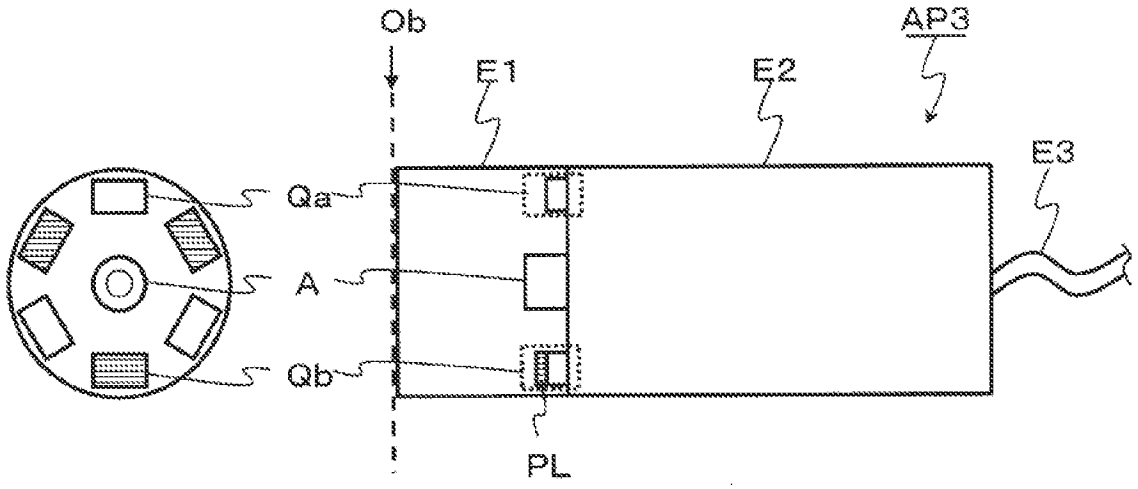
(c)



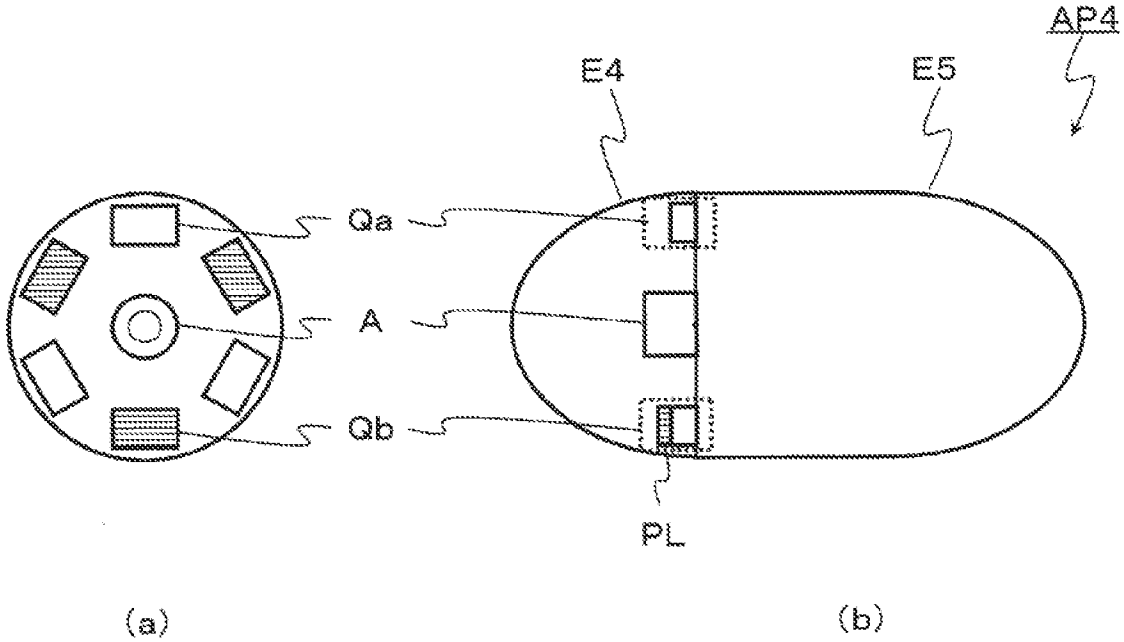
[図30]


(a)
M1
M2
M1
M2
Pg2
Pg1
P2B
P4B
P2A
(G2)
P4A
(B)
P3A
(R)
P1A
(G1)
P3B
P1B
y
x
(b)
M1
M2
M1
M2
P2B
(G2)
P4B
(B)
P3B
(R)
P1B
(G1)
y
x

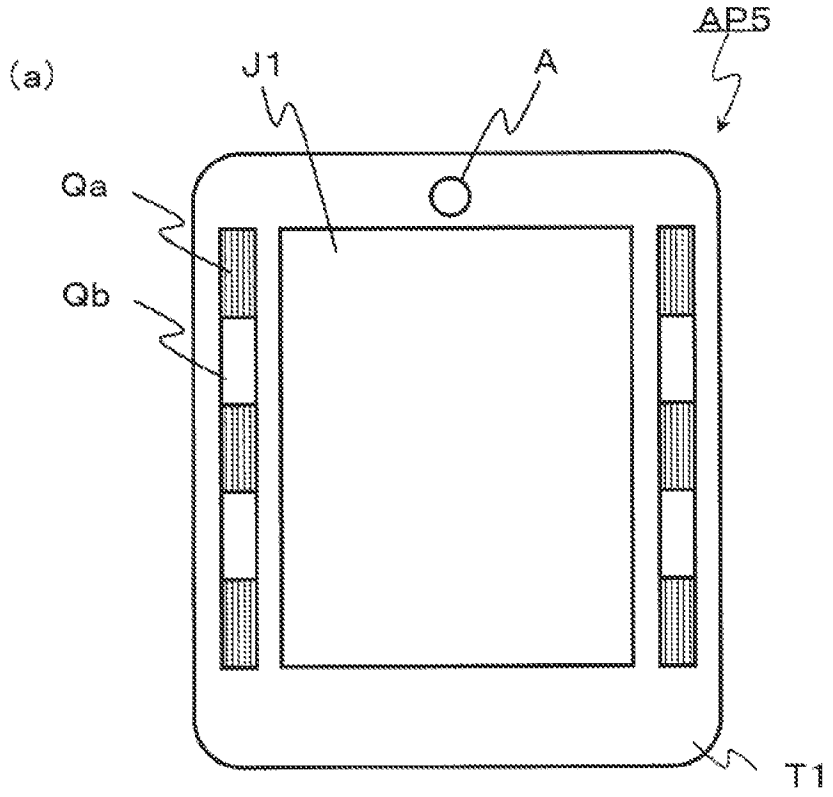
[図31]

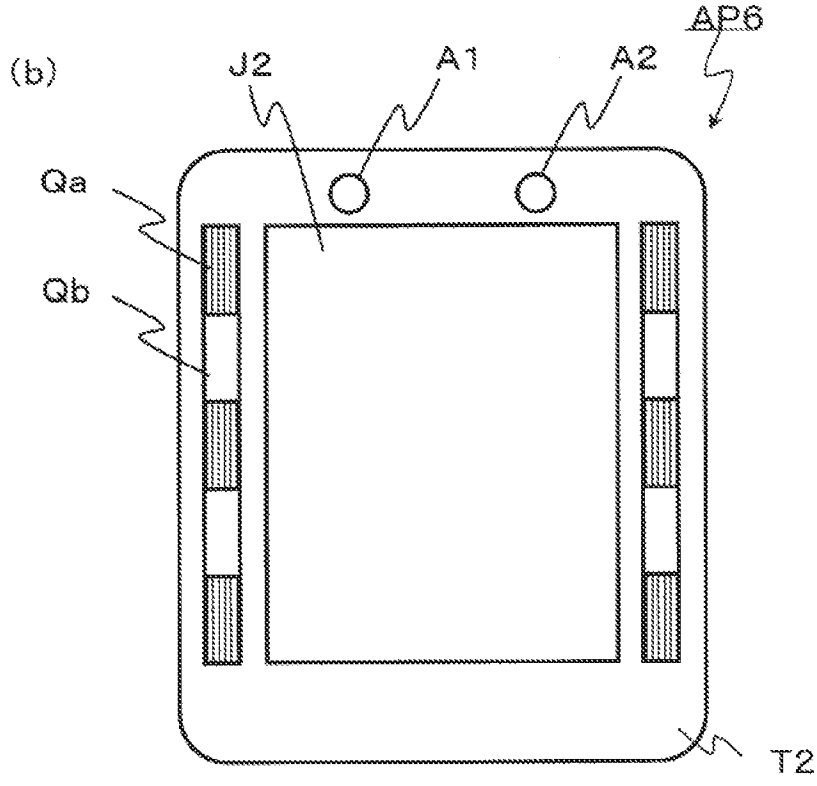


[図32]

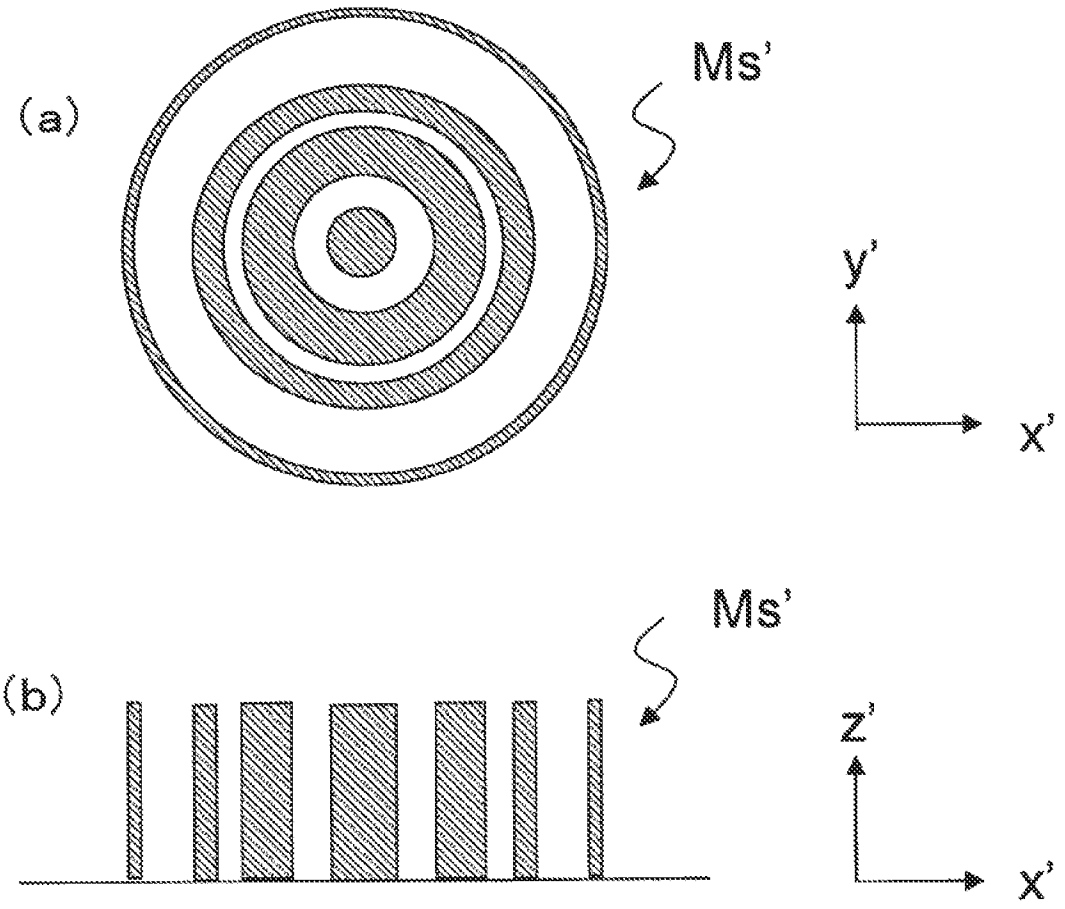


[図33]

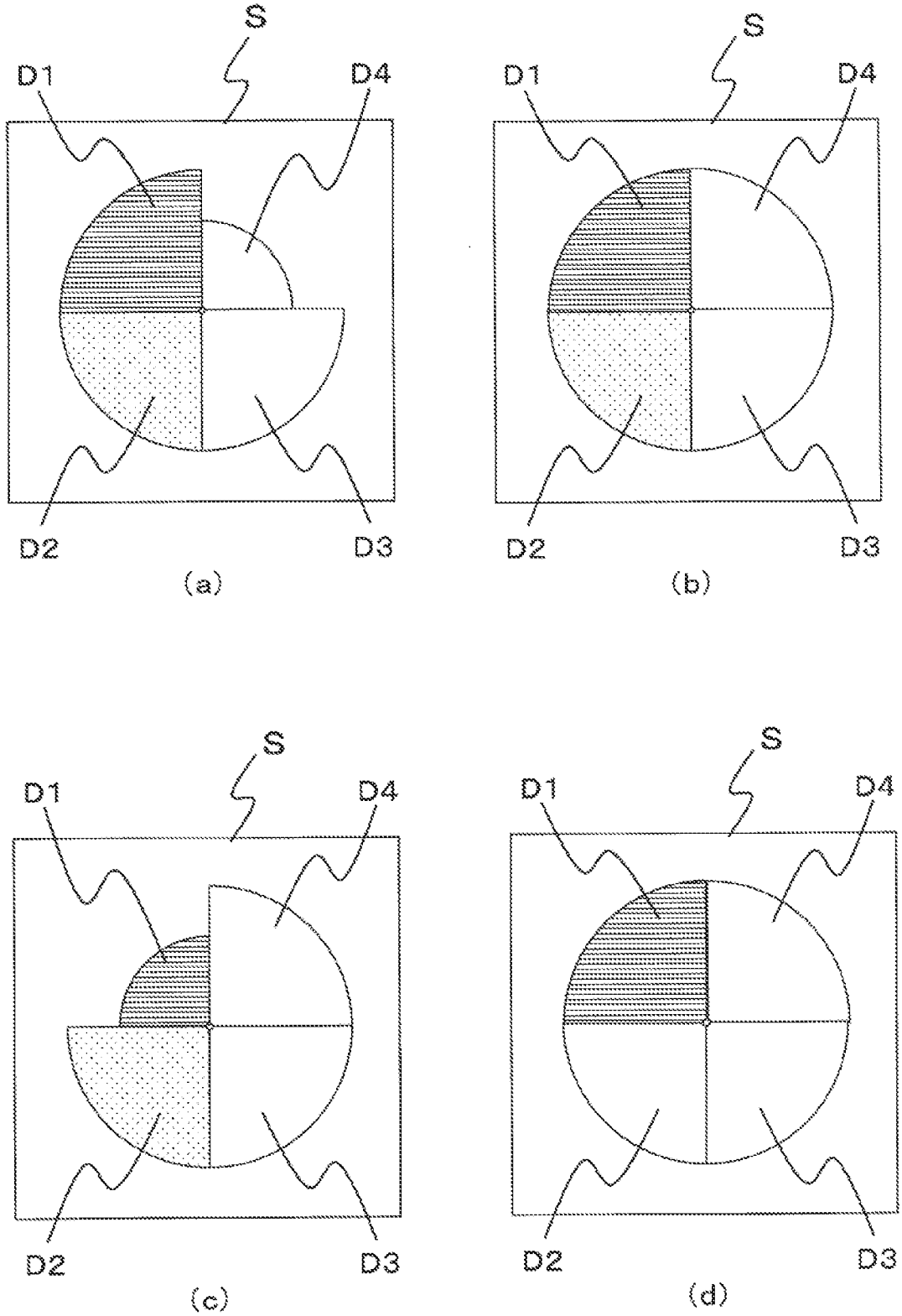




[図34]



[図35]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/000566

A. CLASSIFICATION OF SUBJECT MATTER
G01N21/27(2006.01)i, *A61B1/00*(2006.01)i, *G01N21/21*(2006.01)i, *G02B3/00*(2006.01)i, *G02B3/06*(2006.01)i, *G02F1/13*(2006.01)i, *A61B5/00*(2006.01)n

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01N21/00-21/61, G01J3/00-3/52, G01J4/00-4/04, G01J7/00-9/04, A61B1/00-1/32, A61B5/00-5/01, G02B1/00-1/08, G02B3/00-3/14, G02F1/13, H04N5/30-5/335, H04N9/04-9/11

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
JSTPlus/JMEDPlus/JST7580(JDreamIII), WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 10-048535 A (Terumo Corp.), 20 February 1998 (20.02.1998), paragraphs [0014] to [0018], [0021] to [0024]; fig. 1, 2, 5 to 8 (Family: none)	1-25,28-36 26,27
Y A	JP 2003-523646 A (Visionsense Ltd.), 05 August 2003 (05.08.2003), paragraphs [0011] to [0074]; fig. 1 to 19 & US 6396873 B1 & US 2001/0017649 A1 & US 2001/0033326 A1 & EP 1163541 A & WO 2000/060927 A2 & AU 2686700 A & CA 2366854 A & IL 145057 D	1-25,28-36 26,27

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 April, 2013 (22.04.13)	07 May, 2013 (07.05.13)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	WO 2011/148851 A1 (Sony Corp.), 01 December 2011 (01.12.2011), paragraphs [0031] to [0053], [0057] to [0060]; fig. 1 to 5, 8 & JP 2012-230341 A	1-25,28-36 26,27
Y A	JP 2012-003080 A (Olympus Corp.), 05 January 2012 (05.01.2012), paragraphs [0067] to [0077] & US 2011/0310280 A1 & CN 102289131 A	7-12,16-19, 22-25,28-36 26,27
A	JP 2000-214527 A (Hitachi, Ltd.), 04 August 2000 (04.08.2000), fig. 31 & US 2003/0197812 A1 & US 2003/0202127 A1 & US 2005/0088576 A1 & KR 10-2000-0053562 A & CN 1261755 A	1-36
A	JP 2004-046162 A (Eastman Kodak Co.), 12 February 2004 (12.02.2004), entire text; all drawings & US 2003/0231880 A1 & EP 1372027 A2 & CN 1467560 A	1-36
A	JP 2011-150686 A (Ricoh Co., Ltd.), 04 August 2011 (04.08.2011), entire text; all drawings & US 2012/0268602 A1 & EP 2517175 A & WO 2011/078199 A1 & KR 10-2012-0085935 A & CN 102782720 A	1-36
A	JP 2009-139356 A (Photonic Lattice, Inc.), 25 June 2009 (25.06.2009), entire text; all drawings (Family: none)	1-36

国際調査報告

国際出願番号　ＰＣＴ／ＪＰ２０１３／０００５６６

Ａ．　発明の属する分野の分類（国際特許分類（ＩＰＣ））

Int.Cl.　G01N21/27(2006.01)i, A61B1/00(2006.01)i, G01N21/21(2006.01)i, G02B3/00(2006.01)i, G02B3/06(2006.01)i, G02F1/13(2006.01)i, A61B5/00(2006.01)n

Ｂ．　調査を行った分野

調査を行った最小限資料（国際特許分類（ＩＰＣ））

Int.Cl.　G01N21/00-21/61, G01J3/00-3/52, G01J4/00-4/04, G01J7/00-9/04, A61B1/00-1/32, A61B5/00-5/01, G02B1/00-1/08, G02B3/00-3/14, G02F1/13, H04N5/30-5/335, H04N9/04-9/11

最小限資料以外の資料で調査を行った分野に含まれるもの

日本国実用新案公報　１９２２－１９９６年
日本国公開実用新案公報　１９７１－２０１３年
日本国実用新案登録公報　１９９６－２０１３年
日本国登録実用新案公報　１９９４－２０１３年

国際調査で使用した電子データベース（データベースの名称、調査に使用した用語）

JSTPlus/JMEDPlus/JST7580(JDreamIII), WPI

Ｃ．　関連すると認められる文献

引用文献のカテゴリー＊	引用文献名　及び一部の箇所が関連するときは、その関連する箇所の表示	関連する請求項の番号
Y A	JP 10-048535 A（テルモ株式会社）1998.02.20, 段落００１４－段落００１８、段落００２１－段落００２４、図１、図２，図５－図８（ファミリーなし）	1-25, 28-36 26, 27
Y A	JP 2003-523646 A（ヴィジョンセンス　リミテッド）2003.08.05, 段落００１１－段落００７４、図１－図１９ & US 6396873 B1 & US 2001/0017649 A1 & US 2001/0033326 A1 & EP 1163541 A & WO 2000/050927 A2 & AU 2686700 A & CA 2366854 A & IL 145057 D	1-25, 28-36 26, 27

☑　Ｃ欄の続きにも文献が列挙されている。　☐　パテントファミリーに関する別紙を参照。

＊　引用文献のカテゴリー
「Ａ」特に関連のある文献ではなく、一般的技術水準を示すもの
「Ｅ」国際出願日前の出願または特許であるが、国際出願日以後に公表されたもの
「Ｌ」優先権主張に疑義を提起する文献又は他の文献の発行日若しくは他の特別な理由を確立するために引用する文献（理由を付す）
「Ｏ」口頭による開示、使用、展示等に言及する文献
「Ｐ」国際出願日前で、かつ優先権の主張の基礎となる出願の日の後に公表された文献
「Ｔ」国際出願日又は優先日後に公表された文献であって出願と矛盾するものではなく、発明の原理又は理論の理解のために引用するもの
「Ｘ」特に関連のある文献であって、当該文献のみで発明の新規性又は進歩性がないと考えられるもの
「Ｙ」特に関連のある文献であって、当該文献と他の１以上の文献との、当業者にとって自明である組合せによって進歩性がないと考えられるもの
「＆」同一パテントファミリー文献

国際調査を完了した日	国際調査報告の発送日
２２．０４．２０１３	０７．０５．２０１３

国際調査機関の名称及びあて先	特許庁審査官（権限のある職員）		
日本国特許庁（ＩＳＡ／ＪＰ） 郵便番号１００－８９１５ 東京都千代田区霞が関三丁目４番３号	横尾　雅一	2W	3716
	電話番号　０３－３５８１－１１０１　内線　３２９２		

様式ＰＣＴ／ＩＳＡ／２１０（第２ページ）（２００９年７月）

Ｃ（続き）．　関連すると認められる文献

引用文献のカテゴリー＊	引用文献名　及び一部の箇所が関連するときは、その関連する箇所の表示	関連する請求項の番号
Y A	WO 2011/148851 A1（ソニー株式会社）2011.12.01，段落００３１－段落００５３、段落００５７－段落００６０、図１－図５、図８ & JP 2012-230341 A	1-25, 28-36 26, 27
Y A	JP 2012-003080 A（オリンパス株式会社）2012.01.05，段落００６７－段落００７７ & US 2011/0310280 A1 & CN 102289131 A	7-12, 16-19, 22-25, 28-36 26, 27
A	JP 2000-214527 A（株式会社日立製作所）2000.08.04，図３１ & US 2003/0197812 A1 & US 2003/0202127 A1 & US 2005/0088576 A1 & KR 10-2000-0053562 A & CN 1261755 A	1-36
A	JP 2004-046162 A（イーストマン　コダック　カンパニー）2004.02.12，全文、全図 & US 2003/0231880 A1 & EP 1372027 A2 & CN 1467560 A	1-36
A	JP 2011-150686 A（株式会社リコー）2011.08.04，全文、全図 & US 2012/0268602 A1 & EP 2517175 A & WO 2011/078199 A1 & KR 10-2012-0085935 A & CN 102782720 A	1-36
A	JP 2009-139356 A（株式会社フォトニックラティス）2009.06.25，全文、全図（ファミリーなし）	1-36

Hesai Exhibit 1002, Page 165

I hereby certify that this correspondence is being filed via EFS-Web with the United States Patent and Trademark Office on April 6, 2022.

KILPATRICK TOWNSEND & STOCKTON LLP

By: /Erica M. Rojas/
Erica M. Rojas

PATENT
Attorney Docket No.: 103033-P004USC4-1289479
Client Ref. No.: P004USC4

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	Confirmation No.: 1540
Angus Pacala et al.	Examiner: Mark Hellner
Application No.: 17/552,303	Art Unit: 3645
Filed: December 15, 2021	
For: OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	**AFTER NON-FINAL AMENDMENT**
Customer No.: 20350	

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

In response to the Non-Final Office Action mailed February 28, 2022, please enter the following amendments and consider the following remarks:

Amendments to the Claims are reflected in the listing of claims which begins on page 2 of this paper.

Remarks/Arguments begin on page 11 of this paper.

AMENDMENTS TO THE CLAIMS

This listing of claims will replace all prior versions, and listings of claims in the application.

Listing of Claims:

1. (Original) An optical system for collecting distance information, the optical system comprising:

an optical imaging transmit module comprising a bulk transmitting optic and an illumination source comprising a plurality of optical emitters arranged behind the bulk transmitting optic, wherein each optical emitter in the plurality of optical emitters can project light at a nominal wavelength through the bulk transmitting optic and into a field ahead of the optical system;

an optical imaging receive module comprising a bulk receiving optic and a plurality of pixels arranged behind the bulk receiving optic, wherein each pixel in the plurality of pixels comprises a plurality of single photon avalanche diodes (SPADs) and wherein the plurality of pixels includes a first set of pixels arranged in a first column and a second set of pixels arranged in a second column horizontally and vertically offset from the first column; and

an actuator operable to rotate the optical imaging receive module about a vertical axis over a plurality of scan cycles in which, during each scan cycle, the optical imaging receive module is rotated 360 degrees such that each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by every other pixel in the optical system;

wherein the optical system generates, for each of a plurality of arcuate sampling positions within one scan cycle, data that represents distances from the optical system to external surfaces in the field 360 degrees around the optical system.

2. (Original) The optical system of claim 1 further comprising an optical filter disposed in front of each pixel in the plurality of pixels and operable to allow a set of wavelengths of light, including the nominal wavelength, to pass through the optical filter while blocking light outside the set of wavelengths of light from reaching the plurality of pixels.

3. (Original) The optical system of claim 2 wherein the optical filter comprises a fused silica substrate having a coating formed thereon.

4. (Original) The optical system of claim 1 wherein the actuator includes an electric motor with an optical encoder and the optical system implements closed-loop feedback controls to maintain a rotational speed of the electric motor at a specific frequency based on outputs of the optical encoder.

5. (Original) The optical system of claim 1 wherein the bulk transmitting optic and the bulk receiving optic are each image-space telecentric lenses and the bulk transmitting optic is adjacent to an offset laterally from the bulk receiving optic.

6. (Original) The optical system of claim 1 wherein the optical imaging receive module comprises a plurality of micro-lenses disposed between the bulk receiving optic and the plurality of pixels.

7. (Original) The optical system of claim 1 wherein the circular paths traversed by pixels from the second set of pixels in the second column are interleaved with the circular paths traversed by pixels from the first set of pixels in the first column.

8. (Original) The optical system of claim 1 wherein the optical imaging receive module further comprises a plurality of apertures and a stop region disposed between adjacent apertures in the plurality of apertures, wherein the plurality of apertures includes a first aperture and a second aperture horizontally and vertically offset from the first aperture, the first set of pixels includes a first pixel disposed in a first optical path that extends through the first aperture and the second set of pixels includes a second pixel disposed in a second optical path that extends through the second aperture.

9. (Original) The optical system of claim 1 wherein the optical system implements time of flight techniques to determine distances from the optical system to external surfaces in the field.

10. (Original) An optical system for collecting distance information, the optical system comprising:

an output circuit comprising a bulk transmitting optic and an illumination source configured to output light at a nominal wavelength, the illumination source including a plurality of optical emitters arranged behind the bulk transmitting optic, wherein each optical emitter can project an illuminating beam at the nominal wavelength through the bulk transmitting optic and into a field ahead of the optical system;

an input circuit comprising a bulk receiving optic disposed adjacent to the bulk transmitting optic and a plurality of pixels arranged behind the bulk receiving optic, wherein each pixel in the plurality of pixels comprises a plurality of single photon avalanche diodes (SPADs) and wherein the plurality of pixels includes a first set of pixels arranged in a first column and a second set of pixels arranged in a second column horizontally and vertically offset from the first column; and

an electric motor configured to rotate the input circuit about a vertical axis over a plurality of scan cycles in which, during each scan cycle, the input circuit is rotated 360 degrees such that each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by each other pixel in the optical system;

wherein the optical system collects data from each pixel in the plurality of pixels at a plurality of different arcuate sampling position as the input circuit is rotated through 360 degrees during each scan cycle.

