UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION



PATENT NO. : 10,330,897 B2
APPLICATION NO. : 15/976391
DATED : June 25, 2019
INVENTOR(S) : Michael Dror

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 8 Line 66 Claim 7 should read:
The lens assembly of claim 1, wherein the lens assembly has a f-number F# = 2.8.

Signed and Sealed this
Twenty-third Day of July, 2019

Andrei Iancu
*Director of the United States Patent and Trademark Office*

# Electronic Patent Application Fee Transmittal

| | |
|---|---|
| **Application Number:** | 15976391 |
| **Filing Date:** | 10-May-2018 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Filer:** | Menachem Nathan |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |

Filed as Small Entity

**Filing Fees for** **Utility under 35 USC 111(a)**

| Description | Fee Code | Quantity | Amount | Sub-Total in USD($) |
|---|---|---|---|---|
| **Basic Filing:** | | | | |
| **Pages:** | | | | |
| **Claims:** | | | | |
| **Miscellaneous-Filing:** | | | | |
| **Petition:** | | | | |
| **Patent-Appeals-and-Interference:** | | | | |
| **Post-Allowance-and-Post-Issuance:** | | | | |
| CERTIFICATE OF CORRECTION | 2811 | 1 | 150 | 150 |

| Description | Fee Code | Quantity | Amount | Sub-Total in USD($) |
|---|---|---|---|---|
| **Extension-of-Time:** | | | | |
| **Miscellaneous:** | | | | |
| | | **Total in USD ($)** | | **150** |

# Electronic Acknowledgement Receipt

| | |
|---|---|
| **EFS ID:** | 36434237 |
| **Application Number:** | 15976391 |
| **International Application Number:** | |
| **Confirmation Number:** | 1858 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Customer Number:** | 92342 |
| **Filer:** | Menachem Nathan |
| **Filer Authorized By:** | |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |
| **Receipt Date:** | 27-JUN-2019 |
| **Filing Date:** | 10-MAY-2018 |
| **Time Stamp:** | 15:45:02 |
| **Application Type:** | Utility under 35 USC 111(a) |

## Payment information:

| | |
|---|---|
| Submitted with Payment | yes |
| Payment Type | CARD |
| Payment was successfully received in RAM | $150 |
| RAM confirmation Number | 062819INTEFSW15465201 |
| Deposit Account | |
| Authorized User | |
| The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: | |

## File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 1 | Any request going to L and R | Petiton_for_certificate_of_correction.pdf | 17362<br>f5e59a8eb660585a5d1214d21be7859f65ff91ca | no | 1 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 2 | Request for Certificate of Correction | Certificate_of_Correction.pdf | 140734<br>c0bd2e8b6c1bea28078cbcf1d90225a7cefcd0b4 | no | 2 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 3 | Fee Worksheet (SB06) | fee-info.pdf | 30002<br>a3b9a06dbf36dfa78986d6aa88d2c28bd5bd9068 | no | 2 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| | | **Total Files Size (in bytes):** | 188098 | | |

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

**New Applications Under 35 U.S.C. 111**
**If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.**
**National Stage of an International Application under 35 U.S.C. 371**
**If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.**
**New International Application Filed with the USPTO as a Receiving Office**
**If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.**

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

| | | |
|---|---|---|
| In re Applicant: | § | Patent No,: 10330897 |
| | § | |
| Michael Dror | § | |
| | § | |
| Serial No.: 15/976,391 | | |
| Title: MINIATURE TELEPHOTO LENS ASSEMBLY | | |
| | § | |
| Filed: 05/10/2018 | § | |
| | § | Attorney Docket: Coreph-0080 US CON4 |
| Examiner: Lester, Evelyn A. | | |

**Mail Stop Petitions**
Commissioner for Patents
Alexandria, VA 22313-1450

**REQUEST FOR CERTIFICATE OF CORRECTION**

Applicant hereby provides a draft of a Certificate of Correction related to issued patent 10330897. The correction is in Claim 7, which should end with F# = 2.8, as listed in the last outstanding set of claims.

A Certificate of Correction fee of $150 is paid herewith.

Respectfully submitted,
/Menachem Nathan/
Menachem Nathan
Agent for Applicant
Registration No. 65392

Tel: 516-442-9736

Date: June 27, 2019

PTO/SB/44 (09-07)
Approved for use through 01/31/2020. OMB 0651-0033
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.
(Also Form PTO-1050)

# UNITED STATES PATENT AND TRADEMARK OFFICE
## CERTIFICATE OF CORRECTION

Page 1 of ____

PATENT NO. : 10330897

APPLICATION NO.: 15/976,391

ISSUE DATE : 06/25/2019

INVENTOR(S) : Michael Dror

It is certified that an error appears or errors appear in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

What is claimed is:

7. The lens assembly of claim 1, wherein the lens assembly has a f-number F# = 2.8.

MAILING ADDRESS OF SENDER (Please do not use Customer Number below):

This collection of information is required by 37 CFR 1.322, 1.323, and 1.324. 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 1.0 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: Attention Certificate of Corrections Branch, 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.*

## 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.

UNITED STATES PATENT AND TRADEMARK OFFICE

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

| APPLICATION NO. | ISSUE DATE | PATENT NO. | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 15/976,391 | 06/25/2019 | 10330897 | COREPH-0080 US CON4 | 1858 |

92342 7590 06/05/2019

Nathan & Associates Patent Agents Ltd
P.O.Box 10178
Tel Aviv, 6110101
ISRAEL

# ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

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

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

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

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

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

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

Michael Dror, Nes Ziona, ISRAEL;
Corephotonics Ltd., Tel-Aviv, ISRAEL;
Ephraim Goldenberg, Ashdod, ISRAEL;
Gal Shabtay, Tel Aviv, ISRAEL;

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.

IR103 (Rev. 10/09)

| **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** ( Not for submission under 37 CFR 1.99) | Application Number | 15976391 |
|---|---|---|
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-080 US CON4 |

Change(s) applied to document,
/N.B.H./
3/11/2019

| | | | | | | |
|---|---|---|---|---|---|---|
| | 17 | 20140029116 | A1 | 2014-01-30 | Tsai et al. ~~Largan Precision Co Ltd~~ | |
| | 18 | 20130003195 | A1 | 2013-01-03 | Yoji Kubota et al | |

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

**FOREIGN PATENT DOCUMENTS**

| Examiner Initial* | Cite No | Foreign Document Number3 | Country Code2 | Kind Code4 | Publication Date | Name of Patentee or Applicant of cited Document | Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear | T5 |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2013063097 | WO | A1 | 2013-05-02 | Cahall et al. | | ☐ |
| | 2 | 2014199338 | WO | A2 | 2014-12-18 | COREPHOTONICS LTD | | ☐ |
| | 3 | 2013106289 | JP | | 2013-05-30 | KONICA MINOLTA ADVANCED LAYERS | | ☐ |
| | 4 | 2008064884 | JP | | 2008-03-21 | Kyocera | | ☐ |
| | 5 | 2013105012 | WO | A2 | 2013-07-18 | Goldenberg et al. | | ☐ |
| | 6 | 2015015383 | WO | A2 | 2015-02-05 | Shabtay et al. | | ☐ |
| | 7 | 2008122900 | JP | | 2008-05-29 | Fujinon | | ☐ |



ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /E.A.L/

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**United States Patent and Trademark Office**
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www.uspto.gov

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 15/976,391 | 05/10/2018 | Michael Dror | COREPH-0080 US CON4 | 1858 |

92342 7590 05/10/2019
Nathan & Associates Patent Agents Ltd
P.O.Box 10178
Tel Aviv, 6110101
ISRAEL

| EXAMINER | |
|---|---|
| TALLMAN, ROBERT E | |

| ART UNIT | PAPER NUMBER |
|---|---|
| 2872 | |

| NOTIFICATION DATE | DELIVERY MODE |
|---|---|
| 05/10/2019 | 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):

amirr@natpatent.com
dorong@natpatent.com
info@natpatent.com

| **Corrected** *Notice of Allowability* | **Application No.** 15/976,391 | **Applicant(s)** Dror et al. | |
|---|---|---|---|
| | **Examiner** ROBERT E TALLMAN | **Art Unit** 2872 | **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 TD and IDS filed on 10-27-18 and 1-5-19 respectively.
☐ 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 1-30 . 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 areply 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 _____.
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 _____.

/Robert E. Tallman/
Primary Examiner, Art Unit 2872

## 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 (IDS) submitted on 03 July 2018 has been amended to include the date of Japanese reference, JP 1966-006865, as being 1966-4-18. This amendment is on line 12 of the foreign reference section appearing on page 5 of the IDS.

## EXAMINER'S AMENDMENT

An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Examiner notes that the amendments to these claims is the inclusion of a period at the end of the claim limitations as noted below.

The application has been amended as follows:

2. (Currently amended) The lens assembly of claim 1, wherein the TTL is equal or smaller than 6.0mm and wherein the lens assembly has a f-number F# < 2.9.

7. (Currently amended) The lens assembly of claim 1, wherein the lens assembly has a f-number F#=2.

18. (Currently amended) The lens assembly of claim 17, wherein the TTL is equal or smaller than 6.0mm and wherein the lens assembly has a f-number F# < 2.9.

19. (Currently amended) The lens assembly of claim 17, wherein the TTL is equal or smaller than 6.0mm and wherein lens element $L_{1\_1}$ has an image-side surface diameter between 2.3mm and 2.5mm.

23. (Currently amended) The lens assembly of claim 17, wherein the lens assembly has a f-number F# = 2.8.

***Conclusion***

Any inquiry concerning this communication or earlier communications from the examiner should be directed to ROBERT E TALLMAN whose telephone number is (571)270-3958. The examiner can normally be reached on Monday-Friday 10 a.m. -6 p.m.

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

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Ricky Mack can be reached on 571-272-2333. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/Robert E. Tallman/
Primary Examiner, Art Unit 2872
06 May 2019

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

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

| **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** ( Not for submission under 37 CFR 1.99) | | |
|---|---|---|
| | Application Number | 15976391 |
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-080 US CON4 |

| U.S.PATENTS | | | | | | |
|---|---|---|---|---|---|---|
| Examiner Initial* | Cite No | Patent Number | Kind Code1 | Issue Date | Name of Patentee or Applicant of cited Document | Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear |
| | 1 | 8395851 | | 2013-03-12 | Tang et al. | |
| | 2 | 8508860 | | 2013-08-13 | Tang et al. | |
| | 3 | 8072695 | | 2011-12-06 | Lee et al. | |
| | 4 | 7826151 | | 2010-11-02 | Tsung-Han Tsai | |
| | 5 | 5946142 | A | 1999-08-31 | Hirata et al. | |
| | 6 | 8233224 | B2 | 2012-07-31 | Chen | |
| | 7 | 8310768 | B2 | 2012-11-13 | Lin et al. | |
| | 8 | 5172235 | A | 1992-12-15 | Wilm et al. | |



ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /E.A.L/

| INFORMATION DISCLOSURE STATEMENT BY APPLICANT ( Not for submission under 37 CFR 1.99) | | |
|---|---|---|
| | Application Number | 15976391 |
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-080 US CON4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 9 | 8046026 | B2 | 2011-10-25 | Koa | |
| | 10 | 8731390 | B2 | 2014-05-20 | Goldenberg et al. | |
| | 11 | 9405099 | B2 | 2016-08-02 | Jo et al. | |
| | 12 | 8553106 | B2 | 2013-10-08 | Lawrence Scarff | |

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

**U.S.PATENT APPLICATION PUBLICATIONS**

| Examiner Initial* | Cite No | Publication Number | Kind Code1 | Publication Date | Name of Patentee or Applicant of cited Document | Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear |
|---|---|---|---|---|---|---|
| | 1 | 20100254029 | A1 | 2010-10-07 | Yoshikazu Shinohara | |
| | 2 | 20120314296 | A1 | 2012-12-13 | Shabtay et al. | |
| | 3 | 20070229987 | A1 | 2007-10-04 | Shinohara | |
| | 4 | 20130038947 | A1 | 2013-02-14 | Tsai et al. | |
| | ~~5~~ | ~~20070229987~~ | ~~A1~~ | ~~2007-10-04~~ | ~~Tang et al.~~ Repeat App# of 3 above. | |



ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /E.A.L/

| **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** ( Not for submission under 37 CFR 1.99) | | |
|---|---|---|
| | Application Number | 15976391 |
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-080 US CON4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 6 | 20120087020 | A1 | 2010-04-12 | Deng et al. | |
| | 7 | 20110115965 | A1 | 2011-05-19 | Engelhardt et al. | |
| | 8 | 20080166115 | A1 | 2008-07-10 | Sachs et al. | |
| | 9 | 20150085174 | A1 | 2015-03-24 | Shabtay et al. | |
| | 10 | 20150029601 | A1 | 2015-01-29 | Dror et al. | |
| | 11 | 20060187312 | A1 | 2006-08-24 | Labaziewicz et al. | |
| | 12 | 20110080487 | A1 | 2011-04-07 | Vankataraman et al. | |
| | 13 | 20090002839 | A1 | 2009-01-01 | Sato Kenichi | |
| | 14 | 20080218613 | A1 | 2008-09-11 | Janson et al. | |
| | 15 | 20080187310 | A1 | 2008-08-24 | Janson et al. | |
| | 16 | 20140293453 | A1 | 2014-10-02 | Tatsuyuki OGINO | |



ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /E.A.L/

| **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** ( Not for submission under 37 CFR 1.99) | | |
|---|---|---|
| | Application Number | 15976391 |
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-080 US CON4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 17 | 20140029116 | A1 | 2014-01-30 | Largan Precision Co Ltd | |
| | 18 | 20130003195 | A1 | 2013-01-03 | Yoji Kubota et al | |

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

**FOREIGN PATENT DOCUMENTS**

| Examiner Initial* | Cite No | Foreign Document Number3 | Country Code2 i | Kind Code4 | Publication Date | Name of Patentee or Applicant of cited Document | Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear | T5 |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2013063097 | WO | A1 | 2013-05-02 | Cahall et al. | | ☐ |
| | 2 | 2014199338 | WO | A2 | 2014-12-18 | COREPHOTONICS LTD | | ☐ |
| | 3 | 2013106289 | JP | | 2013-05-30 | KONICA MINOLTA ADVANCED LAYERS | | ☐ |
| | 4 | 2008064884 | JP | | 2008-03-21 | Kyocera | | ☐ |
| | 5 | 2013105012 | WO | A2 | 2013-07-18 | Goldenberg et al. | | ☐ |
| | 6 | 2015015383 | WO | A2 | 2015-02-05 | Shabtay et al. | | ☐ |
| | 7 | 2008122900 | JP | | 2008-05-29 | Fujinon | | ☐ |



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| INFORMATION DISCLOSURE STATEMENT BY APPLICANT ( Not for submission under 37 CFR 1.99) | | |
|---|---|---|
| | Application Number | 15976391 |
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-080 US CON4 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 8 | 2011138175 | JP | | 2011-07-14 | Konica | | ☐ |
| | 9 | 1976016135 | JP | | 1976-05-21 | | | ☐ |
| | 10 | 2007306282 | JP | | 2007-11-22 | CITIZEN ELECTRONICS CO LTD | | ☐ |
| | 11 | 1995113952 | JP | | 1995-05-02 | Nikon | | ☐ |
| | 12 | 1966006865 | JP | | 1966-4-18 | | | ☐ |
| | 13 | 20100040357 | KR | | 2010-04-20 | LG Innotek | | ☐ |
| | 14 | 20100119673 | KR | | 2010-11-10 | Kolen | | ☐ |

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**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, pages(s), volume-issue number(s), publisher, city and/or country where published. | T5 |
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| INFORMATION DISCLOSURE STATEMENT BY APPLICANT ( Not for submission under 37 CFR 1.99) | | |
|---|---|---|
| | Application Number | 15976391 |
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-080 US CON4 |

| EXAMINER SIGNATURE | | | |
|---|---|---|---|
| Examiner Signature | /EVELYN A LESTER/ | Date Considered | 09/28/2018 |

*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.



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| INFORMATION DISCLOSURE STATEMENT BY APPLICANT ( Not for submission under 37 CFR 1.99) | | |
|---|---|---|
| | Application Number | 15976391 |
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-080 US CON4 |

**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 | /Menachem Nathan/ | Date (YYYY-MM-DD) | 2018-06-28 |
|---|---|---|---|
| Name/Print | MENACHEM NATHAN | Registration Number | 65392 |

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.**



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# Privacy Act Statement

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

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

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

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

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

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

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

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

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

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

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



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## 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)

92342 7590 03/04/2019
Nathan & Associates Patent Agents Ltd
P.O.Box 10178
Tel Aviv, 6110101
ISRAEL

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. |
|---|---|---|---|---|
| 15/976,391 | 05/10/2018 | Michael Dror | COREPH-0080 US CON4 | 1858 |

TITLE OF INVENTION: MINIATURE TELEPHOTO LENS ASSEMBLY

| APPLN. TYPE | ENTITY STATUS | ISSUE FEE DUE | PUBLICATION FEE DUE | PREV. PAID ISSUE FEE | TOTAL FEE(S) DUE | DATE DUE |
|---|---|---|---|---|---|---|
| nonprovisional | SMALL | $500 | $0.00 | $0.00 | $500 | 06/04/2019 |

| EXAMINER | ART UNIT | CLASS-SUBCLASS |
|---|---|---|
| LESTER, EVELYN A | 2872 | 359-714000 |

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

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

❏ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

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

1 Nathan & Associates
2 Menachem Nathan
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
Corephotonics Ltd.

(B) RESIDENCE: (CITY and STATE OR COUNTRY)
Tel Aviv, Israel

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 /Menachem Nathan/ Date 03/08/2019

Typed or printed name Menachem Nathan Registration No. 65392

# Electronic Patent Application Fee Transmittal

| | |
|---|---|
| **Application Number:** | 15976391 |
| **Filing Date:** | 10-May-2018 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Filer:** | Menachem Nathan |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |

Filed as Small Entity

**Filing Fees for Utility under 35 USC 111(a)**

| Description | Fee Code | Quantity | Amount | Sub-Total in USD($) |
|---|---|---|---|---|
| **Basic Filing:** | | | | |
| **Pages:** | | | | |
| **Claims:** | | | | |
| **Miscellaneous-Filing:** | | | | |
| **Petition:** | | | | |
| **Patent-Appeals-and-Interference:** | | | | |
| **Post-Allowance-and-Post-Issuance:** | | | | |
| UTILITY APPL ISSUE FEE | 2501 | 1 | 500 | 500 |

| Description | Fee Code | Quantity | Amount | Sub-Total in USD($) |
| --- | --- | --- | --- | --- |
| **Extension-of-Time:** | | | | |
| **Miscellaneous:** | | | | |
| | | **Total in USD ($)** | | **500** |

## Electronic Acknowledgement Receipt

| | |
|---|---|
| **EFS ID:** | 35360959 |
| **Application Number:** | 15976391 |
| **International Application Number:** | |
| **Confirmation Number:** | 1858 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Customer Number:** | 92342 |
| **Filer:** | Menachem Nathan |
| **Filer Authorized By:** | |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |
| **Receipt Date:** | 08-MAR-2019 |
| **Filing Date:** | 10-MAY-2018 |
| **Time Stamp:** | 06:49:26 |
| **Application Type:** | Utility under 35 USC 111(a) |

## Payment information:

| | |
|---|---|
| Submitted with Payment | yes |
| Payment Type | CARD |
| Payment was successfully received in RAM | $500 |
| RAM confirmation Number | 030819INTEFSW06503500 |
| Deposit Account | |
| Authorized User | |

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| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 1 | Issue Fee Payment (PTO-85B) | Issue_Fee.pdf | 154809<br>5d916f20476d8b8928f4632d1266e5d17df15bec | no | 1 |

**Warnings:**

**Information:**

| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 2 | Fee Worksheet (SB06) | fee-info.pdf | 29999<br>1447623a4b7774f3efde832fab7b6d2d00edd40e | no | 2 |

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**New Applications Under 35 U.S.C. 111**
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United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

# NOTICE OF ALLOWANCE AND FEE(S) DUE

92342 7590 03/04/2019
Nathan & Associates Patent Agents Ltd
P.O.Box 10178
Tel Aviv, 6110101
ISRAEL

| EXAMINER | |
|---|---|
| LESTER, EVELYN A | |
| ART UNIT | PAPER NUMBER |
| 2872 | |

DATE MAILED: 03/04/2019

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 15/976,391 | 05/10/2018 | Michael Dror | COREPH-0080 US CON4 | 1858 |

TITLE OF INVENTION: MINIATURE TELEPHOTO LENS ASSEMBLY

| APPLN. TYPE | ENTITY STATUS | ISSUE FEE DUE | PUBLICATION FEE DUE | PREV. PAID ISSUE FEE | TOTAL FEE(S) DUE | DATE DUE |
|---|---|---|---|---|---|---|
| nonprovisional | SMALL | $500 | $0.00 | $0.00 | $500 | 06/04/2019 |

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

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

**HOW TO REPLY TO THIS NOTICE:**

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

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

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

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

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

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

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

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Tel Aviv, 6110101
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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. |
|---|---|---|---|---|
| 15/976,391 | 05/10/2018 | Michael Dror | COREPH-0080 US CON4 | 1858 |

TITLE OF INVENTION: MINIATURE TELEPHOTO LENS ASSEMBLY

| APPLN. TYPE | ENTITY STATUS | ISSUE FEE DUE | PUBLICATION FEE DUE | PREV. PAID ISSUE FEE | TOTAL FEE(S) DUE | DATE DUE |
|---|---|---|---|---|---|---|
| nonprovisional | SMALL | $500 | $0.00 | $0.00 | $500 | 06/04/2019 |

| EXAMINER | ART UNIT | CLASS-SUBCLASS |
|---|---|---|
| LESTER, EVELYN A | 2872 | 359-714000 |

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

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

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

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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

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❑ 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 DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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www.uspto.gov

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 15/976,391 | 05/10/2018 | Michael Dror | COREPH-0080 US CON4 | 1858 |

92342 7590 03/04/2019

Nathan & Associates Patent Agents Ltd
P.O.Box 10178
Tel Aviv, 6110101
ISRAEL

| EXAMINER | |
|---|---|
| LESTER, EVELYN A | |
| **ART UNIT** | **PAPER NUMBER** |
| 2872 | |

DATE MAILED: 03/04/2019

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

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

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

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

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

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

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

## Privacy Act Statement

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

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

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

| Notice of Allowability | Application No. 15/976,391 | Applicant(s) Dror et al. | |
|---|---|---|---|
| | Examiner EVELYN A LESTER | Art Unit 2872 | 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 TD and IDS filed on 10-27-18 and 1-5-19, respectively.
☐ 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 1-24 . 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 areply 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 1-5-19.
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 _____.

/EVELYN A LESTER/
Primary Examiner, Art Unit 2872

### *Notice of Pre-AIA or AIA Status*

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

### *Terminal Disclaimer*

2. The terminal disclaimer filed on 10-27-18 disclaiming the terminal portion of any patent granted on this application which would extend beyond the expiration date of U.S. patent applications (should they issue as patents), serial numbers: 15/976,422 and 15/817,235; and U.S. Patents: 9,857,568; 9,568,712; and 9,402,032, has been reviewed and is accepted. The terminal disclaimer has been recorded.

## REASONS FOR ALLOWANCE

3. The following is an examiner's statement of reasons for allowance:

The prior art does not show or fairly suggest the claimed invention of a lens assembly having the claimed structure and claimed limitations, wherein a rejection under 35 USC 102 or 103 would be improper. Please particularly note the combination of claimed elements and claimed limitations, including the terminal disclaimer filed on 10-27-18 which was approved. Since the obviousness-type double patenting rejection was the only rejection of record in the office action mailed on 10-18-18.