11. (Original) The optical system of claim 10 wherein each pixel in the plurality of pixels has a field of view that is non-overlapping with fields of view of all other pixels in the plurality of pixels, and the illumination source is configured to project illuminating beams into the field ahead of the optical system according to an illumination pattern where each beam in the illumination pattern is coincident with a field of view of one pixel in the plurality of pixels.

12. (Original) The optical system of claim 11 wherein each scan cycle includes a plurality of sampling periods and, during each sampling period in the plurality of sampling periods, the optical system activates each emitter in the plurality of optical emitters to project the illumination pattern and determines a number of SPADs in each pixel that recorded an incident photon since a previous sampling period.

13. (Original) The optical system of claim 12 wherein, during each sampling period of the plurality of sampling periods within one scan cycle, the optical system determines distances to objects in the field based on a difference between a time at which an optical emitter is fired and a time at which incident photons are detected at a pixel having a field of view that overlaps with a field of view of the fired optical emitter.

14. (Original) The optical system of claim 10 wherein

the input circuit further comprises a plurality of apertures and stop region disposed between adjacent apertures in the plurality of apertures, wherein the plurality of apertures comprises a first aperture, a second aperture horizontally and vertically offset from the first aperture, a third aperture aligned vertically with the first aperture and vertically offset from the first and second apertures; and a fourth aperture aligned vertically with the second aperture and vertically offset from the first, second and third apertures;

the first set of pixels includes a first pixel and a third pixel and the second set of pixels includes a second pixel and a fourth pixel;

the plurality of optical emitters includes a first emitter, a second emitter, a third emitter and a fourth emitter; and

the first pixel has a field of view coincident with the first emitter such that the first pixel is operable to detect photons emitted from the first emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the first aperture; the second pixel has a field of view coincident with the second emitter such that the second pixel is operable to detect photons emitted from the second emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the second aperture; the third pixel has a field of view coincident with the third emitter such that the third pixel is operable to detect photons emitted from the third emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the third aperture; and the fourth pixel has a field of view coincident with the fourth emitter such that the fourth pixel is operable to detect photons emitted from the fourth emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the fourth aperture.

15. (Original) The optical system of claim 10 further comprising and an optical filter disposed between the bulk receiving optic and the plurality of pixels and configured to allow a narrow band of wavelengths of light, including the nominal wavelength, to pass through the optical filter while blocking light outside the narrow band.

16. (Original) An optical system for collecting distance information, the optical system comprising:

a light receiving unit comprising a bulk receiving optic and a plurality of pixels arranged behind the bulk receiving optic, wherein each pixel in the plurality of pixels comprises a plurality of single photon avalanche diodes (SPADs) and has a field of view that is non-overlapping with the fields of view of all other pixels in the plurality of pixels, and wherein the plurality of pixels includes a first set of pixels arranged in a first pixel column and a second set of pixels arranged in a second pixel column horizontally and vertically offset from the first pixel column;

a light transmitting unit comprising a bulk transmitting optic spaced apart from the bulk receiving optic and an illumination source configured to output light at a nominal wavelength, the illumination source including a plurality of optical emitters arranged behind the bulk transmitting optic, wherein each optical emitter projects an illuminating beam at the nominal wavelength through the bulk transmitting optic and into a field ahead of the optical system such that the plurality of optical emitters project a plurality of illuminating beams according to an illumination pattern that substantially matches, in size and geometry across a range of distances from the optical system, the fields of view of the plurality of pixels; and

an electric motor operable to rotate the light receiving unit about a vertical axis over a plurality of scan cycles in which, during each scan cycle, the light receiving unit is rotated 360 degrees such that each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by the other pixels in the plurality of pixels.

17. (Original) The optical system of claim 16 wherein the optical system generates, for each of a plurality of arcuate sampling positions within one scan cycle, data that represents distances from the optical system to external surfaces in the field 360 degrees around the optical system and implements time of flight techniques to transform the generated data into distances from the optical system.

18. (Original) The optical system of claim 16 further comprising and an optical filter disposed between the bulk receiving optic and each pixel in the plurality of pixels, wherein the optical filter is configured to allow a set of wavelengths of light, including the nominal wavelength, to pass through the optical filter while blocking light outside the set of wavelengths of light from reaching the plurality of pixels.

19. (Original) The optical system of claim 16 wherein:

the first set of pixels includes a first pixel and the second set of pixels includes a second pixel;

the light receiving unit further comprises a plurality of apertures including a first aperture and a second aperture horizontally and vertically offset from the first aperture;

the first aperture is disposed in a first optical path that extends from the bulk imaging optic, through the first aperture and to the first pixel; and

the first aperture is disposed in a second optical path that extends from the bulk imaging optic, through the second aperture and to the second pixel.

20. (Original) The optical system of claim 19 wherein:

the plurality of optical emitters includes a first emitter and a second emitter; and

the first pixel has a field of view that is coincident with the first emitter such that the first pixel is operable to detect photons emitted from the first emitter and received through the bulk receiving optic after being reflected from surfaces within the field and passed through the first aperture; and

the second pixel has a field of view that is coincident with the second emitter such that the second pixel is operable to detect photons emitted from the second emitter and received through the bulk receiving optic after being reflected from surfaces within the field and passed through the second aperture.

21. (Original) The optical system of claim 16 wherein:

the light receiving unit further comprises a plurality of apertures including a first aperture, a second aperture horizontally and vertically offset from the first aperture, a third aperture aligned vertically with the first aperture and vertically offset from the first and second apertures; and a fourth aperture aligned vertically with the second aperture and vertically offset from the first, second and third apertures;

the first set of pixels includes a first pixel and a third pixel and the second set of pixels includes a second pixel and a fourth pixel;

the plurality of optical emitters includes a first emitter, a second emitter, a third emitter and a fourth emitter; and

the first pixel has a field of view coincident with the first emitter such that the first pixel is operable to detect photons emitted from the first emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the first aperture; the second pixel has a field of view coincident with the second emitter such that the second pixel is operable to detect photons emitted from the second emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the second aperture; the third pixel has a field of view coincident with the third emitter such that the third pixel is operable to detect photons emitted from the third emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the third aperture; and the fourth pixel has a field of view coincident with the fourth emitter such that the fourth pixel is operable to detect photons emitted from the fourth emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the fourth aperture.

22. (Original) The optical system of claim 16 wherein the circular paths traversed by pixels from the second set of pixels in the second pixel column are interleaved with the circular paths traversed by pixels from the first set of pixels in the first pixel column.

23. (Original) An optical system for collecting distance information, the optical system comprising:

an optical imaging transmit module comprising a bulk transmitting optic and an illumination source comprising a plurality of optical emitters arranged behind the bulk transmitting optic, wherein the plurality of optical emitters project a plurality of beams of light at an operating wavelength through the bulk transmitting optic and into a field ahead of the optical system;

an optical imaging receive module comprising a bulk receiving optic and a plurality of pixels arranged behind the bulk receiving optic, wherein each pixel in the plurality of pixels comprises a plurality of single photon avalanche diodes (SPADs) and wherein the plurality of pixels includes a first set of pixels arranged in a first column and a second set of pixels arranged in a second column horizontally and vertically offset from the first column; and

an actuator operable to rotate the optical imaging receive module about a vertical axis over a plurality of scan cycles in which, during each scan cycle, the optical imaging receive module is rotated 360 degrees such that each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by every other pixel in the optical system;

wherein the optical system generates, for each of a plurality of arcuate sampling positions within one scan cycle, data that represents distances from the optical system to external surfaces in the field 360 degrees around the optical system.

24. (Original) The optical system of claim 23 wherein the optical system further comprises an optical bandpass filter disposed between the bulk transmitting optic and the plurality of pixels and having a center wavelength matched to the operating wavelength of the plurality of optical emitters.

25. (Original) The optical system of claim 23 wherein the optical imaging receive module further comprises a plurality of apertures and a stop region disposed between adjacent apertures in the plurality of apertures, wherein the plurality of apertures includes a first aperture and a second aperture horizontally and vertically offset from the first aperture, the first set of pixels includes a first pixel disposed in a first optical path that extends through the first aperture and the second set of pixels includes a second pixel disposed in a second optical path that extends through the second aperture.

26. (Original) The optical system of claim 23 wherein the illumination source comprises a plurality of vertical cavity surface emitting lasers (VCSELs).

27. (Original) The optical system of claim 26 wherein the optical system implements time of flight techniques to determine distances from the optical system to external surfaces in the field.

REMARKS/ARGUMENTS

Upon entry of the present amendment, claims 1-27 will be pending in this application. No claims have been amended, no claims have been canceled, and no new claims have been added. No new matter is added.

Claims 3, 5, 7-8, 11-14, 19-22, and 25 were objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Claims 1-2, 4, 6, 9-10, 15-18, 23-24, and 26-27 were rejected under nonstatutory double patenting as allegedly being unpatentable over claims 1-27 of U.S. Patent No. 10,222,458.

Based on the following remarks, Applicant respectfully requests reconsideration and allowance of the pending claims.

Allowable Subject Matter

Applicant thanks the Examiner of the indication that claims 3, 5, 7-8, 11-14, 19-22, and 25 objected to as being dependent upon a rejected base claim, but would be allowable if rewritten to overcome the claim objection and placed in independent form including all of the limitations of the base claim and any intervening claims.

As noted below, Applicants have obtained and filed concurrently a terminal disclaimer to alleviate the double patenting rejection of the independent claims from which each of claims 3, 5, 7-8, 11-14, 19-22, and 25 depend in one manner or another. Accordingly, Applicants believe that claims 3, 5, 7-8, 11-14, 19-22, and 25 are in condition and, in order to save fees associated with adding additional independent claims, are not placed in independent form at this time.

Double Patenting

Claims 1-2, 4, 6, 9-10, 15-18, 23-24, and 26-27 are rejected on the grounds of non-statutory double patenting as allegedly being unpatentable over claims 1-27 of U.S. Patent No. 10,222,458. Without agreeing with this rejection, and in the interest of expediting prosecution of the present application to allowance, Applicant respectfully traverses this rejection in light of a

Terminal Disclaimer and the appropriate fee submitted herewith. Accordingly, withdrawal of the double patenting rejection is requested.

CONCLUSION

In view of the foregoing, Applicant believes all claims now pending in this application are in condition for allowance. The issuance of a formal Notice of Allowance at an early date is respectfully requested.

Except for the issue fees payable under 37 C.F.R. § 1.18, the Director is authorized to charge any additional fees during pendency of this application, including any required extension of time fees, or credit any overpayment to Deposit Account Number 20-1430. This paragraph is intended to be a constructive petition for extension of time in accordance with 37 C.F.R. § 1.136(a)(3).

If the Examiner believes a telephone conference would expedite prosecution of this application, please contact the undersigned at 858-350-6104 or wshaffer@kilpatricktownsend.com.

Respectfully submitted,

/ William L. Shaffer /

William L. Shaffer
Registration No. 37,234

UNITED STATES
PATENT AND TRADEMARK OFFICE

P.O. Box 1450
Alexandria, VA 22313 - 1450
www.uspto.gov

ELECTRONIC ACKNOWLEDGEMENT RECEIPT

APPLICATION #	RECEIPT DATE / TIME	ATTORNEY DOCKET #
17/552,303	**04/06/2022 04:45:27 PM ET**	**103033-P004USC4-1289479**

Title of Invention

OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

Application Information

APPLICATION TYPE	Utility - Nonprovisional Application under 35 USC 111(a)	PATENT #	-
CONFIRMATION #	1540	FILED BY	Erica Rojas
PATENT CENTER #	60608347	FILING DATE	12/15/2021
CUSTOMER #	20350	FIRST NAMED INVENTOR	Angus PACALA
CORRESPONDENCE ADDRESS	-	AUTHORIZED BY	Bill Shaffer

Documents

TOTAL DOCUMENTS: 6

DOCUMENT		PAGES	DESCRIPTION	SIZE (KB)
NPL_OAKR1020197008085.pdf		8	Non Patent Literature	309 KB
WO2013114891.pdf		120	Foreign Reference	5804 KB
2022-04-06_Response_to_Non_Final_OA_103033-P004USC4-1289479.pdf		12	-	107 KB
2022-04-06_Response_to_Non_Final_OA_103033-P004USC4-1289479-A....pdf	(1-1)	1	Amendment/Request for Reconsideration-After Non-Final Rejection	78 KB

2022-04-06_Response_to_Non_Final_OA_103033-P004USC4-1289479-CLM.pdf	(2-10)	9	Claims	97 KB
2022-04-06_Response_to_Non_Final_OA_103033-P004USC4-1289479-REM.pdf	(11-12)	2	Applicant Arguments/Remarks Made in an Amendment	80 KB
2022-04-06_Supplemental_IDS_103033-P004USC4-1289479.pdf		2	Information Disclosure Statement (IDS) Form (SB08)	212 KB

Warning: This is not a USPTO supplied IDS fillable form. Data in the form cannot be automatically loaded to other USPTO systems.

Digest

DOCUMENT	MESSAGE DIGEST(SHA-512)
NPL_OAKR1020197008085.pdf	13283144FDBA4382BDD0109160425CF70922F14FC3327B71887FBABEDF6008CEFFE23CDB843B33290EC82E23E4A59EE79F15ED88DAE1B352E900D8A3F3F86208
WO2013114891.pdf	B12849B10E811A08E034A1F7DE4ABC0B567F477A0933512D665FD1DAC8C5B84EF43E254D8BFCE32F584D89EA642F7046D09C5D5568D66E37BE75B8D9DF3EF9B7
2022-04-06_Response_to_Non_Final_OA_103033-P004USC4-1289479.pdf	22EF55D958DEF91920A198BBA6BF3A1EC520B6DA76E5CEF934290645F9ED250C6621B3F97A2142FB7751832C6357F199085482D0C2E798441F8DF7CC72641E3C
2022-04-06_Response_to_Non_Final_OA_103033-P004USC4-1289479-A....pdf	33FA724B2BD62FCC5F4A5A42EAC6C83FBBD1E441493C5A5435CE05102F3C3901420B7292A61313D5E2AC8AEA22C09547EFB8AFD5B09E5212C148E836BD3D723F

2022-04-06_Response_to_Non_Final_OA_103033-P004USC4-1289479-CLM.pdf	C2BF7884FCBDF6D882AD4FC42B83323828ECBF03AFE07866985EBC76AF1652A6274B6B5DA393366A9A7988D177485140797EBDC44C234E505918FF6650C8FFED
2022-04-06_Response_to_Non_Final_OA_103033-P004USC4-1289479-REM.pdf	DD786BA646A0BF7D005162FEE189BE506209D627B2569DCDBFE9671C1BBF151CFF6DAE129B190F637EC3B613F40EF289062042B8E821BB9DD46848AF8EADA1D9
2022-04-06_Supplemental_IDS_103033-P004USC4-1289479.pdf	0DCBAE98F3CDD92C807960A7E765FAE4D592777DE6CAE03E85A40B3332B83F80DFFC069701E4273EDE779D03893F14E4F5D53A5087928BE5B03360CAC6D874A5

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

New Applications Under 35 U.S.C. 111

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

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

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

New International Application Filed with the USPTO as a Receiving Office

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

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 17/552,303	Filing Date 12/15/2021	☐ To be Mailed

ENTITY: ☐ LARGE ☑ SMALL ☐ MICRO

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A		N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A		N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*		x $50 =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*		x $240 =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).				
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))					
* If the difference in column 1 is less than zero, enter "0" in column 2.				TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT	04/06/2022	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 27	Minus	** 27	= 0		x $50 =	0
	Independent (37 CFR 1.16(h))	* 4	Minus	*** 4	= 0		x $240 =	0
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	0

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=		x $0 =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=		x $0 =	
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.	OPAC
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".	/BRIDGET C. MONROE/
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".	
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.	

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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

UNITED STATES PATENT AND TRADEMARK OFFICE

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

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/552,303	12/15/2021	Angus PACALA	103033-P004USC4-1289479	1540

20350 7590 02/28/2022

Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

EXAMINER	
HELLNER, MARK	

ART UNIT	PAPER NUMBER
3645	

NOTIFICATION DATE	DELIVERY MODE
02/28/2022	ELECTRONIC

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

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

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

KTSDocketing2@kilpatrick.foundationip.com
ipefiling@kilpatricktownsend.com

Office Action Summary	Application No. 17/552,303	Applicant(s) PACALA et al.	
	Examiner MARK HELLNER	Art Unit 3645	AIA (FITF) Status Yes

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

Period for Reply

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

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

Status

1)☐ Responsive to communication(s) filed on _____.

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

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

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

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

Disposition of Claims*

5) ☑ Claim(s) 1-27 is/are pending in the application.

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

6) ☐ Claim(s) _____ is/are allowed.

7) ☑ Claim(s) 1-2,4,6,9-10,15-18,23-24 and 26-27 is/are rejected.

8) ☑ Claim(s) 3,5,7-8,11-14,19-22 and 25 is/are objected to.

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

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

Application Papers

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

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

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

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

Priority under 35 U.S.C. § 119

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

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

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

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

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

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

Attachment(s)

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

2) ☑ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date 12/15/2021.

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

4) ☐ Other: _____.

DETAILED ACTION

Notice of Pre-AIA or AIA Status

The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

Information Disclosure Statement

The information disclosure statement filed 12/15/2021 has been considered by the Examiner.

Double Patenting

The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the "right to exclude" granted by a patent and to prevent possible harassment by multiple assignees. A nonstatutory double patenting rejection is appropriate where the conflicting claims are not identical, but at least one examined application claim is not patentably distinct from the reference claim(s) because the examined application claim is either anticipated by, or would have been obvious over, the reference claim(s). See, e.g., *In re Berg*, 140 F.3d 1428, 46 USPQ2d 1226 (Fed. Cir. 1998); *In re Goodman*, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); *In re Van Ornum*, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); *In re Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) or 1.321(d) may be used to overcome an actual or provisional rejection based on nonstatutory double patenting provided the reference application or patent either is shown to be commonly owned with the examined application, or claims an invention made as a result of activities undertaken within the scope of a joint research agreement. See MPEP § 717.02 for applications subject to examination under the first inventor to file provisions of the AIA as explained in MPEP § 2159.

See MPEP § 2146 *et seq.* for applications not subject to examination under the first inventor to file provisions of the AIA. A terminal disclaimer must be signed in compliance with 37 CFR 1.321(b).

The USPTO Internet website contains terminal disclaimer forms which may be used. Please visit www.uspto.gov/patent/patents-forms. The filing date of the application in which the form is filed determines what form (e.g., PTO/SB/25, PTO/SB/26, PTO/AIA/25, or PTO/AIA/26) should be used. A web-based eTerminal Disclaimer may be filled out completely online using web-screens. An eTerminal Disclaimer that meets all requirements is auto-processed and approved immediately upon submission. For more information about eTerminal Disclaimers, refer to www.uspto.gov/patents/process/file/efs/guidance/eTD-info-I.jsp.

Claims 1, 2, 4, 6, 9, 10, 15-18, 23, 24, 26 and 27 are rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-27 of U.S. Patent No. 10,222,458. Although the claims at issue are not identical, they are not patentably distinct from each other because the subject matter of the claims of the present application are taught or suggested by the claims of U.S. Patent No. 10,222,458 as follows:

Claim 1 of the present application recites:

An optical system for collecting distance information **[taught by line 1 of claims 1 of U.S. Patent No. 10,222,458]**, the optical system comprising: an optical imaging transmit module comprising a bulk transmitting optic and an illumination source comprising a plurality of optical emitters arranged behind the bulk transmitting optic, wherein each optical emitter in the plurality of optical emitters can project light at a nominal wavelength through the bulk transmitting optic and into a field ahead of the optical system **[taught by lines 15-20 of claim 1 of U.S. Patent No. 10,222,458]**; an optical imaging receive module comprising a bulk receiving optic and a plurality of pixels arranged behind the bulk receiving optic, wherein each pixel in the plurality of pixels comprises a plurality of single photon avalanche diodes (SPADs) and wherein the plurality of pixels includes a first set of pixels arranged in a first column and a second set of

pixels arranged in a second column horizontally and vertically offset from the first column **[taught by U.S. Patent No. 10,222,458: lines 3-14 of claim 1, claim 6 and claim 7]**; and an actuator operable to rotate the optical imaging receive module about a vertical axis over a plurality of scan cycles in which, during each scan cycle, the optical imaging receive module is rotated 360 degrees **[taught by lines 21-24 of claim 1 of U.S. Patent No. 10,222,458]** such that each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by every other pixel in the optical system **[taught by claim 8 of U.S. Patent No. 10,222,458]**; wherein the optical system generates, for each of a plurality of arcuate sampling positions within one scan cycle, data that represents distances from the optical system to external surfaces in the field 360 degrees around the optical system **[this limitation would have been obvious in view of claim 1 of U.S. Patent No. 10,222,458 because the preamble of that claim recites a system for performing distance measurements]**.

Claim 2 is taught by claim 5 of U.S. Patent No. 10,222,458.

Claim 4 is taught by claim 2 of U.S. Patent No. 10,222,458.

Claim 6 is taught by lines 5-6 of claim 1 of U.S. Patent No. 10,222,458.

Claim 9 would have been obvious because time-of-flight is a common method of determining distance.

Claim 10 recites:

An optical system for collecting distance information, the optical system comprising: an output circuit comprising a bulk transmitting optic and an illumination source configured to output light at a nominal wavelength, the illumination source including a plurality of optical emitters arranged behind the bulk transmitting optic, wherein each optical emitter can project an illuminating beam at the nominal wavelength through the bulk transmitting optic and into a field ahead of the optical system **[this subject matter is suggested to a skilled artisan by claim 1, lines 15-21 of U.S. Patent No. 10,222,458]**; an input circuit comprising a bulk receiving optic

disposed adjacent to the bulk transmitting optic and a plurality of pixels arranged behind the bulk receiving optic, wherein each pixel in the plurality of pixels comprises a plurality of single photon avalanche diodes (SPADs) and wherein the plurality of pixels includes a first set of pixels arranged in a first column and a second set of pixels arranged in a second column horizontally and vertically offset from the first column **[this subject matter is suggested to a skilled artisan by U.S. Patent No. 10,222,458 – claim 1, lines 3-14; claim 10; and claim 7]**; an electric motor configured to rotate the input circuit about a vertical axis over a plurality of scan cycles in which, during each scan cycle, the input circuit is rotated 360 degrees such that each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by each other pixel in the optical system **[this subject matter is suggested to a skilled artisan by U.S. Patent No. 10,222,458 – claim 1, lines 21-24; claim 8]**; wherein the optical system collects data from each pixel in the plurality of pixels at a plurality of different arcuate sampling position as the input circuit is rotated through 360 degrees during each scan cycle **[this limitation would have been obvious because unique circular paths create different arcuate sampling positions for each pixel]**.

Claim 15 is taught by claim 5 of U.S. Patent No. 10,222,458.

Claim 16 recites:

An optical system for collecting distance information, the optical system comprising:

a light receiving unit comprising a bulk receiving optic and a plurality of pixels arranged behind the bulk receiving optic, wherein each pixel in the plurality of pixels comprises a plurality of single photon avalanche diodes (SPADs) and has a field of view that is non-overlapping with the fields of view of all other pixels in the plurality of pixels, and wherein the plurality of pixels includes a first set of pixels arranged in a first pixel column and a second set of pixels arranged in a second pixel column horizontally and vertically offset from the first pixel column **[this subject matter is suggested to a skilled artisan by U.S. Patent No. 10,222,458 – claim 1, lines 3-14; claim 10; and claim 7]**; a light transmitting unit comprising a bulk transmitting optic

spaced apart from the bulk receiving optic and an illumination source configured to output light at a nominal wavelength, the illumination source including a plurality of optical emitters arranged behind the bulk transmitting optic, wherein each optical emitter projects an illuminating beam at the nominal wavelength through the bulk transmitting optic and into a field ahead of the optical system such that the plurality of optical emitters project a plurality of illuminating beams according to an illumination pattern that substantially matches, in size and geometry across a range of distances from the optical system, the fields of view of the plurality of pixels **[this subject matter is suggested to a skilled artisan by claim 1, lines 15-21 and claim 13 of U.S. Patent No. 10,222,458]**; and an electric motor operable to rotate the light receiving unit about a vertical axis over a plurality of scan cycles in which, during each scan cycle, the light receiving unit is rotated 360 degrees such that each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by the other pixels in the plurality of pixels **[this subject matter is suggested to a skilled artisan by U.S. Patent No. 10,222,458 – claim 1, lines 21-24; claim 8].**

Claim 17 would have been obvious because time-of-flight was well-established as a method for determining distance.

Claim 18 is taught by claim 5 of U.S. Patent No. 10,222,458.

Claim 23 recites:

An optical system for collecting distance information, the optical system comprising: an optical imaging transmit module comprising a bulk transmitting optic and an illumination source comprising a plurality of optical emitters arranged behind the bulk transmitting optic, wherein the plurality of optical emitters project a plurality of beams of light at an operating wavelength through the bulk transmitting optic and into a field ahead of the optical system **[taught by lines 15-20 of claim 1 of U.S. Patent No. 10,222,458]**; an optical imaging receive module comprising a bulk receiving optic and a plurality of pixels arranged behind the bulk receiving optic, wherein each pixel in the plurality of pixels comprises a plurality of single photon

avalanche diodes (SPADs) and wherein the plurality of pixels includes a first set of pixels arranged in a first column and a second set of pixels arranged in a second column horizontally and vertically offset from the first column **[taught by U.S. Patent No. 10,222,458: lines 3-14 of claim 1, claim 6 and claim 7]**; and an actuator operable to rotate the optical imaging receive module about a vertical axis over a plurality of scan cycles in which, during each scan cycle, the optical imaging receive module is rotated 360 degrees such that each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by every other pixel in the optical system **[taught by lines 21-24 of claim 1 and claim 8 of U.S. Patent No. 10,222,458]**; wherein the optical system generates, for each of a plurality of arcuate sampling positions within one scan cycle, data that represents distances from the optical system to external surfaces in the field 360 degrees around the optical system **[this limitation would have been obvious because the unique circular paths create a plurality of arcuate sampling positions]**.

Claim 24 is taught by claim 5 of U.S. Patent No. 10,222,458.

Claim 26 is taught by claim 10 of U.S. Patent No. 10,222,458.

Claim 27 would have been obvious because time-of-flight was a well-established method of determining distance.

Allowable Subject Matter

Claims 3, 5, 7, 8, 11-14, 19-22 and 25 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Relevant Prior Art

Hall (2017/0269215) teaches scanning a plurality of beams over 360 degrees of rotation.

Figure 6a of Pennecot et al (2015/0055117) teaches a plurality of detectors (632a-c) arranged in a block element (632) wherein there is an offset in both the vertical and horizontal direction.

However, claims 1-27 of the present application require that each pixel traverse a unique parallel to and vertically offset from a unique circular path by every other pixel wherein a plurality of arcuate sampling positions are created in one scan cycle.

As a result, claims 1-27 are not being rejected under either 35 USC 102 or 103.

Any inquiry concerning this communication should be directed to MARK HELLNER at telephone number (571)272-6981.

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

/MARK HELLNER/
Primary Examiner, Art Unit 3645

Notice of References Cited	Application/Control No. 17/552,303	Applicant(s)/Patent Under Reexamination PACALA et al.	
	Examiner MARK HELLNER	Art Unit 3645	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-10222458-B2	03-2019	Pacala; Angus	G01S17/08	1/1
*	B	US-20170269215-A1	09-2017	Hall; David S.	G01S7/4811	1/1
*	C	US-20150055117-A1	02-2015	Pennecot; Gaetan	G01S17/89	356/4.01
	D					
	E					
	F					
	G					
	H					
	I					
	J					
	K					
	L					
	M					

FOREIGN PATENT DOCUMENTS

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

NON-PATENT DOCUMENTS

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

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

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/552,303	PACALA et al.
	Examiner	Art Unit
	MARK HELLNER	3645

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

CLAIMS

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

CLAIM		DATE								
Final	Original	02/23/2022								
	1	✓								
	2	✓								
	3	O								
	4	✓								
	5	O								
	6	✓								
	7	O								
	8	O								
	9	✓								
	10	✓								
	11	O								
	12	O								
	13	O								
	14	O								
	15	✓								
	16	✓								
	17	✓								
	18	✓								
	19	O								
	20	O								
	21	O								
	22	O								
	23	✓								
	24	✓								
	25	O								
	26	✓								
	27	✓								

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/552,303	PACALA et al.
	Examiner	Art Unit
	MARK HELLNER	3645

CPC - Searched*		
Symbol	Date	Examiner
G01S7/4816, 4817; G01S17/08, 89 - text limited	02/23/2022	/MH/

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner

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

Search Notes		
Search Notes	Date	Examiner
inventor and assignee search; key word search	02/23/2022	/MH/

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

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

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

Application Number	Not Yet Assigned 17/552,303
Filing Date	Not Yet Assigned
First Named Inventor	Angus Pacala
Art Unit	Not Yet Assigned
Examiner Name	Not Yet Assigned
Attorney Docket Number	103033-P004USC4-1289479

U.S. PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code [1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	1	4358851	A	1982-11-09	Scifres, et al.	
	2	4634272	A	1987-01-06	Endo	
	3	4676599	A	1987-06-30	Cruz	
	4	4702600	A	1987-10-27	Handrich, et al.	
	5	4744667	A	1988- 05-17	Fay, et al.	
	6	4851664		1989-07-25	Rieger	
	7	5267016	A	1993-11-30	Meinzer, et al.	
	8	5288992	A	1994-02-22	Fohl	
	9	5602391	A	1997-02-11	Pines, et al.	
	10	5982552	A	1999-11-09	Nakama, et al.	
	11	6014232	A	2000-01-11	Clarke	
	12	6133989	A	2000-10-17	Stettner, et al.	
	13	6255133	B1	2001-07-03	Ormond, et al.	
	14	6374024	B1	2002-04-16	Iijima	
	15	6414746	B1	2002-07-02	Stettner, et al.	
	16	6690019	B2	2004-02-10	Stettner, et al.	
	17	6721262	B1	2004-04-13	Jordache, et al.	
	18	7091462	B2	2006-08-15	Wilson, et al.	
	19	D531525	S	2006-11-07	Dold, et al.	
	20	7170542	B2	2007-01-30	Hanina, et al.	
	21	7295298	B2	2007-11-13	Willhoeft, et al.	
	22	7345271	B2	2008-03-18	Boehlau, et al.	
	23	7421159	B2	2008-09-02	Yang, et al.	
	24	7433042	B1	2008-10-07	Cavanaugh, et al.	
	25	7808706	B2	2010-10-05	Fadel, et al.	
	26	7969558	B2	2011-06-28	Hall	

02/23/2022
/MARK HELLNER/

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.H/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

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

Application Number	Not Yet Assigned
Filing Date	Not Yet Assigned
First Named Inventor	Angus Pacala
Art Unit	Not Yet Assigned
Examiner Name	Not Yet Assigned
Attorney Docket Number	103033-P004USC4-1289479

	27	8013983	B2	2011-09-06	Lin, et al.	
	28	8089618	B2	2012-01-03	Yang	
	29	8130367	B2	2012-03-06	Stettner, et al.	
	30	D659030	S	2012- 05-08	Anselment, et al.	
	31	8319949	B2	2012-11-27	Cantin, et al.	
	32	8330840	B2	2012-12-11	Lenchenkov	
	33	8374405	B2	2013-02-12	Lee, et al.	
	34	8384997	B2	2013-02-26	Shpunt, et al.	
	35	8494252	B2	2013-07-23	Freedman, et al.	
	36	8675181	B2	2014-03-18	Hall	
	37	8717488	B2	2014- 05-06	Shpunt, et al.	
	38	8742325	B1	2014-06-03	Droz, et al.	
	39	8743176	B2	2014-06-03	Stettner, et al.	
	40	8761495	B2	2014-06-24	Freedman, et al.	
	41	8767190	B2	2014-07-01	Hall	
	42	8829406	B2	2014-09-09	Akerman, et al.	
	43	8836922	B1	2014-09-16	Pennecot, et al.	
	44	8848039	B2	2014-09-30	Spektor, et al.	
	45	9041915	B2	2015- 05-26	Earhart, et al.	
	46	9063549	B1	2015-06-23	Pennecot, et al.	
	47	9071763	B1	2015-06-30	Templeton, et al.	
	48	9086273	B1	2015-07-21	Gruver, et al.	
	49	9111444	B2	2015-08-18	Kaganovich	
	50	9157790	B2	2015-10-13	Shpunt, et al.	
	51	9164511	B1	2015-10-20	Ferguson, et al.	
	52	9176051	B2	2015-11-03	Mappes, et al.	
	53	9229109	B2	2016-01-05	Stettner, et al.	
	54	9285464	B2	2016-03-15	Pennecot, et al.	
	55	9285477	B1	2016-03-15	Smith, et al.	

75494573v.1

/MARK HELLNER/

02/23/2022

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.H/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

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

Application Number	17/552,322 Not Yet Assigned
Filing Date	Not Yet Assigned
First Named Inventor	Angus Pacala
Art Unit	Not Yet Assigned
Examiner Name	Not Yet Assigned
Attorney Docket Number	103033-P004USC4-1289479

	56	9299731	B1	2016-03-29	Lenius, et al.	
	57	9368936	B1	2016-06-14	Lenius, et al.	
	58	9369689	B1	2016-06-14	Tran, et al.	
	59	9383753	B1	2016-07-05	Templeton, et al.	
	60	9425654	B2	2016-08-23	Lenius, et al.	
	61	9435891	B2	2016-09-06	Oggier	
	62	9470520	B2	2016-10-18	Schwarz, et al.	
	63	9489601	B2	2016-11-08	Fairfield, et al.	
	64	9525863	B2	2016-12-20	Nawasra, et al.	
	65	9529079	B1	2016-12-27	Droz, et al.	
	66	9551791	B2	2017-01-24	Van Den Bossche, et al.	
	67	9989406	B2	2018-06-05	Pacala, et al.	
	68	9992477	B2	2018-06-05	Pacala, et al.	
	69	10063849	B2	2018-08-28	Pacala, et al.	
	70	10183541	B2	2019-01-22	Van Den Bossche, et al.	
	71	10222458	B2	2019-03-05	Pacala, et al.	
	72	10809359	B2	2020-10-20	Pacala, et al.	
	73	10948572	B2	2021-03-16	Pacala, et al.	
	74	10222475	B2	2019-03-15	Pacala, et al.	
	75	10663586	B2	2020-05-26	Pacala, et al.	
	76	11025885	B2	2021-06-01	Pacala, et al.	
	77	11086013	B2	2021-08-10	Pacala, et al.	
	78	11131773	B2	2021-09-28	Pacala, et al.	
	79	11150347	B2	2021-10-19	Pacala, et al.	
	80	11175405	B2	2021-11-16	Pacala, et al.	
	81	11178381	B2	2021-11-16	Pacala, et al.	
	82	11190750	B2	2021-11-30	Pacala, et al.	
	83	11196979	B2	2021-12-07	Pacala, et al.	
	84	11202056	B2	2021-12-14	Pacala, et al.	

75494573v.1 /MARK HELLNER/ 02/23/2022

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.H/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned 17/552,303
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

U.S. PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code [1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	85	20030006676	A1	2003-01-09	Smith, et al.	
	86	20030047752	A1	2003-03-13	Campbell, et al.	
	87	20040061502	A1	2004-04-01	Hasser	
	88	20040223071	A1	2004-11-11	Wells, et al.	
	89	20050030409	A1	2005-02-10	Matherson, et al.	
	90	20060244851	A1	2006-11-02	Cartlidge	
	91	20070007563	A1	2007-01-11	Mouli	
	92	20070060806	A1	2007-03-15	Hunter, et al.	
	93	20070071056	A1	2007-03-29	Chen	
	94	20070228262	A1	2007-10-04	Cantin, et al.	
	95	20080121826	A1	2008-05-29	Manley, et al.	
	96	20080153189	A1	2008-06-26	Plaine, et al.	
	97	20090016642	A1	2009-01-15	Hart	
	98	20090040629	A1	2009-02-12	Bechtel, et al.	
	99	20090179142	A1	2009-07-16	Duparre, et al.	
	100	20090295910	A1	2009-12-03	Mir, et al.	
	101	20100008588	A1	2010-01-14	Feldkhun, et al.	
	102	20100020306	A1	2010-01-28	Hall	
	103	20100110275	A1	2010- 05-06	Mathieu	
	104	20100123893	A1	2010-05-20	Yang	
	105	20100204964	A1	2010-08-12	Pack, et al.	

/MARK HELLNER/ 02/23/2022

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.H/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned 17/552,303
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	106	20110025843	A1	2011-02-03	Oggier, et al.	
	107	20110032398	A1	2011-02-10	Lenchenkov	
	108	20110037849	A1	2011-02-17	Niclass, et al.	
	109	20110116262	A1	2011-05-19	Marson	
	110	20110216304	A1	2011-09-08	Hall	
	111	20120044476	A1	2012-02-23	Earhart, et al.	
	112	20120140109	A1	2012-06-07	Shpunt, et al.	
	113	20120154914	A1	2012-06-21	Moriguchi, et al.	
	114	20120182464	A1	2012-07-19	Shpunt, et al.	
	115	20120287417	A1	2012-11-15	Mimeault	
	116	20120320164	A1	2012-12-20	Lipton	
	117	20130044310	A1	2013-02-21	Mimeault	
	118	20130141549	A1	2013-06-06	Beers, et al.	
	119	20130206967	A1	2013-08-15	Shpunt, et al.	
	120	20130229646	A1	2013-09-05	Sakurai	
	121	20130294089	A1	2013-11-07	Freedman, et al.	
	122	20130300840	A1	2013-11-14	Borowski	
	123	20140055661	A1	2014-02-27	Imamura, et al.	
	124	20140118335	A1	2014- 05-01	Gurman	
	125	20140118493	A1	2014- 05-01	Sali, et al.	
	126	20140153001	A1	2014-06-05	Chayat, et al.	
	127	20140158900	A1	2014-06-12	Yoon, et al.	
	128	20140168631	A1	2014-06-19	Haslim, et al.	
	129	20140176933	A1	2014-06-26	Haslim, et al.	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.H/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned ~~14/552,303~~
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	130	20140211194	A1	2014-07-31	Pacala, et al.	
	131	20140269796	A1	2014-09-18	Geske, et al.	
	132	20140285628	A1	2014-09-25	Shpunt, et al.	
	133	20140291491	A1	2014-10-02	Shpunt, et al.	
	134	20140313519	A1	2014-10-23	Shpunt, et al.	
	135	20140375977	A1	2014-12-25	Ludwig, et al.	
	136	20140376092	A1	2014-12-25	Mor	
	137	20150002636	A1	2015-01-01	Brown	
	138	20150034809	A1	2015-02-05	Droz, et al.	
	139	20150055117	A1	2015-02-26	Pennecot, et al.	
	140	20150131080	A1	2015-05-14	Retterath, et al.	
	141	20150184999	A1	2015-07-02	Stettner	
	142	20150192677	A1	2015-07-09	Yu, et al.	
	143	20150260830	A1	2015-09-17	Ghosh, et al.	
	144	20150268450	A1	2015-09-24	Ueno, et al.	
	145	20150292948	A1	2015-10-15	Goldring, et al.	
	146	20150293224	A1	2015-10-15	Eldada, et al.	
	147	20150316473	A1	2015-11-05	Kester, et al.	
	148	20150355470	A1	2015-12-10	Herschbach	
	149	20150358601	A1	2015-12-10	Oggier	
	150	20150378241	A1	2015-12-31	Eldada	
	151	20150379371	A1	2015-12-31	Yoon, et al.	
	152	20160003946	A1	2016-01-07	Gilliland, et al.	
	153	20160047895	A1	2016-02-18	Dussan	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.H/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

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

Application Number	Not Yet Assigned 17/552,303
Filing Date	Not Yet Assigned
First Named Inventor	Angus Pacala
Art Unit	Not Yet Assigned
Examiner Name	Not Yet Assigned
Attorney Docket Number	103033-P004USC4-1289479

	154	20160047896	A1	2016-02-18	Dussan	
	155	20160047897	A1	2016-02-18	Dussan	
	156	20160047898	A1	2016-02-18	Dussan	
	157	20160047899	A1	2016-02-18	Dussan	
	158	20160047900	A1	2016-02-18	Dussan	
	159	20160047901	A1	2016-02-18	Pacala, et al.	
	160	20160047903	A1	2016-02-18	Dussan	
	161	20160049765	A1	2016-02-18	Eldada	
	162	20160097858	A1	2016-04-07	Mundhenk, et al.	
	163	20160150963	A1	2016-06-02	Roukes, et al.	
	164	20160161600	A1	2016-06-09	Eldada, et al.	
	165	20160218727	A1	2016-07-28	Maki	
	166	20160265902	A1	2016-09-15	Nawasra, et al.	
	167	20160291134	A1	2016-10-06	Droz, et al.	
	168	20160306032	A1	2016-10-20	Schwarz, et al.	
	169	20160327779	A1	2016-11-10	Hillman	
	170	20160328619	A1	2016-11-10	Yi, et al.	
	171	20170146640	A1	2017-05-25	Hall, et al.	
	172	20170219426	A1	2017-08-03	Pacala, et al.	
	173	20170219695	A1	2017-08-03	Hall, et al.	
	174	20170269197	A1	2017-09-21	Hall, et al.	
	175	20170269198	A1	2017-09-21	Hall, et al.	
	176	20170269209	A1	2017-09-21	Hall, et al.	
	177	20170269215	A1	2017-09-21	Hall, et al.	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.H/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

17/552,303

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	178	20170289524	A1	2017-10-05	Pacala, et al.	
	179	20170350983	A1	2017-12-07	Hall, et al.	
	180	20180059222	A1	2018-03-01	Pacala, et al.	
	181	20180152691	A1	2018-05-31	Pacala, et al.	
	182	20180209841	A1	2018-07-26	Pacala, et al.	
	183	20180267143	A1	2018-09-20	Alcalde, et al.	
	184	20180299554	A1	2018-10-18	Van Dyck, et al.	
	185	20190041498	A1	2019-02-07	Droz, et al.	

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T[5]
	186	0095725	EP	A1	1983-12-07	Tokyo Shibaura Denki Kabushiki Kaisha		
	187	036407	JP	A	1991-01-11	Daido Steel Co. Ltd.		
	188	05256691	JP	A	1993-10-05	Fujitsu Limited		
	189	0749417	JP	A	1995-02-21	Fujitsu Ltd.		
	190	2003004850	JP	A	2003-01-08	Denso Corp.		
	191	101281914	CN	A	2008-10-08	Robert Bosch GmbH		
	192	101288105	CN	A	2008-10-15	Prime Sense Ltd.		
	193	2124069	EP	A1	2009-11-25	IBEO Automobile Sensor GmbH		
	194	2009153699	WO	A1	2009-12-23	Philips Intellectual Property & Standards GmbH		
	195	102292676	CN	A	2011-12-21	Micronic Laser Systems AB		
	196	2012142952	JP	A	2012-07-26	Nikon Corporation		
	197	2013201466	JP	A	2013-10-03	Fujifilm Corp.		

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.H/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	~~17/552,303~~ Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	198	103460024	CN	A	2013-12-18	Matsushita Electric Industrial Co., Ltd.		
	199	2015052616	WO	A1	2015-04-16	Koninklijke Philips N.V.		
	200	104597609	CN	A	2015- 05-06	Boe Technology Group Co., Ltd.		
	201	3045935	EP	A1	2016-07-20	XenomatiX BVBA		
	202	2016116733	WO	A1	2016-07-28	Milan Momcilo Popovich		
	203	2016125165	WO	A2	2016-08-11	Verifood Ltd.		
	204	2016161438	JP	A	2016-09-05	Denso Corp.		
	205	3002548	EP	B1	2016-09-14	Sick AG		
	206	2017132704	WO	A1	2017-08-03	Velodyne Lidar, Inc.		
	207	2018039432	WO	A1	2018-03-01	Ouster Inc.		
	208	2018065426	WO	A1	2018-04-12	XenomatiX N.V.		
	209	2018065427	WO	A1	2018-04-12	XenomatiX N.V.		
	210	2018065428	WO	A2	2018-04-12	XenomatiX N.V.		
	211	2018065429	WO	A1	2018-04-12	XenomatiX N.V.		
	212	3316000	EP	A1	2018- 05-02	XenomatiX N.V.		
	213	2018122415	WO	A1	2018-07-05	XenomatiX N.V.		
	214	2018197441	WO	A1	2018-11-01	XenomatiX N.V.		

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	215	"HDL-32E", User's Manual 2010, Velodyne Lidar, Incorporated, Available Online at: https://www.yumpu.com/en/document/view/11661149/hdl-32e-manual-velodyne-lidar, August 2016, 28 pages.	
	216	"HDL-32E", Data Sheet 2010, Velodyne Lidar, Incorporated, Available Online at: http://pdf.directindustry.com/pdf/velodynelidar/hdl-32e-datasheet/182407-676098.html, 2017, 3 pages.	
	217	"HDL-32E", Velodyne Lidar, Incorporated, Available Online at: http://www.velodynelidar.com/hdl-32e.html, December 6, 2017, 3 pages.	

75494573v.1

/MARK HELLNER/ 02/23/2022

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.H/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	~~17/552,303~~ Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	218	"HDL-64E", Velodyne Lidar, Incorporated, Available online at: http://www.velodynelidar.com/hdl-64e.html, December 6, 2017, 12 pages.	
	219	"HDL-64E S2", Data Sheet, Velodyne Lidar, Inc., Available online at: http://velodynelidar.com/lidar/products/brochure/HDL-64E%20S2%20datasheet_2010_lowres.pdf, 2017, 2 pages.	
	220	"HDL-64E S2 and S2.1", Velodyne Lidar, Incorporated, User's Manual and Programming Guide, Firmware version 4, 2007, 43 pages.	
	221	"HDL-64E S3", Velodyne Lidar, Incorporated, S3 User's Manual and Programming Guide Revision J, December 2017, 54 pages.	
	222	"Puck Hi-Res", Velodyne Lidar, Incorporated, Available Online at: http://www.velodynelidar.com/vlp-16-hi-res.html, December 13, 2017, 2 pages.	
	223	"Puck Hi-Res Data Sheet", Velodyne Lidar, Incorporated, September 2016, 2 pages.	
	224	"Puck Hi-Res User Manual", Velodyne Lidar, Incorporated, September 2016, 49 pages.	
	225	"Puck Lite", Velodyne Lidar, Incorporated, Our Lightest Sensor Ever, Available Online at: http://velodynelidar.com/vlp-16-lite.html, April 2016, 2 pages.	
	226	"Puck Lite Data Sheet", Velodyne Lidar, Incorporated, February 2016, 2 pages.	
	227	"Puck Lite User Manual", Velodyne Lidar, Incorporated, February 2016, 49 pages.	
	228	"Ultra Puck VLP-32C", Velodyne Lidar, Incorporated, Available Online at: http://velodynelidar.com/vlp-32c.html, November 2017, 4 pages.	
	229	"Velodyne LiDAR Puck", Velodyne Lidar, Incorporated, Available online at: http://www.velodynelidar.com/vlp-16.html, December 6, 2017, 48 pages.	
	230	"Velodyne LiDAR Puck", Velodyne Lidar, Incorporated, User's Manual and Programming Guide, 2014, 49 pages.	
	231	"VLP-16", Velodyne Lidar, Incorporated, Puck, Real Time 3D Lidar Sensor, 2014, 2 pages.	
	232	Application No 15/419,053, Non-Final Office Action, Mailed On July 28, 2017, 18 pages.	
	233	Application No 15/685,384, Non-Final Office Action, Mailed On August 17, 2020, 6 pages.	

75494573v.1

/MARK HELLNER/ ~~09/23/2020~~

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.H/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	234	Application No 15/685,384, Non-Final Office Action, Mailed On November 15, 2019, 6 pages.	
	235	Application No 15/685,384, Notice of Allowance, Mailed On February 12, 2020, 5 pages.	
	236	Application No 15/685,384, Notice of Allowance, Mailed On November 18, 2020, 7 pages.	
	237	15/934,613, "Corrected Notice of Allowability", December 28, 2018, 2 pages.	
	238	Application No 15/934,613, Non-Final Office Action, Mailed On July 6, 2018, 6 pages.	
	239	Application No 15/934,613, Notice of Allowance, Mailed On November 23, 2018, 5 pages.	
	240	16/123,988, "Corrected Notice of Allowability", June 22, 2020, 2 pages.	
	241	16/123,988, "Corrected Notice of Allowability", July 23, 2020, 3 pages.	
	242	16/123,988, "Ex Parte Quayle Action", February 3, 2020, 5 pages.	
	243	Application No 16/123,988, Notice of Allowance, Mailed On May 15, 2020, 5 pages.	
	244	AU2017315762, "First Examination Report", July 19, 2019, 5 pages.	
	245	AU2017315762, "Second Examination Report", November 13, 2019, 4 pages.	
	246	BRONZI et al., "100 000 Frames/s 64x32 Single Photon Detector Array for 2-D Imaging and 3-D Ranging", Institute of Electrical and Electronics Engineers Journal of Selected Topic in Quantum Electronics, Volume 20, No. 6, November-December 2014, 10 pages.	
	247	CHARBON et al., "SPAD-Based Sensors", TOF Range-Imaging Cameras, April 9, 2013, pp. 11-38.	
	248	Application No CN201780062843.6, Notice of Decision to Grant, Mailed On May 11, 2021, 6 pages.	
	249	Application No CN201780062843.6, Office Action, Mailed On September 28, 2020, 11 pages.	
	250	COVA et al., "Single-Photon Counting Detectors", Institute of Electrical and Electronics Engineers Photonics Journal, Volume 3, No. 2, April 2011, pp. 274-277.	

/MARK HELLNER/

02/23/2022

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.H/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

17/552,303

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	251	Application No EP17844396.6, Extended European Search Report, Mailed On May 29, 2020, 9 pages.	
	252	GUERRIERI et al., "Two-Dimensional SPAD Imaging Camera for Photon Counting", Institute of Electrical and Electronics Engineers Photonics Journal, Volume 2, No. 5, October 2010, pp. 759-774.	
	253	Application No IL265003, Office Action, Mailed On October 13, 2021, 9 pages.	
	254	IN201947008121, "First Examination Report", August 2, 2021, 7 pages.	
	255	ITZLER et al., "Geiger-Mode Avalanche Photodiode Focal Plane Arrays for Three-dimensional Imaging LADAR", Proc of SPIE, Volume 7808, 2010, pp. 78080C-1-78080C-14.	
	256	Application No JP2019-531544, Notice of Decision to Grant, Mailed On November 16, 2020, 1 page.	
	257	Application No JP2019-531544, Office Action, Mailed On July 20, 2020, 5 pages.	
	258	Application No JP2020-208324, Office Action, Mailed On September 13, 2021, 7 pages.	
	259	KILPELA et al., "Precise Pulsed Time-of-Flight Laser Range Finder for Industrial Distance Measurements", Review of Scientific Instruments, Volume 72, No. 4, April 2001, pp. 2197-2202.	
	260	Application No PCT/US2017/039306, International Search Report and Written Opinion, Mailed On November 7, 2017, 21 pages.	
	261	PCT/US2017/039306, "Invitation to Pay Additional Fees and, Where Applicable, Protest Fee", August 31, 2017, 2 pages.	
	262	Application No PCT/US2017/048379, International Preliminary Report on Patentability, Mailed On March 7, 2019, 10 pages.	
	263	Application No PCT/US2017/048379, International Search Report and Written Opinion, Mailed On November 2, 2017, 11 pages.	
	264	Application No SG11201901600W, Notice of Decision to Grant, Mailed On April 13, 2021, 5 pages.	
	265	Application No SG11201901600W, Written Opinion, Mailed On March 28, 2020, 13 pages.	

/MARK HELLNER/ 14 02/23/2022

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.H/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

17/552,303

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

EXAMINER SIGNATURE

Examiner Signature	/MARK HELLNER/	Date Considered	02/23/2022

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

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

CERTIFICATION STATEMENT

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

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

OR

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

☐ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

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

Signature	/ William L. Shaffer /	Date (YYYY-MM-DD)	2021-12-15
Name/Print	William L. Shaffer	Registration Number	37,234

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.H/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.H/

PE2E SEARCH - Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	British Equivalents	Time Stamp
L1	0	ouster.in.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:48 AM
L2	127	ouster.as.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:48 AM
L3	567	pacala.in.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:49 AM
L4	210	frichtl.in.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:49 AM
L5	654	younge.in.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:49 AM
L6	1162	L2 OR L3 OR L4 OR l5	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:49 AM
L7	14185	bulk WITH optic	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD,	OR	ON	ON	2022/02/23 11:50 AM

			DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)				
L8	121	L6 AND l7	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:50 AM
L9	520775	vertical$4 WITH offset	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:50 AM
L10	37	L8 AND l9	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 11:51 AM
L11	8	"10222458".pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 12:06 PM
L12	2	"9992477".pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 12:10 PM
L13	14	("2014005561" OR "20150055117").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 12:25 PM
L14	2	"9992477".pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD,	OR	ON	ON	2022/02/23 04:41 PM

			DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)				
L15	2	"20170269215".pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 04:42 PM
L16	16	("2014005561" OR "20150055117" OR "20170269215").pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 04:46 PM
L17	12225	G01S7/4816.cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 05:07 PM
L18	22737	G01S7/4817.cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 05:07 PM
L19	24187	G01S17/08.cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 05:07 PM
L20	42409	G01S17/89.cpc.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 05:07 PM
L21	82059	L17 OR L18 OR L19 OR l20	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD,	OR	ON	ON	2022/02/23 05:07 PM

			DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)				
L22	3475	pixels SAME (detect$4 OR scan$4) SAME ((unique OR individual OR distinct) WITH (path OR arcuate OR circular))	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 05:10 PM
L23	86	L21 AND l22	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 05:10 PM
L24	8	"10222458".pn.	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 05:11 PM
L25	174	("4358851" | "4634272" | "4676599" | "4702600" | "4744667" | "4851664" | "5267016" | "5288992" | "5982552" | "6014232" | "6133989" | "6255133" | "6374024" | "6414746" | "6690019" | "6721262" | "7091462" | "D531525" | "7170542" | "7295298" | "7345271" | "7421159" | "7433042" | "7808706" | "7969558" | "8013983" | "8089618" | "8130367" | "D659030" | "8319949" | "8330840" | "8374405" | "8384997" | "8494252" | "8675181" | "8717488" | "8742325" | "8743176" | "8761495" | "8767190" | "8829406" | "8836922" | "8848039" | "9041915" | "9063549" | "9071763" | "9086273" | "9111444" | "9157790" | "9164511" | "9176051" | "9229109" | "9285464" | "9285477" | "9299731" | "9368936"	(US-PGPUB; USPAT; USOCR)	OR	ON	ON	2022/02/23 05:11 PM

		| "9369689" | "9383753" | "9425654" | "9435891" | "9470520" | "9489601" | "9525863" | "9529079" | "9989406" | "9992477" | "10063849" | "20030006676" | "20030047752" | "20040061502" | "20040223071" | "20050030409" | "20060244851" | "20070007563" | "20070060806" | "20070071056" | "20070228262" | "20080121826" | "20080153189" | "20090016642" | "20090040629" | "20090179142" | "20090295910" | "20100008588" | "20100020306" | "20100110275" | "20100123893" | "20100204964" | "20110025843" | "20110032398" | "20110037849" | "20110116262" | "20110216304" | "20120044476" | "20120140109" | "20120154914" | "20120182464" | "20120287417" | "20120320164" | "20130044310" | "20130141549" | "20130206967" | "20130294089" | "20130300840" | "20140118335" | "20140118493" | "20140153001" | "20140158900" | "20140168631" | "20140176933" | "20140211194" | "20140269796" | "20140285628" | "20140291491" | "20140313519" | "20140375977" | "20140376092" | "20150002636" | "20150131080" |					

		"20150184999" | "20150192677" | "20150292948" | "20150293224" | "20150316473" | "20150355470" | "20150358601" | "20150378241" | "20150379371" | "20160003946" | "20160047895" | "20160047896" | "20160047897" | "20160047898" | "20160047899" | "20160047900" | "20160047901" | "20160047903" | "20160049765" | "20160097858" | "20160150963" | "20160161600" | "20160218727" | "20160265902" | "20160291134" | "20160306032" | "20160327779" | "20160328619" | "20170146640" | "20170219426" | "20170219695" | "20170269197" | "20170269198" | "20170269215" | "20170289524" | "20170350983" | "20180059222" | "20180152691" | "20180209841" | "20180267143").pn. OR ("10222458").urpn. AND (PGPB | USPT | USOC).dbnm.					
L26	28939	pixel SAME ((vertical OR horizontal) WITH offset)	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/02/23 05:13 PM
L27	113	L22 AND l26	(US-PGPUB; USPAT; USOCR; FIT (AU, AP, AT, CA, CH, CN, DD, DE, EA, EP, ES, FR, GB, JP, KR, OA, RU, SU, WO); FPRS; EPO;	OR	ON	ON	2022/02/23 05:13 PM

			JPO; DERWENT; IBM_TDB)				

PE2E SEARCH - Search History (Interference)

There are no Interference searches to show.