Further, "The Patent Trial and Appeal Board" cases: IPR-2018-01140 and IPR-2018-01146, were reviewed for content, i.e. prior art and arguments were considered in light of the present claims. Also, IPR-2018-01356 was considered, but the decision to go to trial was denied in this case. Lastly, IPR-2019-00030 was considered to the extent possible, as no decision for the case has been made of record to date.

Therefore, in light of the Applicants' arguments and/or amendments filed on 10-27-18, the claimed invention is considered to be in condition for allowance as being novel and nonobvious over the prior art.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

***Conclusion***

4. Any inquiry concerning this communication or earlier communications from the examiner should be directed to EVELYN A LESTER whose telephone number is (571)272-2332. The examiner can normally be reached on M-F: 10am-6pm (ET); subject to flex-schedule..

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

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Ricky Mack can be reached on (571) 272-2333. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/EVELYN A LESTER/
Primary Examiner
Art Unit 2872

# *Issue Classification*

| | | |
|---|---|---|
| | **Application/Control No.**<br>15/976,391 | **Applicant(s)/Patent Under Reexamination**<br>Dror et al. |
| | **Examiner**<br>EVELYN A LESTER | **Art Unit**<br>2872 |

| **CPC** | | | | | | |
|---|---|---|---|---|---|---|
| **Symbol** | | | | | **Type** | **Version** |
| G02B | / | 13 | / | 0045 | F | 2013-01-01 |
| G02B | / | 13 | / | 02 | I | 2013-01-01 |
| G02B | / | 9 | / | 60 | I | 2013-01-01 |
| G02B | / | 27 | / | 0025 | I | 2013-01-01 |
| G02B | / | 1 | / | 041 | I | 2013-01-01 |
| G02B | / | 27 | / | 646 | I | 2013-01-01 |
| G02B | / | 13 | / | 002 | A | 2013-01-01 |
| G02B | / | 5 | / | 005 | A | 2013-01-01 |
| H04N | / | 2201 | / | 00 | A | 2013-01-01 |
| G02B | / | 9 | / | 00 | A | 2013-01-01 |
| H04N | / | 2101 | / | 00 | A | 2013-01-01 |
| Y10T | / | 29 | / | 4913 | A | 2015-01-15 |

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

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|---|---|---|---|
| NONE<br>(Assistant Examiner) | (Date) | **Total Claims Allowed:**<br>30 | |
| /EVELYN A LESTER/<br>Primary Examiner, Art Unit 2872<br>(Primary Examiner) | 14 February 2019<br>(Date) | O.G. Print Claim(s)<br>1 | O.G. Print Figure<br>1A |

| *Issue Classification* | Application/Control No. 15/976,391 | Applicant(s)/Patent Under Reexamination Dror et al. |
|---|---|---|
| | Examiner EVELYN A LESTER | Art Unit 2872 |

| INTERNATIONAL CLASSIFICATION | | | | |
|---|---|---|---|---|
| CLAIMED | | | | |
| | / | | / | |

| NON-CLAIMED | | | | |
|---|---|---|---|---|
| | / | | / | |

| US ORIGINAL CLASSIFICATION | |
|---|---|
| CLASS | SUBCLASS |
| 359 | 714 |

| CROSS REFERENCES(S) | | | | | | |
|---|---|---|---|---|---|---|
| CLASS | SUBCLASS (ONE SUBCLASS PER BLOCK) | | | | | |
| 359 | 739 | 740 | 763 | 764 | | |

| NONE<br>(Assistant Examiner) (Date) | Total Claims Allowed:<br>30 | |
|---|---|---|
| /EVELYN A LESTER/<br>Primary Examiner, Art Unit 2872 14 February 2019<br>(Primary Examiner) (Date) | O.G. Print Claim(s)<br>1 | O.G. Print Figure<br>1A |

U.S. Patent and Trademark Office Part of Paper No.: 20190214

| *Issue Classification* | Application/Control No. 15/976,391 | Applicant(s)/Patent Under Reexamination Dror et al. |
|---|---|---|
| | Examiner EVELYN A LESTER | Art Unit 2872 |

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

**CLAIMS**

| Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 10 | | 19 | | 28 | | | | | | | | |
| | 2 | | 11 | | 20 | | 29 | | | | | | | | |
| | 3 | | 12 | | 21 | | 30 | | | | | | | | |
| | 4 | | 13 | | 22 | | | | | | | | | | |
| | 5 | | 14 | | 23 | | | | | | | | | | |
| | 6 | | 15 | | 24 | | | | | | | | | | |
| | 7 | | 16 | | 25 | | | | | | | | | | |
| | 8 | | 17 | | 26 | | | | | | | | | | |
| | 9 | | 18 | | 27 | | | | | | | | | | |

| | | | |
|---|---|---|---|
| NONE<br><br>(Assistant Examiner) | (Date) | Total Claims Allowed:<br>30 | |
| /EVELYN A LESTER/<br>Primary Examiner, Art Unit 2872<br>(Primary Examiner) | 14 February 2019<br>(Date) | O.G. Print Claim(s)<br>1 | O.G. Print Figure<br>1A |

| *Search Notes* | Application/Control No. 15/976,391 | Applicant(s)/Patent Under Reexamination Dror et al. |
|---|---|---|
| | Examiner EVELYN A LESTER | Art Unit 2872 |

| CPC - Searched* | | |
|---|---|---|
| **Symbol** | **Date** | **Examiner** |
| G02B 13/0045; G02B 9/60; G02B 27/0025; G02B 5/005; G02B 13/02; G02B 1/041; G02B 13/002; G02B9/00; G02B 27/646; H04N 2201/00; Y10T 29/4913. | 10-14-18 | EAL |
| Update search of the above from 10-1-18 | 02/14/2019 | EAL |

| CPC Combination Sets - Searched* | | |
|---|---|---|
| **Symbol** | **Date** | **Examiner** |
| | | |

| US Classification - Searched* | | | |
|---|---|---|---|
| **Class** | **Subclass** | **Date** | **Examiner** |
| 359 | 714, 739, 740, 763, 764 | 10-14-18 | EAL |
| Update | search of the above from 10-1-18 | 02/14/2019 | EAL |

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

| Search Notes | | |
|---|---|---|
| **Search Notes** | **Date** | **Examiner** |
| EAST Search: USPAT, US=PGPUB, JPO, EPO, DERWENT, IBM-TDB. | 10-14-18 | EAL |
| Classification searches in CPC and USPC, crossed with text search. | 10-14-18 | EAL |
| Inventor and Assignee searches in EAST | 10-14-18 | EAL |
| EAST Search: USPAT, US=PGPUB, JPO, EPO, DERWENT, IBM-TDB. | 02/14/2019 | EAL |
| Classification update searches in CPC and USPC, crossed with text search. | 02/14/2019 | EAL |

| | |
|---|---|
| /EVELYN A LESTER/<br>Primary Examiner.Art Unit 2872 | |

| Search Notes | Application/Control No. 15/976,391 | Applicant(s)/Patent Under Reexamination Dror et al. |
|---|---|---|
| | Examiner EVELYN A LESTER | Art Unit 2872 |

| Interference Search | | | |
|---|---|---|---|
| **US Class/CPC Symbol** | **US Subclass/CPC Group** | **Date** | **Examiner** |
| Same as the | above for CPC and USPC crossed with text search | 02/14/2019 | EAL |

| | |
|---|---|
| /EVELYN A LESTER/<br>Primary Examiner.Art Unit 2872 | |

**EAST Search History**

**EAST Search History (Prior Art)**

| Ref # | Hits | Search Query | DBs | Default Operator | Plurals | Time Stamp |
|---|---|---|---|---|---|---|
| L1 | 12617 | 359/713,714,715-717,739,740,745-748,754-795.ccls. | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2019/02/14 20:25 |
| L2 | 16755 | ( (G02B13/0045 OR G02B9/62 OR G02B9/60 OR G02B13/18 OR G02B13/004 OR G02B9/64 OR G02B5/005 OR G02B13/00 OR G02B9/12).CPC. ) | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2019/02/14 20:25 |
| L3 | 1730861 | @pd>="20181001" | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2019/02/14 20:26 |
| L4 | 23642 | 1 or 2 | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2019/02/14 20:26 |
| L5 | 1786907 | lens$2 | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2019/02/14 20:27 |
| L6 | 936187 | object with image | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2019/02/14 20:27 |
| L7 | 263818 | total near4 length | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2019/02/14 20:27 |
| L8 | 102939 | aspheric$6 or non-spheric$6 or nonspheric$6 | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2019/02/14 20:27 |
| L9 | 1547162 | positive with negative | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2019/02/14 20:27 |
| L10 | 415287 | optical near2 axis | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2019/02/14 20:27 |

| | | | | | | |
|---|---|---|---|---|---|---|
| L11 | 6847 | L5 and L6 and L7 and L8 and L9 and L10 | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2019/02/14 20:27 |
| L12 | 1205 | 3 and 4 | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2019/02/14 20:34 |
| L13 | 199 | 11 and 12 | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2019/02/14 20:34 |
| L15 | 16755 | ( (G02B13/0045 OR G02B9/62 OR G02B9/60 OR G02B13/18 OR G02B13/004 OR G02B9/64 OR G02B5/005 OR G02B13/00 OR G02B9/12).CPC. ) | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2019/02/14 20:35 |

**EAST Search History (Interference)**

| Ref # | Hits | Search Query | DBs | Default Operator | Plurals | Time Stamp |
|---|---|---|---|---|---|---|
| L14 | 7564 | 359/713,714,715-717,739,740,745-748,754-795.ccls. | US-PGPUB; USPAT | OR | ON | 2019/02/14 20:35 |
| L16 | 674651 | object with image | US-PGPUB; USPAT | OR | ON | 2019/02/14 20:35 |
| L17 | 233632 | total near4 length | US-PGPUB; USPAT | OR | ON | 2019/02/14 20:36 |
| L18 | 1223562 | positive with negative | US-PGPUB; USPAT | OR | ON | 2019/02/14 20:36 |
| L19 | 9835 | ( (G02B13/0045 OR G02B9/62 OR G02B9/60 OR G02B13/18 OR G02B13/004 OR G02B9/64 OR G02B5/005 OR G02B13/00 OR G02B9/12).CPC. ) | US-PGPUB; USPAT | OR | ON | 2019/02/14 20:36 |
| L20 | 13773 | 14 or 19 | US-PGPUB; USPAT | OR | ON | 2019/02/14 20:37 |
| L21 | 10903 | 16 and 17 and 18 | US-PGPUB; USPAT | OR | ON | 2019/02/14 20:37 |
| L22 | 4405 | 20 and 21 | US-PGPUB; USPAT | OR | ON | 2019/02/14 20:37 |

**2/14/2019 8:39:53 PM**
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Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

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

| **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** ( **Not for submission under 37 CFR 1.99)** | | |
|---|---|---|
| | Application Number | 15976391 |
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-0080 US CON4 |

**U.S.PATENTS** Remove

| Examiner Initial* | Cite No | Patent Number | Kind Code[1] | Issue Date | Name of Patentee or Applicant of cited Document | Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear |
|---|---|---|---|---|---|---|
| | 1 | 8149523 | B2 | 2012-04-03 | Yuichi Ozaki | |
| | 2 | 9279957 | B2 | 2016-03-08 | Kanda et al. | |
| | 3 | 9488802 | B2 | 2016-11-08 | Chen et al. | |
| | 4 | 9185291 | B1 | 2015-11-10 | Shabtay at el. | |
| | 5 | 8958164 | B2 | 2015-02-17 | Kwon et al. | |

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|---|---|---|---|---|---|---|
| | 1 | 20170115471 | A1 | 2017-04-27 | Yoshikazu Shinohara | |



ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /E.A.L/

| **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** ( Not for submission under 37 CFR 1.99) | | |
|---|---|---|
| | Application Number | 15976391 |
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-0080 US CON4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 2 | 20140362274 | A1 | 2014-12-11 | Christie et al. | |
| | 3 | 20110001838 | A1 | 2011-01-06 | Sung Hwan Lee | |

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| Examiner Initial* | Cite No | Foreign Document Number[3] | Country Code[2] i | Kind Code[4] | Publication Date | Name of Patentee or Applicant of cited Document | Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear | T[5] |
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**EXAMINER SIGNATURE**

| Examiner Signature | /EVELYN A LESTER/ | Date Considered | 02/14/2019 |
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ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /E.A.L/

| INFORMATION DISCLOSURE STATEMENT BY APPLICANT ( Not for submission under 37 CFR 1.99) | | |
|---|---|---|
| | Application Number | 15976391 |
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-0080 US CON4 |

**CERTIFICATION STATEMENT**

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

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**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 | /Menachem Nathan/ | Date (YYYY-MM-DD) | 2019-01-05 |
|---|---|---|---|
| Name/Print | MENACHEM NATHAN | Registration Number | 65392 |

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PTO/SB/08a (02-18)
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| **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** ( **Not for submission under 37 CFR 1.99)** | | |
|---|---|---|
| | Application Number | 15976391 |
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-0080 US CON4 |

**U.S.PATENTS** Remove

| Examiner Initial* | Cite No | Patent Number | Kind Code1 | Issue Date | Name of Patentee or Applicant of cited Document | Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear |
|---|---|---|---|---|---|---|
| | 1 | 8149523 | B2 | 2012-04-03 | Yuichi Ozaki | |
| | 2 | 9279957 | B2 | 2016-03-08 | Kanda et al. | |
| | 3 | 9488802 | B2 | 2016-11-08 | Chen et al. | |
| | 4 | 9185291 | B1 | 2015-11-10 | Shabtay at el. | |
| | 5 | 8958164 | B2 | 2015-02-17 | Kwon et al. | |

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| Examiner Initial* | Cite No | Publication Number | Kind Code1 | Publication Date | Name of Patentee or Applicant of cited Document | Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear |
|---|---|---|---|---|---|---|
| | 1 | 20170115471 | A1 | 2017-04-27 | Yoshikazu Shinohara | |

| INFORMATION DISCLOSURE STATEMENT BY APPLICANT ( Not for submission under 37 CFR 1.99) | | |
|---|---|---|
| | Application Number | 15976391 |
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
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| Signature | /Menachem Nathan/ | Date (YYYY-MM-DD) | 2019-01-05 |
|---|---|---|---|
| Name/Print | MENACHEM NATHAN | Registration Number | 65392 |

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# UTILITY PATENT APPLICATION TRANSMITTAL

*(Only for new nonprovisional applications under 37 CFR 1.53(b))*

| | |
|---|---|
| *Attorney Docket No.* | COREPH-0080 US CON4 |
| *First Named Inventor* | Michael Dror |
| *Title* | MINIATURE TELEPHOTO LENS ASSEMBLY |
| *Express Mail Label No.* | |

## APPLICATION ELEMENTS

*See MPEP chapter 600 concerning utility patent application contents.*

*ADDRESS TO:* **Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450**

1. ☐ **Fee Transmittal Form** (PTO/SB/17 or equivalent)
2. ☐ **Applicant asserts small entity status.** See 37 CFR 1.27
3. ☐ **Applicant certifies micro entity status.** See 37 CFR 1.29. Applicant must attach form PTO/SB/15A or B or equivalent.
4. ☐ **Specification** [*Total Pages* ____]
   Both the claims and abstract must start on a new page.
   *(See MPEP § 608.01(a) for information on the preferred arrangement)*
5. ☐ **Drawing(s)** (35 U.S.C. 113) [*Total Sheets* ____]
6. **Inventor's Oath or Declaration** [*Total Pages* ____]
   *(including substitute statements under 37 CFR 1.64 and assignments serving as an oath or declaration under 37 CFR 1.63(e))*
   a. ☐ Newly executed (original or copy)
   b. ☐ A copy from a prior application (37 CFR 1.63(d))
7. ☐ **Application Data Sheet** ** See note below.*
   See 37 CFR 1.76 (PTO/AIA/14 or equivalent)
8. **CD-ROM or CD-R**
   in duplicate, large table, or Computer Program (*Appendix*)
   ☐ Landscape Table on CD
9. **Nucleotide and/or Amino Acid Sequence Submission**
   (*if applicable, items a. – c. are required*)
   a. ☐ Computer Readable Form (CRF)
   b. ☐ Specification Sequence Listing on:
      i. ☐ CD-ROM or CD-R (2 copies); or
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## ACCOMPANYING APPLICATION PAPERS

10. ☐ **Assignment Papers**
    (cover sheet & document(s))
    Name of Assignee ____
11. ☐ **37 CFR 3.73(c) Statement** (*when there is an assignee*) ☐ **Power of Attorney**
12. ☐ **English Translation Document** (*if applicable*)
13. ☑ **Information Disclosure Statement**
    (PTO/SB/08 or PTO-1449)
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14. ☐ **Preliminary Amendment**
15. ☐ **Return Receipt Postcard**
    (*MPEP § 503*) (*Should be specifically itemized*)
16. ☐ **Certified Copy of Priority Document(s)**
    (*if foreign priority is claimed*)
17. ☐ **Nonpublication Request**
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***Note**: (1) Benefit claims under 37 CFR 1.78 and foreign priority claims under 1.55 **must** be included in an Application Data Sheet (ADS).
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| Name | | | | | |
| Address | | | | | |
| City | | State | | Zip Code | |
| Country | | Telephone | | Email | |

| | | | |
|---|---|---|---|
| Signature | /Menachem Nathan/ | Date | 01-05-2019 |
| Name (Print/Type) | MENACHEM NATHAN | Registration No. (Attorney/Agent) | 65,392 |

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| Electronic Acknowledgement Receipt | |
|---|---|
| **EFS ID:** | 34771127 |
| **Application Number:** | 15976391 |
| **International Application Number:** | |
| **Confirmation Number:** | 1858 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Customer Number:** | 92342 |
| **Filer:** | Menachem Nathan |
| **Filer Authorized By:** | |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |
| **Receipt Date:** | 05-JAN-2019 |
| **Filing Date:** | 10-MAY-2018 |
| **Time Stamp:** | 07:44:17 |
| **Application Type:** | Utility under 35 USC 111(a) |

## Payment information:

| | |
|---|---|
| Submitted with Payment | no |

## File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 1 | Information Disclosure Statement (IDS) Form (SB08) | Lens_IDS2.pdf | 1034613<br>056961149744d4c690ad2fc03bade21a0b03349a | no | 4 |

**Warnings:**

| Information: | | | | | |
|---|---|---|---|---|---|
| 2 | Transmittal Letter | Lens_IDS2_TF.pdf | 277373<br>96a8c73737d16411e89c9e355c5a74fea19cd1fc | no | 2 |
| Warnings: | | | | | |
| Information: | | | | | |

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**<u>New Applications Under 35 U.S.C. 111</u>**
**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.**
**<u>National Stage of an International Application under 35 U.S.C. 371</u>**
**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.**
**<u>New International Application Filed with the USPTO as a Receiving Office</u>**
**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.**

| **Doc Code: DIST.E.FILE**<br>**Document Description: Electronic Terminal Disclaimer - Filed** | PTO/SB/25<br>PTO/SB/26<br>U.S. Patent and Trademark Office<br>Department of Commerce |
|---|---|

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|---|---|
| Electronic Petition Request | **TERMINAL DISCLAIMER TO OBVIATE A PROVISIONAL DOUBLE PATENTING REJECTION OVER A PENDING "REFERENCE" APPLICATION**<br>**AND TERMINAL DISCLAIMER TO OBVIATE A DOUBLE PATENTING REJECTION OVER A "PRIOR" PATENT** |
| Application Number | 15976391 |
| Filing Date | 10-May-2018 |
| First Named Inventor | Michael Dror |
| Attorney Docket Number | COREPH-0080 US CON4 |
| Title of Invention | MINIATURE TELEPHOTO LENS ASSEMBLY |

☒ 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 |
|---|---|
| Corephotonics Ltd. | 100 % |

The owner(s) of 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 any patent granted on pending reference Application Number(s)

15976422 filed on 05/10/2018

15817235 filed on 11/19/2017

as the term of any patent granted on said reference application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending reference application. 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 any patent granted on the reference application 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 any patent granted on the instant application that would extend to the expiration date of the full statutory term of any patent granted on said reference application, "as the term of any patent granted on said reference application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending reference application," in the event that any such patent granted on the pending reference application: 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 shortened by any terminal disclaimer filed prior to its grant.

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)

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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.

Applicants 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 65392

( ) 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 | /Menachem Nathan/ |
| Name | Menachem Nathan |

*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:** | 15976391 |
| **Filing Date:** | 10-May-2018 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Filer:** | Menachem Nathan |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |

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 | 160 | 160 |
| **Pages:** | | | | |
| **Claims:** | | | | |
| **Miscellaneous-Filing:** | | | | |
| **Petition:** | | | | |
| **Patent-Appeals-and-Interference:** | | | | |
| **Post-Allowance-and-Post-Issuance:** | | | | |

| Description | Fee Code | Quantity | Amount | Sub-Total in USD($) |
|---|---|---|---|---|
| **Extension-of-Time:** | | | | |
| **Miscellaneous:** | | | | |
| | | **Total in USD ($)** | | **160** |

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

Application No.: 15976391

Filing Date: 10-May-2018

Applicant/Patent under Reexamination: Dror

Electronic Terminal Disclaimer filed on October 27, 2018

☒ 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:** | 34136514 |
| **Application Number:** | 15976391 |
| **International Application Number:** | |
| **Confirmation Number:** | 1858 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Customer Number:** | 92342 |
| **Filer:** | Menachem Nathan |
| **Filer Authorized By:** | |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |
| **Receipt Date:** | 27-OCT-2018 |
| **Filing Date:** | 10-MAY-2018 |
| **Time Stamp:** | 15:56:08 |
| **Application Type:** | Utility under 35 USC 111(a) |

## Payment information:

| | |
|---|---|
| Submitted with Payment | yes |
| Payment Type | CARD |
| Payment was successfully received in RAM | $160 |
| RAM confirmation Number | 102918INTEFSW15560500 |
| Deposit Account | |
| Authorized User | |

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

## File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 1 | Terminal Disclaimer-Filed (Electronic) | eTerminal-Disclaimer.pdf | 37485<br>304dc2921e6b8cf720eff5b4bf123529ebef7e82 | no | 3 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 2 | Fee Worksheet (SB06) | fee-info.pdf | 30124<br>b0db95cf20a264a60ebbdb6d5fb16960666719cb | no | 2 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| | | | **Total Files Size (in bytes):** | 67609 | |

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**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.**
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| **EFS ID:** | 34136514 |
| **Application Number:** | 15976391 |
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| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Customer Number:** | 92342 |
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| Authorized User | |
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**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 | 37485<br>304dc2921e6b8cf720eff5b4bf123529ebef7e82 | no | 3 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 2 | Fee Worksheet (SB06) | fee-info.pdf | 30124<br>b0db95cf20a264a60ebbdb6d5fb16960666719cb | no | 2 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| | | **Total Files Size (in bytes):** | 67609 | | |

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

Application No.: 15976391

Filing Date: 10-May-2018

Applicant/Patent under Reexamination: Dror

Electronic Terminal Disclaimer filed on October 27, 2018

☒ 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

| | |
|---|---|
| **Doc Code: DIST.E.FILE**<br>**Document Description: Electronic Terminal Disclaimer - Filed** | PTO/SB/25<br>PTO/SB/26<br>U.S. Patent and Trademark Office<br>Department of Commerce |

| | |
|---|---|
| Electronic Petition Request | **TERMINAL DISCLAIMER TO OBVIATE A PROVISIONAL DOUBLE PATENTING REJECTION OVER A PENDING "REFERENCE" APPLICATION**<br>**AND TERMINAL DISCLAIMER TO OBVIATE A DOUBLE PATENTING REJECTION OVER A "PRIOR" PATENT** |
| Application Number | 15976391 |
| Filing Date | 10-May-2018 |
| First Named Inventor | Michael Dror |
| Attorney Docket Number | COREPH-0080 US CON4 |
| Title of Invention | MINIATURE TELEPHOTO LENS ASSEMBLY |

☒ 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 |
|---|---|
| Corephotonics Ltd. | 100 % |

The owner(s) of 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 any patent granted on pending reference Application Number(s)

15976422 filed on 05/10/2018

15817235 filed on 11/19/2017

as the term of any patent granted on said reference application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending reference application. 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 any patent granted on the reference application are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

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- is held unenforceable;
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- 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.