UNITED STATES PATENT AND TRADEMARK OFFICE

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

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/552,303	12/15/2021	Angus PACALA	103033-P004USC4-1289479	1540

20350 7590 02/11/2022

Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

EXAMINER	
CENTRAL, DOCKET	

ART UNIT	PAPER NUMBER
OPAP	

NOTIFICATION DATE	DELIVERY MODE
02/11/2022	ELECTRONIC

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

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

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

KTSDocketing2@kilpatrick.foundationip.com
ipefiling@kilpatricktownsend.com

Decision Granting Request for Prioritized Examination (Track I)	**Application No.** 17/552,303	**Applicant(s)** PACALA et al.	
	Examiner DIANE C GOODWYN	**Art Unit** OPET	**AIA (FITF) Status** Yes

1. THE REQUEST FILED 15 December 2021 IS **GRANTED** .

   The above-identified application has met the requirements for prioritized examination
   - A. ☑ for an original nonprovisional application (Track I).
   - B. ☐ for an application undergoing continued examination (RCE).

2. **The above-identified application will undergo prioritized examination**. The application will be accorded special status throughout its entire course of prosecution until one of the following occurs:
   - A. filing a **petition for extension of time** to extend the time period for filing a reply;
   - B. filing an **amendment to amend the application to contain more than four independent claims, more than thirty total claims** , or a multiple dependent claim;
   - C. filing a **request for continued examination** ;
   - D. filing a notice of appeal;
   - E. filing a request for suspension of action;
   - F. mailing of a notice of allowance;
   - G. mailing of a final Office action;
   - H. completion of examination as defined in 37 CFR 41.102; or
   - I. abandonment of the application.

Telephone inquiries with regard to this decision should be directed to DIANE GOODWYN at (571) 272-6735. In his/her absence, calls may be directed to Petition Help Desk at (571) 272-3282.

/DIANE C GOODWYN/ Paralegal Specialist, OPET	

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 17/552,303

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	80		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	350		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	400		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	27 minus 20 =	* 7	x 50 =	350	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	4 minus 3 =	* 1	x 240 =	240			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	1420		TOTAL	

APPLICATION AS AMENDED - PART II

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

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

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

UNITED STATES PATENT AND TRADEMARK OFFICE

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

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
17/552,303	12/15/2021	2621	1420	103033-P004USC4-1289479	27	4

CONFIRMATION NO. 1540

FILING RECEIPT

20350
Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

OC000000130700164

Date Mailed: 12/28/2021

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

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

Inventor(s)

Angus PACALA, San Francisco, CA;
Mark FRICHTL, San Francisco, CA;
Marvin SHU, San Francisco, CA;
Eric YOUNGE, San Francisco, CA;

Applicant(s)

Ouster, Inc., San Francisco, CA;

Assignment For Published Patent Application

Ouster, Inc., San Francisco, CA

Power of Attorney: The patent practitioners associated with Customer Number 20350

Domestic Priority data as claimed by applicant

This application is a CON of 17/194,068 03/05/2021
which is a CON of 15/685,384 08/24/2017 PAT 10948572
which claims benefit of 62/379,130 08/24/2016

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

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

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

If Required, Foreign Filing License Granted: 12/27/2021
The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 17/552,303**
Projected Publication Date: 04/07/2022
Non-Publication Request: No
Early Publication Request: No
**** SMALL ENTITY ****
Title

OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

Preliminary Class

345

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

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

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

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

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

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

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative,

this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

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

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

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

NOT GRANTED

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

SelectUSA

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

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

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

U.S. PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code [1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	1	4358851	A	1982-11-09	Scifres, et al.	
	2	4634272	A	1987-01-06	Endo	
	3	4676599	A	1987-06-30	Cruz	
	4	4702600	A	1987-10-27	Handrich, et al.	
	5	4744667	A	1988- 05-17	Fay, et al.	
	6	4851664		1989-07-25	Rieger	
	7	5267016	A	1993-11-30	Meinzer, et al.	
	8	5288992	A	1994-02-22	Fohl	
	9	5602391	A	1997-02-11	Pines, et al.	
	10	5982552	A	1999-11-09	Nakama, et al.	
	11	6014232	A	2000-01-11	Clarke	
	12	6133989	A	2000-10-17	Stettner, et al.	
	13	6255133	B1	2001-07-03	Ormond, et al.	
	14	6374024	B1	2002-04-16	Iijima	
	15	6414746	B1	2002-07-02	Stettner, et al.	
	16	6690019	B2	2004-02-10	Stettner, et al.	
	17	6721262	B1	2004-04-13	Jordache, et al.	
	18	7091462	B2	2006-08-15	Wilson, et al.	
	19	D531525	S	2006-11-07	Dold, et al.	
	20	7170542	B2	2007-01-30	Hanina, et al.	
	21	7295298	B2	2007-11-13	Willhoeft, et al.	
	22	7345271	B2	2008-03-18	Boehlau, et al.	
	23	7421159	B2	2008-09-02	Yang, et al.	
	24	7433042	B1	2008-10-07	Cavanaugh, et al.	
	25	7808706	B2	2010-10-05	Fadel, et al.	
	26	7969558	B2	2011-06-28	Hall	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	27	8013983	B2	2011-09-06	Lin, et al.	
	28	8089618	B2	2012-01-03	Yang	
	29	8130367	B2	2012-03-06	Stettner, et al.	
	30	D659030	S	2012- 05-08	Anselment, et al.	
	31	8319949	B2	2012-11-27	Cantin, et al.	
	32	8330840	B2	2012-12-11	Lenchenkov	
	33	8374405	B2	2013-02-12	Lee, et al.	
	34	8384997	B2	2013-02-26	Shpunt, et al.	
	35	8494252	B2	2013-07-23	Freedman, et al.	
	36	8675181	B2	2014-03-18	Hall	
	37	8717488	B2	2014- 05-06	Shpunt, et al.	
	38	8742325	B1	2014-06-03	Droz, et al.	
	39	8743176	B2	2014-06-03	Stettner, et al.	
	40	8761495	B2	2014-06-24	Freedman, et al.	
	41	8767190	B2	2014-07-01	Hall	
	42	8829406	B2	2014-09-09	Akerman, et al.	
	43	8836922	B1	2014-09-16	Pennecot, et al.	
	44	8848039	B2	2014-09-30	Spektor, et al.	
	45	9041915	B2	2015- 05-26	Earhart, et al.	
	46	9063549	B1	2015-06-23	Pennecot, et al.	
	47	9071763	B1	2015-06-30	Templeton, et al.	
	48	9086273	B1	2015-07-21	Gruver, et al.	
	49	9111444	B2	2015-08-18	Kaganovich	
	50	9157790	B2	2015-10-13	Shpunt, et al.	
	51	9164511	B1	2015-10-20	Ferguson, et al.	
	52	9176051	B2	2015-11-03	Mappes, et al.	
	53	9229109	B2	2016-01-05	Stettner, et al.	
	54	9285464	B2	2016-03-15	Pennecot, et al.	
	55	9285477	B1	2016-03-15	Smith, et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	56	9299731	B1	2016-03-29	Lenius, et al.	
	57	9368936	B1	2016-06-14	Lenius, et al.	
	58	9369689	B1	2016-06-14	Tran, et al.	
	59	9383753	B1	2016-07-05	Templeton, et al.	
	60	9425654	B2	2016-08-23	Lenius, et al.	
	61	9435891	B2	2016-09-06	Oggier	
	62	9470520	B2	2016-10-18	Schwarz, et al.	
	63	9489601	B2	2016-11-08	Fairfield, et al.	
	64	9525863	B2	2016-12-20	Nawasra, et al.	
	65	9529079	B1	2016-12-27	Droz, et al.	
	66	9551791	B2	2017-01-24	Van Den Bossche, et al.	
	67	9989406	B2	2018-06-05	Pacala, et al.	
	68	9992477	B2	2018-06-05	Pacala, et al.	
	69	10063849	B2	2018-08-28	Pacala, et al.	
	70	10183541	B2	2019-01-22	Van Den Bossche, et al.	
	71	10222458	B2	2019-03-05	Pacala, et al.	
	72	10809359	B2	2020-10-20	Pacala, et al.	
	73	10948572	B2	2021-03-16	Pacala, et al.	
	74	10222475	B2	2019-03-15	Pacala, et al.	
	75	10663586	B2	2020-05-26	Pacala, et al.	
	76	11025885	B2	2021-06-01	Pacala, et al.	
	77	11086013	B2	2021-08-10	Pacala, et al.	
	78	11131773	B2	2021-09-28	Pacala, et al.	
	79	11150347	B2	2021-10-19	Pacala, et al.	
	80	11175405	B2	2021-11-16	Pacala, et al.	
	81	11178381	B2	2021-11-16	Pacala, et al.	
	82	11190750	B2	2021-11-30	Pacala, et al.	
	83	11196979	B2	2021-12-07	Pacala, et al.	
	84	11202056	B2	2021-12-14	Pacala, et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

U.S. PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code [1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	85	20030006676	A1	2003-01-09	Smith, et al.	
	86	20030047752	A1	2003-03-13	Campbell, et al.	
	87	20040061502	A1	2004-04-01	Hasser	
	88	20040223071	A1	2004-11-11	Wells, et al.	
	89	20050030409	A1	2005-02-10	Matherson, et al.	
	90	20060244851	A1	2006-11-02	Cartlidge	
	91	20070007563	A1	2007-01-11	Mouli	
	92	20070060806	A1	2007-03-15	Hunter, et al.	
	93	20070071056	A1	2007-03-29	Chen	
	94	20070228262	A1	2007-10-04	Cantin, et al.	
	95	20080121826	A1	2008-05-29	Manley, et al.	
	96	20080153189	A1	2008-06-26	Plaine, et al.	
	97	20090016642	A1	2009-01-15	Hart	
	98	20090040629	A1	2009-02-12	Bechtel, et al.	
	99	20090179142	A1	2009-07-16	Duparre, et al.	
	100	20090295910	A1	2009-12-03	Mir, et al.	
	101	20100008588	A1	2010-01-14	Feldkhun, et al.	
	102	20100020306	A1	2010-01-28	Hall	
	103	20100110275	A1	2010- 05-06	Mathieu	
	104	20100123893	A1	2010-05-20	Yang	
	105	20100204964	A1	2010-08-12	Pack, et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	106	20110025843	A1	2011-02-03	Oggier, et al.	
	107	20110032398	A1	2011-02-10	Lenchenkov	
	108	20110037849	A1	2011-02-17	Niclass, et al.	
	109	20110116262	A1	2011-05-19	Marson	
	110	20110216304	A1	2011-09-08	Hall	
	111	20120044476	A1	2012-02-23	Earhart, et al.	
	112	20120140109	A1	2012-06-07	Shpunt, et al.	
	113	20120154914	A1	2012-06-21	Moriguchi, et al.	
	114	20120182464	A1	2012-07-19	Shpunt, et al.	
	115	20120287417	A1	2012-11-15	Mimeault	
	116	20120320164	A1	2012-12-20	Lipton	
	117	20130044310	A1	2013-02-21	Mimeault	
	118	20130141549	A1	2013-06-06	Beers, et al.	
	119	20130206967	A1	2013-08-15	Shpunt, et al.	
	120	20130229646	A1	2013-09-05	Sakurai	
	121	20130294089	A1	2013-11-07	Freedman, et al.	
	122	20130300840	A1	2013-11-14	Borowski	
	123	20140055661	A1	2014-02-27	Imamura, et al.	
	124	20140118335	A1	2014- 05-01	Gurman	
	125	20140118493	A1	2014- 05-01	Sali, et al.	
	126	20140153001	A1	2014-06-05	Chayat, et al.	
	127	20140158900	A1	2014-06-12	Yoon, et al.	
	128	20140168631	A1	2014-06-19	Haslim, et al.	
	129	20140176933	A1	2014-06-26	Haslim, et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	130	20140211194	A1	2014-07-31	Pacala, et al.	
	131	20140269796	A1	2014-09-18	Geske, et al.	
	132	20140285628	A1	2014-09-25	Shpunt, et al.	
	133	20140291491	A1	2014-10-02	Shpunt, et al.	
	134	20140313519	A1	2014-10-23	Shpunt, et al.	
	135	20140375977	A1	2014-12-25	Ludwig, et al.	
	136	20140376092	A1	2014-12-25	Mor	
	137	20150002636	A1	2015-01-01	Brown	
	138	20150034809	A1	2015-02-05	Droz, et al.	
	139	20150055117	A1	2015-02-26	Pennecot, et al.	
	140	20150131080	A1	2015-05-14	Retterath, et al.	
	141	20150184999	A1	2015-07-02	Stettner	
	142	20150192677	A1	2015-07-09	Yu, et al.	
	143	20150260830	A1	2015-09-17	Ghosh, et al.	
	144	20150268450	A1	2015-09-24	Ueno, et al.	
	145	20150292948	A1	2015-10-15	Goldring, et al.	
	146	20150293224	A1	2015-10-15	Eldada, et al.	
	147	20150316473	A1	2015-11-05	Kester, et al.	
	148	20150355470	A1	2015-12-10	Herschbach	
	149	20150358601	A1	2015-12-10	Oggier	
	150	20150378241	A1	2015-12-31	Eldada	
	151	20150379371	A1	2015-12-31	Yoon, et al.	
	152	20160003946	A1	2016-01-07	Gilliland, et al.	
	153	20160047895	A1	2016-02-18	Dussan	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	154	20160047896	A1	2016-02-18	Dussan	
	155	20160047897	A1	2016-02-18	Dussan	
	156	20160047898	A1	2016-02-18	Dussan	
	157	20160047899	A1	2016-02-18	Dussan	
	158	20160047900	A1	2016-02-18	Dussan	
	159	20160047901	A1	2016-02-18	Pacala, et al.	
	160	20160047903	A1	2016-02-18	Dussan	
	161	20160049765	A1	2016-02-18	Eldada	
	162	20160097858	A1	2016-04-07	Mundhenk, et al.	
	163	20160150963	A1	2016-06-02	Roukes, et al.	
	164	20160161600	A1	2016-06-09	Eldada, et al.	
	165	20160218727	A1	2016-07-28	Maki	
	166	20160265902	A1	2016-09-15	Nawasra, et al.	
	167	20160291134	A1	2016-10-06	Droz, et al.	
	168	20160306032	A1	2016-10-20	Schwarz, et al.	
	169	20160327779	A1	2016-11-10	Hillman	
	170	20160328619	A1	2016-11-10	Yi, et al.	
	171	20170146640	A1	2017-05-25	Hall, et al.	
	172	20170219426	A1	2017-08-03	Pacala, et al.	
	173	20170219695	A1	2017-08-03	Hall, et al.	
	174	20170269197	A1	2017-09-21	Hall, et al.	
	175	20170269198	A1	2017-09-21	Hall, et al.	
	176	20170269209	A1	2017-09-21	Hall, et al.	
	177	20170269215	A1	2017-09-21	Hall, et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	178	20170289524	A1	2017-10-05	Pacala, et al.	
	179	20170350983	A1	2017-12-07	Hall, et al.	
	180	20180059222	A1	2018-03-01	Pacala, et al.	
	181	20180152691	A1	2018-05-31	Pacala, et al.	
	182	20180209841	A1	2018-07-26	Pacala, et al.	
	183	20180267143	A1	2018-09-20	Alcalde, et al.	
	184	20180299554	A1	2018-10-18	Van Dyck, et al.	
	185	20190041498	A1	2019-02-07	Droz, et al.	

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T[5]
	186	0095725	EP	A1	1983-12-07	Tokyo Shibaura Denki Kabushiki Kaisha		
	187	036407	JP	A	1991-01-11	Daido Steel Co. Ltd.		
	188	05256691	JP	A	1993-10-05	Fujitsu Limited		
	189	0749417	JP	A	1995-02-21	Fujitsu Ltd.		
	190	2003004850	JP	A	2003-01-08	Denso Corp.		
	191	101281914	CN	A	2008-10-08	Robert Bosch GmbH		
	192	101288105	CN	A	2008-10-15	Prime Sense Ltd.		
	193	2124069	EP	A1	2009-11-25	IBEO Automobile Sensor GmbH		
	194	2009153699	WO	A1	2009-12-23	Philips Intellectual Property & Standards GmbH		
	195	102292676	CN	A	2011-12-21	Micronic Laser Systems AB		
	196	2012142952	JP	A	2012-07-26	Nikon Corporation		
	197	2013201466	JP	A	2013-10-03	Fujifilm Corp.		

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	198	103460024	CN	A	2013-12-18	Matsushita Electric Industrial Co., Ltd.		
	199	2015052616	WO	A1	2015-04-16	Koninklijke Philips N.V.		
	200	104597609	CN	A	2015- 05-06	Boe Technology Group Co., Ltd.		
	201	3045935	EP	A1	2016-07-20	XenomatiX BVBA		
	202	2016116733	WO	A1	2016-07-28	Milan Momcilo Popovich		
	203	2016125165	WO	A2	2016-08-11	Verifood Ltd.		
	204	2016161438	JP	A	2016-09-05	Denso Corp.		
	205	3002548	EP	B1	2016-09-14	Sick AG		
	206	2017132704	WO	A1	2017-08-03	Velodyne Lidar, Inc.		
	207	2018039432	WO	A1	2018-03-01	Ouster Inc.		
	208	2018065426	WO	A1	2018-04-12	XenomatiX N.V.		
	209	2018065427	WO	A1	2018-04-12	XenomatiX N.V.		
	210	2018065428	WO	A2	2018-04-12	XenomatiX N.V.		
	211	2018065429	WO	A1	2018-04-12	XenomatiX N.V.		
	212	3316000	EP	A1	2018- 05-02	XenomatiX N.V.		
	213	2018122415	WO	A1	2018-07-05	XenomatiX N.V.		
	214	2018197441	WO	A1	2018-11-01	XenomatiX N.V.		

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	215	"HDL-32E", User's Manual 2010, Velodyne Lidar, Incorporated, Available Online at: https://www.yumpu.com/en/document/view/11661149/hdl-32e-manual-velodyne-lidar, August 2016, 28 pages.	
	216	"HDL-32E", Data Sheet 2010, Velodyne Lidar, Incorporated, Available Online at: http://pdf.directindustry.com/pdf/velodynelidar/hdl-32e-datasheet/182407-676098.html, 2017, 3 pages.	
	217	"HDL-32E", Velodyne Lidar, Incorporated, Available Online at: http://www.velodynelidar.com/hdl-32e.html, December 6, 2017, 3 pages.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	218	"HDL-64E", Velodyne Lidar, Incorporated, Available online at: http://www.velodynelidar.com/hdl-64e.html, December 6, 2017, 12 pages.	
	219	"HDL-64E S2", Data Sheet, Velodyne Lidar, Inc., Available online at: http://velodynelidar.com/lidar/products/brochure/HDL-64E%20S2%20datasheet_2010_lowres.pdf, 2017, 2 pages.	
	220	"HDL-64E S2 and S2.1", Velodyne Lidar, Incorporated, User's Manual and Programming Guide, Firmware version 4, 2007, 43 pages.	
	221	"HDL-64E S3", Velodyne Lidar, Incorporated, S3 User's Manual and Programming Guide Revision J, December 2017, 54 pages.	
	222	"Puck Hi-Res", Velodyne Lidar, Incorporated, Available Online at: http://www.velodynelidar.com/vlp-16-hi-res.html, December 13, 2017, 2 pages.	
	223	"Puck Hi-Res Data Sheet", Velodyne Lidar, Incorporated, September 2016, 2 pages.	
	224	"Puck Hi-Res User Manual", Velodyne Lidar, Incorporated, September 2016, 49 pages.	
	225	"Puck Lite", Velodyne Lidar, Incorporated, Our Lightest Sensor Ever, Available Online at: http://velodynelidar.com/vlp-16-lite.html, April 2016, 2 pages.	
	226	"Puck Lite Data Sheet", Velodyne Lidar, Incorporated, February 2016, 2 pages.	
	227	"Puck Lite User Manual", Velodyne Lidar, Incorporated, February 2016, 49 pages.	
	228	"Ultra Puck VLP-32C", Velodyne Lidar, Incorporated, Available Online at: http://velodynelidar.com/vlp-32c.html, November 2017, 4 pages.	
	229	"Velodyne LiDAR Puck", Velodyne Lidar, Incorporated, Available online at: http://www.velodynelidar.com/vlp-16.html, December 6, 2017, 48 pages.	
	230	"Velodyne LiDAR Puck", Velodyne Lidar, Incorporated, User's Manual and Programming Guide, 2014, 49 pages.	
	231	"VLP-16", Velodyne Lidar, Incorporated, Puck, Real Time 3D Lidar Sensor, 2014, 2 pages.	
	232	Application No 15/419,053, Non-Final Office Action, Mailed On July 28, 2017, 18 pages.	
	233	Application No 15/685,384, Non-Final Office Action, Mailed On August 17, 2020, 6 pages.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	234	Application No 15/685,384, Non-Final Office Action, Mailed On November 15, 2019, 6 pages.	
	235	Application No 15/685,384, Notice of Allowance, Mailed On February 12, 2020, 5 pages.	
	236	Application No 15/685,384, Notice of Allowance, Mailed On November 18, 2020, 7 pages.	
	237	15/934,613, "Corrected Notice of Allowability", December 28, 2018, 2 pages.	
	238	Application No 15/934,613, Non-Final Office Action, Mailed On July 6, 2018, 6 pages.	
	239	Application No 15/934,613, Notice of Allowance, Mailed On November 23, 2018, 5 pages.	
	240	16/123,988, "Corrected Notice of Allowability", June 22, 2020, 2 pages.	
	241	16/123,988, "Corrected Notice of Allowability", July 23, 2020, 3 pages.	
	242	16/123,988, "Ex Parte Quayle Action", February 3, 2020, 5 pages.	
	243	Application No 16/123,988, Notice of Allowance, Mailed On May 15, 2020, 5 pages.	
	244	AU2017315762, "First Examination Report", July 19, 2019, 5 pages.	
	245	AU2017315762, "Second Examination Report", November 13, 2019, 4 pages.	
	246	BRONZI et al., "100 000 Frames/s 64x32 Single Photon Detector Array for 2-D Imaging and 3-D Ranging", Institute of Electrical and Electronics Engineers Journal of Selected Topic in Quantum Electronics, Volume 20, No. 6, November-December 2014, 10 pages.	
	247	CHARBON et al., "SPAD-Based Sensors", TOF Range-Imaging Cameras, April 9, 2013, pp. 11-38.	
	248	Application No CN201780062843.6, Notice of Decision to Grant, Mailed On May 11, 2021, 6 pages.	
	249	Application No CN201780062843.6, Office Action, Mailed On September 28, 2020, 11 pages.	
	250	COVA et al., "Single-Photon Counting Detectors", Institute of Electrical and Electronics Engineers Photonics Journal, Volume 3, No. 2, April 2011, pp. 274-277.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

	251	Application No EP17844396.6, Extended European Search Report, Mailed On May 29, 2020, 9 pages.	
	252	GUERRIERI et al., "Two-Dimensional SPAD Imaging Camera for Photon Counting", Institute of Electrical and Electronics Engineers Photonics Journal, Volume 2, No. 5, October 2010, pp. 759-774.	
	253	Application No IL265003, Office Action, Mailed On October 13, 2021, 9 pages.	
	254	IN201947008121, "First Examination Report", August 2, 2021, 7 pages.	
	255	ITZLER et al., "Geiger-Mode Avalanche Photodiode Focal Plane Arrays for Three-dimensional Imaging LADAR", Proc of SPIE, Volume 7808, 2010, pp. 78080C-1-78080C-14.	
	256	Application No JP2019-531544, Notice of Decision to Grant, Mailed On November 16, 2020, 1 page.	
	257	Application No JP2019-531544, Office Action, Mailed On July 20, 2020, 5 pages.	
	258	Application No JP2020-208324, Office Action, Mailed On September 13, 2021, 7 pages.	
	259	KILPELA et al., "Precise Pulsed Time-of-Flight Laser Range Finder for Industrial Distance Measurements", Review of Scientific Instruments, Volume 72, No. 4, April 2001, pp. 2197-2202.	
	260	Application No PCT/US2017/039306, International Search Report and Written Opinion, Mailed On November 7, 2017, 21 pages.	
	261	PCT/US2017/039306, "Invitation to Pay Additional Fees and, Where Applicable, Protest Fee", August 31, 2017, 2 pages.	
	262	Application No PCT/US2017/048379, International Preliminary Report on Patentability, Mailed On March 7, 2019, 10 pages.	
	263	Application No PCT/US2017/048379, International Search Report and Written Opinion, Mailed On November 2, 2017, 11 pages.	
	264	Application No SG11201901600W, Notice of Decision to Grant, Mailed On April 13, 2021, 5 pages.	
	265	Application No SG11201901600W, Written Opinion, Mailed On March 28, 2020, 13 pages.	

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

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

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

CERTIFICATION STATEMENT

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

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

OR

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

☐ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

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

Signature	/ William L. Shaffer /	Date (YYYY-MM-DD)	2021-12-15
Name/Print	William L. Shaffer	Registration Number	37,234

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	Not Yet Assigned
	Filing Date	Not Yet Assigned
	First Named Inventor	Angus Pacala
	Art Unit	Not Yet Assigned
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	103033-P004USC4-1289479

is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	Optical System For Collecting Distance Information Within A Field
First Named Inventor/Applicant Name:	Angus Pacala
Filer:	William Leland Shaffer/Erica Rojas
Attorney Docket Number:	103033-P004USC4-1289479

Filed as Small Entity

Filing Fees for Track I Prioritized Examination - Nonprovisional Application under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
UTILITY FILING FEE (ELECTRONIC FILING)	4011	1	80	80
UTILITY SEARCH FEE	2111	1	350	350
UTILITY EXAMINATION FEE	2311	1	400	400
REQUEST FOR PRIORITIZED EXAMINATION	2817	1	2100	2100
Pages:				
Claims:				
CLAIMS IN EXCESS OF 20	2202	7	50	350
INDEPENDENT CLAIMS IN EXCESS OF 3	2201	1	240	240

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous-Filing:				
PUBL. FEE- EARLY, VOLUNTARY, OR NORMAL	1504	1	0	0
PROCESSING FEE, EXCEPT PROV. APPLS.	2830	1	70	70
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**3590**

Electronic Acknowledgement Receipt

EFS ID:	44528222
Application Number:	17552303
International Application Number:	
Confirmation Number:	1540
Title of Invention:	Optical System For Collecting Distance Information Within A Field
First Named Inventor/Applicant Name:	Angus Pacala
Customer Number:	20350
Filer:	William Leland Shaffer/Erica Rojas
Filer Authorized By:	William Leland Shaffer
Attorney Docket Number:	103033-P004USC4-1289479
Receipt Date:	15-DEC-2021
Filing Date:	
Time Stamp:	19:08:20
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$3590
RAM confirmation Number	E2021BEJ09024519
Deposit Account	201430
Authorized User	Erica Rojas

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

37 CFR 1.16 (National application filing, search, and examination fees)

37 CFR 1.17 (Patent application and reexamination processing fees)

37 CFR 1.19 (Document supply fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		2021-12-15_Track_One_Application_103033-P004USC4-1289479.pdf	259751 e52ed4ed294627fcaf19bbf4fdcf46e9d4752f2a	yes	42

Multipart Description/PDF files in .zip description

Document Description	Start	End
Specification	1	33
Claims	34	41
Abstract	42	42

Warnings:

Information:

2	Drawings-only black and white line drawings	2021-12-15_Drawings_103033-P004USC4-1289479.pdf	5001212 fb3fca38e70fb38fb6055a6eaf6b6d13403f64fe	no	15

Warnings:

Information:

3	Application Data Sheet	2021-12-15_Application_Data_Sheet_103033-P004USC4-1289479.pdf	1792756 6a9e247121e34c661701eea0434e591c495464bf	no	9

Warnings:

Information:

4	TrackOne Request	2021-12-15_Track_One_Request_103033-P004USC4-1289479.pdf	1005265 2146aa5a45a459eff03ea9452c7918be5fba7dec	no	2

Warnings:

Information:

5	Oath or Declaration filed	2021-12-15_Declarations_103033-P004USC4-1289479.pdf	339336 c8b3c9e844825998b1dd65a3b8df6593767284c5	no	4

Warnings:					
Information:					
6	Power of Attorney	2021-12-15_Power_of_Attorney_103033-P004USC4-1289479.pdf	819559 807f4ecaaf4180ca277d2668edf0c982ae997e08	no	2
Warnings:					
Information:					
7	Non Patent Literature	NPL_IL_265003_OA_10132021.pdf	2255295 de95d21e27346b8cc7b5179a9f31181d922b479a	no	9
Warnings:					
Information:					
8	Non Patent Literature	NPL_SG_11201901600W_DectoGrant_04132021.pdf	1031638 40db925185384887e2132cdcfd7b91d76a64efbd	no	5
Warnings:					
Information:					
9	Non Patent Literature	NPL_CN_201780062843-6_DectoGrant_05112021.pdf	198964 afa3d05e456b083263f117690c2ceb83a323b9ed	no	6
Warnings:					
Information:					
10		2021-12-15_Information_Disclosure_Statement_103033-P004USC4-1289479.pdf	304875 a9b2df279fae1a2ce4431c3e998179a5ebb44a3d	yes	16

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Transmittal Letter	1	2
	Information Disclosure Statement (IDS) Form (SB08)	3	16

Warnings:					
Information:					
11	Fee Worksheet (SB06)	fee-info.pdf	55552 7f9d2f440f4fe54c5f8c9b0e310470d8433c0a0f	no	2
Warnings:					

Information:	
Total Files Size (in bytes):	13064203

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

New Applications Under 35 U.S.C. 111

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

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

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

New International Application Filed with the USPTO as a Receiving Office

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

OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

CROSS-REFERENCE TO RELATED PATENT APPLICATION

[0001] This application is a continuation of U.S. Patent Application No. 17/194,068 filed, March 5, 2021, which is a continuation of U.S. Patent Application No. 15/685,384, filed August 24, 2017, which claims the benefit and priority to U.S. Provisional Application 62/379,130, filed on August 24, 2016. The contents of each of the 17/194,068, 15/685,384 and 62/379,130 applications are incorporated by reference herein for all purposes.

TECHNICAL FIELD

[0002] This invention relates generally to the field of optical sensors and more specifically to a new and useful system optical system for collecting distance information in the field of optical sensors.

BACKGROUND

[0003] Light detection and ranging (LiDAR) systems have been used in a wide range of applications, e.g., agriculture, forest planning and management, environmental assessment, survey, mapping, imaging, and vehicle automation etc. Unlike cameras, LiDAR systems can be operated at night and under any weather. Further, LiDAR systems are not affected by low sun angles, and can provide distance contours directly based upon returned lights from illuminated objects.

[0004] However, it remains a challenge to provide 2D or 3D distance information with higher precision, lower costs and faster results.

SUMMARY

[0005] Systems and methods in accordance with various examples of the present disclosure provide a solution to the above-mentioned problems. An example optical system for collecting distance information comprises a bulk receiving optic configured to collect illumination beams of a plurality of illumination sources reflected from a field outside the optical system; a pixel array comprising at least a first column of pixels and a second column of pixels, each pixel in the first column of pixels being offset from an adjacent pixel in the first column of pixels by a first pixel pitch, the second column of pixels being horizontally offset from the first column of pixels by the first pixel pitch, the second column of pixels being vertically offset from the first column of pixels by a first vertical pitch; and a set of input channels interposed between the first transmitting bulk receiving optic and the pixel array, the set of input channels comprising at least a first plurality of input channels and a second plurality of input channels, each of the first plurality of input channels configured to communicate one of the collected illumination beams from the first transmitting bulk receiving optic to a corresponding pixel in the first column of pixels, each of the second plurality of input channels configured to communicate one of the collected illumination beams from the bulk receiving optic to a corresponding pixel in the second column of pixels.

[0006] In one aspect of the present disclosure, the bulk receiving optic has a first focal length and defines a focal plane opposite the field. The set of input channels comprise an aperture layer disposed substantially coincident the focal plane, the aperture layer comprising a set of apertures that comprises at least a first plurality of apertures and a second plurality of

apertures; a set of lens, the set of lens comprising at least a first plurality of lens and a second plurality of lens, each of the first plurality of lens corresponding to one of the first plurality of apertures, each of the second plurality of lens corresponding to one of the second plurality of apertures; and an optical filter disposed adjacent to the set of lens and opposite the set of apertures.

[0007] In another aspect of the present disclosure, each input channel in the set of input channels is coaxial with a corresponding pixel in the pixel array such that the set of input channels is positioned in a skewed grid array substantially similar to the pixel array.

[0008] In yet another aspect of the present disclosure, each input channel in the set of input channels comprises a lens in the set of lens and a corresponding aperture in the set of apertures, the lens being substantially aligned with the corresponding aperture.

[0009] In yet another aspect of the present disclosure, each of the set of lens has a second focal length, and is configured to offset the focal plane opposite the bulk receiving optic by the second focal length and collimate light rays having wavelengths substantially equivalent to an operating wavelength of the optical system.

[00010] In yet another aspect of the present disclosure, the optical system further comprises a second transmitting bulk transmitting optic. The plurality of illumination sources is positioned along a focal plane of the second transmitting bulk transmitting optic, each illumination beam projected by the second transmitting bulk transmitting optic having substantially the same size and geometry as a field of view of a corresponding input channel in the set of input channels.

[00011] In yet another aspect of the present disclosure, the aperture layer is separately fabricated by selectively metallizing a glass wafer and etching the set of apertures into metallized glass wafer.

[00012] In yet another aspect of the present disclosure, the pixel array is integrated on a semiconductor wafer. The bulk receiving optic and the set of input channels are fabricated on the semiconductor wafer using at least one of photolithography technique or wafer-level bond technique.

[00013] In yet another aspect of the present disclosure, the fix first pixel pitch is n times of the first vertical pitch, in which n is a positive integer.

[00014] In yet another aspect of the present disclosure, the optical system further comprises an actuator configured to rotate the pixel array, the set of input channels and the bulk receiving optic around a vertical axis. The actuator comprises a rotary electric motor and an optical encoder, the rotary electric motor configured to control a rotational speed of the pixel array, the set of input channels and the bulk receiving optic based upon outputs of the optical encoder, the optical encoder coupled to the pixel array via a closed-loop feedback circuit.

[00015] An example method of making an optical system for collecting distance information comprises providing a bulk receiving optic configured to collect illumination beams of a plurality of illumination sources reflected from a field outside the optical system; providing a pixel array that comprises at least a first column of pixels and a second column of pixels, each pixel in the first column of pixels being offset from an adjacent pixel in the first column of pixels by a first pixel pitch, the second column of pixels being horizontally offset from the first column of pixels by the first pixel pitch, the second column of pixels being vertically offset from the first column of pixels by a first vertical pitch; and positioning a set of input channels interposed

between the bulk receiving optic and the pixel array, the set of input channels comprising at least a first plurality of input channels and a second plurality of input channels, each of the first plurality of input channels configured to communicate one of collected illumination beams from the first transmitting bulk receiving optic to a corresponding pixel in the first column of pixels, each of the second plurality of input channels configured to communicate one of the collected illumination beams from the bulk receiving optic to a corresponding pixel in the second column of pixels.

[00016] An example method of collecting distance information comprises using an optical system that has a bulk receiving optic configured to collect reflected illumination beams of a plurality of illumination sources from a field outside the optical system; a pixel array comprising at least a first column of pixels and a second column of pixels, each pixel in the first column of pixels being offset from an adjacent pixel in the first column of pixels by a first pixel pitch, the second column of pixels being horizontally offset from the first column of pixels by the first pixel pitch, the second column of pixels being vertically offset from the first column of pixels by a first vertical pitch; and a set of input channels interposed between the first transmitting bulk receiving optic and the pixel array, the set of input channels comprising at least a first plurality of input channels and a second plurality of input channels, each of the first plurality of input channels configured to communicate one of collected illumination beams from the first transmitting bulk receiving optic to a corresponding pixel in the first column of pixels, each of the second plurality of input channels configured to communicate one of the collected illumination beams from the first transmitting bulk receiving optic to a corresponding pixel in the second column of pixels.

[00017] An example method of collecting distance information comprises providing an optical system that has a bulk receiving optic configured to collect reflected illumination beams of a plurality of illumination sources from a field outside the optical system; a pixel array comprising at least a first column of pixels and a second column of pixels, each pixel in the first column of pixels being offset from an adjacent pixel in the first column of pixels by a first pixel pitch, the second column of pixels being horizontally offset from the first column of pixels by the first pixel pitch, the second column of pixels being vertically offset from the first column of pixels by a first vertical pitch; and a set of input channels interposed between the bulk receiving optic and the pixel array, the set of input channels comprising at least a first plurality of input channels and a second plurality of input channels, each of the first plurality of input channels configured to communicate one of collected illumination beams from the bulk receiving optic to a corresponding pixel in the first column of pixels, each of the second plurality of input channels configured to communicate one of the collected illumination beams from the bulk receiving optic to a corresponding pixel in the second column of pixels.

BRIEF DESCRIPTION OF THE FIGURES

[00018] FIGURE 1 is a schematic representation of a system;

[00019] FIGURE 2 is a schematic representation of one variation of the system;

[00020] FIGURES 3A and 3B are graphical representations of one variation of the system;

[00021] FIGURE 4 is a schematic representation of one variation of the system; and

FIGURES 5A1-5A2, 5B1-5B3, 5C1-5C3, and 5D1-5D3

[00022] are graphical representations of one variation of the system.

DESCRIPTION OF THE EMBODIMENTS

[00023] The following description of embodiments of the invention is not intended to limit the invention to these embodiments but rather to enable a person skilled in the art to make and use this invention. Variations, configurations, implementations, example implementations, and examples described herein are optional and are not exclusive to the variations, configurations, implementations, example implementations, and examples they describe. The invention described herein can include any and all permutations of these variations, configurations, implementations, example implementations, and examples.

1. SYSTEM

[00024] As shown in FIGURES 1 and 2, a system for collecting distance information within a field includes: a bulk receiving optic; a pixel block; a first set of input channels; and a second set of input channels. The pixel block includes: a first column of pixels, each pixel in the first column vertically offset from an adjacent pixel in the first column by a pixel pitch; and a second column of pixels horizontally offset from the first column by the pixel pitch and vertically offset from the first column by a vertical pitch, each pixel in the second column vertically offset from an adjacent pixel in the second column by the pixel pitch, the vertical pitch comprising a fraction of the pixel pitch. The first set of input channels interposed between the bulk receiving optic and the pixel block, each input channel in the first set of input channels configured to communicate light incident from the bulk receiving optic to a corresponding pixel in the first column of pixels. The second set of input channels horizontally offset from the set of input channels and interposed between the bulk receiving optic and the pixel block, each input channel in the second set of input channels configured to communicate light incident from the bulk receiving optic to a corresponding pixel in the second column of pixels.

2. Applications

[00025] The system functions as an image sensor that, when rotated about an axis parallel to a column of pixels, collects three-dimensional distance data of a volume occupied by the system. In particular, during operation, the system can collect three-dimensional distance data over each of a sequence of scan cycles and can reconstruct these into a virtual three-dimensional representation of the volume occupied by the system, such as based on recorded times between transmission of an illuminating beam from an illumination source and detection of photons at the same or similar frequency or temporal patter at each pixel or by implementing phase-based measurement techniques.

[00026] The system includes two or more columns of pixels in a skewed grid array layout, wherein adjacent columns of pixels are vertically and horizontally offset such that the set of pixels project onto a single vertical column of pixels with one pixel per row. The system also includes one input channel per pixel, and the input channels pass light from a common bulk receiving optic to their corresponding pixels. The system can also include an actuator that rotates the pixel block, the input channels, and the bulk receiving optic about a vertical axis such that each pixel (and each corresponding input channel) traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by each other pixel in the system during a single rotation of the rotary actuator (hereinafter a "scan cycle"). The system can collect data from each pixel at each of multiple arcuate sampling positions within one scan cycle and combine these data collected from multiple columns of pixels into a single vertical column of distances – to external surfaces within (approximately) a single vertical plane coincident the axis of rotation of the system – for each arcuate sampling period within the scan cycle.

Therefore, the system can output data (e.g., distance values) in a format substantially similar to data output by a similar scanning system including only a single column of pixels. However, because the system includes multiple vertically- and horizontally-offset columns of pixels, each pixel in the system can define a greater height – and therefore include a greater number of detectors and exhibit a greater dynamic range – than a pixel in the similar scanning system of approximately the same overall height and including the same number of pixels at the same effective (vertical) pixel pitch.

[00027] The system can output a matrix of range values per scan cycle, wherein all range values in one row of the matrix correspond to outputs of one specific pixel in the pixel block, and wherein each range value in one row of the matrix corresponds to an output of the corresponding pixel at a unique angular position of the sensor block within one scan cycle. Because adjacent pixels columns in the system are horizontally and vertically offset from one another, the system populates each row of a matrix for a scan cycle with one range value at a time (i.e., per target angular sampling position) rather than simultaneously. Horizontal and vertical offset between adjacent columns of pixels also enables each pixel in the system to span a greater area (and thus include more detectors) for a given effective vertical pitch of the system, thereby yielding a relatively large ratio of dynamic range to size of the optical system. Furthermore, though the area of each pixel on the pixel block spans a relatively large area, each pixel is paired with an input channel including an aperture that constrains the field of view of the pixel such that the pixel retains relatively high spatial selectivity. Therefore, the system can include horizontally and vertically offset columns of pixels and corresponding input channels that enable: high dynamic range through large pixel areas; high spatial selectivity through small fields of view for

each pixel; and high resolution through small effective pixel vertical pitch within a compact system.

3. Pixel

[00028] The system includes multiple pixels, and each pixel can include one or more detectors configured to detect incident light. For example, a pixel can output a count of incident photons, a time between incident photons, a time of incident photons (e.g., relative to an illumination output time), or other relevant data, and the system can transform these data into distances from the system to external surfaces in the fields of view of these pixels. By merging these distances with the position of pixels at which these data originated and relative positions of these pixels at a time that these data were collected, the system (or other device accessing these data) can reconstruct a three-dimensional (virtual or mathematical) model of a space occupied by the system, such as in the form of 3D image represented by a rectangular matrix of range values, wherein each range value in the matrix corresponds to a polar coordinate in 3D space.

[00029] Each detector within a pixel can be configured to detect a single photon per sampling period. A pixel can thus include multiple detectors in order to increase the dynamic range of the pixel; in particular, the dynamic range of the pixel (and therefore of the system) can increase as a number of detectors integrated into each pixel increases, and the number of detectors that can be integrated into a pixel can scale linearly with the area of the pixel. For example, a pixel can include an array of single-photon avalanche diode detectors ("SPADs"), such as 32 detectors on a 6x6 grid array less one detector in each of four corners, as shown in FIGURE 4. For detectors ten microns in diameter, the pixel can define a footprint approximately

400 microns square. However, the system can include any other type of pixel including any other number of detectors.

4. Pixel Pattern

[0030] The system includes a pixel block including: a first column of pixels, each pixel in the first column vertically offset from an adjacent pixel in the first column by a pixel pitch; and a second column of pixels horizontally offset from the first column by the pixel pitch and vertically offset from the first column by a vertical pitch, each pixel in the second column vertically offset from an adjacent pixel in the second column by the pixel pitch, the vertical pitch comprising a fraction of the pixel pitch. Generally, the pixel block includes multiple rows and columns of pixels in a skewed grid array, wherein each column includes multiple pixels vertically aligned, and wherein each row corresponds to a unique vertical distance from the nominal axis of the bulk receiving optic and includes a single pixel, as shown in FIGURES 1, 2, and 4. In particular, the pixel block can include multiple columns of pixels laterally and vertically offset – compared to a single column of pixels – to enable each pixel to be taller and wider – thereby enabling each pixel to include a greater number of detectors and increasing the dynamic range of the system – without necessitating a taller pixel block to accommodate such greater vertical pitch between pixels.

[0031] In one implementation, the pixel block and pixels are integrated into a singular integrated circuit. For example, the pixel block and pixels can be defined in a single application-specific integrated circuit (or "ASIC"). In this example, each input channel can include an aperture that limits the field of view of a corresponding pixel on the ASIC in order to achieve greater spatial selectivity for the pixel.

4.1 Pixel Pattern: 32 x 2:

[0032] In one configuration, the system includes two columns of pixels, such as a 32 x 2 array of pixels and a corresponding 32 x 2 array of input channels that share a common bulk receiving optic. In this configuration, the system may exhibit a bulk resolution identical to that of a single-column system including the same number of pixels arranged on a pixel block of approximately the same height at the same effective vertical pixel pitch, but the two-column system may exhibit greater dynamic range than the single-column system. In particular, pixels in both a first column and a second column of the two-column system can be offset vertically by a second vertical pitch double a first vertical pitch of the single-column system (e.g., 200 microns versus 100 microns), and the second column of pixels can be offset vertically from the first column of pixels by half of the second virtual pitch, thereby providing space in the two-column system for pixels twice the height of pixels in the single-column system given the same number of pixels arranged on a pixel block of approximately the same height. Therefore, for square pixels, each pixel in the two-column system can define an area approximately four times that of a pixel in the single-column system, can thus include approximately four times the number of detectors as a pixel in the single-column system, and can thus exhibit approximately four times the dynamic range of a pixel in the single-column system. For example, for a pixel block approximately 640 microns tall and including 64 pixels (i.e., a 100-micron vertical pitch): the single-column system can include 64 100-micron-square pixels, each pixel including four 50-micron-wide detectors; and the two-column system can include a first column of 32 200-micron-square pixels and a second column of 32 200-micron-square pixels, each pixel including eight 50-micron-wide detectors.

[0033] However, because the two-column system includes two columns of pixels, wherein both columns are horizontally offset from a horizontal center of the system (i.e., a y-axis of the pixel block), pixels in the first column can exhibit fields of view angularly offset – in the horizontal plane – from fields of view of pixels in the second column. Thus, the fields of view of pixels in the first column can be offset laterally from fields of view of pixels in the second column by greater amounts at increasing distances from the system. Horizontal offset between the two columns of pixels that share the same bulk receiving optic can thus manifest as angular offset – in a horizontal plane – between the fields of view of the first column of pixels and the fields of view of the second column of pixels (hereinafter "horizontal distortion").

[0034] Furthermore, such horizontal distortion may not be uniform across pixels in one pixel column. In particular, the field of view of a pixel in the first pixel column can be angularly offset from a center (e.g., normal) axis of the bulk lens as a function of distance of the pixel from the center axis of the bulk optic such that a pixel at the bottom of the first pixel column exhibits a maximum negative angular offset in the horizontal plane and such that a pixel at the top of the first pixel column exhibits a similar maximum positive angular offset in the horizontal plane. However, the system can compensate for such variations in horizontal offset angles (e.g., "yaw" angles) of fields of view of pixels in each column in a correction matrix, as described below.

4.2 Pixel Pattern: 16 x 4:

[0035] In another configuration shown in FIGURES 1 and 2, the system includes four columns of pixels, such as a 16 x 4 array of pixels and a corresponding 16 x 4 array of input channels that share a common bulk receiving optic. In this configuration, the system may exhibit a bulk resolution identical to that of one- and two-column systems including the same number of

pixels arranged on a pixel block of approximately the same height at the same effective vertical pixel pitch, but the four-column system may exhibit greater dynamic range than the one- and two-column systems. In particular, pixels in each column of the four-column system can be offset vertically by a fourth vertical pitch half the second vertical pitch of the two-column system (e.g., 400 microns versus 200 microns), and each column of pixels in the four-column system can be offset vertically from an adjacent column of pixels by one-quarter of the fourth virtual pitch, thereby providing space in the four-column system for pixels twice the height of pixels in the two-column system given the same number of pixels arranged on a pixel block of approximately the same height. Therefore, for square pixels, each pixel in the four-column system can define an area approximately four times that of a pixel in the two-column system, can thus include approximately four times the number of detectors as a pixel in the two-column system, and can thus exhibit approximately four times the dynamic range of a pixel in the two-column system. In the example above, for a pixel block approximately 640 microns tall and including 64 pixels, the four-column system can include four columns of pixels, each column including sixteen 400-micron-square pixels, each pixel including 32 50-micron-wide detectors.

[0036] However, because the four-column system includes four columns of pixels, all horizontally offset from a center of the system, pixels in a leftmost column can exhibit fields of view angularly offset – in the horizontal plane – from fields of view of pixels in a rightmost column greater than (e.g., twice) the angular offset – in the horizontal plane – between fields of view of pixels in the first and second columns of the two-column system described above. The four-column system can thus exhibit greater horizontal distortion than the two-column system, such as shown in FIGURE 3A.

4.3 Pixel Pattern: 8 x 8:

[0037] In yet another configuration, the system includes eight columns of pixels, such as an 8 x 8 array of pixels and a corresponding 8 x 8 array of input channels that share a common bulk receiving optic. In this configuration, the system may exhibit a bulk resolution identical to that of one-, two-, and four-column systems including the same number of pixels arranged on a pixel block of approximately the same height at the same effective vertical pixel pitch , but the eight-column system may exhibit greater dynamic range than the one-, two-, and four-column systems. In particular, pixels in each column of the eight -column system can be offset vertically by an eight vertical pitch twice the fourth vertical pitch of the four-column system (e.g., 800 microns versus 400 microns), and each column of pixels in the eight-column system can be offset vertically from an adjacent column of pixels by one-eighth of the eight virtual pitch, thereby providing space in the eight-column system for pixels twice the height of pixels in the four-column system given the same number of pixels arranged on a pixel block of approximately the same height. Therefore, for square pixels, each pixel in the eight-column system can define an area approximately four times that of a pixel in the four-column system, can thus include approximately four times the number of detectors as a pixel in the four-column system, and can thus exhibit approximately four times the dynamic range of a pixel in the four-column system. In the example above, for a pixel block approximately 640 microns tall and including 64 pixels, the eight-column system can include eight columns of pixels, each column includes eight 800-micron-square pixels, each pixel including ~120 50-micron-wide detectors.

[0038] However, because the eight-column system includes eight columns of pixels, all horizontally offset from a center of the system, pixels in a leftmost column can exhibit fields of view angularly offset – in the horizontal plane – from fields of view of pixels in a rightmost

column twice the angular offset – in the horizontal plane – between fields of view of pixels in the leftmost and rightmost columns of the four-column system. The eight-column system can thus exhibit greater horizontal distortion than the four-column system described above.

[0039] However, the system can include any other number of pixels arranged in any other number of columns or rows to achieve at least a threshold resolution, a minimum dynamic range, a maximum horizontal and/or vertical optical distortion of the fields of views of pixels on the periphery of the pixel block, or a maximum width and/or height of the pixel block, etc.

5. Bulk Receiving Optic and Input Channels

[0040] As shown in FIGURES 1, 3A, and 3B, the system also includes: a bulk receiving optic; a first set of input channels interposed between the bulk receiving optic and the pixel block, each input channel in the first set of input channels configured to communicate light incident from the bulk receiving optic to a corresponding pixel in the first column of pixels; and a second set of input channels horizontally offset from the set of input channels and interposed between the bulk receiving optic and the pixel block, each input channel in the second set of input channels configured to communicate light incident from the bulk receiving optic to a corresponding pixel in the second column of pixels. Generally, the bulk receiving optic functions to collect light (i.e., electromagnetic radiation) from outside the system; and each input channel functions to collect light from the bulk receiving optic, to filter this light, and to pass light over a relatively narrow wavelength band to a corresponding pixel in the pixel block.

[0041] In one implementation, each input channel is coaxial with its corresponding pixel such that the first and second sets of input channels are arranged in a skewed grid array substantially similar to the skewed grid array defined by the pixels, as described above. Each

input channel can include: an aperture arranged on the focal plane; a filter configured to pass perpendicular incident light at an operating frequency (or within a narrow operating band); an input lens interposed between the aperture and the filter and configured to output collimated light to the filter; and an output lens adjacent the filter opposite the input lens and configured to spread light passed by the filter across a corresponding pixel in the pixel block (and/or to re-focus light passed by the filter into the active areas of a corresponding pixel). Generally, the bulk receiving optic, apertures, input lenses, optical filter, and the pixels cooperate to collect light (e.g., ambient light and light output by the illumination source), to collimate this light, to reject all light outside of a narrow band of wavelengths including a center output wavelength of an illumination source (described below), and to detect light that reached the pixel. The system can thus transform an incident photon count, a time between incident photons, an incident photon time relative to an illumination beam output time, etc. recorded by a particular pixel during one sampling period into a distance from the system to an external surface in a field of view of the particular pixel, as defined by a corresponding input channel and the bulk receiving optic.

[0042] In this implementation, the set of input channels can be defined in a single input block including: an aperture layer arranged behind the bulk receiving optic and defining one input aperture per input channel; a lens layer adjacent the aperture layer opposite the bulk receiving optic and defining an input lens substantially axially aligned with a corresponding input aperture for each input channel; and an optical filter adjacent the lens layer opposite the aperture layer and spanning the lens layer. In this implementation, the bulk receiving optic is characterized by a bulk focal distance, is offset from a focal plane by the bulk focal distance, and functions to project incident light rays from outside the system toward the focal plane. For example, the bulk receiving optic can include multiple lenses, such as one or more bi-convex

lenses (shown in FIGURES 1 and 4) and/or plano-convex lenses, that cooperate to form a converging lens characterized by a particular bulk focal length at or near the center wavelength of perpendicular light rays passed by the optical filter (i.e., a "nominal operating wavelength of the system"). (The bulk receiving lens can also define a nominal axis perpendicular to the focal plane, as referenced below.)

[0043] The aperture layer: includes a relatively thin opaque structure arranged behind the bulk receiving optic and coincident the focal plane; and defines one aperture per input channel and a stop region around the apertures. The stop region of the aperture layer rejects (e.g., blocks, absorbs, reflects) incident light rays, and each aperture passes incident light rays toward its corresponding input lens. For example, the aperture layer can define a set of apertures, wherein each aperture is of a diameter approaching a diffraction-limited diameter to maximize geometrical selectivity of the field of view of the system.

[0044] In this implementation, the input lens is characterized by a second focal length, is offset from the focal plane by the second focal length, collimates lights rays passed by the aperture, and passes collimated light rays to the optical filter. For example, the input block can include one input lens per channel, wherein each input lens includes a converging lens characterized by a ray cone substantially matched to a ray cone of the bulk receiving optic and can be offset from the focal plane of the bulk receiving optic by a relatively short second focal length to preserve the aperture of the bulk receiving optic and to collimate light passed by a corresponding aperture. The optical filter receives collimated light – in a spectrum of wavelengths – from the input lens, passes a relatively narrow band of wavelengths of light (e.g., the operating wavelength +/- 0.25 nanometers) to the corresponding pixel, and blocks (e.g.,

reflects, absorbs) light outside of this narrow wavelength band. For example, the optical filter can include a narrow optical bandpass filter.

[0045] In one example in which the system includes an illumination source, as described below, the illumination source can output light (predominantly) at a nominal wavelength of 900 nm, and the optical filter can define a planar optical bandpass filter configured to pass light (incident on the optical filter at an angle of 90°) between 899.95 nm and 900.05 nm and configured to block substantially all light (incident on the optical filter at an angle of 90°) outside of this band. A pixel in the set of pixels can thus receive light (i.e., "photons") passed by the optical filter, detect these incident photons, and output a signal corresponding to a number or rate of detected photons during a sampling period.