Applicants claims the following fee status:

◉ Small Entity

○ Micro Entity

○ Regular Undiscounted

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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 65392

○ 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 | /Menachem Nathan/ |
| Name | Menachem Nathan |

*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 Acknowledgement Receipt

| | |
|---|---|
| **EFS ID:** | 34136527 |
| **Application Number:** | 15976391 |
| **International Application Number:** | |
| **Confirmation Number:** | 1858 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Customer Number:** | 92342 |
| **Filer:** | Menachem Nathan |
| **Filer Authorized By:** | |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |
| **Receipt Date:** | 27-OCT-2018 |
| **Filing Date:** | 10-MAY-2018 |
| **Time Stamp:** | 16:08:44 |
| **Application Type:** | Utility under 35 USC 111(a) |

## Payment information:

| | |
|---|---|
| Submitted with Payment | no |

## File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 1 | Amendment/Req. Reconsideration-After Non-Final Reject | OA_Response.pdf | 46327<br>3b51ae216a1144d7253dc0c2f98123cd42c66f36 | no | 8 |

**Warnings:**

**Information:**

| | | | | | |
|---|---|---|---|---|---|
| 2 | Terminal Disclaimer Filed | efilingAck_eTerminal_Disclaimer.pdf | 64534<br>7676c08eaf9179d95c4793e0e368c121d1a59a78 | no | 3 |

**Warnings:**

The PDF file has been signed with a digital signature and the legal effect of the document will be based on the contents of the file not the digital signature.

**Information:**

| | | | | | |
|---|---|---|---|---|---|
| 3 | Terminal Disclaimer Filed | eTerminal_Disclaimer_Filing.pdf | 100540<br>36e530dbc0ace4f04f956303da6d1b71371ba408 | no | 3 |

**Warnings:**

**Information:**

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|---|---|
| **Total Files Size (in bytes):** | 211401 |

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

**New Applications Under 35 U.S.C. 111**

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

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

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

**New International Application Filed with the USPTO as a Receiving Office**

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

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

| | | |
|---|---|---|
| In re Applicant: | § | Confirmation No. 1858 |
| | § | |
| Michael Dror | § | |
| | § | |
| Serial No.: 15/976,391 | | |
| Title: MINIATURE TELEPHOTO LENS ASSEMBLY | | |
| | § | |
| Filed: 05/10/2018 | § | |
| | § | Attorney Docket: Coreph-0080 US CON4 |

Examiner: Lester, Evelyn A.

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

RESPONSE

This is in response to the United States Patent and Trademark Office Action having a Notification Date of 10/22/2018, which response is made timely.

**Amendment to the Specification** is presented in page 2**.**

**Amendments to the Claims** begin on page 3.

**Remarks/Arguments** begin on page 7.

IN THE SPECIFICATION:

Please amend the "CROSS REFERENCE TO RELATED APPLICATIONS" section as follows:

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a Continuation application of US patent application No. 15/817,235 filed November 19, 2017, which was a Continuation application of US patent application No. 15/418,925 filed January 30, 2017, now Pat. No. 9,857,568, which was a Continuation in Part application of US patent application No. 15/170,472 filed June 1, 2016, now Pat. No. 9,568,712, which was a Continuation application of US patent application No. 14/932,319 filed November 4, 2015, now Pat. No. 9,402,032, which was a Continuation application of US patent application No. 14/367,924 filed June 22, 2014, now abandoned, which was a 371 Continuation application of international application PCT/IB2014/062465 filed June 20, 2014, and is related to and claims priority from US Provisional Patent Application No. 61/842,987 filed July 4, 2013, which is incorporated herein by reference in its entirety.

IN THE CLAIMS

Please amend the claims as follows:

1. (Original) A lens assembly, comprising: a plurality of lens elements arranged along an optical axis and spaced apart by respective spaces, wherein the lens assembly has an effective focal length (EFL), a total track length (TTL) of 6.5 millimeters or less and a ratio TTL/EFL < 1.0, wherein the plurality of lens elements includes, in order from an object side to an image side, a first group comprising lens elements $L_{1\_1}$, $L_{1\_2}$ and $L_{1\_3}$ with respective focal lengths $f_{1\_1}$, $f_{1\_2}$ and $f_{1\_3}$ and a second group comprising lens elements $L_{2\_1}$ and $L_{2\_2}$, wherein the first and second groups of lens elements are separated by a gap that is larger than twice any other gap between lens elements, wherein lens element $L_{1\_1}$ has positive refractive power and lens element $L_{1\_2}$ has negative refractive power and wherein lens elements $L_{2\_1}$ and $L_{2\_2}$ have opposite refractive powers.

2. (Original) The lens assembly of claim 1, wherein the TTL is equal or smaller than 6.0mm and wherein the lens assembly has a f-number F# < 2.9

3. (Original) The lens assembly of claim 1, wherein the TTL is equal or smaller than 6.0mm and wherein lens element $L_{1\_1}$ has an image-side surface diameter between 2.3mm and 2.5mm.

4. (Original) The lens assembly of claim 1, wherein $f_{1\_1}$<TTL/2.

5. (Original) The lens assembly of claim 1, wherein the lens assembly has a f-number F# < 2.9.

6. (Original) The lens assembly of claim 5, wherein lens element $L_{1\_1}$ has a concave image-side surface.

7. (Original) The lens assembly of claim 1, wherein the lens assembly has a f-number F# = 2.8

8. (Original) The lens assembly of claim 5, wherein lens element $L_{1\_1}$ has a convex image-side surface.

9. (Original) The lens assembly of claim 1, wherein $1.2x|f_{1\_3}| > 1.5xf_{1\_1}$.

10. (Original) The lens assembly of claim 1, wherein $1.2x|f_{1\_3}| > |f_{1\_2}| > 1.5xf_{1\_1}$.

11. (Original) The lens assembly of claim 1, wherein a combined power of lens elements $L_{1\_2}$ and $L_{1\_3}$ is negative.

12. (Original) The lens assembly of claim 1, wherein $L_{1\_3}$ has negative refractive power.

13. (Original) The lens assembly of claim 1, wherein the gap between lens elements $L_{2\_1}$ and $L_{2\_2}$ is smaller than $1.5xd_{2\_2}$, where $d_{2\_2}$ is a thickness of lens element $L_{2\_2}$ along the optical axis.

14. (Original) The lens assembly of claim 1, wherein lens elements $L_{2\_1}$ and $L_{2\_2}$ are separated by a gap smaller than TTL/20.

15. (Original) The lens assembly of claim 1, wherein $L_{2\_1}$ and $L_{2\_2}$ are made of different lens materials having different Abbe numbers, such that one lens element has Abbe number that is smaller than 30 and the other lens element has an Abbe number that is larger than 50.

16. (Original) The lens assembly of claim 2, wherein the lens assembly further includes a ratio between a largest optical axis thickness L11 and a circumferential edge thickness L1e of lens element $L_{1\_1}$ of L11/L1e < 3.

17. (Currently amended) A lens assembly, comprising a plurality of lens elements arranged along an optical axis and spaced apart by respective spaces, wherein the lens assembly has an effective focal length (EFL), wherein a lens system that includes the lens assembly plus a window positioned between the ~~fifth~~ plurality of lens elements and an image plane has a total track length (TTL) of 6.5 millimeters or less, wherein a ratio TTL/EFL < 1.0, wherein the plurality of lens elements includes, in order from an object side to an image side, a first group comprising lens elements $L_{1\_1}$, $L_{1\_2}$ and $L_{1\_3}$ with respective focal lengths

$f_{1\_1}$, $f_{1\_2}$ and $f_{1\_3}$, and a second group comprising lens elements $L_{2\_1}$ and $L_{2\_2}$, wherein lens element $L_{1\_1}$ has positive refractive power and lens element $L_{1\_2}$ has negative refractive power, wherein $1.2x|f_{1\_3}|>|f_{1\_2}|>1.5xf_{1\_1}$ and wherein lens elements $L_{2\_1}$ and $L_{2\_2}$ have opposite refractive powers.

18. (Original) The lens assembly of claim 17, wherein the TTL is equal or smaller than 6.0mm and wherein the lens assembly has a f-number F# < 2.9

19. (Original) The lens assembly of claim 17, wherein the TTL is equal or smaller than 6.0mm and wherein lens element $L_{1\_1}$ has an image-side surface diameter between 2.3mm and 2.5mm

20. (Original) The lens assembly of claim 17, wherein $f_{1\_1} < TTL/2$.

21. (Original) The lens assembly of claim 17, wherein the lens assembly has a f-number F# < 2.9.

22. (Original) The lens assembly of claim 21, wherein lens element $L_{1\_1}$ has a concave image-side surface.

23. (Original) The lens assembly of claim 17, wherein the lens assembly has a f-number F# = 2.8

24. (Original) The lens assembly of claim 21, wherein lens element $L_{1\_1}$ has a convex image-side surface.

25. (Original) The lens assembly of claim 17, wherein a combined power of lens elements $L_{1\_2}$ and $L_{1\_3}$ is negative.

26. (Original) The lens assembly of claim 17, wherein $L_{1\_3}$ has negative refractive power.

27. (Original) The lens assembly of claim 17, wherein a gap between lens elements $L_{2\_1}$ and $L_{2\_2}$ is smaller than $1.5xd_5$, where $d_5$ is a thickness of lens element $L_{2\_2}$ along the optical axis.

28. (Original) The lens assembly of claim 17, wherein lens elements $L_{2\_1}$ and $L_{2\_2}$ are separated by a gap smaller than TTL/20.

29. (Original) The lens assembly of claim 17, wherein $L_{2\_1}$ and $L_{2\_2}$ are made of different lens materials having different Abbe numbers, such that one lens element has an Abbe number that is smaller than 30 and the other lens element has an Abbe number that is larger than 50.

30. (Original) The lens assembly of claim 18, wherein the lens assembly further includes a ratio between a largest optical axis thickness L11 and a circumferential edge thickness L1e of lens element $L_{1\_1}$ of $L11/L1e < 3$.

## REMARKS

Reconsideration of this application is respectfully requested. Based on the following Remarks, Applicant respectfully requests the Examiner to reconsider and withdraw all outstanding rejections.

### Status of Claims

Claims 1-30 are pending in the application. All claims were rejected in the Office Action dated 10/18/2018. The rejection is respectfully traversed.

Although not mentioned by Examiner, Applicant has identified an <u>inadvertent and obvious </u>mistake in the language of claim 17, introduced with the preliminary amendment filed on August 3, 2018, where the recitation "the fifth lens element" has no antecedence. Applicant hereby amends these claims to recite "the ~~fifth~~ <u>plurality of </u>lens element<u>s</u>", which does have antecedence. The amendment is supported by FIGS. 1A, 2A and 3A and their description.

### Information Disclosure Statement (IDS)

Applicant acknowledges Examiner's action regarding the IDS filed 09-20-2018.

### Specification

As requested by Examiner, Applicant hereby updates the status of related U.S. patent applications in the CROSS REFERENCE TO RELATED APPLICATIONS section.

### Non-statutory double patenting

Claims 1-30 have been provisionally rejected on the ground of non-statutory double patenting over claims 1- of co-pending Application No. 15/817,235 (also known as U.S. Pub. 2018/0120541 A1), claims 1-12 of co-pending Application No. 15/976,422 (also known as U.S. Pub. 2018/0275375 A1), claims 1-20 of U.S. Patent No. 9,402,032 B2, claims 1- of U.S. Patent No. 9,568,712 B2, and claims 1-5 of U.S. Patent No. 9,857,568 B2.

In response, Applicant files herewith an eTerminal Disclaimer in compliance with 37 CFR 1.321(c) or 1.321 (d) and signed in compliance with 37 CFR 1.321(b). Withdrawal of the rejection and allowance of all claims is respectfully requested.

***Conclusion***

All of the stated grounds of rejection have been properly traversed or rendered moot. Applicant therefore respectfully requests that the Examiner reconsider and withdraw all presently outstanding rejections. Applicant believes that a full and complete response has been made to the outstanding Office Action and, as such, the present application is in condition for allowance. If the Examiner believes, for any reason, that further personal communication will expedite prosecution of this application, the Examiner is invited to telephone the undersigned at the number provided.

Prompt and favorable consideration of this Amendment is respectfully requested.

Respectfully submitted,

/ Menachem Nathan /
Menachem Nathan
Agent for Applicant
Registration No. 65392

Date: October 27, 2018

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 15/976,391 | Filing Date 05/10/2018 | ☐ 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 $230 = | |
| ☐ 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 | 10/27/2018 | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | | RATE ($) | ADDITIONAL FEE ($) |
| | Total (37 CFR 1.16(i)) | * 30 | Minus | ** 30 | = 0 | | x $50 = | 0 |
| | Independent (37 CFR 1.16(h)) | * 2 | Minus | *** 3 | = 0 | | x $230 = | 0 |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | |
| | | | | | | | TOTAL ADD'L FEE | 0 |

| | | (Column 1) | | (Column 2) | (Column 3) | | | |
|---|---|---|---|---|---|---|---|---|
| AMENDMENT | | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | | RATE ($) | ADDITIONAL FEE ($) |
| | Total (37 CFR 1.16(i)) | * | Minus | ** | = | | x $0 = | |
| | Independent (37 CFR 1.16(h)) | * | Minus | *** | = | | x $0 = | |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | |
| | | | | | | | TOTAL ADD'L FEE | |

| | |
|---|---|
| * If the entry in column 1 is less than the entry in column 2, write "0" in column 3. | LIE |
| ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". | /RAMONA D WILSON/ |
| *** 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.*

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| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 15/976,391 | 05/10/2018 | Michael Dror | COREPH-0080 US CON4 | 1858 |

92342 7590 10/18/2018
Nathan & Associates Patent Agents Ltd
P.O.Box 10178
Tel Aviv, 6110101
ISRAEL

| EXAMINER | |
|---|---|
| LESTER, EVELYN A | |

| ART UNIT | PAPER NUMBER |
|---|---|
| 2872 | |

| NOTIFICATION DATE | DELIVERY MODE |
|---|---|
| 10/18/2018 | 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):

info@natpatent.com
amirr@natpatent.com
dorong@natpatent.com

PTOL-90A (Rev. 04/07)

| Office Action Summary | Application No. 15/976,391 | Applicant(s) DROR ET AL. | |
|---|---|---|---|
| | Examiner EVELYN A. LESTER | Art Unit 2872 | AIA (First Inventor to File) 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) *1-30* 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) *1-30* is/are rejected.

8)☐ Claim(s) _____ 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 *5-10-18* 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 *7-3-18; 7-9-18; 9-20-18*.

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

4) ☐ Other: _____.

The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

## DETAILED ACTION

### *Information Disclosure Statement*

1. In the Information Disclosure Statement (IDS) filed on 9-20-18, having 12 pages, several of the documents have been lined through because they are repeat recitations from other filed IDS's.

2. Also, as noted on page 2 of the IDS, documents 3 and 5 listed under U.S. Patent Application Publications, have the same publication number. Upon verifying in EAST, the document number “20070229987” belongs to “Shinohara” as listed for document number 3. Therefore, since it is unclear what the publication number for document number 5 is, this citation has been crossed out.

### *Specification*

3. The disclosure is objected to because of the following informalities: The status of related U.S. patent applications need to be updated by amendment.

Appropriate correction is required.

**_Double Patenting_**

4. 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 §§ 706.02(l)(1) - 706.02(l)(3) 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.

5. Claims 1-30 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1- of copending Application No. 15/817,235 (also known as U.S. Patent Pub. 2018/0120541 A1). Although the claims at issue are not identical, they are not patentably distinct from each other because the application claimed inventions are but obvious variations of each other.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

The application claimed invention(s) recite(s) the same structural limitations in their independent claims and/or the dependent claims dependent on those independent claims, making the scope of the claimed inventions, of each application, the same or at least so similar that one of ordinary skill in the art of lens assemblies would understand that each claimed invention is essentially the same as the other claimed invention(s). As noted for example the limitation of the "total track length (TTL) of 6.5 or less" is the same in the claimed inventions of the other patent applications. Further, each application claimed invention has 5 lens elements, which include a positive first lens, a negative second lens and a negative third, regardless of the lens labels provided in the recitation of the claimed invention. Also the fourth and fifth lens elements each have an opposite refractive power, again regardless of lens labeling, i.e. such as $L_{2-1}$ and $L_{2-2}$ are the same lenses as the fourth and fifth lens elements recited in the other application(s) claimed invention(s). Additionally, all of the same conditional recitations are the same as recited in each claimed invention of the application(s).

Therefore, the claimed invention of the present application is hereby anticipated by or at the very least very obvious to one of ordinary skill in the art, as being a similar invention, especially in scope.

6. Claims 1-30 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-12 of copending Application No. 15/976,422 (also known as U.S. Patent Pub. 2018/0275375 A1). Although the claims at issue are not identical, they are not patentably distinct from each other because the application claimed invention and the patent claimed invention are but obvious variations of each other.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

The application claimed invention(s) recite(s) the same structural limitations in their independent claims and/or the dependent claims dependent on those independent claims, making the scope of the claimed inventions, of each application, the same or at least so similar that one of ordinary skill in the art of lens assemblies would understand that each claimed invention is essentially the same as the other claimed invention(s). As noted for example the limitation of the “total track length (TTL) of 6.5 or less” is the same in the claimed inventions of the other patent applications. Further, each application claimed invention has 5 lens elements, which include a positive first lens, a negative second lens and a negative third, regardless of the lens labels provided in the recitation of the claimed invention. Also the fourth and fifth lens elements each have an opposite refractive power, again regardless of lens labeling, i.e. such as $L_{2-1}$ and $L_{2-2}$ are the same lenses as the fourth and fifth lens elements recited in the other application(s) claimed invention(s). Additionally, all of the same conditional recitations are the same as recited in each claimed invention of the application(s).

Therefore, the claimed invention of the present application is hereby anticipated by or at the very least very obvious to one of ordinary skill in the art, as being a similar invention, especially in scope.

7. Claims 1-30 are rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-20 of U.S. Patent No. 9,402,032 B2. Although the claims at issue are not identical, they are not patentably distinct from each other because the application claimed invention and the patent claimed invention are but obvious variations of each other.

The application claimed invention recites the same structural limitations in their independent claims and/or the dependent claims of those independent claims as compared to the patent claimed invention, making the scope of the claimed inventions, of each, the same or at least so similar that one of ordinary skill in the art of lens assemblies would understand that each claimed invention is essentially the same as the other claimed invention(s). As noted for example the limitation of the “total track length (TTL) of 6.5 or less” is the same in the claimed inventions of each the application claimed invention and the patent claimed invention. Further, each application claimed invention and patent claimed invention has 5 lens elements, which include a positive first lens, a negative second lens and a negative third, regardless of the lens labels provided in the recitation of the claimed invention. Also the fourth and fifth lens elements each have an opposite refractive power, again regardless of lens labeling, i.e. such as $L_{2-1}$ and $L_{2-2}$ are the same lenses as the fourth and fifth lens elements recited in the application claimed invention and the patent claimed invention. Additionally, all of the same conditional recitations are the same as recited in each claimed invention of the application(s).

Therefore, the claimed invention of the present application is hereby anticipated by or at the very least very obvious to one of ordinary skill in the art, as being a similar invention as compared to the patent claimed invention, especially in scope.

.

8. Claims 1-30 are rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1- of U.S. Patent No. 9,568,712 B2. Although the claims at issue are not identical, they are not patentably distinct from each other because the application claimed invention and the patent claimed invention are but obvious variations of each other.

The application claimed invention recites the same structural limitations in their independent claims and/or the dependent claims of those independent claims as compared to the patent claimed invention, making the scope of the claimed inventions, of each, the same or at least so similar that one of ordinary skill in the art of lens assemblies would understand that each claimed invention is essentially the same as the other claimed invention(s). As noted for example the limitation of the “total track length (TTL) of 6.5 or less” is the same in the claimed inventions of each the application claimed invention and the patent claimed invention. Further, each application claimed invention and patent claimed invention has 5 lens elements, which include a positive first lens, a negative second lens and a negative third, regardless of the lens labels provided in the recitation of the claimed invention. Also the fourth and fifth lens elements each have an opposite refractive power, again regardless of lens labeling, i.e. such as $L_{2-1}$ and $L_{2-2}$ are the same lenses as the fourth and fifth lens elements recited in the application claimed invention and the patent claimed invention. Additionally, all of the same conditional recitations are the same as recited in each claimed invention of the application(s).

Therefore, the claimed invention of the present application is hereby anticipated by or at the very least very obvious to one of ordinary skill in the art, as being a similar invention as compared to the patent claimed invention, especially in scope.

.

9. Claims 1-30 are rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-5 of U.S. Patent No. 9,857,568 B2. Although the claims at issue are not identical, they are not patentably distinct from each other because the application claimed invention and the patent claimed invention are but obvious variations of each other.

The application claimed invention recites the same structural limitations in their independent claims and/or the dependent claims of those independent claims as compared to the patent claimed invention, making the scope of the claimed inventions, of each, the same or at least so similar that one of ordinary skill in the art of lens assemblies would understand that each claimed invention is essentially the same as the other claimed invention(s). As noted for example the limitation of the “total track length (TTL) of 6.5 or less” is the same in the claimed inventions of each the application claimed invention and the patent claimed invention. Further, each application claimed invention and patent claimed invention has 5 lens elements, which include a positive first lens, a negative second lens and a negative third, regardless of the lens labels provided in the recitation of the claimed invention. Also the fourth and fifth lens elements each have an opposite refractive power, again regardless of lens labeling, i.e. such as $L_{2-1}$ and $L_{2-2}$ are the same lenses as the fourth and fifth lens elements recited in the application claimed invention and the patent claimed invention. Additionally, all of the same conditional recitations are the same as recited in each claimed invention of the application(s).

Therefore, the claimed invention of the present application is hereby anticipated by or at the very least very obvious to one of ordinary skill in the art, as being a similar invention as compared to the patent claimed invention, especially in scope.

### ***Conclusion***

10. Any inquiry concerning this communication or earlier communications from the examiner should be directed to EVELYN A. LESTER whose telephone number is (571)272-2332. The examiner can normally be reached on M-F, subject to an increased flex schedule.

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

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Ricky L. Mack can be reached on (571) 272-2333. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/EVELYN A. LESTER/
Primary Examiner
Art Unit 2872

| Notice of References Cited | Application/Control No. 15/976,391 | Applicant(s)/Patent Under Reexamination DROR ET AL. | |
|---|---|---|---|
| | Examiner EVELYN A. LESTER | Art Unit 2872 | 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-9,402,032 B2 | 07-2016 | Dror; Michael | G02B9/60 | 1/1 |
| * | B | US-9,568,712 B2 | 02-2017 | Dror; Michael | G02B9/60 | 1/1 |
| * | C | US-9,857,568 B2 | 01-2018 | Dror; Michael | G02B13/0045 | 1/1 |
| * | D | US-2018/0120541 A1 | 05-2018 | Dror; Michael | G02B13/0045 | 1/1 |
| * | E | US-2018/0275375 A1 | 09-2018 | Dror; Michael | G02B13/0045 | 1/1 |
| | F | US- | | | | |
| | G | US- | | | | |
| | H | US- | | | | |
| | I | US- | | | | |
| | J | US- | | | | |
| | K | US- | | | | |
| | L | US- | | | | |
| | M | US- | | | | |

**FOREIGN PATENT DOCUMENTS**

| * | | Document Number Country Code-Number-Kind Code | Date MM-YYYY | Country | Name | CPC Classification |
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| | N | | | | | |
| | O | | | | | |
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**NON-PATENT DOCUMENTS**

| * | | Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages) |
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*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.