[0046] In this implementation, the bulk receiving optic, the aperture layer, the lens layer, the optical filter, and the output lenses can be fabricated and then aligned with and mounted onto the pixel block. In one example, the optical filter is fabricated by coating a fused silica substrate. Photoactive optical polymer is then deposited over the optical filter, a lens mold defining an array of lens forms placed over the photoactive optical polymer, and a UV light source activated to cure the photoactive optical polymer into a pattern of lenses across the optical filter. Standoffs are similarly molded or formed across the optical filter via photolithography techniques. The aperture layer is separately fabricated by selectively metallizing a glass wafer and etching apertures into this metallic layer; the glass wafer is then bonded or otherwise mounted to these standoffs. In this example, the assembly is subsequently inverted, and a second set of standoffs is similarly fabricated across the optical filter opposite the lens layer. The pixel block (e.g., a discrete image sensor) is aligned with and bonded to the second set of standoffs; the bulk receiving optic is similarly mounted over the aperture layer to complete the system.

[0047] Alternatively, the pixel block can be fabricated on a semiconductor wafer (e.g., in the form of an application-specific integrated circuit), and the bulk receiving optic, the aperture layer, the lens layer, and the optical filter can be fabricated directly onto the semiconductor wafer – over the pixel block – via photolithography and wafer-level bonding techniques. However, the bulk receiving optic, the aperture layer, the lens layer, the optical filter, and the pixel block can be fabricated and assembled in any other way and according to any other method or technique.

6. Output Circuit

[0048] The system can include an output circuit, including a bulk transmitting optic and an illumination source. In one implementation, the bulk transmitting optic: is substantially identical to the bulk receiving optic in material, geometry (e.g., focal length), optical properties, and/or thermal isolation, etc.; and is adjacent and offset laterally and/or vertically from the bulk receiving optic.

[0049] In one example, the illumination source includes a monolithic VCSEL array of optical emitters arranged behind the bulk transmitting optic. In this example, the illumination source can include a laser diode array defining a column of optical emitters characterized by an emitter pitch distance substantially identical to the aperture pitch distance. In this example, each optical emitter can output an illuminating beam of an initial diameter substantially identical to (or slightly greater than) the diameter of a corresponding aperture in the aperture layer, and the illumination source can be arranged along the focal plane of the bulk transmitting optic such that each illuminating beam projected from the bulk transmitting optic into the field ahead of the system is of substantially the same size and geometry as the field of view of a corresponding input channel – and therefore the field of view of a corresponding pixel – at any distance from

the system. Therefore, the illumination source and the bulk transmitting optic can cooperate to project substantially illuminating beams into the fields of view of the input channels with relatively little or no light projected beyond these fields of view of the input channels.

[0050] In this example, the system can selectively project illuminating beams into a field ahead of the system according to an illumination pattern that substantially matches – in size and geometry across a range of distances from the system – the fields of view of the input channels (e.g., fields of view defined by the apertures). Therefore, the illumination source can illuminate substantially only surfaces in the field ahead of the system that are within the fields of view of corresponding pixels such that minimal power output by the system via the illumination source is wasted by illuminating surfaces in the field for which the pixels are blind. Furthermore, the center output wavelength of the illumination source can be matched to the center wavelength passed by the filter. The system can thus achieve a relatively high ratio of signal (e.g., photons originating from the illumination source and passed to the pixels on the sensor block) to noise (e.g., photons not originating from the illumination source, such as ambient light, and passed to the pixels on the sensor block).

7. Data Acquisition

[0051] During operation, the system can collect light data from the set of pixels and transform these light data into distance values during a single sampling period. In one implementation, during a sampling period, the system: activates the illumination source of the output circuit in order to project light into fields of view of each pixel and input channel; records a time that the illumination source was activated (an "illumination timestamp"); and reads each detector in each pixel, such as by storing in memory a number of detectors in each pixel that

recorded an incident photon since a last sampling period and incident times of these photons and then clearing all detectors in each pixel. During a sampling period, the system can also calculate a distance to a surface in a field of view of a pixel based on a difference between the illumination timestamp and a time of peak frequency of incident photons since the last sampling period for each pixel in the set. For example, for each pixel, upon conclusion of a sampling period, the system can implement time of flight techniques to transform an illumination timestamp and a time of peak incident photon rate at a pixel between the current and a last sampling period into a distance from the system to an external surface within the field of view of the pixel. However, the system can implement any other method of technique to illuminate fields of view of each pixel and input channel during a sampling period and to process data collected from the set of pixels into distance values or related values.

[0052] The system can further include an actuator configured to rotate the pixel block, input block, and bulk receiving optic during operation. For example: the rotary actuator can include a rotary electric motor with an optical encoder; the pixel block, input block, and bulk receiving optic can be mounted in-unit on an output shaft of the rotary electric motor; and the system can implement closed-loop feedback controls to maintain the rotational speed of the rotary electric motor at 60Hz (or 360rpm) based on outputs of the optical encoder.

[0053] As described below, the system can execute one sampling period at each of a number of arcuate sampling positions per single rotation of the pixel block. For example, the system can execute 2048 arcuate sampling positions and output a single nominal matrix containing 2048 columns of distance values per each 360° rotation of the pixel block (i.e., scan cycle), wherein a single nominal matrix generated during a scan cycle thus represents distances

from the system to external surfaces 360° around the sensor (at some viewing angle defined by the bulk receiving optic and a number of pixels in each column of pixels).

8. Nominal Matrix

[0054] Because the system includes multiple columns of pixels, data output by the set of pixels during a single sampling period corresponds to multiple columns of distance values, each column corresponding to a unique yaw angle relative to the pixel block. Similarly, because each pixel in the system is arranged at a unique vertical position (i.e., because the array of pixels project to a single column of non-overlapping pixels), data output by the set of pixels during a single sampling period corresponds to multiple rows of distance values, wherein each row includes a single distance value and corresponds to a unique pitch angle relative to the pixel block. In particular, the system can assemble data collected from the set of pixels during a single sampling period into multiple incomplete columns of distance values, wherein each incomplete column of distance values corresponds to one unique yaw angle.

[0055] However, the system can combine distance values generated from data collected from a second column of pixels during a first sampling period with distance values generated from data collected by a first column of pixels during a second sampling period in order to complete a second column of distance values, as shown in FIGURES 5A1-5A2. The system can repeat this process at each arcuate sampling position during a single rotation of the system (i.e., a single scan cycle) in order to generate a matrix (or other data container) containing one complete column of distance values for non-overlapping pitch angles for each arcuate sampling position implemented by the system, as shown in FIGURES 5D1-5D3.

[0056] In one example, the system includes a 16 x 4 array of pixels with a vertical offset of Y between adjacent columns of pixels and a pixel pitch of 4Y in each column of pixels, as shown in FIGURES 2 and 4. In this example, the system implements 2048 sampling periods per rotation for an angular offset of 0.176° between adjacent arcuate sampling positions. At a first arcuate sampling position of 0°, the system executes a first sampling routine, as described above. The system then: populates the [(1,1), (5,1), (9,1),...(57,1), and (61,1)] positions within a distance matrix with distance values calculated from data received from the first, second, third, fourth,... fifteenth, and sixteenth pixels in the first column, respectively, during the first sampling period; populates the [(2,2), (6,2), (10,2),...(58,2), and (62,2)] positions within the distance matrix with distance values calculated from data received from the first, second, third, fourth,... fifteenth, and sixteenth pixels in the second column, respectively; populates the [(3,3), (7,3), (11,3),...(59,3), and (63,3)] positions within the distance matrix with distance values calculated from data received from the first, second, third, fourth,... fifteenth, and sixteenth pixels in the third column, respectively; and populates the [(4,4), (8,4), (12,4),...(60,4), and (64,4)] positions within the distance matrix with distance values calculated from data received from the first, second, third, fourth,... fifteenth, and sixteenth pixels in the fourth column, respectively, as shown in FIGURES 5A1-5A2.

[0057] During the same scan cycle, the rotary actuator rotates the pixel block to a next arcuate sampling position of 0.176°, and the system then executes a second sampling routine. During the second sampling, the system: populates the [(1,2), (5,2), (9,2),...(57,2), and (61,2)] positions within the distance matrix with distance values calculated from data received from the first, second, third, fourth,... fifteenth, and sixteenth pixels in the first column, respectively, during the second sampling period; populates the [(2,3), (6,3), (10,3),...(58,3), and (62,3)]

positions within the distance matrix with distance values calculated from data received from the first, second, third, fourth,... fifteenth, and sixteenth pixels in the second column, respectively; populates the [(3,4), (7,4), (11,4),...(59,4), and (63,4)] positions within the distance matrix with distance values calculated from data received from the first, second, third, fourth,... fifteenth, and sixteenth pixels in the third column, respectively; and populates the [(4,5), (8,5), (12,5),...(60,5), and (64,5)] positions within the distance matrix with distance values calculated from data received from the first, second, third, fourth,... fifteenth, and sixteenth pixels in the fourth column, respectively, as shown in FIGURES 5B1-5B3. The system repeats this process for each subsequent arcuate sampling position of the scan cycle, such as shown in FIGURES 5C1-5C3 and 5D1-5D3, in order to form a 2048 x 64 matrix containing 2048 columns, wherein each column corresponds to a unique yaw angle relative to the rotary actuator and contains 64 distance values, wherein each distance value in a column corresponds to a unique pitch angle relative to the pixel block, as shown in FIGURE 3B.

[0058] The system can thus construct one nominal matrix containing a column of distance values corresponding to each arcuate sampling position within a single 360° rotation of the pixel per scan cycle. In particular, the system can generate one nominal matrix – per scan cycle – representing distances of surfaces from the pixel block about a full 360° rotation axis of the system. For example, the rotary actuator can rotate the system at a rate of 360 rpm, and the system can generate one nominal matrix per 16.7 milliseconds (i.e., at a rate of 60Hz).

[0059] Furthermore, to achieve vertical alignment of the pixel columns at each sampling position, two adjacent columns of pixels (and two corresponding columns of input channels) can be horizontally offset by a horizontal pitch distance corresponding to a focal length of the bulk receiving optic and an angular pitch between adjacent arcuate sampling positions. In one

example, the pixel block includes a 16 x 4 array of pixels, the bulk receiving optic is characterized by a focal length of 10 millimeters, each input channel is coaxial with its corresponding pixel, and the system implements 2048 sampling periods per scan cycle (i.e., per rotation). In this example, the angular offset between adjacent arcuate sampling positions is .176°, and the horizontal offset between adjacent pixel columns – and adjacent columns of corresponding apertures – is 400 microns such that the second column of pixels at a second arcuate sampling position of .176° is vertically aligned with a first column of pixels in a first arcuate sampling position of 0°. During a single scan cycle, the system can thus sample all pixels at each of the 2048 arcuate sampling positions to collect 2048 columns of light data in a single 360° rotation.

9. Distortion Correction

[0060] Because the system contains multiple laterally-offset columns of pixels sharing a common bulk receiving optic, the fields of view of pixels in two adjacent columns of pixels may not share the same yaw angle relative to the pixel block, as shown in FIGURE 3A. Thus, a column in a nominal matrix constructed from data collected over a sequence of sampling periods during a scan cycle can contain a set of distance values representing multiple different true yaw angles relative to the pixel block. For example, for the system described above that includes a 16 x 4 skewed grid array of pixels: pixels in the first column can exhibit fields of view offset -.03° in yaw from the nominal axis of the bulk receiving optic; pixels in the second column can exhibit fields of view offset-.01° in yaw from the nominal axis of the bulk receiving optic; pixels in the third column can exhibit fields of view offset+.01° in yaw from the nominal axis of the bulk receiving optic; and pixels in the fourth column can exhibit fields of view offset +.03° in yaw

from the nominal axis of the bulk receiving optic given a particular operating temperature. In this example: a (1,1) distance value in the nominal matrix can thus represent a distance to a surface in a field of view angularly offset from the nominal axis of the bulk receiving optic by -.03° in yaw; a (2,1) distance value in the nominal matrix can thus represent a distance to a surface in a field of view angularly offset from the nominal axis of the bulk receiving optic by -.01° in yaw; ... a (63,1) distance value in the nominal matrix can thus represent a distance to a surface in a field of view angularly offset from the nominal axis of the bulk receiving optic by +.01° in yaw; and a (64,1) distance value in the nominal matrix can thus represent a distance to a surface in a field of view angularly offset from the nominal axis of the bulk receiving optic by +.03° in yaw at the particular operating temperature.

[0061] Similarly, because pixels in a single column within the system are vertically offset but share a common bulk receiving optic, the fields of view of two adjacent pixels in one column of pixels may not share the same pitch angle relative to the pixel block, as shown in FIGURE 3B. Thus, a column in a nominal matrix constructed from data collected during a scan cycle can contain a set of distance values representing multiple different true yaw pitch angles relative to the pixel block. For example, for the system described above that includes a 16 x 4 skewed grid array of pixels: a first pixel in the first column can exhibit a field of view offset +.25° in pitch from the nominal axis of the bulk receiving optic; a second pixel in the first column can exhibit a field of view offset +.22° in pitch from the nominal axis of the bulk receiving optic; ...a sixteenth pixel in the first column can exhibit a field of view offset -.25° in pitch from the nominal axis of the bulk receiving optic; a first pixel in the second column can exhibit a field of view offset +.243° in pitch from the nominal axis of the bulk receiving optic; a second pixel in the second column can exhibit a field of view offset +.235° in pitch from the nominal axis of the bulk

receiving optic; ... a sixteenth pixel in the second column can exhibit a field of view offset -.258° in pitch from the nominal axis of the bulk receiving optic; etc. In this example: a (1,1) distance value in the nominal matrix can thus represent a distance to a surface in a field of view angularly offset from the nominal axis of the bulk receiving optic by +.25° in pitch; a (2,1) distance value in the nominal matrix can represent a distance to a surface in a field of view angularly offset from the nominal axis of the bulk receiving optic by +.243° in pitch; a (3,1) distance value in the nominal matrix can represent a distance to a surface in a field of view angularly offset from the nominal axis of the bulk receiving optic by +.235° in pitch; a (4,1) distance value in the nominal matrix can represent a distance to a surface in a field of view angularly offset from the nominal axis of the bulk receiving optic by +.228° in pitch; a (5,1) distance value in the nominal matrix can represent a distance to a surface in a field of view angularly offset from the nominal axis of the bulk receiving optic by +.22° in pitch; etc.

[0062] The system can thus generate a nominal matrix containing distance values – corresponding to data collected by the set of pixels during a scan cycle – representing distances to surfaces in fields of view offset from the nominal axis of the bulk receiving optic in both pitch and yaw axes. In particular, the system can generate a nominal matrix containing a column of distance values representing a single "ideal" yaw angle of 0° relative to the sensor block (e.g., similar to fields of view of a single column of pixels), but the real horizontal offset between columns of pixels in the system can yield a difference between this ideal yaw angle and the actual yaw angle of fields of view of pixels represented in this column of distance values in the nominal matrix; this difference can manifest as distortion of distance data along the horizontal axis. Similarly, pixels in a single column of pixels can exhibit fields of view that increase in pitch angle offset from the nominal axis of the bulk receiving optic with increasing distance from

the center of the grid array of pixels, which can manifest as a lowest resolution at the first and last rows and as a greatest resolution at the center row(s) in the nominal matrix.

[0063] The system can thus pair a nominal matrix with a correction matrix defining pitch and yaw offset angles for each entry in the nominal matrix. In particular, by merging distance values contained in a nominal matrix output in a scan cycle with corresponding angular values contained in a correction matrix, the system (or other device) can calculate positions of surfaces detected during the scan cycle to an improved degree of accuracy. For example, for pixels in the first column of pixels that exhibit fields of view offset -.03° in yaw from the nominal axis of the bulk receiving optic, the correction matrix can define a five-centimeter leftward correction of a (1,1) distance value of 100 meters in the nominal matrix (e.g., 100 meters x sin(-.03°) = 5.2 centimeters).

[0064] Furthermore, pitch and yaw offset angles of a field of a view of each pixel in the system can vary with (i.e., be a function of) the focal length of the bulk receiving optic, and the focal length of the bulk receiving optic can vary with temperature of the system. Therefore, the system can pair the nominal matrix with a correction matrix based on a temperature of the system, such as for a bulk receiving optic including one or more polymer lenses. In one implementation, the system stores a set of preset correction matrices, wherein each correction matrix corresponds to a particular temperature and contains pitch and yaw offset angles for the field of view of each pixel in the system at the particular temperature. In this implementation, the system: can also include a temperature sensor thermally coupled to the bulk receiving optic; can sample the temperature sensor during operation (e.g., once per scan cycle); and can pair a nominal matrix generated from data collected during a scan cycle with a correction matrix – selected from the set of correction matrices – corresponding to a temperature nearest a

temperature of the bulk receiving optic recorded during the same scan cycle. For example, for the system that operates within a temperature range from 119°F to 121°F, the system can contain 21 preset correction matrices, each correction matrix corresponding to one of 21 0.1°F temperature steps between 119°F and 121°F, inclusive. For example, each correction matrix can be generated empirically by characterizing the fields of view of pixels within the system at select operating temperatures.

[0065] Alternatively, the system can implement a parametric model or other parametric function to generate a correction matrix based on the temperature of the bulk receiving optic (or other element within the system). However, the system can implement any other method or technique to pair a nominal matrix generated from data collected during a scan cycle with a correction matrix representing horizontal and vertical distortion of data contained within the nominal matrix.

10. Increased Resolution

[0066] In one variation, the system increases a number of angular sampling executed positions per rotation in order to increase the resolution of a nominal matrix generated during a scan cycle. In one implementation, the system includes a skewed grid array of pixels, wherein adjacent columns of pixels (and corresponding columns of input channels) are offset laterally by a distance corresponding to X-number of radial steps in a single rotation (e.g., 2048 steps at .176° between steps) but executes 2X equidistant arcuate sampling positions per complete rotation (e.g., 4096 arcuate sampling positions at .088° between steps per scan cycle).

[0067] In the example described above in which the system includes a 16 x 4 array of pixels, the system executes a first sampling routine at a first arcuate sampling position of 0° and

then: populates the [(1,1), (5,1), (9,1),...(57,1), and (61,1)] positions within a first column in a distance matrix with distance values calculated from data received from the first, second, third, fourth,... fifteenth, and sixteenth pixels in the first column of pixels, respectively, during the first sampling period; populates the [(2,3), (6,3), (10,3),...(58,3), and (62,3)] positions within the third column of the distance matrix with distance values calculated from data received from the first, second, third, fourth,... fifteenth, and sixteenth pixels in the second column of pixels, respectively; populates the [(3,5), (7,5), (11,5),...(59,5), and (63,5)] positions within the fifth column of the distance matrix with distance values calculated from data received from the first, second, third, fourth,... fifteenth, and sixteenth pixels in the third column of pixels, respectively; and populates the [(4,7), (8,7), (12,7),...(60,7), and (64,7)] positions within the seventh column of the distance matrix with distance values calculated from data received from the first, second, third, fourth,... fifteenth, and sixteenth pixels in the fourth column of pixels, respectively.

[0068] In this example, the rotary actuator rotates the pixel block, and the system executes a second sampling routine once the pixel block reaches a next arcuate sampling position of 0.088°. The system then: populates the [(1,2), (5,2), (9,2),...(57,2), and (61,2)] positions within a second column in the distance matrix with distance values calculated from data received from the first, second, third, fourth,... fifteenth, and sixteenth pixels in the first column of pixels, respectively, during the first sampling period; populates the [(2,4), (6,4), (10,4),...(58,4), and (62,4)] positions within the fourth column of the distance matrix with distance values calculated from data received from the first, second, third, fourth,... fifteenth, and sixteenth pixels in the second column of pixels, respectively; populates the [(3,6), (7,6), (11,6),...(59,6), and (63,6)] positions within the sixth column of the distance matrix with distance values calculated from data received from the first, second, third, fourth,... fifteenth, and sixteenth pixels in the third

column of pixels, respectively; and populates the [(4,8), (8,8), (12,8),...(60,8), and (64,8)] positions within the eight column of the distance matrix with distance values calculated from data received from the first, second, third, fourth,... fifteenth, and sixteenth pixels in the fourth column, respectively.

[0069] The system repeats this process once upon reaching a third arcuate sampling position at .176°, then at a fourth arcuate sampling position of .264°, and for each subsequent arcuate sampling position in a full rotation of the pixel block in order to form a 4096 x 64 matrix containing 4096 columns, wherein each column corresponds to a unique yaw angle relative to the rotary actuator and contains 64 distance values, wherein each distance value in a column corresponds to a unique pitch angle relative to the pixel block.

[0070] However, the system can execute a sampling period at any other number of arcuate sampling positions during a complete rotation of the pixel block (e.g., during a compete scan cycle), and the system can implement any other method or technique to transform data collected from the set of pixels during a scan cycle into a nominal matrix of distances from the system to external surfaces nearby.

[0071] The systems and methods described herein can be embodied and/or implemented at least in part as a machine configured to receive a computer-readable medium storing computer-readable instructions. The instructions can be executed by computer-executable components integrated with the application, applet, host, server, network, website, communication service, communication interface, hardware/firmware/software elements of a user computer or mobile device, wristband, smartphone, or any suitable combination thereof. Other systems and methods of the embodiment can be embodied and/or implemented at least in part as a machine configured to receive a computer-readable medium storing computer-readable

instructions. The instructions can be executed by computer-executable components integrated by computer-executable components integrated with apparatuses and networks of the type described above. The computer-readable medium can be stored on any suitable computer readable media such as RAMs, ROMs, flash memory, EEPROMs, optical devices (CD or DVD), hard drives, floppy drives, or any suitable device. The computer-executable component can be a processor but any suitable dedicated hardware device can (alternatively or additionally) execute the instructions.

[0072] As a person skilled in the art will recognize from the previous detailed description and from the figures and claims, modifications and changes can be made to the embodiments of the invention without departing from the scope of this invention as defined in the following claims.

CLAIMS

What is claimed is:

1. An optical system for collecting distance information, the optical system comprising:

an optical imaging transmit module comprising a bulk transmitting optic and an illumination source comprising a plurality of optical emitters arranged behind the bulk transmitting optic, wherein each optical emitter in the plurality of optical emitters can project light at a nominal wavelength through the bulk transmitting optic and into a field ahead of the optical system;

an optical imaging receive module comprising a bulk receiving optic and a plurality of pixels arranged behind the bulk receiving optic, wherein each pixel in the plurality of pixels comprises a plurality of single photon avalanche diodes (SPADs) and wherein the plurality of pixels includes a first set of pixels arranged in a first column and a second set of pixels arranged in a second column horizontally and vertically offset from the first column; and

an actuator operable to rotate the optical imaging receive module about a vertical axis over a plurality of scan cycles in which, during each scan cycle, the optical imaging receive module is rotated 360 degrees such that each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by every other pixel in the optical system;

wherein the optical system generates, for each of a plurality of arcuate sampling positions within one scan cycle, data that represents distances from the optical system to external surfaces in the field 360 degrees around the optical system.

2. The optical system of claim 1 further comprising an optical filter disposed in front of each pixel in the plurality of pixels and operable to allow a set of wavelengths of light, including the nominal wavelength, to pass through the optical filter while blocking light outside the set of wavelengths of light from reaching the plurality of pixels.

3. The optical system of claim 2 wherein the optical filter comprises a fused silica substrate having a coating formed thereon.

4. The optical system of claim 1 wherein the actuator includes an electric motor with an optical encoder and the optical system implements closed-loop feedback controls to maintain a rotational speed of the electric motor at a specific frequency based on outputs of the optical encoder.

5. The optical system of claim 1 wherein the bulk transmitting optic and the bulk receiving optic are each image-space telecentric lenses and the bulk transmitting optic is adjacent to an offset laterally from the bulk receiving optic.

6. The optical system of claim 1 wherein the optical imaging receive module comprises a plurality of micro-lenses disposed between the bulk receiving optic and the plurality of pixels.

7. The optical system of claim 1 wherein the circular paths traversed by pixels from the second set of pixels in the second column are interleaved with the circular paths traversed by pixels from the first set of pixels in the first column.

8. The optical system of claim 1 wherein the optical imaging receive module further comprises a plurality of apertures and a stop region disposed between adjacent apertures in the plurality of apertures, wherein the plurality of apertures includes a first aperture and a second aperture horizontally and vertically offset from the first aperture, the first set of pixels includes a first pixel disposed in a first optical path that extends through the first aperture and the second set of pixels includes a second pixel disposed in a second optical path that extends through the second aperture.

9. The optical system of claim 1 wherein the optical system implements time of flight techniques to determine distances from the optical system to external surfaces in the field.

10. An optical system for collecting distance information, the optical system comprising:

an output circuit comprising a bulk transmitting optic and an illumination source configured to output light at a nominal wavelength, the illumination source including a plurality

of optical emitters arranged behind the bulk transmitting optic, wherein each optical emitter can project an illuminating beam at the nominal wavelength through the bulk transmitting optic and into a field ahead of the optical system;

an input circuit comprising a bulk receiving optic disposed adjacent to the bulk transmitting optic and a plurality of pixels arranged behind the bulk receiving optic, wherein each pixel in the plurality of pixels comprises a plurality of single photon avalanche diodes (SPADs) and wherein the plurality of pixels includes a first set of pixels arranged in a first column and a second set of pixels arranged in a second column horizontally and vertically offset from the first column; and

an electric motor configured to rotate the input circuit about a vertical axis over a plurality of scan cycles in which, during each scan cycle, the input circuit is rotated 360 degrees such that each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by each other pixel in the optical system;

wherein the optical system collects data from each pixel in the plurality of pixels at a plurality of different arcuate sampling position as the input circuit is rotated through 360 degrees during each scan cycle.

11. The optical system of claim 10 wherein each pixel in the plurality of pixels has a field of view that is non-overlapping with fields of view of all other pixels in the plurality of pixels, and the illumination source is configured to project illuminating beams into the field ahead of the optical system according to an illumination pattern where each beam in the illumination pattern is coincident with a field of view of one pixel in the plurality of pixels.

12. The optical system of claim 11 wherein each scan cycle includes a plurality of sampling periods and, during each sampling period in the plurality of sampling periods, the optical system activates each emitter in the plurality of optical emitters to project the illumination pattern and determines a number of SPADs in each pixel that recorded an incident photon since a previous sampling period.

13. The optical system of claim 12 wherein, during each sampling period of the plurality of sampling periods within one scan cycle, the optical system determines distances to objects in the field based on a difference between a time at which an optical emitter is fired

and a time at which incident photons are detected at a pixel having a field of view that overlaps with a field of view of the fired optical emitter.

14. The optical system of claim 10 wherein

the input circuit further comprises a plurality of apertures and stop region disposed between adjacent apertures in the plurality of apertures, wherein the plurality of apertures comprises a first aperture, a second aperture horizontally and vertically offset from the first aperture, a third aperture aligned vertically with the first aperture and vertically offset from the first and second apertures; and a fourth aperture aligned vertically with the second aperture and vertically offset from the first, second and third apertures;

the first set of pixels includes a first pixel and a third pixel and the second set of pixels includes a second pixel and a fourth pixel;

the plurality of optical emitters includes a first emitter, a second emitter, a third emitter and a fourth emitter; and

the first pixel has a field of view coincident with the first emitter such that the first pixel is operable to detect photons emitted from the first emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the first aperture; the second pixel has a field of view coincident with the second emitter such that the second pixel is operable to detect photons emitted from the second emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the second aperture; the third pixel has a field of view coincident with the third emitter such that the third pixel is operable to detect photons emitted from the third emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the third aperture; and the fourth pixel has a field of view coincident with the fourth emitter such that the fourth pixel is operable to detect photons emitted from the fourth emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the fourth aperture.

15. The optical system of claim 10 further comprising and an optical filter disposed between the bulk receiving optic and the plurality of pixels and configured to allow a narrow band of wavelengths of light, including the nominal wavelength, to pass through the optical filter while blocking light outside the narrow band.

16. An optical system for collecting distance information, the optical system comprising:

a light receiving unit comprising a bulk receiving optic and a plurality of pixels arranged behind the bulk receiving optic, wherein each pixel in the plurality of pixels comprises a plurality of single photon avalanche diodes (SPADs) and has a field of view that is non-overlapping with the fields of view of all other pixels in the plurality of pixels, and wherein the plurality of pixels includes a first set of pixels arranged in a first pixel column and a second set of pixels arranged in a second pixel column horizontally and vertically offset from the first pixel column;

a light transmitting unit comprising a bulk transmitting optic spaced apart from the bulk receiving optic and an illumination source configured to output light at a nominal wavelength, the illumination source including a plurality of optical emitters arranged behind the bulk transmitting optic, wherein each optical emitter projects an illuminating beam at the nominal wavelength through the bulk transmitting optic and into a field ahead of the optical system such that the plurality of optical emitters project a plurality of illuminating beams according to an illumination pattern that substantially matches, in size and geometry across a range of distances from the optical system, the fields of view of the plurality of pixels; and

an electric motor operable to rotate the light receiving unit about a vertical axis over a plurality of scan cycles in which, during each scan cycle, the light receiving unit is rotated 360 degrees such that each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by the other pixels in the plurality of pixels.

17. The optical system of claim 16 wherein the optical system generates, for each of a plurality of arcuate sampling positions within one scan cycle, data that represents distances from the optical system to external surfaces in the field 360 degrees around the optical system and implements time of flight techniques to transform the generated data into distances from the optical system.

18. The optical system of claim 16 further comprising and an optical filter disposed between the bulk receiving optic and each pixel in the plurality of pixels, wherein the optical filter is configured to allow a set of wavelengths of light, including the nominal

wavelength, to pass through the optical filter while blocking light outside the set of wavelengths of light from reaching the plurality of pixels.

19. The optical system of claim 16 wherein:

the first set of pixels includes a first pixel and the second set of pixels includes a second pixel;

the light receiving unit further comprises a plurality of apertures including a first aperture and a second aperture horizontally and vertically offset from the first aperture;

the first aperture is disposed in a first optical path that extends from the bulk imaging optic, through the first aperture and to the first pixel; and

the first aperture is disposed in a second optical path that extends from the bulk imaging optic, through the second aperture and to the second pixel.

20. The optical system of claim 19 wherein:

the plurality of optical emitters includes a first emitter and a second emitter; and

the first pixel has a field of view that is coincident with the first emitter such that the first pixel is operable to detect photons emitted from the first emitter and received through the bulk receiving optic after being reflected from surfaces within the field and passed through the first aperture; and

the second pixel has a field of view that is coincident with the second emitter such that the second pixel is operable to detect photons emitted from the second emitter and received through the bulk receiving optic after being reflected from surfaces within the field and passed through the second aperture.

21. The optical system of claim 16 wherein:

the light receiving unit further comprises a plurality of apertures including a first aperture, a second aperture horizontally and vertically offset from the first aperture, a third aperture aligned vertically with the first aperture and vertically offset from the first and second apertures; and a fourth aperture aligned vertically with the second aperture and vertically offset from the first, second and third apertures;

the first set of pixels includes a first pixel and a third pixel and the second set of pixels includes a second pixel and a fourth pixel;

the plurality of optical emitters includes a first emitter, a second emitter, a third emitter and a fourth emitter; and

the first pixel has a field of view coincident with the first emitter such that the first pixel is operable to detect photons emitted from the first emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the first aperture; the second pixel has a field of view coincident with the second emitter such that the second pixel is operable to detect photons emitted from the second emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the second aperture; the third pixel has a field of view coincident with the third emitter such that the third pixel is operable to detect photons emitted from the third emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the third aperture; and the fourth pixel has a field of view coincident with the fourth emitter such that the fourth pixel is operable to detect photons emitted from the fourth emitter and received through the bulk imaging optic after being reflected from surfaces within the field and passed through the fourth aperture.

22. The optical system of claim 16 wherein the circular paths traversed by pixels from the second set of pixels in the second pixel column are interleaved with the circular paths traversed by pixels from the first set of pixels in the first pixel column.

23. An optical system for collecting distance information, the optical system comprising:

an optical imaging transmit module comprising a bulk transmitting optic and an illumination source comprising a plurality of optical emitters arranged behind the bulk transmitting optic, wherein the plurality of optical emitters project a plurality of beams of light at an operating wavelength through the bulk transmitting optic and into a field ahead of the optical system;

an optical imaging receive module comprising a bulk receiving optic and a plurality of pixels arranged behind the bulk receiving optic, wherein each pixel in the plurality of pixels comprises a plurality of single photon avalanche diodes (SPADs) and wherein the plurality of pixels includes a first set of pixels arranged in a first column and a second set of pixels arranged in a second column horizontally and vertically offset from the first column; and

an actuator operable to rotate the optical imaging receive module about a vertical axis over a plurality of scan cycles in which, during each scan cycle, the optical imaging receive module is rotated 360 degrees such that each pixel in the plurality of pixels traverses a unique circular path parallel to and vertically offset from a unique circular path traversed by every other pixel in the optical system;

wherein the optical system generates, for each of a plurality of arcuate sampling positions within one scan cycle, data that represents distances from the optical system to external surfaces in the field 360 degrees around the optical system.

24. The optical system of claim 23 wherein the optical system further comprises an optical bandpass filter disposed between the bulk transmitting optic and the plurality of pixels and having a center wavelength matched to the operating wavelength of the plurality of optical emitters.

25. The optical system of claim 23 wherein the optical imaging receive module further comprises a plurality of apertures and a stop region disposed between adjacent apertures in the plurality of apertures, wherein the plurality of apertures includes a first aperture and a second aperture horizontally and vertically offset from the first aperture, the first set of pixels includes a first pixel disposed in a first optical path that extends through the first aperture and the second set of pixels includes a second pixel disposed in a second optical path that extends through the second aperture.

26. The optical system of claim 23 wherein the illumination source comprises a plurality of vertical cavity surface emitting lasers (VCSELs).

27. The optical system of claim 26 wherein the optical system implements time of flight techniques to determine distances from the optical system to external surfaces in the field.

ABSTRACT

Optical systems and methods for collecting distance information are disclosed. An example optical system includes a first transmitting optic, a plurality of illumination sources, a pixel array comprising at least a first column of pixels and a second column of pixels, each pixel in the first column of pixels being offset from an adjacent pixel in the first column of pixels by a first pixel pitch, the second column of pixels being horizontally offset from the first column of pixels by the first pixel pitch, the second column of pixels being vertically offset from the first column of pixels by a first vertical pitch; and a set of input channels interposed between the first transmitting optic and the pixel array.

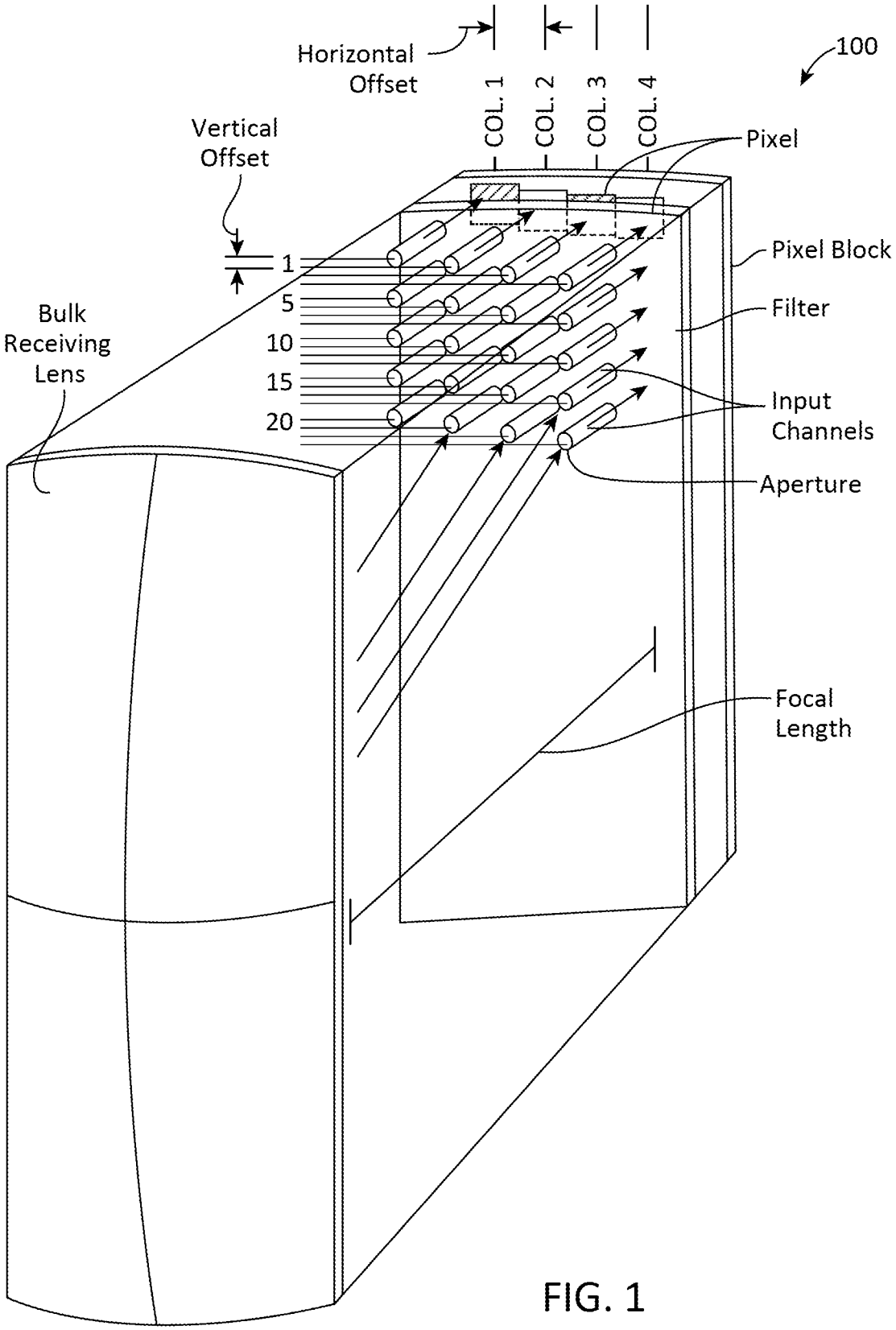

Horizontal Offset
100
COL. 1
COL. 2
COL. 3
COL. 4
Vertical Offset
Pixel
Pixel Block
Filter
Input Channels
Aperture
Focal Length
Bulk Receiving Lens
1
5
10
15
20

FIG. 1

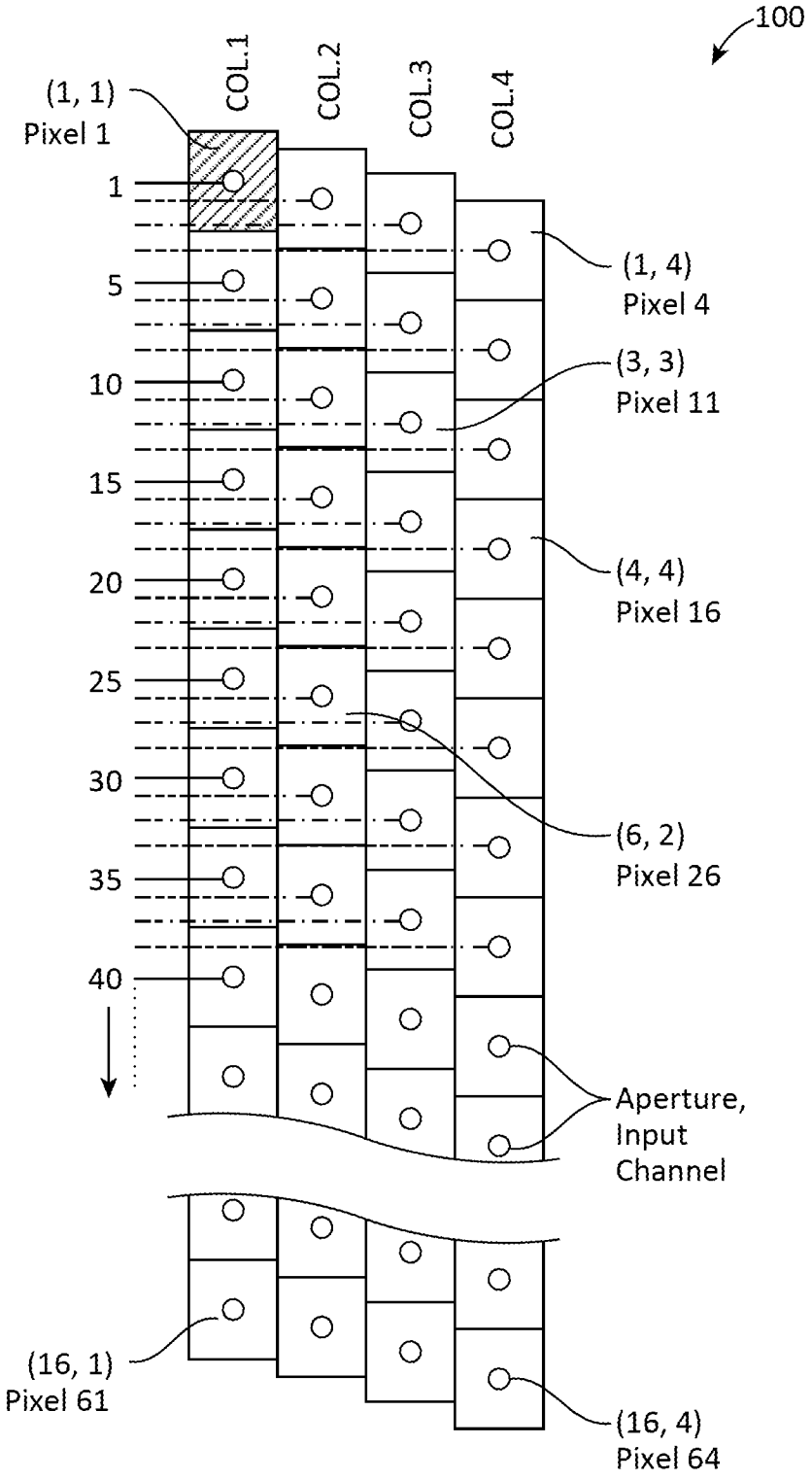

100
COL.1
COL.2
COL.3
COL.4
(1, 1)
Pixel 1
1
5
10
15
20
25
30
35
40
(1, 4)
Pixel 4
(3, 3)
Pixel 11
(4, 4)
Pixel 16
(6, 2)
Pixel 26
Aperture,
Input
Channel
(16, 1)
Pixel 61
(16, 4)
Pixel 64

FIG. 2

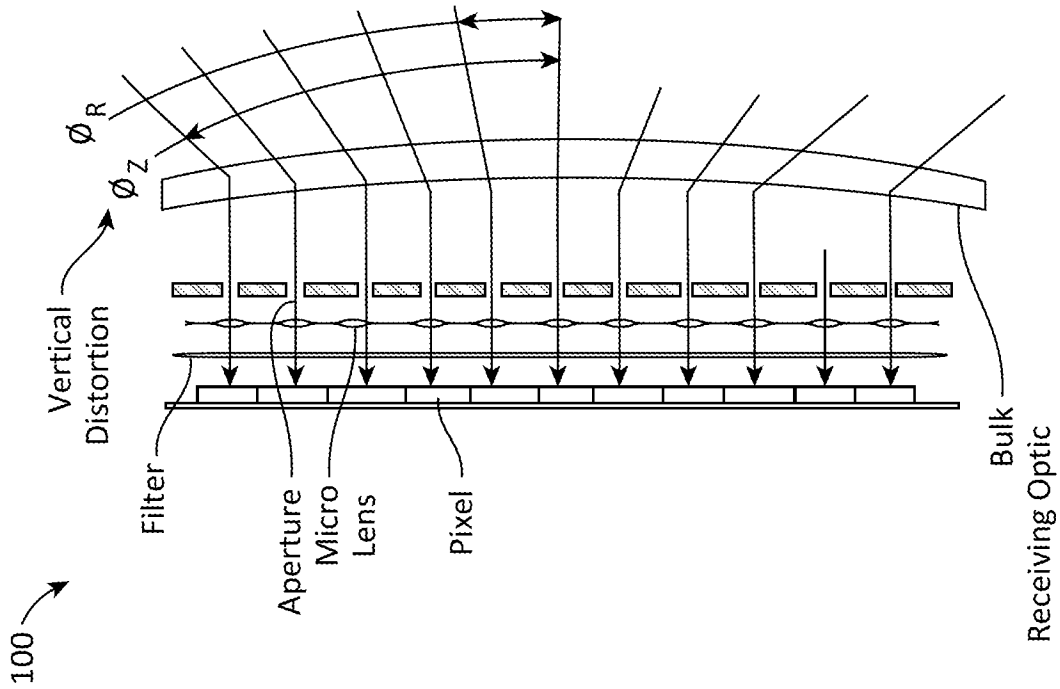

100
Vertical Distortion
ϕ_R
ϕ_Z
Filter
Aperture
Micro Lens
Pixel
Bulk Receiving Optic

FIG. 3B

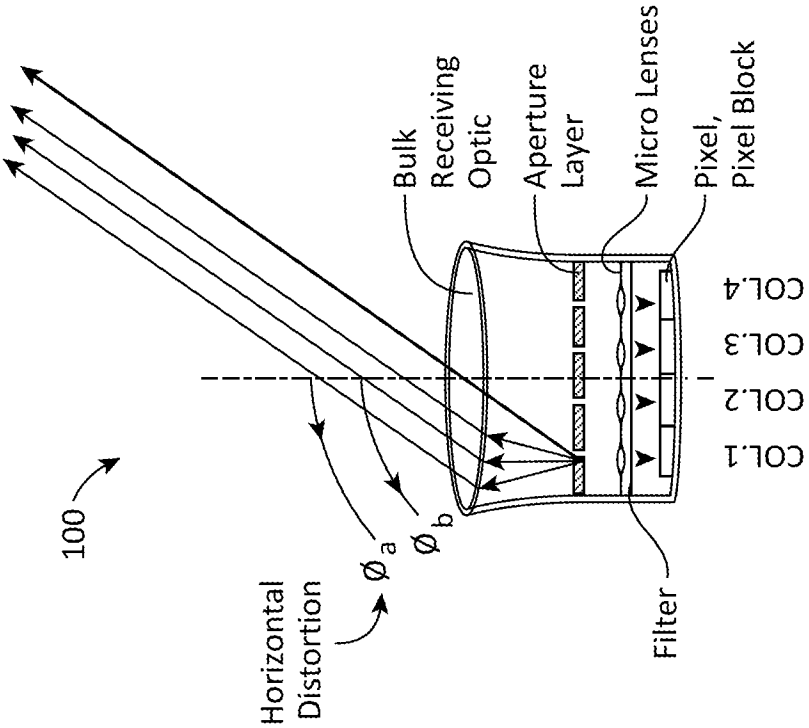

100
Horizontal Distortion
ϕ_a
ϕ_b
Bulk Receiving Optic
Aperture Layer
Micro Lenses
Pixel, Pixel Block
Filter
COL.1
COL.2
COL.3
COL.4

FIG. 3A

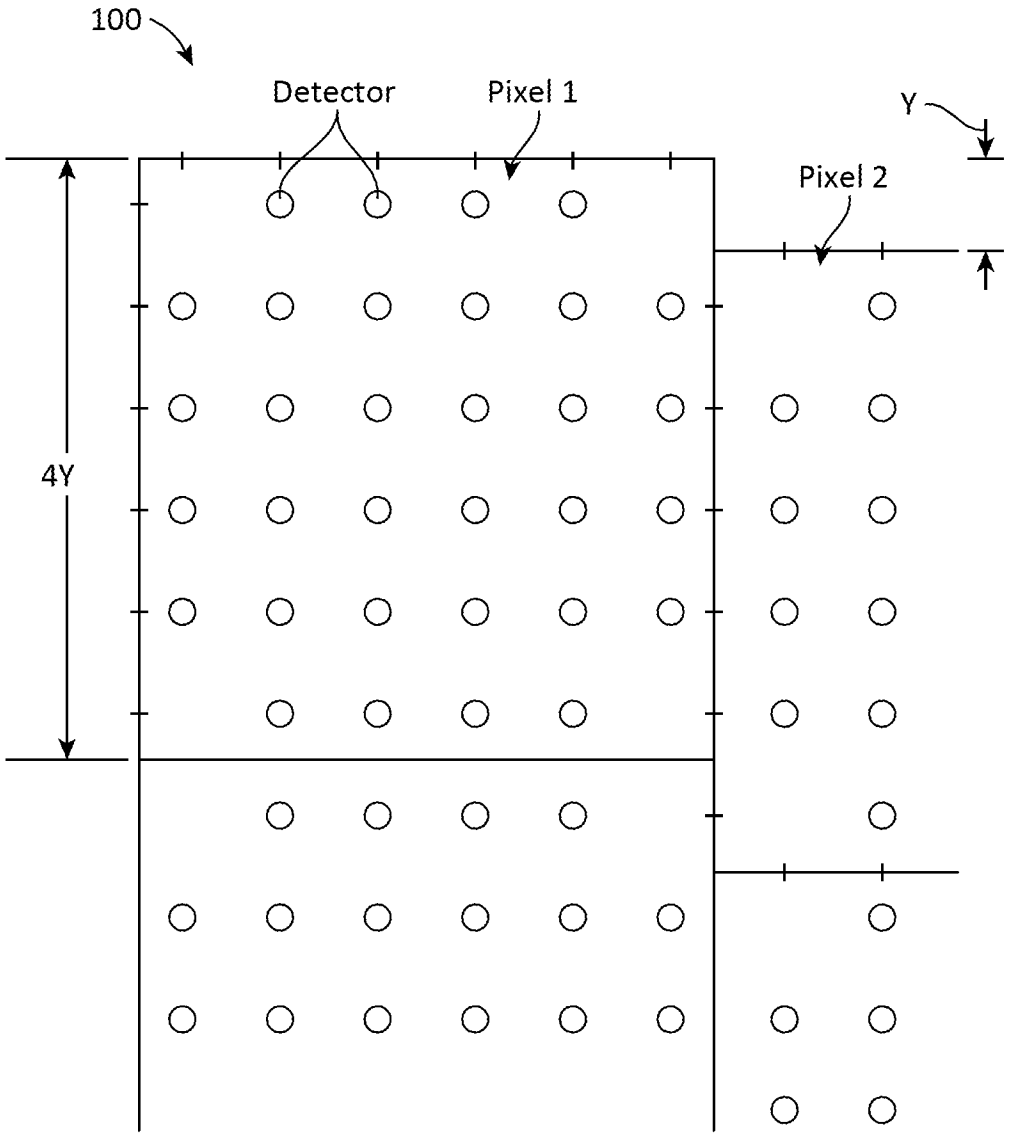


FIG. 4

Nominal Matrix @ 0° arcuate sampling position:

d(1,1) @0°	--	--	--	--	--	--	--	
--	d(1,2) @0°	--	--	--	--	--	--	
--	--	d(1,3) @0°	--	--	--	--	--	
--	--	--	d(1,4) @0°	--	--	--	--	
d(2,1) @0°	--	--	--	--	--	--	--	
--	d(2,2) @0°	--	--	--	--	--	--	
--	--	d(2,3) @0°	--	--	--	--	--	
--	--	--	d(2,4) @0°	--	--	--	--	
d(3,1) @0°	--	--	--	--	--	--	--	
--	d(3,2) @0°	--	--	--	--	--	--	
--	--	d(3,3) @0°	--	--	--	--	--	
--	--	--	d(3,4) @0°	--	--	--	--	
d(4,1) @0°	--	--	--	--	--	--	--	
--	d(4,2) @0°	--	--	--	--	--	--	
--	--	d(4,3) @0°	--	--	--	--	--	
--	--	--	d(4,4) @0°	--	--	--	--	
d(5,1) @0°	--	--	--	--	--	--	--	•••
--	d(5,2) @0°	--	--	--	--	--	--	
--	--	d(5,3) @0°	--	--	--	--	--	
--	--	--	d(5,4) @0°	--	--	--	--	
d(6,1) @0°	--	--	--	--	--	--	--	
--	d(6,2) @0°	--	--	--	--	--	--	
--	--	d(6,3) @0°	--	--	--	--	--	
--	--	--	d(6,4) @0°	--	--	--	--	
d(7,1) @0°	--	--	--	--	--	--	--	
--	d(7,2) @0°	--	--	--	--	--	--	
--	--	d(7,3) @0°	--	--	--	--	--	
--	--	--	d(7,4) @0°	--	--	--	--	
d(8,1) @0°	--	--	--	--	--	--	--	
--	d(8,2) @0°	--	--	--	--	--	--	
--	--	d(8,3) @0°	--	--	--	--	--	
--	--	--	d(8,4) @0°	--	--	--	--	
d(9,1) @0°	--	--	--	--	--	--	--	
--	d(9,2) @0°	--	--	--	--	--	--	

FIG. 5A1

Hesai Exhibit 1002, Page 288

d(9,3) @0°
d(9,4) @0°
d(10,1) @0°
d(10,2) @0°
d(10,3) @0°
d(10,4) @0°
d(11,1) @0°
d(11,2) @0°
d(11,3) @0°
d(11,4) @0°
d(12,1) @0°
d(12,2) @0°
d(12,3) @0°
d(12,4) @0°
d(13,1) @0°
d(13,2) @0°
d(13,3) @0°
d(13,4) @0°
d(14,1) @0°
d(14,2) @0°
d(14,3) @0°
d(14,4) @0°
d(15,1) @0°
d(15,2) @0°
d(15,3) @0°
d(15,4) @0°
d(16,1) @0°
d(16,2) @0°
d(16,3) @0°
d(16,4) @0°

FIG. 5A2

Nominal Matrix @ .176° arcuate sampling position:

d(1,1) @0°	d(1,1) @.176°	--	--	--	--	--	--
--	d(1,2) @0°	d(1,2) @.176°	--	--	--	--	--
--	--	d(1,3) @0°	d(1,3) @.176°	--	--	--	--
--	--	--	d(1,4) @0°	d(1,4) @.176°	--	--	--
d(2,1) @0°	d(2,1) @.176°	--	--	--	--	--	--
--	d(2,2) @0°	d(2,2) @.176°	--	--	--	--	--
--	--	d(2,3) @0°	d(2,3) @.176°	--	--	--	--
--	--	--	d(2,4) @0°	d(2,4) @.176°	--	--	--
d(3,1) @0°	d(3,1) @.176°	--	--	--	--	--	--
--	d(3,2) @0°	d(3,2) @.176°	--	--	--	--	--
--	--	d(3,3) @0°	d(3,3) @.176°	--	--	--	--
--	--	--	d(3,4) @0°	d(3,4) @.176°	--	--	--
d(4,1) @0°	d(4,1) @.176°	--	--	--	--	--	--
--	d(4,2) @0°	d(4,2) @.176°	--	--	--	--	--
--	--	d(4,3) @0°	d(4,3) @.176°	--	--	--	--
--	--	--	d(4,4) @0°	d(4,4) @.176°	--	--	--
d(5,1) @0°	d(5,1) @.176°	--	--	--	--	--	--
--	d(5,2) @0°	d(5,2) @.176°	--	--	--	--	--
--	--	d(5,3) @0°	d(5,3) @.176°	--	--	--	--
--	--	--	d(5,4) @0°	d(5,4) @.176°	--	--	--
d(6,1) @0°	d(6,1) @.176°	--	--	--	--	--	--
--	d(6,2) @0°	d(6,2) @.176°	--	--	--	--	--
--	--	d(6,3) @0°	d(6,3) @.176°	--	--	--	--
--	--	--	d(6,4) @0°	d(6,4) @.176°	--	--	--