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

PTO/SB/08a (02-18)
Approved for use through 11/30/2020. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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| **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** ( Not for submission under 37 CFR 1.99) | | |
|---|---|---|
| | Application Number | 15976391 |
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-080 US CON4 |

| U.S.PATENTS | | | | | | |
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| Examiner Initial* | Cite No | Patent Number | Kind Code1 | Issue Date | Name of Patentee or Applicant of cited Document | Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear |
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| Examiner Initial* | Cite No | Publication Number | Kind Code1 | Publication Date | Name of Patentee or Applicant of cited Document | Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear |
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| | Examiner Name | | |
| | Attorney Docket Number | | COREPH-080 US CON4 |

| **EXAMINER SIGNATURE** | | | |
|---|---|---|---|
| Examiner Signature | /EVELYN A LESTER/ | Date Considered | 09/28/2018 |
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| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-080 US CON4 |

**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 | /Menachem Nathan/ | Date (YYYY-MM-DD) | 2018-06-28 |
|---|---|---|---|
| Name/Print | MENACHEM NATHAN | Registration Number | 65392 |

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.**



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| ***Search Notes*** | **Application/Control No.**<br>15976391 | **Applicant(s)/Patent Under Reexamination**<br>DROR ET AL. |
|---|---|---|
| | **Examiner**<br>EVELYN A LESTER | **Art Unit**<br>2872 |

## CPC- SEARCHED

| Symbol | Date | Examiner |
|---|---|---|
| G02B 13/0045; G02B 9/60; G02B 27/0025; G02B 5/005; G02B 13/02; G02B 1/041; G02B 13/002; G02B9/00; G02B 27/646; H04N 2201/00; Y10T 29/4913. | 10-14-18 | EAL |

## CPC COMBINATION SETS - SEARCHED

| Symbol | Date | Examiner |
|---|---|---|
| | | |

## US CLASSIFICATION SEARCHED

| Class | Subclass | Date | Examiner |
|---|---|---|---|
| 359 | 714, 739, 740, 763, 764 | 10-14-18 | EAL |

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

## SEARCH NOTES

| Search Notes | Date | Examiner |
|---|---|---|
| EAST Search: USPAT, US=PGPUB, JPO, EPO, DERWENT, IBM-TDB. | 10-14-18 | EAL |
| Classification searches in CPC and USPC, crossed with text search. | 10-14-18 | EAL |
| Inventor and Assignee searches in EAST | 10-14-18 | EAL |

## INTERFERENCE SEARCH

| US Class/ CPC Symbol | US Subclass / CPC Group | Date | Examiner |
|---|---|---|---|
| | | | |

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| | /EVELYN A LESTER/<br>Primary Examiner.Art Unit 2872 |

**EAST Search History**

**EAST Search History (Prior Art)**

| Ref # | Hits | Search Query | DBs | Default Operator | Plurals | Time Stamp |
|---|---|---|---|---|---|---|
| L1 | 1750645 | lens$2 | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:16 |
| L2 | 912007 | object with image | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:16 |
| L3 | 257631 | total near4 length | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:16 |
| L4 | 100576 | aspheric$6 or non-spheric$6 or nonspheric$6 | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:16 |
| L5 | 1511172 | positive with negative | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:16 |
| L6 | 407792 | optical near2 axis | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:16 |
| L7 | 6591 | L1 and L2 and L3 and L4 and L5 and L6 | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:16 |
| L8 | 167037 | focal near2 length | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:16 |
| L9 | 21420 | fifth near2 lens | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:16 |
| L10 | 7216911 | plastic or resin | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:16 |

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|---|---|---|---|---|---|---|
| L11 | 167037 | focal near2 length | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:16 |
| L12 | 88558 | meniscus | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:17 |
| L13 | 12468 | 359/713,714,715-717,739,740,745-748,754-795.ccls. | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:17 |
| L14 | 15761 | ( (G02B13/0045 OR G02B9/62 OR G02B9/60 OR G02B13/18 OR G02B13/004 OR G02B9/64 OR G02B5/005 OR G02B13/00 OR G02B9/12).CPC. ) | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:17 |
| L15 | 61 | corephotonics.as. | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:18 |
| L16 | 46 | dror-michael.in. | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:18 |
| L17 | 100 | goldenberg-ephraim.in. | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:19 |
| L18 | 113 | shabtay-gal.in. | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:19 |
| L19 | 2618 | 8 and 9 and 10 and 11 and 12 | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:19 |
| L20 | 1306 | 7 and 19 | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:19 |
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| L23 | 919 | 21 or 22 | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:20 |

**EAST Search History (Interference)**

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**10/14/2018 8:21:13 PM**
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| | Examiner Name | |
| | Attorney Docket Number | COREPH-0080 US CON4 |

**U.S.PATENTS**

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| Examiner Signature | /EVELYN A LESTER/ | Date Considered | 09/28/2018 |

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| | | | |
|---|---|---|---|
| Signature | /Menachem Nathan/ | Date (YYYY-MM-DD) | 2018-07-09 |
| Name/Print | MENACHEM NATHAN | Registration Number | 65392 |

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

PTO/SB/08a (01-10)
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| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-0080 US CON4 |

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| | Examiner EVELYN A LESTER | Art Unit 2872 |

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| = | Allowed | ÷ | Restricted | I | Interference | O | Objected |

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

| CLAIM | | DATE | | | | | | | | |
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| Final | Original | 10/15/2018 | | | | | | | | |
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| | 26 | ✓ | | | | | | | | |
| | 27 | ✓ | | | | | | | | |
| | 28 | ✓ | | | | | | | | |
| | 29 | ✓ | | | | | | | | |
| | 30 | ✓ | | | | | | | | |

**EAST Search History**

**EAST Search History (Prior Art)**

| Ref # | Hits | Search Query | DBs | Default Operator | Plurals | Time Stamp |
|---|---|---|---|---|---|---|
| L1 | 11 | "9402032".pn. | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 19:48 |
| L2 | 2 | "9568712".pn. | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 19:50 |
| L3 | 4 | "9857568".pn. | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 19:51 |
| L4 | 2 | "20090185289".pn. | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 19:58 |
| L5 | 2 | "20150029601" | US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2018/10/14 20:06 |

**EAST Search History (Interference)**

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**CONFIRMATION NO. 1858**

| SERIAL NUMBER | FILING or 371(c) DATE | CLASS | GROUP ART UNIT | ATTORNEY DOCKET NO. |
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| 15/976,391 | 05/10/2018<br>**RULE** | 359 | 2872 | COREPH-0080 US CON4 |

**APPLICANTS**
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**INVENTORS**
Michael Dror, Nes Ziona, ISRAEL;
Ephraim Goldenberg, Ashdod, ISRAEL;
Gal Shabtay, Tel Aviv, ISRAEL;

** **CONTINUING DATA** *************************
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| | | STATE OR COUNTRY | SHEETS DRAWINGS | TOTAL CLAIMS | INDEPENDENT CLAIMS |
|---|---|---|---|---|---|
| Foreign Priority claimed ❑ Yes ☑ No<br>35 USC 119(a-d) conditions met ❑ Yes ☑ No<br>Verified and Acknowledged /EVELYN A LESTER/ Examiner's Signature | ❑ Met after Allowance<br>Initials | ISRAEL | 6 | 30 | 2 |

**ADDRESS**

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ISRAEL

**TITLE**

MINIATURE TELEPHOTO LENS ASSEMBLY

| | | |
|---|---|---|
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**CONFIRMATION NO. 1858**

**PUBLICATION NOTICE**

*OC000000102640242*

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Nathan & Associates Patent Agents Ltd
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Tel Aviv, 6110101
ISRAEL

**Title:**MINIATURE TELEPHOTO LENS ASSEMBLY

**Publication No.**US-2018-0275374-A1
**Publication Date:**09/27/2018

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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.

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| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
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| | First Named Inventor | Michael Dror |
| | Art Unit | |
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5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

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

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

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

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

# UTILITY PATENT APPLICATION TRANSMITTAL

*(Only for new nonprovisional applications under 37 CFR 1.53(b))*

| | |
|---|---|
| *Attorney Docket No.* | COREPH-0080 US CON4 |
| *First Named Inventor* | Michael Dror |
| *Title* | MINIATURE TELEPHOTO LENS ASSEMBLY |
| *Express Mail Label No.* | |

## APPLICATION ELEMENTS

*See MPEP chapter 600 concerning utility patent application contents.*

*ADDRESS TO:* **Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450**

1. [ ] **Fee Transmittal Form** (PTO/SB/17 or equivalent)
2. [ ] **Applicant asserts small entity status.** See 37 CFR 1.27
3. [ ] **Applicant certifies micro entity status.** See 37 CFR 1.29. Applicant must attach form PTO/SB/15A or B or equivalent.
4. [ ] **Specification** [*Total Pages* ____] Both the claims and abstract must start on a new page. *(See MPEP § 608.01(a) for information on the preferred arrangement)*
5. [ ] **Drawing(s)** (35 U.S.C. 113) [*Total Sheets* ____]
6. **Inventor's Oath or Declaration** [*Total Pages* ____] *(including substitute statements under 37 CFR 1.64 and assignments serving as an oath or declaration under 37 CFR 1.63(e))*
   - a. [ ] Newly executed (original or copy)
   - b. [ ] A copy from a prior application (37 CFR 1.63(d))
7. [ ] **Application Data Sheet** ** See note below.* See 37 CFR 1.76 (PTO/AIA/14 or equivalent)
8. **CD-ROM or CD-R** in duplicate, large table, or Computer Program (*Appendix*)
   - [ ] Landscape Table on CD
9. **Nucleotide and/or Amino Acid Sequence Submission** (*if applicable, items a. – c. are required*)
   - a. [ ] Computer Readable Form (CRF)
   - b. [ ] Specification Sequence Listing on:
     - i. [ ] CD-ROM or CD-R (2 copies); or
     - ii. [ ] Paper
   - c. [ ] Statements verifying identity of above copies

## ACCOMPANYING APPLICATION PAPERS

10. [ ] **Assignment Papers** (cover sheet & document(s)) Name of Assignee ____
11. [ ] **37 CFR 3.73(c) Statement** (*when there is an assignee*) [ ] **Power of Attorney**
12. [ ] **English Translation Document** (*if applicable*)
13. [x] **Information Disclosure Statement** (PTO/SB/08 or PTO-1449)
    - [x] Copies of citations attached
14. [ ] **Preliminary Amendment**
15. [ ] **Return Receipt Postcard** (*MPEP § 503*) (*Should be specifically itemized*)
16. [ ] **Certified Copy of Priority Document(s)** (*if foreign priority is claimed*)
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18. [x] **Other:** Remarks - This is an IDS. Citation or identification of any reference in this IDS shall not be construed as an admission that such reference is available as prior art.

***Note**: (1) Benefit claims under 37 CFR 1.78 and foreign priority claims under 1.55 **must** be included in an Application Data Sheet (ADS).
(2) For applications filed under 35 U.S.C. 111, the application must contain an ADS specifying the applicant if the applicant is an assignee, person to whom the inventor is under an obligation to assign, or person who otherwise shows sufficient proprietary interest in the matter. See 37 CFR 1.46(b).

## 19. CORRESPONDENCE ADDRESS

[x] The address associated with Customer Number: 92342 **OR** [ ] Correspondence address below

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| City | | State | | Zip Code | |
| Country | | Telephone | | Email | |

| | | | |
|---|---|---|---|
| Signature | /Menachem Nathan/ | Date | 09-20-2018 |
| Name (Print/Type) | MENACHEM NATHAN | Registration No. (Attorney/Agent) | 65392 |

This collection of information is required by 37 CFR 1.53(b). 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 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.**

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

## Abstract

PROBLEM TO BE SOLVED: To provide a thin camera module that can selectively obtain images of different magnifications, and is suitable to portable equipment.
SOLUTION: The camera module comprises a plurality of lens units 21, 22 having different focal lengths, image sensor chips 25a and 25b which process imaging signals based upon light made incident through the lens units, and a selecting means of selecting the light made incident through the plurality of lens units and imaging signals based upon the light. This selecting means is operative to select light made incident through one of the plurality of lens units or an imaging signal based upon the light.
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# JP2007306282A

JP Application

Download PDF Find Prior Art Similar

**Other languages:** Japanese

**Inventor:** Yasuaki Kayanuma, Anzhao

**Original Assignee:** Citizen Electronics Co Ltd, Citizen Electronics Co., Ltd.

**Priority date :** 2006-05-11

Family: JP (1)

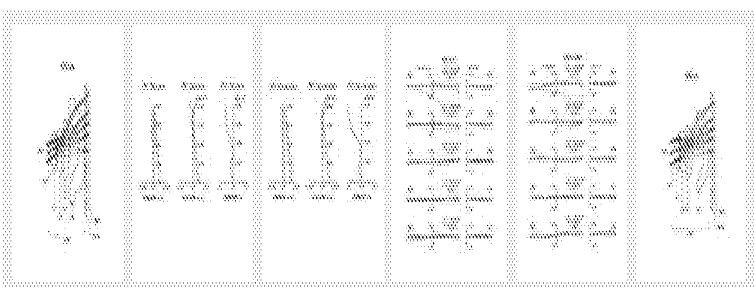
| Date | App/Pub Number | Status |
|---|---|---|
| 2006-05-11 | JP2006132321A | Pending |
| 2007-11-22 | JP2007306282A | Application |

# Imaging apparatus


## Abstract

PROBLEM TO BE SOLVED: To provide high image quality with high resolution for an entire wide variable power region.SOLUTION: An imaging apparatus includes first and second imaging optical systems LN1 and LN2 with single focus, which look the same direction. A focal length of the second imaging optical system LN2 is longer than that of the first imaging optical system LN1. Zooming is performed from a wide angle end to an intermediate focal length state with an electronic zoom by segmentation of an image obtained in the first imaging optical system LN1, and zooming is performed from the intermediate focal length state to a telescopic end with an electronic zoom by segmentation of an image obtained in the second imaging optical system. Thus, zooming from the wide angle end to the telescopic end is performed as a whole. Both the first and second imaging optical systems LN1 and LN2 consist of four or more lenses of first lenses of positive power and second lenses of negative power in order from an object side, the lenses nearest to the image side are negative lenses, composite focal lengths of the first lenses and the second lenses are positive and they satisfy a conditional expression 1.0<fFw/fFm<1.5.


## Images (23)



JP2013106289A

JP Application

Download PDF Find Prior Art Similar


**Other languages:** Japanese

**Inventor:** Kenji Konno, 賢治 今野, Keiji Matsuzaka, 啓二 松坂, Keiko Yamada, 恵子 山田

**Original Assignee:** Konica Minolta Advanced Layers Inc, コニカミノルタアドバンストレイヤー株式会社

**Priority date :** 2011-11-16


Family: JP (1)

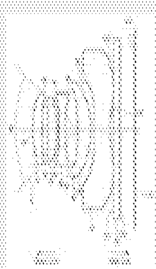
| Date | App/Pub Number | Status |
|---|---|---|
| 2011-11-16 | JP2011250322A | Active |
| 2013-05-30 | JP2013106289A | Application |
| 2015-07-01 | JP5741395B2 | Grant |

# Optical system


## Abstract

An optical system according to an embodiment comprises: a first lens, a second lens, a third lens, a fourth lens, and a fifth lens arranged from the top of an object in order and satisfies an equation 1, |Sag 2/Sag 1| < 2, and an equation 2,|H5/Sag 5| > 1. In equation 1, Sag 1 is the Sag value of the surface of the first lens in an object side, and Sag 2 is the Sag value of the surface of the first lens in an image side. In equation 2, H5 is the height of an inflection point on the surface of the fifth lens in the image side, and Sag 5 is the Sag value of the inflection point on the surface of the fifth lens in the image side.


## Images (1)



KR20140023552A

KR Application

Download PDF   Find Prior Art   Similar

**Other languages:** Korean

**Inventor:** Kim Bum Geun

**Original Assignee:** LG Innotek Co., Ltd.

**Priority date :** 2012-08-16

Family: KR (1)

| Date | App/Pub Number | Status |
|---|---|---|
| 2012-08-16 | KR20120089538A | |
| 2014-02-27 | KR20140023552A | Application |

**Info:** Cited by (1), Legal events, Similar documents, Priority and Related Applications

**External links:** Espacenet, Global Dossier, Discuss

# Photographic lens subjected to short distance correction


## Abstract

PURPOSE:To correct satisfactorily various aberrations even in case of photographing of a short distance, and to make a titled lens durable enough even in a state that a diaphragm is opened by setting a prescribed air space by a refererence image magnification state between a positive lens component of an object side and a lens group of an image side, reducing the space at the time of focusing to a short distance object, and also magnifying the space behind a negative lens component. CONSTITUTION:As for a deformed Gauss type lens of an F1.4 class, the image surface moves in the positive direction as an image magnification is raised, therefore, the image surface is corrected to the negative direction by magnifying an air space d6 behind a negative maniscus lens L3, and also an asymmetrical property of a comatic aberration is corrected. In this case, the lenses L2, L3 can be moved to the front side as one body in a state that the lenses L1, L4-L7 remain fixed by setting a correcting amount of an air space d2 between a positive lens L1 and a positive meniscus lens L2, and a correcting amount of the space d6 to the same amount, and also the correcting amount can be decided independently to the lenses L2, L3, respectively. Accordingly, in a fast photographic lens of an area extending from a standard to a telephoto, various aberrations are corrected satisfactorily even in case of a short distance photographing, and an excellent image-forming performance can be maintained at all times.


JPS59121015A

JP Application

Find Prior Art   Similar

**Inventor:** Yasushi Matsui

**Original Assignee:** Nippon Kogaku KK <Nikon>

**Priority date :** 1982-12-28

**Family:** JP (1)

| Date | App/Pub Number | Status |
|---|---|---|
| 1982-12-28 | JP22753782A | Expired - Lifetime |
| 1984-07-12 | JPS59121015A | Application |
| 1993-08-09 | JPH05532482 | Grant |

**Info:** Patent citations (2), Cited by (2), Similar documents, Priority and Related Applications

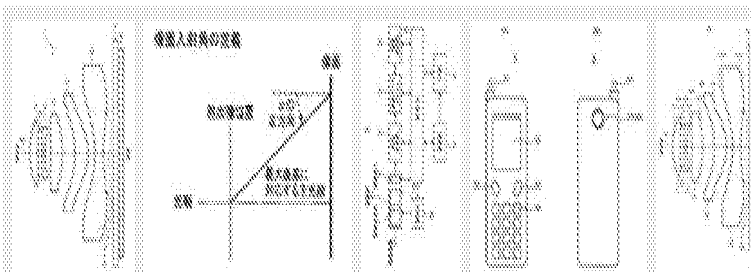
**External links:** Espacenet, Global Dossier, Discuss

# Imaging optical system, imaging apparatus and digital instrument


## Abstract

PROBLEM TO BE SOLVED: To provide an imaging optical system composed of five lenses able to correct various aberrations more satisfactorily while achieving a smaller size, and an imaging apparatus and a digital instrument that have the optical system.SOLUTION: An imaging optical system 1 includes, in order from an object side, first to fifth lenses 11 to 15. The first lens 11 is convex on the object side and has positive refractive power, a second lens 12 has negative refractive power, and the fifth lens 15 has negative refractive power and has an aspherical shape that is concave on an image side and has a vertical contact at a position other than the position of an intersection with the center axis. If the focal distance of the entire system is f, the focal distance of the fifth lens 15 is f5, an amount of sag on an object side surface on the principal ray at the maximum field angle is z5o, the thickness of a core is t5, the length of the optical path of an e line on the principal ray at the maximum field angle is p5e, the length of the optical path of a c line on the principal ray on the axis is p5c, the maximum image height is Y, and the entire optical length is TL, the imaging optical system satisfies 0.2<|f5/f|<0.5, 1<|z5o/t5|<4, 2.5<p5e/p5c<5 and 0.63<Y/TL<0.9.


## Images (14)



JP2012203234A

JP Application

Download PDF | Find Prior Art | Similar

Other languages: Japanese

Inventor: Keiji Matsuzaka, Keiko Yamada, 恵子 山田, 慶二 松坂

Original Assignee: Konica Minolta Advanced Layers Inc, コニカミノルタアドバンストレイヤー株式会社

Priority date : 2011-03-25

Family: JP (1)

| Date | App/Pub Number | Status |
|---|---|---|
| 2011-03-25 | JP2011068208A | Pending |
| 2012-10-22 | JP2012203234A | Application |

Info: Patent citations (7), Cited by (4), Legal events, Similar documents, Priority and Related Applications

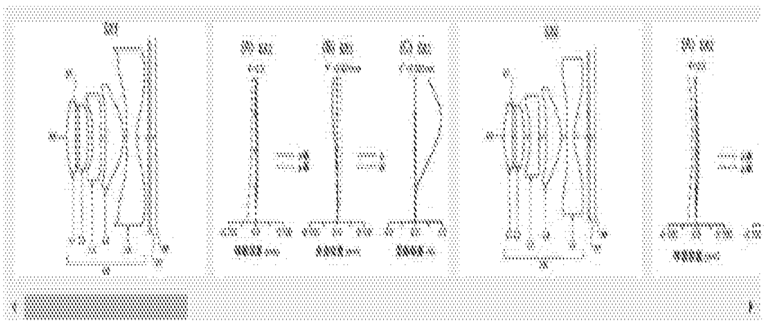
External links: Espacenet, Global Dossier, Discuss

# Image-capturing lens


## Abstract

An image-capturing lens comprises in order from the object side a positive first lens, a stop, a positive second lens, a negative third lens, a positive fourth lens, and a negative fifth lens, satisfies the conditional expression of $0 < f1/f2 < 1.26$ (where f1 is the focal length of the first lens and f2 is the focal length of the second lens), and forms an image of an object on the image-capturing surface of an image-capturing element.


## Images (15)



## WO2013058111A1

WO Application

Find Prior Art   Similar

**Other languages:** French, Japanese

**Inventor:** 田中 宏明

**Original Assignee:** コニカミノルタアドバンストレイヤー株式会社

**Priority date :** 2011-10-20

**Family:** JP (1) WO (1)

| Date | App/Pub Number | Status |
|---|---|---|
| 2012-10-03 | PCT/JP2012/075631 | |
| 2013-04-25 | WO2013058111A1 | Application |

**Info:** Patent citations (14), Cited by (4), Legal events, Similar documents, Priority and Related Applications

**External links:** Espacenet, Global Dossier, PatentScope, Discuss

# Photographic telephoto lens


## Abstract

PURPOSE: To achieve the balance of aberration correction and prevent the degradation in the positive coma aberration and distortion aberration produced from the refracting power of the front group by making the combined thickness of the 5 group type through combination of positive and negative single lenses smaller under the specified conditions.
CONSTITUTION: The front group disposed with a biconvex single lens $L_1$ whose convex face of a larger curvature is opposed to the object side as the 1st group subsequently from the object side, a plane-concave or negative meniscus single lens $L_2$ whose object side is a concave lens as the 2nd group and a positive meniscus single lens $L_3$ whose convex face of a larger curvature is faced to the object side as well as the rear group disposed with a megative neniscus single lens $L_4$ whose convex face is faced to the image side as the 4th group and a positive single lens $L_5$ on the image side as the 5th group are disposed on the optical axis by leaving a specified distance. The formulas (1) thru (7) are satisfied in respective specifications. (f is focal length, d is axial air spacing, r is radius of curvature and ν is Abbe number).

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## JPS54157620A

JP Application

Find Prior Art   Similar

**Inventor:** Toshiro Shimokura

**Original Assignee:** Konishiroku Photo Ind Co Ltd

**Priority date :** 1978-06-01

**Family:** JP (1)

| Date | App/Pub Number | Status |
|---|---|---|
| 1978-06-01 | JP6491078A | Expired |
| 1979-12-12 | JPS54157620A | Application |
| 1981-12-21 | JPS5653725B2 | Grant |

**Info:** Patent citations (4), Cited by (1), Similar documents, Priority and Related Applications

**External links:** Espacenet, Global Dossier, Discuss

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
2 May 2013 (02.05.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/063097 A1

(51) International Patent Classification:
*G02B 13/00* (2006.01) *H04N 5/232* (2006.01)

(21) International Application Number:
PCT/US20 12/06 1668

(22) International Filing Date:
24 October 2012 (24.10.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/550,789 24 October 2011 (24. 10.2011) US

(71) Applicant *(for all designated States except US)*: **DIGITALOPTICS CORPORATION MEMS** [US/US]; 400 E. Live Oak Avenue, Arcadia, California 91006 (US).

(72) Inventors; and
(71) Applicants *(for US only)*: **CAHALL, Scott** [US/US]; 9815 David Taylor Drive, Charlotte, North Carolina 28262 (US). **SCHMIDT, Jack** [US/US]; 9815 David Taylor Drive, Charlotte, North Carolina 28262 (US).

(74) Agents: **JOSHI, Vinay** et al; TUROCY & WATSON, LLP, 127 Public Square, 57th FL, Key Tower, Cleveland, Ohio 44114 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: 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) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (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).

**Declarations under Rule 4.17:**

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.1 7(H))*

**Published:**

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) **Title:** OPTICAL OBJECTIVE HAVING FIVE LENSES WITH FRONT FOCUSING

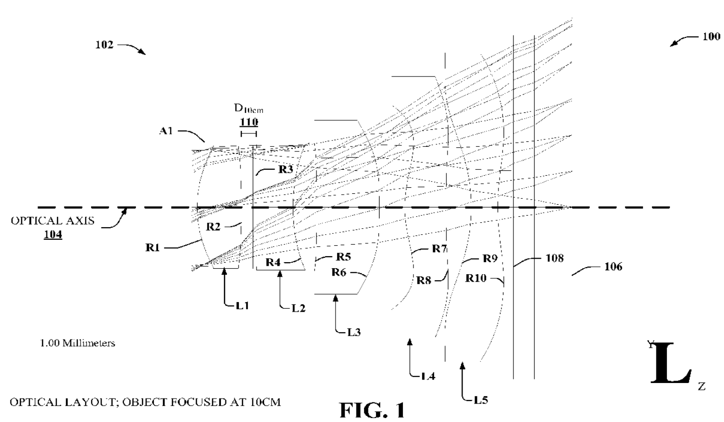


FIG. 1

(57) **Abstract:** Optical system comprising five lenses, a front pupil and achieving focus for objects from close to infinity by adjusting, via a MEMS actuator, the position of a subset of lenses located on the object-side of the optical system. The most object-side, biconvex, lens provides a substantial amount of the system's optical power for achieving focus from an object as close as 10 cm away from the aperture stop.

WO 2013/063097 A1

# OPTICAL OBJECTIVE HAVING FIVE LENSES WITH FRONT FOCUSING

## CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims the benefit of U. S. Provisional Patent Application Serial No. 61/550,789 entitled "OPTICAL SYSTEM WITH MICROELECTROMECHANICAL SYSTEM IMAGE FOCUS ACTUATOR" filed October 24, 2011. The entirety of the above-noted application is incorporated by reference herein.

## TECHNICAL FIELD

**[0002]** The following relates generally to imaging optics, and more particularly to a compact optical lens system with micro electromechanical system (MEMS) actuator for focusing the optical lens system.

## BACKGROUND

**[0003]** Applications for optics and optical devices have become numerous in conjunction with advances in optical fabrication technology. One interesting advancement in optical technology is fabrication of micro lenses, and other optical components on a millimeter or micrometer scale, or less. Compared with traditional optical elements typically on the scale of centimeters or larger, micro optics have made optical systems compatible with smaller devices than traditional telescopes, microscopes, cameras, and so on.

**[0004]** One mechanism facilitating the fabrication of micro optics is wafer-level optics. Wafer-level optics is a fabrication technology that enables design and manufacture of optical components using techniques similar to semiconductor manufacturing. The technology is generally scalable with different size scales (e.g., millimeter, micrometer, etc.). Moreover, wafer-level optics can produce single-element as well as multi-element optical structures, yielding precision aligned stacks of lens elements. The end result of wafer-level optics provide cost effective, miniaturized optical components that enable reduced form factor for optical systems. These optical systems can be employed in a wide range of small or miniature devices, including camera modules for mobile phones, surveillance equipment, miniature video cameras, and the like.

[0005] Although wafer-level optics is one relatively recent technology for fabricating small optical components, some traditional fabrication techniques have been adapted to small-scale optical fabrication as well. For instance, plastic fabrication techniques including injection molding, and others can be employed for manufacturing small-scale optical components. Further, glass fabrication techniques have been adapted for miniaturized optical components, providing high quality optical surfaces for small-scale devices.

[0006] In addition to optical elements, the miniaturization of digital imaging sensors has also facilitated the continuing miniaturization of image capture and recording devices. Improvements in image sensors have provided high resolution image detectors utilizing micro-scale pixilation, and at high signal to noise ratio and increasingly lower cost. In conjunction with micro optics, such as wafer-level optical components, small, relatively inexpensive digital capture and recording devices can match or exceed the capabilities of relatively expensive, yet very high quality camera systems utilizing traditional optics of just a decade ago. Although quality is very high for modern micro optical devices, one persistent limitation has been zoom capability for miniature optical systems. One solution has been the introduction of digital zoom, which sacrifices optical resolution to enlarge an image. For high resolution sensors, this often provides a suitable alternative to traditional optical zoom capability. However, optical zoom provides advantages that digital zoom cannot achieve.

[0007] For example, the inventors of the disclosed subject matter suggest it would be desirable to have a miniature optical system with optical auto-focus capability. Such an optical system that achieves close focus would be additionally desirable.

## SUMMARY

[0008] The following presents a simplified summary of one or more aspects in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated aspects, and is intended to neither identify key or critical elements of all aspects nor delineate the scope of any or all aspects. Its sole purpose is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.

[0009] Particular aspects of the subject disclosure provide a miniaturized optical system. In some aspects, the miniaturized optical system can comprise an injection



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molded optical system. In further aspects, the miniaturized optical system can be an auto-focus optical system comprising five optical components. In still other aspects, the miniaturized optical system can be an auto-focus optical system employing a micro electromechanical system (MEMS) actuator to achieve focusing of the optical system.

**[0010]** In one or more other aspects of the subject disclosure, provided is an optical system that employs a MEMS actuator to achieve close focus. In one such aspect, the close focus can comprise a substantially 10cm object distance. Further, according to other aspects, the optical system can be configured to achieve close focus and infinity focus by adjusting position of a subset of optical components of the optical system. In particular aspects, the subset of optical components can comprise a single optical component of the optical system. In at least one such aspect, the single optical component can be a lens closest along an optical axis of the optical system to an object being imaged by the optical system (referred to as an object-side lens). In such aspect(s), the MEMS actuator can be configured to displace the object-side lens of the optical system a first distance configured to focus an object at infinity onto an image sensor associated with the optical system, and to displace the object-side lens a second distance configured to focus a close object *(e.g.* , an object substantially 10cm from the object-side lens) onto the image sensor.

**[0011]** According to one or more additional aspects, an auto-focus optical system disclosed herein can be configured to include an aperture stop. In a particular aspect, the auto-focus optical system can comprise injection molded plastic lenses, whereas in other aspects, the auto-focus optical system can comprise wafer-level optical lenses, glass lenses, or a suitable combination thereof. In another aspect, the aperture stop can be positioned on an object side of the object-side lens of the optical system. In one alternative aspect, a MEMS actuator can be configured to move a subset of optical components of the optical system to focus an object, while maintaining the aperture stop in a fixed position along an optical axis of the optical system. In another alternative aspect, the MEMS actuator can instead be configured to move both the subset of optical components and the aperture stop relative to the optical axis, to focus the object.

**[0012]** According to still other aspects, disclosed is an auto-focus optical system comprising a plurality of optical components. The plurality of optical components can, in some such aspects, comprise an object-side lens providing a substantial amount of optical power to the optical system. In at least one such aspect, the object-side lens can comprise substantially half or greater than half of the combined focal length of the optical system. In another aspect, the object-side lens can comprise substantially three-quarters or more of the combined focal length of the optical system. In a particular aspect, a MEMS actuator is connected to the object-side lens, and is configured to displace the object-side lens a first distance configured to focus an object at infinity, and a second distance configured to focus an object close to the optical system. According to one specific embodiment, a ratio of the focal length of the object-side lens and of a combined focal length of the optical system can be a function of a difference in magnitude of the first distance and the second distance along an optical axis of the optical system.

**[0013]** According to additional aspects, the subject disclosure provides a micro-optical system comprising five optical lenses. In one such aspect, an objective lens of the five optical lenses can be configured to supply all positive refractive power of the five optical lenses. In this aspect, the remaining four lenses have a combined net negative refractive power. In at least one particular aspect, the remaining four lenses can have respective negative refractive powers, with a combined net negative refractive power. According to an alternative or additional aspect, a third lens of the five optical lenses can a convex object side surface and a concave image side surface. As yet another alternative or additional aspect, a spacing between a fourth of the five optical lenses and a fifth of the five optical lenses can be a largest spacing between lenses of the optical system. In another aspect, the micro-optical system can be an auto-focus system in which a subset of the five optical lenses are movable along an optical axis to refine a focus of the optical system. In one specific aspect, the subset of the five optical lenses can comprise the objective lens, and the subset being movable by a MEMS actuator.

**[0014]** In further aspects of the subject disclosure, provided is a micro-optical system comprising five optical lenses. The five optical lenses can be arranged into a plurality of lens groups, each lens group comprising respective subsets of the five optical lenses. Each group comprises inter-lens distances equal to or less than a distance(s) between the plurality of optical groups. In a further aspect, each lens within at least one of the plurality of lens groups comprises at least one optical surface having both a concave portion and a convex portion. In a particular aspect, an effective focal length of the micro-optical system varies in response to a change in position along an optical axis of a first lens of the five optical lenses, and in an alternative or additional aspect, a back focal length of the micro-optical system remains substantially the same in response to the change in position along the optical axis of the first lens.

**[0015]** To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative aspects of the one or more aspects. These aspects are indicative, however, of but a few of the various ways in which the principles of various aspects can be employed and the described aspects are intended to include all such aspects and their equivalents.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0016]** Figure 1 illustrates a diagram of an example optical imaging system configured to focus a relatively close object, according to various aspects of the subject disclosure.

**[0017]** Figure 2 illustrates a diagram of a sample optical imaging system configured to focus an object substantially at infinity, according to other disclosed aspects.

**[0018]** Figure 3 depicts a diagram of an example optical imaging system comprising a plurality of injection molded optical components.

**[0019]** Figure 4 illustrates a diagram of example field curvature and distortion graphs for a sample optical imaging system focusing a relatively close object.

**[0020]** Figure 5 illustrates a diagram of example field curvature and distortion graphs for the sample optical imaging system of Figure 4, focusing an object substantially at infinity.

**[0021]** Figure 6 depicts a diagram of a sample lateral color graph for an example optical imaging system focusing a relatively close object, according to further aspects.

**[0022]** Figure 7 illustrates a diagram of a sample lateral color graph for the example optical imaging system of Figure 6 focusing an object substantially at infinity, according other aspects.

**[0023]** Figure 8 depicts a diagram of transverse ray fan plots for a disclosed optical imaging system with an object focused at 10cm.

**[0024]** Figure 9 illustrates a diagram of transverse ray fan plots for the disclosed optical imaging system of Figure 8, with an object focused substantially at infinity.

**[0001]** Figure 10 illustrates a cross-section of a sample optical system for focusing an image of an object at 10cm according to aspects of the subject disclosure.



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[0002] Figure 11 illustrates a cross-section of a sample optical system for focusing an image of an object at infinity according to aspects of the subject disclosure.

[0003] Figure 12 illustrates an example graph of field curvature and distortion for an object at 10cm according to aspects of the subject disclosure.

[0004] Figure 13 illustrates an example graph of field curvature and distortion for an object at infinity in other aspects of the subject disclosure.

[0005] Figure 14 illustrates an example graph of primary lateral color for an object at 10cm according to an aspect(s).

[0006] Figure 15 illustrates an example graph of primary lateral color for an object at infinity according to one or more other aspects.

[0007] Figure 16 illustrates an example transverse ray fan plot for various image heights for an object at 10cm according to still other aspects.

[0025] Figure 17 illustrates an example transverse ray fan plot for various image heights for an object at infinity according to at least one other aspect.

[0026] Figure 18 depicts a transverse ray fan plot for a range of field angles for an example micro-optical system according to additional disclosed aspects.

[0027] Figure 19 illustrates a sample diagram of the micro-optical system of Figure 18 including lenses and optical surfaces.

[0028] Figure 20 depicts an example graph of field curvature and distortion for an object focused by the micro-optical system of Figure 18.

[0029] Figure 2 1 illustrates a sample graph of longitudinal aberration for a pupil radius of 0.90 millimeters in an aspect.

[0030] Figure 22 depicts an example graph of lateral color for a disclosed micro-optical system according to further aspects.

[0031] Figure 23 illustrates a transverse ray fan plot for a range of field angles for a micro-optical system focused in the near-field according to disclosed aspects.

[0032] Figure 24 depicts a sample diagram of the micro-optical system of Figure 23 including lenses and optical surfaces.

[0033] Figure 25 illustrates an example diagram of field curvature and distortion for a near-field object focused by the micro-optical system of Figure 23.

[0034] Figure 26 depicts a sample diagram of longitudinal aberration for pupil radius of 0.90 millimeters for a disclosed micro-optical system, in an aspect.

[0035] Figure 27 illustrates an example diagram of lateral color for a disclosed micro-optical system according to still other disclosed aspects.

**[0036]** Figures 28A, 28B, 28C and 28D illustrate diagrams of an example micro-optical system focused at infinity according to further aspects, and related optical performance graphs.

**[0037]** Figures 29A, 29B, 29C and 29D depict the micro-optical system of Figure 28 focused in the near-field and related optical performance graphs.

DETAILED DESCRIPTION

**[0038]** Various aspects are now described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more aspects. It will be evident, however, that such aspect(s) can be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to facilitate describing one or more aspects.

**[0039]** In addition, it should be apparent that the teaching herein can be embodied in a wide variety of forms and that the specific structures or functions disclosed herein are merely representative. Based on the teachings herein one skilled in the art should appreciate that the disclosed aspects can be implemented independently of other aspects, and that two or more of these aspects can be combined in various ways. For example, an apparatus can be implemented and/or a method practiced using any number of the aspects set forth herein. In addition, an apparatus can be implemented and/or a method practiced using other structure and/or functionality in addition to or other than one or more of the aspects set forth herein. As an example, many of the apparatuses and lens systems disclosed herein are described in the context of providing high resolution optical imaging *via* compact fixed position optical lens arrangements. One skilled in the art should appreciate that similar techniques could apply to other optical lens architectures. For example, the lens arrangements used herein may be used in mechanical focus or auto-focus systems whereby the optical arrangement is automatically or manually displaced relative to the image plane.

**[0040]** In at least one aspect of the subject disclosure, an optical imaging system is provided. The optical imaging system can comprise a first group of lenses and a second group of lenses. The optical imaging system can be focused by repositioning the first group of lenses relative to the second group of lenses along an optical axis of the optical imaging system. In at least one aspect of the subject disclosure, the second group of lenses includes an image sensor for the optical imaging system. In particular aspects of the subject disclosure, the first group of lenses can comprise a single lens. For instance, the single lens can include an object-side lens, which is an optical element closes to an object side of the optical imaging system.

**[0041]** Referring now to the drawings, Figure 1 depicts a block diagram of an example optical system 100 according to aspects of the subject disclosure. System 100 comprises an arrangement of optical elements 102 positioned transverse to an optical axis 104. As utilized herein, an optical element refers to a single piece of refractive or reflective material at least partially transparent to electromagnetic radiation at least partially within the visible spectrum *(e.g.,* including wavelengths approximately 400 to 700 nanometers [nm]). Examples of suitable material include ground and polished glass, molded glass or glass formed from a replication molding process, wafer-level optics (WLO), injection-molded plastic, etched micro optics formed on an optical substrate, or the like. Additionally, an optical element will have at least one refractive or reflective surface. One example of an optical element utilized herein is an optical lens. An optical lens is an optical element comprising two opposing refractive surfaces, and an edge between the opposing surfaces that defines an outer diameter (for a circular lens) or perimeter of the lens, and an edge thickness of the lens. A typical arrangement of optical lenses includes a series of lenses 102 at least generally transverse to an axis (optical axis 104). It should be appreciated, however, that other possible arrangements can exist consistent with the subject disclosure. A "lens component" is defined herein as (A) a single lens element spaced so far from any adjacent lens element that the spacing cannot be neglected in computing the image forming properties of the respective lens elements, or (B) two or more lens elements that have adjacent lens surfaces either in full overall contact or so close together that any spacing between the adjacent lens surfaces are so small that the spacing(s) can be neglected in computing image forming properties of the two or more lens elements. Thus, some lens elements can also be lens components, and the terms "lens element" and "lens component" are not mutually exclusive terms. In addition, it should be appreciated that the term "optical component" is utilized herein to refer to a superset of items having significant properties related to imaging optical systems, and includes optical elements such as lens elements and lens components, as well as various optical stops including but not limited to aperture stops, but can also include various other items such as a thin film, a bandpass filter, a lowpass or highpass filter, a polarizing filter, a mirror, *etc.*



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**[0042]** Light entering the left side, or object side, of optical elements 102 can interact sequentially with respective elements (102) and exit the right side, or image side, of the elements 102, toward an optical sensor 106. It should be appreciated that not all light interacting with the left side of the optical elements 102 will be transmitted to the sensor 106; some light can be reflected off of respective elements (102), some light can be scattered away from the optical axis 104 and absorbed (*e.g.* , by an optical stop - not depicted), and so forth. However, in general, the optical elements 102 will receive light from an object on one side of the elements (*e.g.* , the left side) and form a real image of the object on an opposite side of the elements (*e.g.* , on the right side). The real image will be formed along the optical axis 104 a certain distance from the optical elements 102, called an image distance (ID). Notably, the ID depends primarily on a corresponding object distance (OD - distance between the object and the optical elements 102 along the optical axis 104) and a refractive power, or optical power, of the combined optical elements 102.

**[0043]** Sensor 106 can be a digital device comprising a multi-dimensional array (*e.g.* , a two dimensional array) of electro-optical sensors, or pixels. Examples of such a device can include a charge-coupled device (CCD) array, or a complementary metal-oxide semiconductor (CMOS) array, or some other suitable array of optical sensors. Each electro-optical sensor, or pixel, of such array is configured to output an electric signal when irradiated with light. Furthermore, an amount of electric current for the electric signal is directly related to energy density of light irradiating the pixel. Accordingly, by collecting output current levels from each pixel of the array, sensor 106 can digitally reproduce a two dimensional radiant energy pattern of light irradiating the sensor 106. Additionally, where the pixel surface or sensor plane of sensor 106 is placed at the above-mentioned ID, the two dimensional radiant energy pattern that is produced is that of a real optical image generated by optical elements 102. Accordingly, sensor 106 can be utilized to digitally reproduce that image. Resolution of a digital image generated by sensor 106 depends on a number of pixels within an active array of sensor 106. In addition, optical system 100 can comprise a cover plate 108 between the optical elements 102 and image sensor 106, as depicted by Figure 1.

**[0044]** As depicted by optical system 100, optical elements 102 can comprise five optical lenses, including lens LI, lens L2, lens L3, lens L4 and lens L5, from the object-side of optical elements 102 to an image-side of optical elements 102. As depicted, lens LI is a biconvex lens having positive optical power, having convex object-side and convex image-side surfaces, R1 and R2, respectively. Additionally, lens LI can have a relatively strong positive optical power, relative to lenses L2, L3, L4 and L5. In at least one aspect, lens LI can have a relatively strong positive optical power relative to a combination of lenses L2, L3, L4 and L5. In a particular aspect, lens LI can provide at least about half or more of the combined focal length of optical elements 102. In an alternative aspect, lens LI can provide substantially about three-quarters or more of the combined focal length of optical elements 102. In related aspects, the optical power of the object-side lens ($Ll_{power}$) can be about 1.25x the combined optical power of optical elements 102 (*e.g.*, $L1_{power} \leq 1.25*(Ll_{power} + L2_{power} + L3_{power} + L4_{power} + L5_{power})$. In a particular aspect, an aperture stop A1 can be positioned at or in front of an object-side of lens LI. Aperture stop A1 is described in more detail below.

**[0045]** Lens L2 can have an overall negative optical power. Further, lens L2, in one aspect, can have a mildly concave object-side surface R3. In an alternative aspect, object-side surface R3 can be flat, with no optical power. As yet another alternative aspect, object-side surface R3 can be mildly convex. An image-side surface R4 of lens L2 can have concave curvature. Moreover, lens L2 can be configured to provide chromatic aberration correction for optical system 100. In at least one aspect, lens L2 can provide a majority of chromatic aberration correction for optical system 100.

**[0046]** Lens L3 comprises an object-side surface R5 and an image-side surface R6. Object-side surface R5 can be mildly concave, in particular aspects. Moreover, image-side surface R6 can be convex. In a particular aspect, lens L3 can have a positive optical power.

**[0047]** Lens L4 comprises an object-side surface R7 and an image-side surface R8. Object-side surface R7 can have convex curvature near optical axis 104. Moreover, in at least one aspect of the subject disclosure, object-side surface R7 can transition to concave further from optical axis 104. Moreover, image-side surface R8 can be substantially flat with little or no optical power near optical axis 104, and transition to convex curvature away from optical axis 104. In an alternative aspect, image-side surface R8 can be convex near optical axis 104 having significant optical power for low to mid field angles, as well as convex away from optical axis 104. In a particular aspect, lens L4 can have positive power for low field angles (*e.g.*, field angles between zero and about 12 to 15 degrees). In another aspect, lens L4 can have small positive, small negative, or substantially zero optical power for medium field angles



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*(e.g.* , field angles between about 12 to 15 degrees and about 22 to 25 degrees). In yet another aspect, lens L4 can have small positive, small negative, or substantially zero optical power for for high field angles *(e.g.* , field angles between about 22 to 25 degrees and about 33 or more degrees, up to a maximum accepted field angle of optical system 100).

**[0048]** Lens L5 comprises an object-side surface R9 and an image-side surface R10. Object-side surface R9 can have concave curvature for low and medium field angles. In at least one aspect, object-side surface R9 can transition to mildly concave or no curvature for high field angles. Image-side surface R10 can be concave near optical axis 104. Moreover, image-side surface R10 can transition from concave to convex for medium and high field angles, as depicted.

**[0049]** As depicted, optical elements 102 can have respective spaces *(e.g.* , air spacing) between respective lenses LI, L2, L3, L4 and L5. In at least one disclosed embodiment, a first on-axis distance between lens LI and L2 can be substantially small compared with a third on-axis distance between lens L3 and lens L4. In another embodiment, the first on-axis distance can be substantially small compared to a second on-axis distance between lens L2 and L3, and a fourth on-axis distance between lens L4 and L5, in addition to the third on-axis distance. In at least one embodiment, the second, third and fourth on-axis distances can be substantially similar in magnitude, at least in comparison with the first on-axis distance. In other embodiments, these relations between the first, second, third and fourth on-axis distances need not exist. For instance, other relationships between the first, second, third and fourth on-axis distances may exist instead.