FIG. 5B1

Hesai Exhibit 1002, Page 290

d(7,1) @0°	d(7,1) @.176° d(7,2) @0°	--	--	--	--	--	--	--	--	--	--
--	--	d(7,2) @.176° d(7,3) @0°	--	--	--	--	--	--	--	--	--
--	--	--	d(7,3) @.176° d(7,4) @0°	--	--	d(7,4) @.176°	--	--	--	--	--
d(8,1) @0°	d(8,1) @.176° d(8,2) @0°	--	--	--	--	--	--	--	--	--	--
--	--	d(8,2) @.176° d(8,3) @0°	--	--	--	--	--	--	--	--	--
--	--	--	d(8,3) @.176° d(8,4) @0°	--	--	d(8,4) @.176°	--	--	--	--	--
d(9,1) @0°	d(9,1) @.176° d(9,2) @0°	--	--	--	--	--	--	--	--	--	--
--	--	d(9,2) @.176° d(9,3) @0°	--	--	--	--	--	--	--	--	--
--	--	--	d(9,3) @.176° d(9,4) @0°	--	--	d(9,4) @.176°	--	--	--	--	--
d(10,1) @0°	d(10,1) @.176° d(10,2) @0°	--	--	--	--	--	--	--	--	--	--
--	--	d(10,2) @.176° d(10,3) @0°	--	--	--	--	--	--	--	--	--
--	--	--	d(10,3) @.176° d(10,4) @0°	--	--	d(10,4) @.176°	--	--	--	--	--
d(11,1) @0°	d(11,1) @.176° d(11,2) @0°	--	--	--	--	--	--	--	--	--	--
--	--	d(11,2) @.176° d(11,3) @0°	--	--	--	--	--	--	--	--	--
--	--	--	d(11,3) @.176° d(11,4) @0°	--	--	d(11,4) @.176°	--	--	--	--	--
d(12,1) @0°	d(12,1) @.176° d(12,2) @0°	--	--	--	--	--	--	--	--	--	--
--	--	d(12,2) @.176° d(12,3) @0°	--	--	--	--	--	--	--	--	--
--	--	--	d(12,3) @.176° d(12,4) @0°	--	--	d(12,4) @.176°	--	--	--	--	--

FIG. 5B2

| | | |

Nominal Matrix @ .352° arcuate sampling position:

d(1,1) @0°	d(1,1) @.176°	d(1,1) @.352°	--	--	--	--	--
--	d(1,2) @0°	d(1,2) @.176°	d(1,2) @.352°	--	--	--	--
--	--	d(1,3) @0°	d(1,3) @.176°	d(1,3) @.352°	--	--	--
--	--	--	d(1,4) @0°	d(1,4) @.176°	d(1,4) @.352°	--	--
d(2,1) @0°	d(2,1) @.176°	d(2,1) @.352°	--	--	--	--	--
--	d(2,2) @0°	d(2,2) @.176°	d(2,2) @.352°	--	--	--	--
--	--	d(2,3) @0°	d(2,3) @.176°	d(2,3) @.352°	--	--	--
--	--	--	d(2,4) @0°	d(2,4) @.176°	d(2,4) @.352°	--	--
d(3,1) @0°	d(3,1) @.176°	d(3,1) @.352°	--	--	--	--	--
--	d(3,2) @0°	d(3,2) @.176°	d(3,2) @.352°	--	--	--	--
--	--	d(3,3) @0°	d(3,3) @.176°	d(3,3) @.352°	--	--	--
--	--	--	d(3,4) @0°	d(3,4) @.176°	d(3,4) @.352°	--	--
d(4,1) @0°	d(4,1) @.176°	d(4,1) @.352°	--	--	--	--	--
--	d(4,2) @0°	d(4,2) @.176°	d(4,2) @.352°	--	--	--	--
--	--	d(4,3) @0°	d(4,3) @.176°	d(4,3) @.352°	--	--	--
--	--	--	d(4,4) @0°	d(4,4) @.176°	d(4,4) @.352°	--	--
d(5,1) @0°	d(5,1) @.176°	d(5,1) @.352°	--	--	--	--	--
--	d(5,2) @0°	d(5,2) @.176°	d(5,2) @.352°	--	--	--	--
--	--	d(5,3) @0°	d(5,3) @.176°	d(5,3) @.352°	--	--	--
--	--	--	d(5,4) @0°	d(5,4) @.176°	d(5,4) @.352°	--	--
d(6,1) @0°	d(6,1) @.176°	d(6,1) @.352°	--	--	--	--	--
--	d(6,2) @0°	d(6,2) @.176°	d(6,2) @.352°	--	--	--	--
--	--	d(6,3) @0°	d(6,3) @.176°	d(6,3) @.352°	--	--	--
--	--	--	d(6,4) @0°	d(6,4) @.176°	d(6,4) @.352°	--	--
d(7,1) @0°	d(7,1) @.176°	d(7,1) @.352°	--	--	--	--	--
--	d(7,2) @0°	d(7,2) @.176°	d(7,2) @.352°	--	--	--	--
--	--	d(7,3) @0°	d(7,3) @.176°	d(7,3) @.352°	--	--	--
--	--	--	d(7,4) @0°	d(7,4) @.176°	d(7,4) @.352°	--	--

FIG. 5C1

Hesai Exhibit 1002, Page 293

d(8,1) @0°	d(8,1) @.176°	d(8,1) @.352°	--	--	--	--	--	--	--
--	d(8,2) @0°	d(8,2) @.176°	d(8,2) @.352°	--	--	--	--	--	--
--	--	d(8,3) @0°	d(8,3) @.176°	d(8,3) @.352°	--	--	--	--	--
--	--	--	d(8,4) @0°	d(8,4) @.176°	d(8,4) @.352°	--	--	--	--
d(9,1) @0°	d(9,1) @.176°	d(9,1) @.352°	--	--	--	--	--	--	--
--	d(9,2) @0°	d(9,2) @.176°	d(9,2) @.352°	--	--	--	--	--	--
--	--	d(9,3) @0°	d(9,3) @.176°	d(9,3) @.352°	--	--	--	--	--
--	--	--	d(9,4) @0°	d(9,4) @.176°	d(9,4) @.352°	--	--	--	--
d(10,1) @0°	d(10,1) @.176°	d(10,1) @.352°	--	--	--	--	--	--	--
--	d(10,2) @0°	d(10,2) @.176°	d(10,2) @.352°	--	--	--	--	--	--
--	--	d(10,3) @0°	d(10,3) @.176°	d(10,3) @.352°	--	--	--	--	--
--	--	--	d(10,4) @0°	d(10,4) @.176°	d(10,4) @.352°	--	--	--	--
d(11,1) @0°	d(11,1) @.176°	d(11,1) @.352°	--	--	--	--	--	--	--
--	d(11,2) @0°	d(11,2) @.176°	d(11,2) @.352°	--	--	--	--	--	--
--	--	d(11,3) @0°	d(11,3) @.176°	d(11,3) @.352°	--	--	--	--	--
--	--	--	d(11,4) @0°	d(11,4) @.176°	d(11,4) @.352°	--	--	--	--
d(12,1) @0°	d(12,1) @.176°	d(12,1) @.352°	--	--	--	--	--	--	--
--	d(12,2) @0°	d(12,2) @.176°	d(12,2) @.352°	--	--	--	--	--	--
--	--	d(12,3) @0°	d(12,3) @.176°	d(12,3) @.352°	--	--	--	--	--
--	--	--	d(12,4) @0°	d(12,4) @.176°	d(12,4) @.352°	--	--	--	--

FIG. 5C2

d(13,1) @0°	d(13,1) @.176°	d(13,1) @.352°	--	--	--	--	--	--	--
--	d(13,2) @0°	d(13,2) @.176°	d(13,2) @.352°	--	--	--	--	--	--
--	--	d(13,3) @0°	d(13,3) @.176°	d(13,3) @.352°	--	--	--	--	--
--	--	--	d(13,4) @0°	d(13,4) @.176°	d(13,4) @.352°	--	--	--	--
d(14,1) @0°	d(14,1) @.176°	d(14,1) @.352°	--	--	--	--	--	--	--
--	d(14,2) @0°	d(14,2) @.176°	d(14,2) @.352°	--	--	--	--	--	--
--	--	d(14,3) @0°	d(14,3) @.176°	d(14,3) @.352°	--	--	--	--	--
--	--	--	d(14,4) @0°	d(14,4) @.176°	d(14,4) @.352°	--	--	--	--
d(15,1) @0°	d(15,1) @.176°	d(15,1) @.352°	--	--	--	--	--	--	--
--	d(15,2) @0°	d(15,2) @.176°	d(15,2) @.352°	--	--	--	--	--	--
--	--	d(15,3) @0°	d(15,3) @.176°	d(15,3) @.352°	--	--	--	--	--
--	--	--	d(15,4) @0°	d(15,4) @.176°	d(15,4) @.352°	--	--	--	--
d(16,1) @0°	d(16,1) @.176°	d(16,1) @.352°	--	--	--	--	--	--	--
--	d(16,2) @0°	d(16,2) @.176°	d(16,2) @.352°	--	--	--	--	--	--
--	--	d(16,3) @0°	d(16,3) @.176°	d(16,3) @.352°	--	--	--	--	--
--	--	--	d(16,4) @0°	d(16,4) @.176°	d(16,4) @.352°	--	--	--	--

FIG. 5C3

Nominal Matrix @ .528° arcuate sampling position:

d(1,1) @0°	d(1,1) @.176°	d(1,1) @.352°	d(1,1) @.528°	--	--	--	--
--	d(1,2) @0°	d(1,2) @.176°	d(1,2) @.352°	d(1,2) @.528°	--	--	--
--	--	d(1,3) @0°	d(1,3) @.176°	d(1,3) @.352°	d(1,3) @.528°	--	--
--	--	--	d(1,4) @0°	d(1,4) @.176°	d(1,4) @.352°	d(1,4) @.528°	--
d(2,1) @0°	d(2,1) @.176°	d(2,1) @.352°	d(2,1) @.528°	--	--	--	--
--	d(2,2) @0°	d(2,2) @.176°	d(2,2) @.352°	d(2,2) @.528°	--	--	--
--	--	d(2,3) @0°	d(2,3) @.176°	d(2,3) @.352°	d(2,3) @.528°	--	--
--	--	--	d(2,4) @0°	d(2,4) @.176°	d(2,4) @.352°	d(2,4) @.528°	--
d(3,1) @0°	d(3,1) @.176°	d(3,1) @.352°	d(3,1) @.528°	--	--	--	--
--	d(3,2) @0°	d(3,2) @.176°	d(3,2) @.352°	d(3,2) @.528°	--	--	--
--	--	d(3,3) @0°	d(3,3) @.176°	d(3,3) @.352°	d(3,3) @.528°	--	--
--	--	--	d(3,4) @0°	d(3,4) @.176°	d(3,4) @.352°	d(3,4) @.528°	--
d(4,1) @0°	d(4,1) @.176°	d(4,1) @.352°	d(4,1) @.528°	--	--	--	--
--	d(4,2) @0°	d(4,2) @.176°	d(4,2) @.352°	d(4,2) @.528°	--	--	--
--	--	d(4,3) @0°	d(4,3) @.176°	d(4,3) @.352°	d(4,3) @.528°	--	--
--	--	--	d(4,4) @0°	d(4,4) @.176°	d(4,4) @.352°	d(4,4) @.528°	--
d(5,1) @0°	d(5,1) @.176°	d(5,1) @.352°	d(5,1) @.528°	--	--	--	--
--	d(5,2) @0°	d(5,2) @.176°	d(5,2) @.352°	d(5,2) @.528°	--	--	--
--	--	d(5,3) @0°	d(5,3) @.176°	d(5,3) @.352°	d(5,3) @.528°	--	--
--	--	--	d(5,4) @0°	d(5,4) @.176°	d(5,4) @.352°	d(5,4) @.528°	--
d(6,1) @0°	d(6,1) @.176°	d(6,1) @.352°	d(6,1) @.528°	--	--	--	--
--	d(6,2) @0°	d(6,2) @.176°	d(6,2) @.352°	d(6,2) @.528°	--	--	--
--	--	d(6,3) @0°	d(6,3) @.176°	d(6,3) @.352°	d(6,3) @.528°	--	--
--	--	--	d(6,4) @0°	d(6,4) @.176°	d(6,4) @.352°	d(6,4) @.528°	--
d(7,1) @0°	d(7,1) @.176°	d(7,1) @.352°	d(7,1) @.528°	--	--	--	--
--	d(7,2) @0°	d(7,2) @.176°	d(7,2) @.352°	d(7,2) @.528°	--	--	--
--	--	d(7,3) @0°	d(7,3) @.176°	d(7,3) @.352°	d(7,3) @.528°	--	--
--	--	--	d(7,4) @0°	d(7,4) @.176°	d(7,4) @.352°	d(7,4) @.528°	--

FIG. 5D1

Hesai Exhibit 1002, Page 296

d(8,1) @0°	d(8,1) @.176°	d(8,1) @.352°	d(8,1) @.528°	--	--	--	--
--	d(8,2) @0°	d(8,2) @.176°	d(8,2) @.352°	d(8,2) @.528°	--	--	--
--	--	d(8,3) @0°	d(8,3) @.176°	d(8,3) @.352°	d(8,3) @.528°	--	--
--	--	--	d(8,4) @0°	d(8,4) @.176°	d(8,4) @.352°	d(8,4) @.528°	--
d(9,1) @0°	d(9,1) @.176°	d(9,1) @.352°	d(9,1) @.528°	--	--	--	--
--	d(9,2) @0°	d(9,2) @.176°	d(9,2) @.352°	d(9,2) @.528°	--	--	--
--	--	d(9,3) @0°	d(9,3) @.176°	d(9,3) @.352°	d(9,3) @.528°	--	--
--	--	--	d(9,4) @0°	d(9,4) @.176°	d(9,4) @.352°	d(9,4) @.528°	--
d(10,1) @0°	d(10,1) @.176°	d(10,1) @.352°	d(10,1) @.528°	--	--	--	--
--	d(10,2) @0°	d(10,2) @.176°	d(10,2) @.352°	d(10,2) @.528°	--	--	--
--	--	d(10,3) @0°	d(10,3) @.176°	d(10,3) @.352°	d(10,3) @.528°	--	--
--	--	--	d(10,4) @0°	d(10,4) @.176°	d(10,4) @.352°	d(10,4) @.528°	--
d(11,1) @0°	d(11,1) @.176°	d(11,1) @.352°	d(11,1) @.528°	--	--	--	--
--	d(11,2) @0°	d(11,2) @.176°	d(11,2) @.352°	d(11,2) @.528°	--	--	--
--	--	d(11,3) @0°	d(11,3) @.176°	d(11,3) @.352°	d(11,3) @.528°	--	--
--	--	--	d(11,4) @0°	d(11,4) @.176°	d(11,4) @.352°	d(11,4) @.528°	--
d(12,1) @0°	d(12,1) @.176°	d(12,1) @.352°	d(12,1) @.528°	--	--	--	--
--	d(12,2) @0°	d(12,2) @.176°	d(12,2) @.352°	d(12,2) @.528°	--	--	--
--	--	d(12,3) @0°	d(12,3) @.176°	d(12,3) @.352°	d(12,3) @.528°	--	--
--	--	--	d(12,4) @0°	d(12,4) @.176°	d(12,4) @.352°	d(12,4) @.528°	--

FIG. 5D2

Hesai Exhibit 1002, Page 297

d(13,1) @0°	d(13,1) @.176°	d(13,1) @.352°	d(13,1) @.528°	--	--	--	--	--	--
--	d(13,2) @0°	d(13,2) @.176°	d(13,2) @.352°	d(13,2) @.528°	--	--	--	--	--
--	--	d(13,3) @0°	d(13,3) @.176°	d(13,3) @.352°	d(13,3) @.528°	--	--	--	--
--	--	--	d(13,4) @0°	d(13,4) @.176°	d(13,4) @.352°	d(13,4) @.528°	--	--	--
d(14,1) @0°	d(14,1) @.176°	d(14,1) @.352°	d(14,1) @.528°	--	--	--	--	--	--
--	d(14,2) @0°	d(14,2) @.176°	d(14,2) @.352°	d(14,2) @.528°	--	--	--	--	--
--	--	d(14,3) @0°	d(14,3) @.176°	d(14,3) @.352°	d(14,3) @.528°	--	--	--	--
--	--	--	d(14,4) @0°	d(14,4) @.176°	d(14,4) @.352°	d(14,4) @.528°	--	--	--
d(15,1) @0°	d(15,1) @.176°	d(15,1) @.352°	d(15,1) @.528°	--	--	--	--	--	--
--	d(15,2) @0°	d(15,2) @.176°	d(15,2) @.352°	d(15,2) @.528°	--	--	--	--	--
--	--	d(15,3) @0°	d(15,3) @.176°	d(15,3) @.352°	d(15,3) @.528°	--	--	--	--
--	--	--	d(15,4) @0°	d(15,4) @.176°	d(15,4) @.352°	d(15,4) @.528°	--	--	--
d(16,1) @0°	d(16,1) @.176°	d(16,1) @.352°	d(16,1) @.528°	--	--	--	--	--	--
--	d(16,2) @0°	d(16,2) @.176°	d(16,2) @.352°	d(16,2) @.528°	--	--	--	--	--
--	--	d(16,3) @0°	d(16,3) @.176°	d(16,3) @.352°	d(16,3) @.528°	--	--	--	--
--	--	--	d(16,4) @0°	d(16,4) @.176°	d(16,4) @.352°	d(16,4) @.528°	--	--	--

FIG. 5D3

PTO/AIA/14 (11-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P004USC4-1289479
	Application Number	
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	

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

Secrecy Order 37 CFR 5.2:

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

Inventor Information:

Inventor 1 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Angus		PACALA	

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

City	State/Province	Country of Residence
San Francisco	CA	US

Mailing Address of Inventor:

Address 1	350 Treat Avenue
Address 2	
City	San Francisco
State/Province	CA
Postal Code	94103
Country	US

Inventor 2 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Mark		FRICHTL	

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

City	State/Province	Country of Residence
San Francisco	CA	US

Mailing Address of Inventor:

Address 1	350 Treat Avenue
Address 2	
City	San Francisco
State/Province	CA
Postal Code	94103
Country	US

Inventor 3 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Marvin		SHU	

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

PTO/AIA/14 (11-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P004USC4-1289479
	Application Number	
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	

City	San Francisco	State/Province	CA	Country of Residence i	US

Mailing Address of Inventor:

Address 1	350 Treat Avenue		
Address 2			
City	San Francisco	State/Province	CA
Postal Code	94103	Country i	US

Inventor 4 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Eric		YOUNGE	

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

City	San Francisco	State/Province	CA	Country of Residence i	US

Mailing Address of Inventor:

Address 1	350 Treat Avenue		
Address 2			
City	San Francisco	State/Province	CA
Postal Code	94103	Country i	US

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

Correspondence Information:

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

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

Customer Number	20350		
Email Address	ipefiling@kilpatricktownsend.com	Add Email	Remove Email

Application Information:

Title of the Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD		
Attorney Docket Number	103033-P004USC4-1289479	Small Entity Status Claimed	☒
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	15	Suggested Figure for Publication (if any)	

PTO/AIA/14 (11-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P004USC4-1289479
	Application Number	
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	

Filing By Reference:

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

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

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

Publication Information:

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

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

Representative Information:

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

Please Select One:	● Customer Number	US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	20350		

Domestic Benefit/National Stage Information:

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

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
	Continuation of	17194068	2021-03-05

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P004USC4-1289479
	Application Number	
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	

Prior Application Status	Patented	Remove

Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	Patent Number	Issue Date (YYYY-MM-DD)
17194068	Continuation of	15685384	2017-08-24	10948572	2021-03-16

Prior Application Status	Expired	Remove

Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
15685384	Claims benefit of provisional	62379130	2016-08-24

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button. Add

Foreign Priority Information:

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

Remove

Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button. Add

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

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

PTO/AIA/14 (11-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P004USC4-1289479
	Application Number	
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	

Authorization or Opt-Out of Authorization to Permit Access:

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

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

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

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

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

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

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

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

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

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

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

PTO/AIA/14 (11-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P004USC4-1289479
	Application Number	
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	

Applicant Information:

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

Applicant 1 — Remove

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

Clear

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

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

Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here. ☒

Organization Name	Ouster, Inc.		
Mailing Address Information For Applicant:			
Address 1	350 Treat Avenue		
Address 2			
City	San Francisco	**State/Province**	CA
Country	US	Postal Code	94103
Phone Number		Fax Number	
Email Address			

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

Assignee Information including Non-Applicant Assignee Information:

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

PTO/AIA/14 (11-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P004USC4-1289479
	Application Number	
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	

Assignee 1

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

Remove

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

Organization Name	Ouster, Inc.

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1	350 Treat Avenue		
Address 2			
City	San Francisco	**State/Province**	CA
Country i	US	Postal Code	94103
Phone Number		Fax Number	
Email Address			

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

Signature:

Remove

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

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

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

Signature	/ William L. Shaffer /			Date (YYYY-MM-DD)	2021-12-15
First Name	William L.	Last Name	Shaffer	Registration Number	37234

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

PTO/AIA/14 (11-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P004USC4-1289479
	Application Number	
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	

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

Privacy Act Statement

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

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

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

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

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

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

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

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

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

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

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

Doc Code: TRACK1.REQ
Document Description: TrackOne Request

PTO/AIA/424 (04-14)

CERTIFICATION AND REQUEST FOR PRIORITIZED EXAMINATION UNDER 37 CFR 1.102(e) (Page 1 of 1)

First Named Inventor:	Angus Pacala	Nonprovisional Application Number (if known):	N/A
Title of Invention:	Optical System For Collecting Distance Information Within A Field		

APPLICANT HEREBY CERTIFIES THE FOLLOWING AND REQUESTS PRIORITIZED EXAMINATION FOR THE ABOVE-IDENTIFIED APPLICATION.

1. The processing fee set forth in 37 CFR 1.17(i)(1) and the prioritized examination fee set forth in 37 CFR 1.17(c) have been filed with the request. The publication fee requirement is met because that fee, set forth in 37 CFR 1.18(d), is currently $0. The basic filing fee, search fee, and examination fee are filed with the request or have been already been paid. I understand that any required excess claims fees or application size fee must be paid for the application.

2. I understand that the application may not contain, or be amended to contain, more than four independent claims, more than thirty total claims, or any multiple dependent claims, and that any request for an extension of time will cause an outstanding Track I request to be dismissed.

3. The applicable box is checked below:

I. ☑ Original Application (Track One) - Prioritized Examination under § 1.102(e)(1)

i. (a) The application is an original nonprovisional utility application filed under 35 U.S.C. 111(a). This certification and request is being filed with the utility application via EFS-Web.

---OR---

(b) The application is an original nonprovisional plant application filed under 35 U.S.C. 111(a). This certification and request is being filed with the plant application in paper.

ii. An executed inventor's oath or declaration under 37 CFR 1.63 or 37 CFR 1.64 for each inventor, **or** the application data sheet meeting the conditions specified in 37 CFR 1.53(f)(3)(i) is filed with the application.

II. ☐ Request for Continued Examination - Prioritized Examination under § 1.102(e)(2)

i. A request for continued examination has been filed with, or prior to, this form.
ii. If the application is a utility application, this certification and request is being filed via EFS-Web.
iii. The application is an original nonprovisional utility application filed under 35 U.S.C. 111(a), or is a national stage entry under 35 U.S.C. 371.
iv. This certification and request is being filed prior to the mailing of a first Office action responsive to the request for continued examination.
v. No prior request for continued examination has been granted prioritized examination status under 37 CFR 1.102(e)(2).

Signature / William L. Shaffer /	Date 2021-12-15
Name (Print/Typed) William L. Shaffer	Practitioner Registration Number 37,234

Note: *This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. Submit multiple forms if more than one signature is required.**

☑ *Total of 1 forms are submitted.

Privacy Act Statement

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

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

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

PTO/AIA/01 (06-12)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

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

Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number 15/685,384 filed on August 24, 2017.

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

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

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

WARNING:

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

LEGAL NAME OF INVENTOR

Inventor: Angus PACALA Date (Optional): 2018-01-18

Signature: 

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

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

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

PTO/AIA/01 (06-12)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

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

Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number 15/685,384

filed on August 24, 2017.

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

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

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

WARNING:

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

LEGAL NAME OF INVENTOR

Inventor: Mark FRICHTL Date (Optional): 2018-01-17

Signature: Mark Frichtl

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

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

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

PTO/AIA/01 (06-12)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

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

Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number 15/685,384 filed on August 24, 2017.

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

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

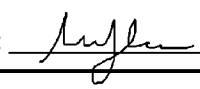
I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

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

LEGAL NAME OF INVENTOR

Inventor: Marvin SHU Date (Optional): 2018-01-18

Signature: 

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

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

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

PTO/AIA/01 (06-12)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

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

Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number 15/685,384

filed on August 24, 2017.

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

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

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

WARNING:

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

LEGAL NAME OF INVENTOR

Inventor: Eric YOUNGE Date (Optional): 1/18/2018

Signature: 

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

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

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

Doc Code: PA..
Document Description: Power of Attorney

PTO/AIA/82A (07-13)
Approved for use through 03/31/2021. OMB 0651-0035
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMITTAL FOR POWER OF ATTORNEY TO ONE OR MORE REGISTERED PRACTITIONERS

NOTE: This form is to be submitted with the Power of Attorney by Applicant form (PTO/AIA/82B) to identify the application to which the Power of Attorney is directed, in accordance with 37 CFR 1.5, unless the application number and filing date are identified in the Power of Attorney by Applicant form. If neither form PTO/AIA/82A nor form PTO/AIA82B identifies the application to which the Power of Attorney is directed, the Power of Attorney will not be recognized in the application.

Application Number	Not Yet Assigned
Filing Date	Filed herewith
First Named Inventor	Angus Pacala
Title	Optical System For Collecting Distance Information Within A Field
Art Unit	Not Yet Assigned
Examiner Name	Not Yet Assigned
Attorney Docket Number	103033-P004USC4-1289479

SIGNATURE of Applicant or Patent Practitioner

Signature	/ William L. Shaffer /	Date (Optional)	
Name	William L. Shaffer	Registration Number	37,234
Title (if Applicant is a juristic entity)			
Applicant Name (if Applicant is a juristic entity)	Ouster, Inc.		

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.

☑ *Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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

Doc Code: PA..
Document Description: Power of Attorney

PTO/AIA/82B (07-13)
Approved for use through 11/30/2014. OMB 0651-0051
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number

POWER OF ATTORNEY BY APPLICANT

I hereby revoke all previous powers of attorney given in the application identified in either the attached transmittal letter or the boxes below.

Application Number	Filing Date

(Note: The boxes above may be left blank if information is provided on form PTO/AIA/82A.)

☑ I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above: 20350

OR

☐ I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

Please recognize or change the correspondence address for the application identified in the attached transmittal letter or the boxes above to:

☑ The address associated with the above-mentioned Customer Number

OR

☐ The address associated with Customer Number:

OR

Firm or Individual Name					
Address					
City		State		Zip	
Country					
Telephone		Email			

I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

Ouster, Inc.

☐ Inventor or Joint Inventor (title not required below)

☐ Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)

☑ Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)

☐ Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

SIGNATURE of Applicant for Patent

The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

Signature	Mark Fricht	Date (Optional)	2017-10-04
Name	Mark Fricht		
Title	CTO		

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.

☑ Total of forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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

I hereby certify that this correspondence is being filed via EFS-Web with the United States Patent and Trademark Office on December 15, 2021.

KILPATRICK TOWNSEND & STOCKTON LLP

By: /Erica M. Rojas/
Erica M. Rojas

PATENT
Attorney Docket No.: 103033-P004USC4-1289479
Client Ref. No.: P004USC4

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	Confirmation No.: Not Yet Assigned
Angus Pacala	Examiner: Not Yet Assigned
Application No.: Not Yet Assigned	Technology Center/Art Unit: Not Yet Assigned
Filed: Filed Herewith	
For: OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	INFORMATION DISCLOSURE STATEMENT
Customer No.: 20350	

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

The references cited on attached form PTO/SB/08A are being called to the attention of the Examiner. In accordance with the provisions of 37 CFR §1.98(a)(2), copies of any cited U.S. Patents and U.S. Patent Application Publications are not provided. In accordance with 37 CFR §1.98(d), copies of the references can be found in 17/194,068, filed March 5, 2021. Copies of the remaining references are enclosed.

It is respectfully requested that the cited references be expressly considered during the prosecution of this application and the references be made of record therein and appear among the "references cited" on any patent to issue therefrom.

As provided for by 37 CFR §1.97(g) and (h), no inference should be made that the information and references cited are prior art merely because they are in this statement and no representation is being made that a search has been conducted or that this statement encompasses all the possible relevant information.

This Information Disclosure Statement is being filed before the mailing date of the first Office Action on the merits.

Applicant believes that no fee is required for submission of this statement. However, if any fees are due for the submission of this Information Disclosure Statement, please deduct those fees from Deposit Account No. 20-1430.

Respectfully submitted,

/ William L. Shaffer /

William L. Shaffer
Registration No. 37,234

KILPATRICK TOWNSEND & STOCKTON LLP

Attachment