**[0050]** In at least one aspect of the subject disclosure, a MEMS actuator can be connected at least to lens LI . The MEMS actuator can be configured to reposition lens LI along optical axis 104 to focus objects at different object distances. As one example, the MEMS actuator can change the first distance between lens LI and lens L2 to focus objects at differing object distances. In at least one aspect, the MEMS actuator can position lens LI a distance $\mathbf{Dio}_{\mathbf{cm}}$ 110 from lens L2 to focus onto sensor 106 an image of an object that is substantially 10 centimeters (cm) from a position of aperture stop A1 on optical axis 104.

**[0051]** According to further aspects, aperture stop A1 can be fixed relative to optical axis 104. In another aspect, aperture stop A1 can be fixed relative to a position of lens LI . In the latter aspect, aperture stop A1 can be moved by a MEMS actuator in conjunction with lens L1 when focusing an image of an object. According to still other aspects, the MEMS actuator can be configured to move lens L1, either alone or in conjunction with aperture stop A1, a total distance along optical axis 104. The total distance can, in a particular aspect, at one end thereof focus an image of an object at infinity, and at an opposite end thereof, focus an image of an object substantially at 10cm from aperture stop A1. As utilized herein, an object at infinity includes an object distance that satisfies the paraxial approximation known in the art of optical imaging science. The paraxial approximation, broadly stated, refers to an object at such a distance that an angle - subtending a first optical ray that is parallel with optical axis 104 and a second optical ray that originates at a point on the object farthest from the optical axis and passes through optical axis 104 at aperture stop A1 - is substantially zero degrees. In yet another aspect, lens L1 can have a focal length that is at least in part a function of a magnitude of the total distance. In still other aspects, a ratio of the focal length of lens L1 and a combined focal length of optical elements 102 can at least in part be a function of the magnitude of the total distance.

**[0052]** Because the pixel array of sensor 106 generates an electronic reproduction of a real image, data generated by sensor 106 (and other sensors disclosed herein) in the form of electric signals can be saved to memory, projected to a display for viewing *(e.g.*, digital display screen), edited in software, and so on. Thus, at least one application of optical system 100 is in conjunction with a digital camera or video camera comprising a digital display. Furthermore, optical system 100 and other optical systems included in the subject disclosure can be implemented in conjunction with a camera module of an electronic device. Such an electronic device can include a wide array of consumer, commercial or industrial devices. Examples include consumer electronics, including a cell phone, smart phone, laptop computer, net-book, PDA, computer monitor, television, flat-screen television, and so forth, surveillance or monitoring equipment, including commercial equipment (e.g., ATM cameras, bank teller window cameras, convenience store cameras, warehouse cameras and so on), personal surveillance equipment *(e.g.*, pen camera, eyeglass camera, button camera, *etc.),* or industrial surveillance equipment *(e.g.*, airfield cameras, freight yard cameras, rail yard camera, and so on). For instance in consumer electronics, because optical system 100 can comprise optical components having physical dimensions on the order of a few millimeters or less, and because at least some of optical elements 102 can have a fixed position, system 100 and other disclosed systems are well suited for various types of mini or micro camera modules. It is to be appreciated, however, that the disclosed systems are not limited to this particular application; rather, other applications known to those of skill in the art or made known by way of the context provided herein, are included within the scope of the subject disclosure.

**[0053]** Figure 2 illustrates a diagram of an example optical imaging system 200 according to additional aspects of the subject disclosure. Optical imaging system 200 can comprise a set of optical elements 202 arranged transverse to an optical axis 204. Furthermore, optical elements 202 can be configured to focus an image onto an image plane 206 of an object located substantially at infinity from an aperture stop A1 of optical imaging system 200. In at least one aspect, optical elements 202 can be substantially similar to optical elements 102 of Figure 1, *supra,* except for the first distance between lens LI and lens L2. Particularly, this first distance in optical imaging system 200 can be a distance DINFINITY 210 configured to focus the object located substantially at infinity, discussed above. Furthermore, as described at Figure 1, *supra,* aperture stop A1 can, in one aspect, be fixed in position relative to optical axis 204. In an alternative aspect, aperture stop A1 can be fixed in position relative to lens LI, and move along optical axis 204 with lens L2.

**[0054]** It should be appreciated that surfaces R1 through R10 of lenses LI through L5 of optical elements 102 and 202 (as well as other optical surfaces described throughout the subject disclosure) can be of varying shapes. In one aspect, one or more of the surfaces can be spherical surfaces. In other aspects, one or more of the surfaces can be conic surfaces. In yet other aspects, one or more of the surfaces can be aspheric surfaces, according to a suitable aspheric equation, such as the even aspheric equation:

(1) $z = \left[\frac{CY^2}{\{1 + (1 - (1 + K)C^2 Y^2)^{1/2}\}}\right] + \sum_i (A_i * Y^i)$, where z is the sag height (in mm) of a line drawn from a point on the aspheric lens surface at a radial distance, Y from the optical axis to the tangential plane of the aspheric surface vertex, C is the curvature of the aspheric lens surface on the optical axis, Y is the radial distance (in mm) from the optical axis, K is the conic constant, and $A_i$ is the $i^{th}$ aspheric coefficient, with the summation over even number i. However, these aspects are not to be construed as limiting the scope of the subject disclosure. Rather, various surfaces can be odd aspheric, or of an aspheric equation comprising even and odd coefficients.

**[0055]** Further to the above, it should be appreciated that lenses of optical



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elements 102 and 202 (and optical lenses of various other optical systems provided throughout the subject disclosure) can be made of various suitable types of transparent material, and formed according to various suitable processes for generating an optical quality surface. In one aspect, lenses LI through L5 can be ground and polished glass, where the glass is selected to have an index of refraction resulting in a desired effective focal length for the combined lenses LI through L5. In another aspect, the lenses can be an optical-quality injected molded plastic (or plastic of optical quality formed by another suitable method), wherein the plastic has an index of refraction suitable to provide the desired effective focal length. In at least one other aspect, the lenses LI through L5 can be etched from a transparent glass, crystalline or other suitable structure (*e.g.* , silicon dioxide - $Si0_2$ wafer) with a lithographic etching process similar to that used to etch semiconductor chips (*e.g.* , solid state memory chip, data processing chip). In a particular aspect, optical elements 102 and optical elements 202 can be described according to the optical prescription of Tables 1 - 9, below.

| Parameter Description | Value |
|---|---|
| Effective Focal Length (in air at system temperature and pressure) | 4.131396 |
| Effective Focal Length (in image space) | 4.131396 |
| Back Focal Length | 0.349633 |
| Total Track Length (TTL) | 5.49089 |
| Image Space F/# | 2.293412 |
| Paraxial Working F/# | 2.44 |
| Working F/# | 2.857105 |
| Image Space NA | 0.1752143 |
| Object Space NA | 0.008991 |
| Stop Radius | 0.90071 |
| Paraxial Image Height | 2.956 |
| Paraxial Magnification | -0.04388 |
| Entrance Pupil Diameter | 1.801419 |
| Entrance Pupil Position | 0.18 |
| Exit Pupil Diameter | 1.236574 |
| Exit Pupil Position | -3.03634 |
| Maximum Radial Field | 2.956 |

| Lens Units | Millimeters (mm) |
|---|---|
| Angular Magnification | 1.183246 |

**Table 1: General Optical Properties**

| Field # | X-Value | Y-Value | Weight |
|---|---|---|---|
| 1 | 0 | 0 | 1 |
| 2 | 0 | 0.571 | 1 |
| 3 | 0 | 1.142 | 1 |
| 4 | 0 | 1.714 | 1 |
| 5 | 0 | 2.285 | 1 |
| 6 | 0 | 2.57 | 1 |
| 7 | 0 | 2.856 | 0.2 |
| 8 | 0 | 2.956 | 0.2 |

**Table 2: Field Type v. Real Image Height (in mm)**

| Field / # | VDX | VDY | VCX | VCY | VAN |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | -0.04364 | 0.000234 | 0.043642 | 0 |
| 6 | 0 | -0.081 | 0.001432 | 0.081006 | 0 |
| 7 | 0 | -0.1227 | 0.004184 | 0.122713 | 0 |
| 8 | 0 | -0.13916 | 0.006035 | 0.139171 | 0 |

**Table 3: Vignetting Factors for Fields of Table 2**

| Wavelength # | Value (in μm) | Weight |
|---|---|---|
| 1 | 0.47 | 91 |
| 2 | 0.51 | 503 |
| 3 | 0.555 | 1000 |
| 4 | 0.61 | 503 |
| 5 | 0.65 | 107 |

**Table 4: Wavelengths Used for Raytracing**

| Surface | Type | Radius | Thickness | Material | Diameter | Conic | Notes |
|---|---|---|---|---|---|---|---|
| Object | Standard | Infinity | 100 | | 132.31 88 | 0 | |
| 1 | Standard | Infinity | 0.1 8 | | 2.036472 | 0 | |
| Stop | Standard | Infinity | -0. 1 | | 1.85939 | 0 | |
| 3 | EvenAsph | 1.974507 | 0.637634 | APEL551 4ML | 1.9071 53 | 0 | |
| 4 | EvenAsph | -13.5665 | 0.166808 | | 1.93921 2 | 0 | |
| 5 | Standard | Infinity | 0.049504 | | 1.93921 2 | 0 | not vignetting |
| 6 | EvenAsph | 68.79989 | 0.528506 | OKP4HT | 1.951 274 | 0 | |
| 7 | EvenAsph | 2.992822 | 0.247886 | | 1.977445 | 0 | |
| 8 | Standard | Infinity | 0.09498 | | 2 | 0 | Vignetting at 1.000 |
| 9 | EvenAsph | 143.3822 | 0.902332 | APEL551 4ML | 2.122436 | 0 | |
| 10 | EvenAsph | -24.6284 | 0.367969 | | 2.741 479 | 0 | |
| 11 | EvenAsph | 1.9791 7 | 0.596974 | APEL551 4ML | 3.225637 | 0 | |
| 12 | EvenAsph | 91.68886 | 0.360983 | | 4.1271 83 | 0 | |
| 13 | EvenAsph | -3. 10061 | 0.38221 5 | APEL551 4ML | 4.395569 | 0 | |
| 14 | EvenAsph | 3.49791 4 | 0.2251 | | 4.876466 | 0 | |
| 15 | EvenAsph | Infinity | 0.3 | N-BK7 | 5.271 775 | 0 | |
| 16 | Standard | Infinity | 0.55 | | 5.427336 | 0 | |
| Image | Standard | | | | 0 | 0 | |

**Table 5: Surface Data Summary**

| Surface | Parameter Description | Value |
|---|---|---|
| R1 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.01328 |
| | Coefficient on r 6 | 0.020358 |
| | Coefficient on r 8 | -0.03418 |
| | Coefficient on r 10 | 0.012665 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R2 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.0043 |
| | Coefficient on r 6 | 0.001395 |
| | Coefficient on r 8 | -0.02717 |
| | Coefficient on r 10 | 0.022646 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |

| | | |
|---|---|---|
| | Coefficient on r 16 | 0 |
| R3 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.01683 |
| | Coefficient on r 6 | 0.019474 |
| | Coefficient on r 8 | -0.03875 |
| | Coefficient on r 10 | 0.034171 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R4 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.01678 |
| | Coefficient on r 6 | 0.057631 |
| | Coefficient on r 8 | -0.06199 |
| | Coefficient on r 10 | 0.029185 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R5 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.07378 |
| | Coefficient on r 6 | 0.078871 |
| | Coefficient on r 8 | -0.04834 |
| | Coefficient on r 10 | 0.007991 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R6 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.20739 |
| | Coefficient on r 6 | 0.12271 |
| | Coefficient on r 8 | -0.04163 |
| | Coefficient on r 10 | 0.006751 |
| | Coefficient on r 12 | 0 |



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| | | |
|---|---|---|
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R7 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.15706 |
| | Coefficient on r 6 | 0.019487 |
| | Coefficient on r 8 | -0.00924 |
| | Coefficient on r 10 | 0.001005 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R8 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | 0.054595 |
| | Coefficient on r 6 | -0.04501 |
| | Coefficient on r 8 | 0.010689 |
| | Coefficient on r 10 | -0.00087 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R9 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.01701 |
| | Coefficient on r 6 | 0.02087 |
| | Coefficient on r 8 | -0.00363 |
| | Coefficient on r 10 | 0.000212 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R10 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.07822 |
| | Coefficient on r 6 | 0.013989 |
| | Coefficient on r 8 | -0.00152 |
| | Coefficient on r 10 | 6.37E-05 |

| | | |
|---|---|---|
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |

**Table 6: Surface Aspheric Coefficients**

| Surface | Edge |
|---|---|
| Object | 100 |
| 1 | 0.18 |
| Stop | 0.13436 |
| 3 | 0.361345 |
| 4 | 0.208736 |
| 5 | 0.052866 |
| 6 | 0.700429 |
| 7 | 0.0726 |
| 8 | 0.054707 |
| 9 | 0.625532 |
| 10 | 0.494114 |
| 11 | 0.625166 |
| 12 | 0.144313 |
| 13 | 0.505743 |
| 14 | 0.480978 |
| 15 | 0.3 |
| 16 | 0.55 |
| Image | 0 |

**Table 7: Edge Thickness Data**

| Temperature (Temp) in degrees Celsius and pressure (Press) in atmospheres | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Surface | Material | Temp | Press | 0.47 | 0.51 | 0.555 | 0.61 | 0.65 |
| 0 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 1 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 2 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 3 | APEL55 14ML | 20 | 1 | 1.552896 | 1.549574 | 1.546504 | 1.543579 | 1.541977 |
| 4 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 5 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 6 | OKP4HT | 20 | 1 | 1.65642 | 1.646281 | 1.637383 | 1.62927 | 1.625419 |
| 7 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 8 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 9 | APEL55 14ML | 20 | 1 | 1.552896 | 1.549574 | 1.546504 | 1.543579 | 1.541977 |
| 10 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 11 | APEL55 14ML | 20 | 1 | 1.552896 | 1.549574 | 1.546504 | 1.543579 | 1.541977 |
| 12 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 13 | APEL55 | 20 | 1 | 1.552896 | 1.549574 | 1.546504 | 1.543579 | 1.541977 |



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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 14ML | | | | | | | |
| 14 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 15 | N-BK7 | 20 | 1 | 1.523605 | 1.520769 | 1.51 8274 | 1.51 5909 | 1.51 452 |
| 16 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 17 | | 20 | 1 | 1 | 1 | 1 | 1 | |

**Table 8: Index of Refraction Data**

| | | Wavelengths (μm): | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.47 | | 0.51 | | 0.555 | |
| Number | Field (mm) | Tan | Sag | Tan | Sag | Tan | Sag |
| 1 | 0 | 2.4569 | 2.4569 | 2.4571 | 2.4571 | 2.4591 | 2.4591 |
| 2 | 0.571 | 2.5045 | 2.4888 | 2.5043 | 2.4886 | 2.506 | 2.4902 |
| 3 | 1.142 | 2.5363 | 2.5666 | 2.5363 | 2.5654 | 2.538 | 2.5662 |
| 4 | 1.714 | 2.6412 | 2.6707 | 2.644 | 2.6687 | 2.6478 | 2.6688 |
| 5 | 2.285 | 3.1763 | 2.8179 | 3.1806 | 2.8155 | 3.1856 | 2.8152 |
| 6 | 2.57 | 3.6191 | 2.9098 | 3.6212 | 2.9074 | 3.6236 | 2.907 |
| 7 | 2.856 | 4.1799 | 3.0168 | 4.1688 | 3.0144 | 4.1575 | 3.014 |
| 8 | 2.956 | 4.4668 | 3.0594 | 4.4391 | 3.0571 | 4.4113 | 3.0567 |

**Table 9: F/Number Data**

| | | Wavelengths (μm) | | | |
|---|---|---|---|---|---|
| | | 0.61 | | 0.65 | |
| Number | Field (mm) | Tan | Sag | Tan | Sag |
| 1 | 0 | 2.4624 | 2.4624 | 2.4666 | 2.4666 |
| 2 | 0.571 | 2.509 | 2.4932 | 2.5132 | 2.4973 |
| 3 | 1.142 | 2.5408 | 2.5684 | 2.5444 | 2.5721 |
| 4 | 1.714 | 2.6522 | 2.6703 | 2.656 | 2.6736 |
| 5 | 2.285 | 3.1911 | 2.8164 | 3.1952 | 2.8194 |
| 6 | 2.57 | 3.6263 | 2.908 | 3.6281 | 2.911 |
| 7 | 2.856 | 4.1459 | 3.0151 | 4.1376 | 3.018 |
| 8 | 2.956 | 4.3835 | 3.0578 | 4.3641 | 3.0606 |

**Table 9A: F/Number Data (Continued)**

**[0056]** Table 1 provides general optical information for an embodiment of optical imaging systems 100 and 200. Table 2 provides image heights in the y axis, measured at the image sensor 106 or image sensor 206, for eight different optical fields, and provides weights for the respective fields. Table 3 includes vignetting data for the eight fields indicated in Table 2. Table 4 depicts wavelengths of respective rays traced



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in optical imaging systems 100 and 200, depicted at Figures 1 and 2. Table 5 provides a summary of general optical surface characteristics for the lenses of optical elements 102 and optical elements 202, including surface type, radius of curvature, thickness, material (from standard glass and plastic catalogues), diameter, conic constant, and notes regarding vignetting. Table 6 describes even aspheric coefficients for the surfaces of Table 5, whereas Table 7 provides edge thickness information for those surfaces. Table 8 provides index of refraction data for multiple wavelengths for the optical fields identified at Table 2. Tables 9 and 9A provide F/# data for those same wavelengths and optical fields.

**[0057]** Figure 3 illustrates a diagram of an example injection molded plastic optical system 300 (also referred to as system 300) according to further aspects of the subject disclosure. System 300 can be formed from multiple injection molded plastic components. In one embodiment, two or more of lenses LI, L2, L3, L4 and L5 can be formed from a single mold. In other embodiments, respective lenses can be formed from separate molds and assembled, as depicted, after molding. In other aspects, formation of lenses LI, L2, L3, L4 and L5 can result from another optical fabrication technique, such as wafer-level optic fabrication. In at least one disclosed aspect, system 300 can be substantially similar to optical imaging system 100. In another aspect, system 300 can be substantially similar to optical imaging system 200. According to yet other aspects, system 300 can comprise MEMS hardware configured to displace lens LI along optical axis 302 to achieve focusing at an image plane 304 of system 300. In a particular embodiment, system 300 can comprise lens surfaces R1 and R2 of lens LI, surfaces R3 and R4 of lens L2, surfaces R5 and R6 of lens L3, surfaces R7 and R8 of lens L4, and surfaces R9 and R10 of lens L5, that are substantially similar to surfaces Rl - R10 described at Figure 1, *supra.*

**[0058]** Figure 4 illustrates a diagram of field curvature and F-Tan(Theta) Distortion (referred to hereinafter as distortion) for an optical imaging system as described herein. Particularly, Figure 4 illustrates field curvature and distortion for an object distance of 10cm, which can correspond with optical imaging system 100 of Figure 1, *supra.* The field curvature and distortion graphs utilize five wavelengths, having wavelengths of 0.470, 0.510, 0.555, 0.610 and 0.650 μιη, respectively, and have a maximum field angle of 33.391 degrees. The left-hand graph depicts field curvature in millimeters along a y-axis at an image plane of an optical imaging system. Field curvature data is depicted for Sagittal rays (delineated as 'S' on Figure 4) and Tangential



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rays (delineated as 'T' on Figure 4). As is clear from the graph, field curvature is minimal for sagittal rays over most of the image plane, and field curvature is within a few microns for tangential rays for most of the image plane, and several microns at the outer edge of the image plane (high y values).

**[0059]** The distortion graph on the right hand side also includes curves for the above five wavelengths. The distortion data is normalized to 0% at the optical axis. Throughout the image plane, distortion is less than about 1.5%, and less than one percent for low field angles.

**[0060]** Figure 5 depicts a diagram of field curvature and distortion for an optical imaging system focusing an object at infinity. Thus, the graphs of Figure 5 can correspond with optical imaging system 200 of Figure 2, *supra.* The field curvature and distortion graphs of Figure 5 employ graphs for the same wavelengths as for Figure 4, for a maximum field angle of 34.897 degrees. Field curvature includes lines for sagittal rays (S) for the indicated wavelengths, as well as transverse rays (T) for those same wavelengths. As depicted, field curvature for an object in focus at 10cm is within about +/- 50 microns.

**[0061]** Distortion at infinity varies a bit more than for the 10cm graph of Figure 4. Distortion is again normalized to 0% on the optical axis. The distortion ranges from about a half percent at medium field angles to about negative one and a half percent at the edge of the image plane. Total distortion for all field angles is about two percent.

**[0062]** Figure 6 illustrates a graph of primary lateral color for an optical imaging system as described herein. Particularly, the primary lateral color graph of Figure 6 is for an object in focus at 10cm object distance, and therefore can correspond with optical imaging system 100 of Figure 1, *supra.* The maximum field for the primary lateral color graph is 2.9560 mm, and ranges in wavelengths between 0.4700 and 0.6500 μιη. As depicted, lateral color variation is well within a half a micron for small field angles, varies to just over negative one microns for medium field angles, and becomes as large as about negative one and a half microns for higher field angles. Overall distortion remains below two microns for the image plane.

**[0063]** Figure 7 illustrates a graph of primary lateral color for an object in focus at infinity. Accordingly, Figure 7 can correspond with optical imaging system 200 of Figure 2, *supra.* Similar to Figure 6, the maximum field is 2.9560 mm for wavelengths between 0.4700 and 0.6500 μιη. For low and medium field angles, primary lateral color remains at or below about one half a micron. Only at larger field angles does the



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primary lateral color exceed half a micron, reaching a peak at just over about two microns at an edge of the image plane.

**[0064]** Figure 8 illustrates several transverse ray fan plots at an image plane of an optical imaging system described herein. Particularly, the transverse ray fan plots of Figure 8 correspond with an object in focus at 10cm object distance, and therefore can correspond with optical imaging system 100 of Figure 1, *supra.* The transverse ray fan plots depict transverse ray error ($e_y$) along a vertical axis, and pupil diameter ($P_y$) along the horizontal axis, for various image heights. Flatter plots indicate optimal performance and minimal error, whereas greater deviations along the vertical axis indicate greater transverse ray error. As is depicted by Figure 8, transverse ray error is minimal for near the optical axis (small image height), and generally increases with image height. The scale ranges from positive 25 microns to negative 25 microns along the x and y axis, respectively. The transverse ray fan plots include wavelengths between 0.470 and 0.650 wavelengths.

**[0065]** Figure 9 depicts several transverse ray fan plots for an object in focus at infinity, and therefore can correspond with optical imaging system 200 of Figure 2, *supra.* Similar to Figure 8, the plots exhibit minimal error near the optical axis, and generally low error for small pupil diameters at all field angles. At higher field angles and particularly higher pupil diameters, the transverse ray error increases. Generally, transverse ray error for the object at infinity is less than for the object at 10cm.

**[0066]** Referring now to the drawings, Figure 10 depicts a cross sectional view of an optical system 1000 for an object at 10cm comprising an arrangement of optical elements 1002 positioned in a like manner relative to an optical axis 1004. Light entering the left side, or object side, of optical elements 1002 can interact sequentially with respective elements 1002 and exit the right side, or image side, of the elements 1002, toward an image sensor 1006. The real image will be formed along the optical axis 1004 a certain distance from the optical elements 1002, called an image distance (ID). Notably, the ID depends primarily on a corresponding object distance (OD - distance between the object and the optical elements 1002 along the optical axis 1004) and a refractive power, or optical power, of the combined optical elements 102.

**[0067]** Sensor 1006 can be a digital device comprising a multi-dimensional array *{e.g.,* a two dimensional array) of electro-optical sensors, or pixels, which can include a CCD array, or a CMOS array, *etc.* Resolution of a digital image generated by sensor 1006 depends on a number of pixels within the sensor plane array 1008, which in turn is dependent on pixel area and total array area. Thus, for example, for relatively square pixels approximately 1.4 microns per side (1.96 square microns), a 0.4 cm square sensor array can comprise as many as 8.1 megapixels (Mp). Said differently, such a sensor would have resolution of about 8Mp. Because the pixel array generates an electronic reproduction of a real image, data generated by sensor 1006 in the form of electric signals can be saved to memory, projected to a display for viewing *(e.g.* , digital display screen), edited in software, and so on.

**[0068]** It should be appreciated that the optical imaging arrangement 1000 depicted in Figure 10 (and other optical imaging systems disclosed herein) is not intended to be drawn to scale. For instance, lens thicknesses, positions and heights are not necessarily depicted in proper proportion with actual sizes. Rather, arrangement 1002 is intended to provide a visual context of an imaging system to aid conceptual understanding of other aspects disclosed herein.

**[0069]** Optical system 1000 comprises a first lens LI, a second lens L2, a third lens L3, a fourth lens L4, and a fifth lens L5 centered upon an optical axis 104. The lenses are numbered starting from the object side to the image side. Thus, lens LI is closest to the object, and lens L5 is closest to the image. Aperture A1 can be embedded into lens LI, or can be fixed to LI physically. Accordingly, in this embodiment, aperture A1 does not move relative to lens LI. In certain aspects of the disclosure, the aperture A1 can have a 50μιη depth.

**[0070]** Lenses LI through L5 each have two opposed refracting surfaces. A radius of curvature for the respective surfaces is denoted by the letter "R" followed by a surface number, starting with the object side surface of lens LI. Thus, the surfaces in order from object side to image side are object side surface R1 and image side surface R2 of lens LI, object side surface R3 and image side surface R4 of lens L2, object side surface R5 and image side surface R6 of lens L3, object side surface R7 and image side surface R8 of lens L4, and object side surface R9 and image side surface R10 of lens L5. The respective surface identifiers (Rl , R2, R3, ..., R10) are also utilized to represent the radius of curvature for the respective surfaces. Additionally, refractive index ¾ denotes the refractive index of the lens medium associated with the $i^{th}$ surface, and v_di is the Abbe number of the lens medium associated with the $i^{th}$ surface.

**[0071]** Lens LI can have a large positive refractive power, with both optical surfaces, R1 and R2, being convex. As utilized herein, the terms large or small refractive power (whether positive or negative) are intended to be relative to other lenses of a particular optical system. Thus, for instance, referring to lens LI as having large positive refractive power implies that lens LI has greater than average positive refractive power as compared with other positive power lenses of optical system 1000. Conversely, a lens having small positive refractive power for optical system 1000 will have less than the average positive refractive power.

**[0072]** In an embodiment, LI can be moveable relative to lenses L2-L5 and the sensor plane 1008. Movement can be achieved using MEMS or other appropriate actuators. In this embodiment, L2-L5 remain fixed relative to the image sensor plane 1008 and image sensor 1006. In some aspects of the disclosure, the range of movement of LI is around IOOμιη. The movement of LI allows optical system 1000 to maintain focus on objects at various distances. In Figure 10, the optical system 1000 is focused on an object at a distance of 10cm from the optical system. In Figure 2, the optical system 1100 is focused on an object at optical infinity.

**[0073]** In certain embodiments, there is an inverse relationship between the refractive power of LI and the range of motion required to focus on objects at various distances. An LI with a higher power requires a shorter range of movement to focus on objects at various distances and vice versa. According to some aspects of the disclosure, the axial gap, or distance between lenses LI and L2 at the optical axis is around 125μιη, with a gap of about 170 μιη at the clear aperture.

**[0074]** L2 can have a meniscus shape (having smaller thickness near the optical axis than away from the optical axis), with optical surface R3 being convex, and optical surface R4 being concave. In some aspects of the disclosure, lens L2 provides most of the chromatic correction for optical system 1000 and has negative refractive power. Lens L3 can be biconvex near the optical axis 1004 as optical surface R5 is convex near the optical axis 1004 and concave away from the optical axis 1004 and image side optical surface R6 is convex. According to some aspects of the disclosure, lens L3 can have a positive refractive power. In certain embodiments, L2 can be mounted on to L3, such that L2 is fixed to L3, and L2 does not touch an optical barrel that arranges lenses LI - L5 of optical system 1000 along optical axis 1004.

**[0075]** Lens L4 has a concave object side optical surface R7, and a convex shaped image side optical surface R8. Lens L5 can be meniscus shaped with a convex optical surface R9 near optical axis 1004 and optical surface R10 that is concave near the optical axis 104.



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**[0076]** It should be appreciated that surfaces R1-R10 (as well as other optical surfaces described throughout the subject disclosure, including optical surfaces for system 200 can be of varying shapes. In one aspect, one or more of the surfaces can be spherical surfaces. In other aspects, one or more of the surfaces can be conic surfaces. In yet other aspects, one or more of the surfaces can be aspheric surfaces, according to a suitable aspheric equation, such as the even aspheric equation:

**[0077]** (1) $z = [\frac{CY^2}{\{1+(1-(1+K)C^2Y^2)^{1/2}\}}] + \sum_i (A_i * Y^i)$, where z is the sag height (in mm) of a line drawn from a point on the aspheric lens surface at a radial distance, Y from the optical axis to the tangential plane of the aspheric surface vertex, C is the curvature of the aspheric lens surface on the optical axis, Y is the radial distance (in mm) from the optical axis, K is the conic constant, and $A_i$ is the $i^{th}$ aspheric coefficient, with the summation over even number i. However, these aspects are not to be construed as limiting the scope of the subject disclosure. Rather, various surfaces can be odd aspheric, or of an aspheric equation comprising even and odd coefficients.

**[0078]** Further to the above, it should be appreciated that lenses L1-L5 of optical system 1000 (and the optical lenses of optical system 1100) can be made of various suitable types of transparent material, formed according to various suitable processes for generating an optical quality surface. In one aspect, the lenses L1-L5 can be ground and polished glass, where the glass is selected to have an index of refraction resulting in a desired effective focal length for the combined lenses L1-L5. In another aspect, the lenses can be an optical-quality injected molded plastic (or plastic of optical quality formed by another suitable method), wherein the plastic has an index of refraction suitable to provide the desired effective focal length. In at least one other aspect, the lenses L1-L5 can be etched from a transparent glass, crystalline or other suitable structure *{e.g.* , silicon dioxide - $Si0_2$ wafer) with a lithographic etching process similar to that used to etch semiconductor chips *{e.g.* , solid state memory chip, data processing chip).

**[0079]** According to various aspects, the lenses LI, L2, L3, L4 and L5 can be made of plastic *{e.g.* , APL5014, OKP4HT, or ZE-330R or another suitable plastic having similar refractive index and Abbe number, or a suitable combination thereof). In one specific aspect, lenses LI, L3, and L5 are made of one plastic *{e.g.* , APL5014) while lenses L2 and L4 are made of different plastics *{e.g.* , OKP4HT and ZE-330R



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respectively). It should be appreciated, however, that in other aspects the lenses can be of other materials having similar Abbe numbers or refractive indices instead.

**[0080]** Turning now to Figure 11, a cross-section of a sample optical system focused at infinity according to aspects of the subject disclosure is shown. The optical system 1100 of Figure 11 is similar to optical system 100, although optical system 1100 is focused on an object at infinity as opposed to at 10 cm. A difference between optical system 1100 and optical system 1000 is that LI is positioned at a different distance from the sensor 1106 relative to lenses L2-L5.

**[0081]** According to one specific aspect of the subject disclosure, a prescription for the respective lenses LI, L2, L3, L4 and L5 is provided in Tables 10-13, below. Table 10 lists general lens data for the respective lenses, and Table 11 lists surface data including radius of curvature (R) (in mm) near the optical axis, distance between surfaces, diameter of the respective lenses, and material of the respective lenses. Furthermore, Table 12 provides aspheric constants $A_i$ for i = 2, 4, 6, 8, 10, 12, 14, 16 of equation (1), *supra,* for aspheric surfaces of Table 11, where the index "i" is denoted by "r" {*e.g.,* as generated in the optical design software program ZEMAX, available from ZEMAX Development Corporation). Table 13 provides refractive index $n_i$ of the $i^{th}$ lens for a set of wavelengths. Table 14 provides a range of fields versus image height, Table 15 provides vignetting information for optical systems 1000 and 1100, Table 16 provides wavelength and weights used for the raytracing of Figures 10 and 11, Table 17 provides surface data for optical systems 1000 and 1100, including radius, thickness, material, diameter, and conic constant. Additionally, Table 18 provides edge thickness information for optical systems 1000 and 1100.

| | |
|---|---|
| Surfaces (including apertures) | 15 |
| Stops | 1 |
| System Aperture | Float by stop size = 0.886727 |
| Apodization | Uniform Factor = 0.00000E+000 |
| Temperature (C) | 2.00000E+001 |
| Pressure (ATM) | 1.00000E+000 |
| Effective Focal Length | 4.28412 (in air at system temp & pressure) |
| Effective Focal Length | 4.28412 (in image space) |



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| | |
|---|---|
| Back Focal Length | 0.5015793 |
| TTL | 5.299934 |
| Image Space F/# | 2.415692 |
| Paraxial Working F/# | 2.415692 |
| Working F/# | 2.40149 |
| Image Space NA | 0.202684 |
| Object Space NA | 8.867272e-011 |
| Stop Radius | 0.8867272 |
| Paraxial Image Height | 2.856 |
| Paraxial Magnification | 0 |
| Entrance Pupil Diameter | 1.773454 |
| Entrance Pupil Position | 0 |
| Field Type | Real Image height in mm |
| Maximum Radial Field | 2.856 |
| Primary Wavelength | 0.555 μm |
| Lens Units | mm |
| Angular Magnification | 1.39828 |

**Table 10: General Properties for Optical Systems 1000 and 1100**

(Optical Properties defined in Optical Design Software Zemax)

| Surface | Type | Radius (mm) | Thickness (mm) | Medium | Diameter (mm) |
|---|---|---|---|---|---|
| OBJ | Standard | Infinity | Infinity | | 0 |
| A1 | Standard | Infinity | 0.05 | | 1.773454 |
| R1 | Even_Asph | 2.031962 | 0.545 | APL5014 | 1.774436 |
| R2 | Even_Asph | -17.60993 | 0.1242087 | | 1.867362 |
| R3 | Even_Asph | 4.178319 | 0.3 | OKP4-HT | 1.941112 |
| R4 | Even_Asph | 1.60308 | 0.3519566 | | 2.054041 |
| R5 | Even_Asph | 5.790688 | 0.6445624 | APL5014 | 2.132792 |
| R6 | Even_Asph | -2.417954 | 0.2002186 | | 2.449247 |
| R7 | Even_Asph | -0.9919052 | 0.3658935 | ZE-330R | 2.5699 |
| R8 | Even_Asph | -1.223582 | 0.5116968 | | 2.686087 |
| R9 | Even_Asph | 12.46394 | 1.123586 | APL5014 | 2.987795 |
| R10 | Even_Asph | 2.132428 | 0.3415114 | | 4.646312 |
| 14 | Standard | Infinity | 0.3 | D263T | 6 |

| | | | | | |
|---|---|---|---|---|---|
| 15 | Standard | Infinity | 0.4913 | | 6 |
| IMA | Standard | Infinity | | | 6.4 |

**Table 11: Surface Data for Lens Elements for Optical System 1000 and 1100**

| Surface | Conic | Note |
|---|---|---|
| OBJ | 0 | |
| A1 | 0 | stop1 |
| R1 | -1 | L1-1 |
| R2 | -1 | L1-2 |
| R3 | -1 | L2-1 |
| R4 | -1 | L2-2 |
| R5 | -1 | L3-1 |
| R6 | -1 | L3-2 |
| R7 | -1 | L4-1 |
| R8 | -1 | L4-2 |
| R9 | -1 | L5-1 |
| R10 | -1 | L5-2 |
| 14 | 0 | Ir cut-off (D263T) |
| 15 | 0 | |
| IMA | | |

**Table 11: Continued**

| Surface | R1 | |
|---|---|---|
| | Coeff on r2 | 0 |
| | Coeff on r4 | 0.021400101 |
| | Coeff on r6 | -0.0044229854 |
| | Coeff on r8 | -0.00018162551 |
| | Coeff on r10 | 0 |
| | Coeff on r12 | 0 |
| | Coeff on r14 | 0 |
| | Coeff on r16 | 0 |
| Surface | R2 | |
| | Coeff on r2 | 0 |
| | Coeff on r4 | 0.0013366226 |
| | Coeff on r6 | 0.0044675095 |

| | | |
|---|---|---|
| | Coeff on r8 | -0.0065254167 |
| | Coeff on rlO | 0 |
| | Coeff on rl2 | 0 |
| | Coeff on rl4 | 0 |
| | Coeff on rl6 | 0 |
| Surface | R3 | |
| | Coeff on r2 | 0 |
| | Coeff on r4 | -0.15575931 |
| | Coeff on r6 | 0.11775238 |
| | Coeff on r8 | -0.040496241 |
| | Coeff on rlO | 0 |
| | Coeff on rl2 | 0 |
| | Coeff on rl4 | 0 |
| | Coeff on rl6 | 0 |
| Surface | R4 | |
| | Coeff on r2 | 0 |
| | Coeff on r4 | -0.17899613 |
| | Coeff on r6 | 0.13165259 |
| | Coeff on r8 | -0.041877243 |
| | Coeff on rlO | 0 |
| | Coeff on rl2 | 0 |
| | Coeff on rl4 | 0 |
| | Coeff on rl6 | 0 |
| Surface | R5 | |
| | Coeff on r2 | 0 |
| | Coeff on r4 | -0.034806957 |
| | Coeff on r6 | -0.055196853 |
| | Coeff on r8 | -0.0076170308 |
| | Coeff on rlO | 0 |
| | Coeff on rl2 | 0 |
| | Coeff on rl4 | 0 |
| | Coeff on rl6 | 0 |
| Surface | R6 | |
| | Coeff on r2 | 0 |
| | Coeff on r4 | 0.020581236 |
| | Coeff on r6 | -0.0065040866 |
| | Coeff on r8 | -0.018006387 |
| | Coeff on rlO | 0 |
| | Coeff on rl2 | 0 |
| | Coeff on rl4 | 0 |
| | Coeff on rl6 | 0 |
| Surface | R7 | |

| | | |
|---|---|---|
| | Coeff on r2 | 0 |
| | Coeff on r4 | 0.17752822 |
| | Coeff on r6 | 0.0025820117 |
| | Coeff on r8 | 0.0073104429 |
| | Coeff on rlO | -0.0065708267 |
| | Coeff on rl2 | 0 |
| | Coeff on rl4 | 0 |
| | Coeff on rl6 | 0 |
| Surface | R8 | |
| | Coeff on r2 | 0 |
| | Coeff on r4 | 0.03288338 |
| | Coeff on r6 | 0.076502466 |
| | Coeff on r8 | -0.06842281 |
| | Coeff on rlO | 0.038984099 |
| | Coeff on rl2 | -0.0076836467 |
| | Coeff on rl4 | 0 |
| | Coeff on rl6 | 0 |
| Surface | R9 | |
| | Coeff on r2 | 0 |
| | Coeff on r4 | -0.1830718 |
| | Coeff on r6 | 0.075510932 |
| | Coeff on r8 | -0.034603365 |
| | Coeff on rlO | 0.0066539539 |
| | Coeff on rl2 | -0.00029016159 |
| | Coeff on rl4 | 0 |
| | Coeff on rl6 | 0 |
| Surface | RIO | |
| | Coeff on r2 | 0 |
| | Coeff on r4 | -0.15124446 |
| | Coeff on r6 | 0.071176496 |
| | Coeff on r8 | -0.029255744 |
| | Coeff on rlO | 0.0080879291 |
| | Coeff on rl2 | -0.0014220241 |
| | Coeff on rl4 | 0.00014276636 |
| | Coeff on rl6 | -6.2275295e-006 |

**Table 12: Aspheric Coefficients for Optical System 1000 and 1100**

| | | | | **Index** (for given wavelength in μm) | | | | |
|---|---|---|---|---|---|---|---|---|
| **Surface** | **Medium** | **Temp** | **Pressure** | 0.47 | 0.41 | 0.555 | 0.61 | 0.65 |
| L1 | APL5014 | 20 | 1 | 1.5518 | 1.5483 | 1.5452 | 1.5424 | 1.5408 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| L2 | OKP4-HT | 20 | 1 | 1.6564 | 1.6458 | 1.6369 | 1.6291 | 1.6248 |
| L3 | APL5014 | 20 | 1 | 1.5518 | 1.5483 | 1.5452 | 1.5424 | 1.5408 |
| L4 | ZE-330R | 20 | 1 | 1.5172 | 1.5139 | 1.5111 | 1.5084 | 1.5069 |
| L5 | APL5014 | 20 | 1 | 1.5518 | 1.5483 | 1.5452 | 1.5424 | 1.5408 |

**Table 13: Index of Refraction for Optical Systems 1000 and 1100**

| Field # | X-Value | Y-Value | Weight |
|---|---|---|---|
| 1 | 0 | 0 | 1 |
| 2 | 0 | 0.571 | 1 |
| 3 | 0 | 1.142 | 1 |
| 4 | 0 | 1.714 | 1 |
| 5 | 0 | 2.285 | 1 |
| 6 | 0 | 2.57 | 1 |
| 7 | 0 | 2.856 | 1 |

**Table 14: Field Type v. Real Image Height (in mm)**

| Field / # | VDX | VDY | VCX | VCY | VAN |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | -0.00376 | 0.00001 | 0.003764 | 0 |
| 3 | 0 | -0.00751 | 0.00003 | 0.007509 | 0 |
| 4 | 0 | -0.01125 | 0.000093 | 0.011253 | 0 |
| 5 | 0 | -0.01512 | 0.00015 | 0.015117 | 0 |
| 6 | 0 | -0.01707 | 0.000226 | 0.017069 | 0 |
| 7 | 0 | -0.019 | 0.000251 | 0.018997 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 |

**Table 15: Vignetting Factors for Fields of Table 2**

| Wavelength # | Value (in μm) | Weight |
|---|---|---|
| 1 | 0.47 | 91 |
| 2 | 0.51 | 503 |
| 3 | 0.555 | 1000 |
| 4 | 0.61 | 503 |
| 5 | 0.65 | 107 |

**Table 16: Wavelengths Used for Raytracing**

| Surface | Type | Radius | Thickness | Material | Diameter | Conic | Notes |
|---|---|---|---|---|---|---|---|



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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Object | Standard | Infinity | Infinity | | 0 | 0 | |
| Stop | Standard | Infinity | 0.05 | | 1.773454 | 0 | |
| 2 | Standard | Infinity | -0.204 | | 1.773454 | 0 | |
| 3 | EvenAsph | 2.031 962 | 0.545 | APL501 4 | 1.774436 | -1 | L1 |
| 4 | EvenAsph | -17.6099 | 0.124209 | | 1.867362 | -1 | |
| 5 | EvenAsph | 4.17831 9 | 0.3 | OKP4HT | 1.941 112 | -1 | L2 |
| 6 | EvenAsph | 1.60308 | 0.351 957 | | 2.054041 | -1 | |
| 7 | EvenAsph | 5.790688 | 0.644562 | APL501 4 | 2.132792 | -1 | L3 |
| 8 | EvenAsph | -2.41 795 | 0.20021 9 | | 2.449247 | -1 | |
| 9 | EvenAsph | -0.991 91 | 0.365894 | ZE-330R | 2.5699 | -1 | L4 |
| 10 | EvenAsph | -1.22358 | 0.51 1697 | | 2.686087 | -1 | |
| 11 | EvenAsph | 12.46394 | 1.123586 | APL501 4 | 2.987795 | -1 | L5 |
| 12 | EvenAsph | 2.132428 | 0.341 511 | | 4.64631 2 | -1 | |
| 13 | Standard | Infinity | 0.3 | D263T | 6 | 0 | IRCF |
| 14 | Standard | Infinity | 0.491 3 | N-BK7 | 6 | 0 | |
| Image | Standard | Infinity | 6.4 | | 0 | 0 | |

**Table 17: Surface Data Summary**

| Surface | Edge |
|---|---|
| Stop | 0.05 |
| 2 | 0.000726 |
| 3 | 0.315728 |
| 4 | 0.189805 |
| 5 | 0.491449 |
| 6 | 0.078721 |
| 7 | 0.308446 |
| 8 | 0.214072 |
| 9 | 0.303193 |
| 10 | 0.428579 |
| 11 | 1.31122 |
| 12 | 0.662695 |
| 13 | 0.3 |
| 14 | 0.4913 |
| Image | 0 |

**Table 18: Edge Thickness Data**

**[0082]** Figure 12 illustrates a graph of field curvature and distortion for optical configuration 1002. Further, the field curvature and distortion values are displayed for several wavelengths ranging from 0.470μιη to 0.650μιη. Field curvature is within about 10 microns for these wavelengths for low field angles, and is less than 100 microns even at the perimeter of the image plane. Further, distortion is well within the range of two and negative two percent. As would be clear to one of skill in the art, aberrations are well compensated for by the subject optical arrangement 1002.

**[0083]** Figure 13 illustrates a graph of field curvature and distortion for optical configuration 1102. Further, the field curvature and distortion values are displayed for several wavelengths ranging from 0.470μιη to 0.650μιη. Field curvature is well within the range of +/- 100 microns, and distortion is well within the range of two and negative two percent. As would be clear to one of skill in the art, aberrations are well compensated for by the subject optical arrangement 1102.

**[0084]** Figure 14 depicts a graph of lateral color for optical arrangement 1002. A maximum field for the graph is 2.8560mm. Additionally, the lateral color curve is over a range of wavelengths from 0.470μιη to 0.650μιη. The primary lateral color for an object in focus at 10cm is about -3.5μιη as depicted by the graph.

**[0085]** Figure 15 depicts a graph of lateral color for optical arrangement 1102 for an object in focus at infinity. A maximum field for the graph is 2.8560mm. Additionally, the lateral color curve is over a range of wavelengths from 0.470μιη to 0.650μιη. The primary lateral color for the object in focus at infinity is about +0.8 microns.

**[0086]** Figure 16 and Figure 17 depict transverse ray fan plots for optical arrangements 1002 and 1102 respectively. The transverse ray fan plots depict transverse aberration ($e_y$ and $e_x$) along the y and x axis for pupil diameters $P_y$ and $P_x$. The transverse ray fan plots are made at image heights 0.000mm (1600 and 1700), 0.5710mm (1602 and 1702), 1.1420mm (1604 and 1704), 1.7140mm (1606 and 1706), 2.2850mm (1608 and 1708), 2.5700mm (1610 and 1710), and 2.8560mm (1612 and 1712). The plots are generally within acceptable ranges for optical imaging and accordingly, the optical arrangements 1002 and 1102 have good imaging quality.

**[0087]** Figure 18 illustrates a diagram of an example ray plot diagram for an optical system 1800 according to alternative aspects of the subject disclosure. System 1800 comprises an arrangement of optical elements 1802. Optical rays are depicted intersecting optical elements 1802 within a field of view of optical system 1800. On-axis rays are focused onto the optical axis at an image plane or focal plane associated with optical elements 1802, and rays originating at larger field angles are depicted as converging at farther distances from the optical axis at the image plane.

**[0088]** A left-most side of optical elements 1802 is an object side of optical system 1800, and a right-most side of optical elements 1802 is an image side of optical system 1800. A real image of the object is formed at the image plane of optical elements 1802 when optical elements 1802 are properly in focus. In at least one aspect of the subject disclosure, optical system 1800 can comprise a variable focus optical system, in which a subset of optical elements 1802 can be moved along the optical axis



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to bring an image of an object into focus at the image plane. In particular aspects, a set of positions of the subset of optical elements 1802 can correspond with a set of object distances having respective images in focus at the image plane. In other words, when the subset of optical elements 1802 is positioned at one of the set of positions, an object at a corresponding one of the set of object distances will be in focus at the image plane. A position of optical elements 1802 as depicted by Figure 18 and Figure 19, *infra,* illustrate an example arrangement in which optical elements of system 1800 are in a position to focus an object located at infinity onto the image plane. A position of optical elements 1802 as depicted by Figures 23 and 24, *infra,* illustrate an example arrangement in which the optical elements are in a position to focus a near-field object onto the image plane.

**[0089]** Figure 19 depicts a diagram of an example optical system 1900 comprising optical elements and optical surfaces according to additional aspects of the subject disclosure. Optical system 1900 can be substantially similar to optical system 1800. As indicated, optical system 1900 is configured to focus an image of an object located in the far-field *{e.g.* , at infinity).

**[0090]** Optical system 1900 can comprise a set of optical elements 1902 centered along an optical axis 1904. Optical elements 1902 can be configured to focus an image that can be captured by a sensor 1908. Sensor 1908 can comprise a multi-dimensional array of optical-sensitive pixels located at an image plane of sensor 1908. The optical-sensitive pixels can output electrical signals in response to electro-magnetic energy *{e.g.,* light) focused by optical elements 1902 upon sensor 1908. Moreover, the electrical signals can have characteristics related to optical characteristics of the electro-magnetic energy. These electrical signals can be utilized to re-produce the image focused by optical elements 1902 and captured by sensor 1908, as described herein or known in the art. Optical system 1900 can also comprise a cover plate 1906 for sensor 1908. Cover plate can protect the optical-sensitive pixels of sensor 1908 from dust or other particles that might otherwise absorb or scatter electro-magnetic energy focused by optical elements 1902, thereby distorting the image.

**[0091]** Optical elements 1902 can comprise five optical lenses, including lens LI, lens L2, lens L3, lens L4 and lens L5 (referred to collectively as lenses LI - L5). The optical lenses are numbered from left - the object side of optical system 1900 - to right - the image side of optical system 1900. The left-most lens, LI, is therefore also referred to herein as the object-side lens. Alternatively, lens LI can be referred to as an objective lens of optical system 1900.

**[0092]** As depicted, lens LI is a bi-convex lens having positive optical power, and having a convex object-side surface Rl and convex image-side surface R2. Furthermore, lens LI can have a strong optical power relative to lenses L2, L3, L4 and L5 of optical elements 1902. In particular aspects, lens LI can have greater positive optical power than either of lenses L2, L3, L4 or L5. In a further aspect, LI can have greater positive optical power than any subset of lenses L2, L3, L4 and L5. In at least one alternative or additional aspect, lens LI can have greater positive optical power than the combination of lenses L2, L3, L4 and L5. As depicted, an aperture stop Al can be located about the object side surface Rl of lens LI .

**[0093]** Lens 2 can be a lens having a negative optical power. Lens L2 can have an object-side surface R3 and an image-side surface R4. Surface R3 can be mildly convex, in some aspects of the subject disclosure. In other aspects, surface R3 can be substantially flat with no significant optical power. In still other aspects of the subject disclosure, surface R3 can have a complex curvature that is convex for a subset of pupil radii *(e.g.* , a range of distances from optical axis 1904) of surface R3, and concave for a different subset of pupil radii of surface R3. As an example, surface R3 can have a concave curvature from the optical axis 1904 to a first pupil radius, and can have a convex curvature from the first pupil radius to a second pupil radius, where the second pupil radius is larger than the first pupil radius. An image side surface R4 can have a concave curvature, providing the majority of negative optical power of lens L2.

**[0094]** Lens L3 can be a meniscus lens having a convex curvature toward the object side of lens L3. As depicted, lens L3 comprises an object side surface R5 and image side surface R6. Object side surface R5 can have convex curvature. In particular aspects, convexity of object side surface R5 can be stronger near optical axis 1904 than near a perimeter of lens L3. Said differently, a radius of curvature of object side surface R5 can increase with increasing pupil radius of object side surface R5, and in at least one aspect become infinite near the perimeter of lens L3. Image side surface R6 can have concave curvature. In at least one aspect, a radius of curvature of image side surface R6 can increase with increasing pupil radius of lens L3. In an alternative or additional aspect, image side surface R6 can be convex near the perimeter of lens L3.

**[0095]** Lens L4 comprises an object side surface R7 and an image side surface R8. Lens L4 can be a meniscus lens toward the image side of optical elements 1902.



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Additionally, lens L4 can have mild positive optical power. In one alternative or additional aspect, positive power of lens L4 can be greater near optical axis 1904 as compared with a periphery of lens L4, whereas in other aspects the positive power can be substantially constant over the surface of image side surface R8.

**[0096]** Lens L5 comprises an object side surface R9 and image side surface R10. Object side surface R9 can have concave curvature for low and medium field angles, and reduced curvature at higher field angles. Image side surface R10 can be concave near optical axis 1904. Further, image side surface R10 can transition from concave to convex for medium and high field angles.

**[0097]** Optical elements 1902 can have respective spaces (air gaps) between respective lenses LI, L2, L3, L4 and L5. In a particular aspect, an on-axis air distance between lens L4 and lens L5 can be a largest of a set of air distances among lenses LI - L5. In an alternative or additional aspect, an air distance between lens L3 and lens L4 can be a second largest of the set of air distances among lenses LI - L5.

**[0098]** In a further aspect of the subject disclosure, an actuator can be connected to a subset of optical elements 1902. In one example, the actuator can be a MEMS actuator, whereas in other aspects the actuator can be another type of actuator known in the art. The actuator can be configured to reposition the subset of optical lenses along optical axis 1904. Repositioning the subset of optical lenses can cause images of objects at different object distances to come into focus at sensor 1908 of optical system 1900. In particular aspects, optical lenses 1902 can be configured to focus an image of an object located in the far field *(e.g.* , infinity, ...) onto sensor 1908. According to further aspects, the subset of optical elements 1902 can be repositioned to focus an object in the near field at sensor 1908. In a specific aspect, the subset of optical elements can include lens LI, and lens LI can be positioned as depicted by Figure 19 by the MEMS actuator to bring an object located at infinity into focus at sensor 1908, and can be positioned as depicted by Figure 23 by the MEMS actuator to bring an object at an object distance of substantially 12.8 centimeters (cm) into focus at sensor 1908.

**[0099]** In a further aspect, aperture stop A1 can be fixed relative to optical axis 1904. In another aspect, aperture stop A1 can be fixed relative to a position of lens LI. In the latter aspect, aperture stop A1 can be moved by a MEMS actuator in conjunction with lens LI when focusing an image of an object onto sensor 1908. According to still other aspects, the MEMS actuator can be configured to move lens LI, either alone or in conjunction with aperture stop A1, a total distance along optical axis 1904. The total



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distance can, at one end thereof, focus an image of an object at infinity on sensor 1908, and at another end thereof, focus an image of an object at an object distance of substantially 12.8cm at sensor 1908.

**[00100]** Lenses LI - L5 can be of various suitable types of suitable optically transparent material, and formed according to a suitable method(s) for generating an optical quality surface. In one aspect, lenses LI - L5 can be ground or polished glass, where the glass is selected to have an index of refraction resulting in a desired effective focal length for the combined lenses LI - L5. In another aspect, the lenses can be an optical-quality injection molded plastic (or plastic of optical quality formed by another suitable fabrication method), wherein the plastic has an index of refraction suitable to provide the desired focal length. In another aspect(s), the lenses LI - L5 can be etched from a transparent glass, crystalline or other suitable structure with a lithographic etching process similar to that used to etch semiconductor chips. In a specific aspect(s), lenses LI - L5 can be of differing glasses, plastics or suitable optical-transparent medium, by one or more of the above or similar suitable fabrication techniques (note that cover 1908 is a fictional material). In a further aspect, optical elements 1902 can have be described according to the optical prescription of Tables 19 - 27A.

| Parameter Description | Value |
|---|---|
| Effective Focal Length (in air at system temperature and pressure) | 4.803702 |
| Effective Focal Length (in image space) | 4.803702 |
| Back Focal Length | 0.1097044 |
| Total Track Length (TTL) | 5.588093 |
| Image Space F/# | 2.668723 |
| Paraxial Working F/# | 2.668742 |
| Working F/# | 2.647852 |
| Image Space NA | 0.1841501 |
| Object Space NA | 9e-007 |
| Stop Radius | 0.9 |
| Paraxial Image Height | 3.492 |
| Paraxial Magnification | -4.803736e-006 |
| Entrance Pupil Diameter | 1.8 |
| Entrance Pupil Position | 0.05 |

| | |
|---|---|
| Exit Pupil Diameter | 1.214476 |
| Exit Pupil Position | -3.231397 |
| Maximum Radial Field | 3.492 |
| Lens Units | Millimeters (mm) |
| Angular Magnification | 1.482119 |

**Table 1: General Optical Properties (Object in Focus at Infinity)**

| Field # | X-Value | Y-Value | Weight |
|---|---|---|---|
| 1 | 0 | 0 | 1 |
| 2 | 0 | 0.339 | 1 |
| 3 | 0 | 0.678 | 1 |
| 4 | 0 | 1.018 | 1 |
| 5 | 0 | 1.357 | 1 |
| 6 | 0 | 1.696 | 1 |
| 7 | 0 | 2.035 | 1 |
| 8 | 0 | 2.375 | 1 |
| 9 | 0 | 2.714 | 1 |
| 10 | 0 | 3.053 | 1 |
| 11 | 0 | 3.392 | 1 |
| 12 | 0 | 3.492 | 1 |

**Table 20: Field Type v. Real Image Height (in mm)**

| Field / # | VDX | VDY | VCX | VCY | VAN |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | -0.005032 | 0.000003 | 0.005032 | 0 |
| 8 | 0 | -0.018773 | 0.000041 | 0.018775 | 0 |
| 9 | 0 | -0.031175 | 0.000230 | 0.031178 | 0 |
| 10 | 0 | -0.062274 | 0.000739 | 0.062281 | 0 |
| 11 | 0 | -0.154303 | 0.005254 | 0.154319 | 0 |
| 12 | 0 | -0.218933 | 0.013148 | 0.218954 | 0 |

**Table 21: Vignetting Factors for Fields of Table 20**

| Wavelength # | Value (in µm) | Weight |
|---|---|---|
| 1 | 0.4358 | 0.15 |
| 2 | 0.4861 | 0.45 |
| 3 | 0.5461 | 1.00 |

| | | |
|---|---|---|
| 4 | 0.5876 | 0.80 |
| 5 | 0.6563 | 0.10 |

**Table 22: Wavelengths Used for Raytracing**

| Surface | Type | Radius | Thickness | Material | Diameter | Conic | Notes |
|---|---|---|---|---|---|---|---|
| Object | Standard | Infinity | 1000000 | | 1471328 | 0 | |
| 1 | Standard | Infinity | 0.05 | | 2.054093 | 0 | Stop1 |
| Stop | Standard | Infinity | -0.176644 | | 1.8 | 0 | A1 |
| 3 | EvenAsph | 2.024203 | 0.721 | ZEONF52R | 1.872 | -1 | R1 |
| 4 | EvenAsph | -11.83444 | 0 | | 1.89 | 0 | R2 |
| 5 | Standard | Infinity | 0.1656548 | | 2.013514 | 0 | Stop 2 |
| 6 | EvenAsph | -250 | 0.32 | EP5000 | 1.91 | 0 | R3 |
| 7 | EvenAsph | 2.745619 | 0.3434152 | | 2.093864 | 0 | R4 |
| 8 | Standard | Infinity | 0.0030239 | | 2.284004 | 0 | Stop 3 |
| 9 | EvenAsph | 2.970147 | 0.3494011 | EP5000 | 2.456709 | 0 | R5 |
| 10 | EvenAsph | 3.958667 | 0.1844251 | | 2.735497 | 0 | R6 |
| 11 | Standard | Infinity | 0.3353069 | | 2.904996 | 0 | Stop 4 |
| 12 | EvenAsph | -4.538803 | 0.5144013 | ZEONF52R | 3.007844 | 0 | R7 |
| 13 | EvenAsph | -1.564577 | 0.2719004 | | 3.349097 | -1 | R8 |
| 14 | Standard | Infinity | 0.421506 | | 5.022903 | 0 | Stop 5 |
| 15 | EvenAsph | -3.333743 | 0.908 | ZEONF52R | 5.142131 | 0 | R9 |
| 16 | EvenAsph | 3.980869 | 0.6500583 | | 6.098372 | 0 | R10 |
| 17 | Standard | Infinity | 0.3 | | 6.850686 | 0 | CG 1908 |
| 18 | Standard | Infinity | 0.1 | | 7.016723 | 0 | |
| Image | Standard | Infinity | | | 7.009976 | 0 | |

**Table 23: Surface Data Summary**

| Surface | Parameter Description | Value |
|---|---|---|
| R1 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | 0.0072492627 |
| | Coefficient on r 6 | -0.0011425636 |
| | Coefficient on r 8 | -0.026147557 |
| | Coefficient on r 10 | 0.02892707 |
| | Coefficient on r 12 | -0.015728565 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |

| | | |
|---|---|---|
| R2 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.018496708 |
| | Coefficient on r 6 | 0.041017657 |
| | Coefficient on r 8 | -0.14989043 |
| | Coefficient on r 10 | 0.18705355 |
| | Coefficient on r 12 | -0.081043198 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R3 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.04452888 |
| | Coefficient on r 6 | 0.1590456 |
| | Coefficient on r 8 | -0.32756888 |
| | Coefficient on r 10 | 0.38155806 |
| | Coefficient on r 12 | -0.15580658 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R4 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.067461498 |
| | Coefficient on r 6 | 0.16544449 |
| | Coefficient on r 8 | -0.23156178 |
| | Coefficient on r 10 | 0.20660588 |
| | Coefficient on r 12 | -0.067541427 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R5 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.10351059 |
| | Coefficient on r 6 | 0.083284677 |
| | Coefficient on r 8 | -0.073446626 |
| | Coefficient on r 10 | 0.031355945 |
| | Coefficient on r 12 | -0.005953706 |
| | Coefficient on r 14 | 0 |

| | | |
|---|---|---|
| | Coefficient on r 16 | 0 |
| R6 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.080839736 |
| | Coefficient on r 6 | 0.05806703 |
| | Coefficient on r 8 | -0.042396061 |
| | Coefficient on r 10 | 0.013117216 |
| | Coefficient on r 12 | -0.001392345 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R7 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.061283862 |
| | Coefficient on r 6 | 0.056005953 |
| | Coefficient on r 8 | -0.023784572 |
| | Coefficient on r 10 | 0.004382924 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R8 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | 0.005176523 |
| | Coefficient on r 6 | 0.02067126 |
| | Coefficient on r 8 | 0.001625502 |
| | Coefficient on r 10 | -0.001134584 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R9 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | 0.019100544 |
| | Coefficient on r 6 | -0.000208483 |
| | Coefficient on r 8 | 5.84E-05 |
| | Coefficient on r 10 | -3.36E-06 |
| | Coefficient on r 12 | 0 |

| | | |
|---|---|---|
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| RIO | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.038366245 |
| | Coefficient on r 6 | 0.004903112 |
| | Coefficient on r 8 | -0.000509017 |
| | Coefficient on r 10 | 1.88E-05 |
| | Coefficient on r 12 | 1.99E-07 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |

**Table 24: Surface Aspheric Coefficients**

| Surface | Edge |
|---|---|
| Object | 1000000 |
| 1 | 0.05 |
| Stop | 0.036971 |
| 3 | 0.45386 |
| 4 | 0.053525 |
| 5 | 0.17191 |
| 6 | 0.53351 |
| 7 | 0.123651 |
| 8 | 0.113652 |
| 9 | 0.301427 |
| 10 | 0.121772 |
| 11 | 0.050401 |
| 12 | 0.30346 |
| 13 | 0.767748 |
| 14 | 0.053483 |
| 15 | 0.953242 |
| 16 | 0.972839 |
| 17 | 0.3 |
| 18 | 0.1 |
| Image | 0 |

**Table 25: Edge Thickness Data**

| Temperature (Temp) in degrees Celsius and pressure (Press) in atmospheres | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Surface | Material | Temp | Press | 0.4358 | 0.4861 | 0.5461 | 0.5876 | 0.6563 |
| 0 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 3 | ZEONF5 | 20 | 1 | 1.5467026 | 1.54130926 | 1.53688 | 1.53462 | 1.531786 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2R | | | | | | | |
| 4 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 5 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 6 | EP5000 | 20 | 1 | 1.671 40227 | 1.6545931 2 | 1.641 717 | 1.635484 | 1.628005 |
| 7 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 8 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 9 | EP5000 | 20 | 1 | 1.671 40227 | 1.6545931 2 | 1.641 717 | 1.635484 | 1.628005 |
| 10 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 11 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 12 | ZEONF5 2R | 20 | 1 | 1.5467026 | 1.541 30926 | 1.53688 | 1.53462 | 1.53 1786 |
| 13 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 14 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 15 | ZEON F52R | 20 | 1 | 1.5467026 | 1.541 309 26 | 1.53688 | 1.53462 | 1.53 1786 |
| 16 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 17 | MODE L | 20 | 1 | 1.5267041 6 | 1.522378 72 | 1.51 871 9 | 1.51 6798 | 1.51 4329 |
| 18 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 19 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |

**Table 26: Index of Refraction Data**

| | | Wavelengths (µm): | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.4358 | | 0.4861 | | 0.5461 | |
| Number | Field (mm) | Tan | Sag | Tan | Sag | Tan | Sag |
| 1 | 0 | 2.6405 | 2.6405 | 2.6425 | 2.6425 | 2.6479 | 2.6479 |
| 2 | 0.339 | 2.6528 | 2.6499 | 2.6546 | 2.6517 | 2.6597 | 2.6568 |
| 3 | 0.678 | 2.681 | 2.6772 | 2.6823 | 2.6783 | 2.6871 | 2.683 |
| 4 | 1.018 | 2.7091 | 2.7201 | 2.7106 | 2.7201 | 2.7153 | 2.7239 |
| 5 | 1.357 | 2.7373 | 2.7739 | 2.7401 | 2.7726 | 2.7455 | 2.7753 |
| 6 | 1.696 | 2.8006 | 2.8361 | 2.8059 | 2.8335 | 2.8128 | 2.8352 |
| 7 | 2.035 | 2.9489 | 2.9083 | 2.9563 | 2.9045 | 2.9645 | 2.9052 |
| 8 | 2.375 | 3.1818 | 2.9917 | 3.1891 | 2.9868 | 3.196 | 2.9866 |
| 9 | 2.714 | 3.5028 | 3.0817 | 3.5075 | 3.076 | 3.5109 | 3.075 |
| 10 | 3.053 | 4.1133 | 3.1794 | 4.1121 | 3.1732 | 4.109 | 3.1717 |
| 11 | 3.392 | 5.1478 | 3.3011 | 5.1473 | 3.2949 | 5.1404 | 3.2931 |
| 12 | 3.492 | 5.7808 | 3.3568 | 5.7754 | 3.3511 | 5.7637 | 3.3495 |

**Table 27: F/Number Data**

| | | Wavelengths (µm) | | | |
|---|---|---|---|---|---|
| | | 0.5876 | | 0.6563 | |
| Number | Field (mm) | Tan | Sag | Tan | Sag |
| 1 | 0 | 2.6519 | 2.6519 | 2.6583 | 2.6583 |
| 2 | 0.339 | 2.6637 | 2.6608 | 2.67 | 2.6671 |
| 3 | 0.678 | 2.6909 | 2.6867 | 2.697 | 2.6927 |
| 4 | 1.018 | 2.719 | 2.7272 | 2.7249 | 2.7327 |



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| | | | | | |
|---|---|---|---|---|---|
| 5 | 1.357 | 2.7494 | 2.7781 | 2.7555 | 2.7831 |
| 6 | 1.696 | 2.81 73 | 2.8375 | 2.824 | 2.841 7 |
| 7 | 2.035 | 2.9694 | 2.907 | 2.9763 | 2.91 06 |
| 8 | 2.375 | 3.2 | 2.9879 | 3.2054 | 2.9909 |
| 9 | 2.71 4 | 3.51 25 | 3.0759 | 3.51 43 | 3.0782 |
| 10 | 3.053 | 4.1067 | 3.1722 | 4.1033 | 3.1 741 |
| 11 | 3.392 | 5.1347 | 3.2934 | 5.1255 | 3.295 |
| 12 | 3.492 | 5.7553 | 3.3499 | 5.7426 | 3.351 5 |

**Table 27A: F/Number Data (Continued)**

**[00101]** Table 19 provides general optical information for an embodiment of optical systems 1800, 1900 of Figures 18 and 19, respectively. Table 20 provides image heights in the y axis, measured at the image sensor 1906 for a set of optical fields, and respective weights for the respective fields. Table 2 1 includes vignetting data for the set of optical fields of Table 20. Table 22 depicts wavelengths of respective rays traced in optical imaging system 1800, depicted at Figure 18. Table 23 provides a summary of general optical surface characteristics for lenses of optical elements 1902, including surface type, radius of curvature, thickness, material (from standard glass and plastic catalogues; not that a fictitious material is used for cover glass 1908), diameter, conic constant and applicable notes. Table 24 describes aspheric coefficients for the surfaces of Table 23, whereas Table 25 provides edge thickness information for those surfaces. Table 26 provides index of refraction data for multiple wavelengths for the optical fields identified at Table 20. Tables 27 and 27A provide F/# data for those same wavelengths and optical fields.

**[00102]** Figure 20 depicts a diagram of field curvature and distortion for the optical systems 1800, 1900 of Figures 18 and 19, *supra.* Particularly, the field curvature and distortion depicted in Figure 20 correspond with the optical elements 1902 configured to focus an image of an object at infinity onto sensor 1906. The field curvature and distortion graphs utilize five wavelengths, including 0.436, 0.486, 0.546, 0.588 and 0.656 μιη respectively. Moreover, the rays are traced with a maximum field of 35.543 degrees. The left-hand graph depicts field curvature in millimeters along a y axis at an image plane of an optical imaging system. Field curvature curves are depicted for Sagittal rays (delineated by an 'S') and Tangential rays (delineated by a 'T'). The range of field curvature over the utilized wavelengths is within a few microns for sagittal and tangential rays. The distortion graphs on the right-hand side of Figure 20 also includes curves for the above five wavelengths. The distortion data is



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normalized to 0% at the optical axis. Throughout the image plane, distortion is less than about -1%, and for mid to low field angles below about + / - one half a percent.

**[00103]** Figure 2 1 illustrates a diagram of longitudinal aberration for a set of wavelengths. Longitudinal aberration of Figure 2 1 relates to optical elements 1902, configured to image an object located at infinity onto sensor 1906. The listed wavelengths include 0.436, 0.486, 0.546, 0.588 and 0.656 μιη. The graph charts longitudinal aberration in millimeters for increasing field angles, for a pupil radius of 0.9mm. At low field angles the longitudinal aberration is generally positive and less than about 0.02 millimeters. At high field angles, the longitudinal aberration is more negative and generally less than about 0.03 millimeters. The longitudinal aberration graph of Figure 2 1 indicates optical elements 1902 provide reasonably good aberration correction for the identified wavelengths.

**[00104]** Figure 22 depicts a graph of lateral color for optical elements 1902 of Figure 19, *supra.* Accordingly, the graph of lateral color relates to optical elements 1902 configured to focus an image of an object located at infinity onto sensor 1906. The maximum field for the lateral color graph is 3.3920 millimeters, and wavelengths for the lateral color graph range from 0.4358 through 0.6563 μιη. In addition, data is referenced to 0.546100 μιη. For most field angles the lateral color is within about + / - 0.5 microns. At high field angles, lower wavelengths exhibit lateral color about - 1 micron or greater, and higher wavelengths exhibit lateral color about 1 micron.

**[00105]** Figure 23 illustrates a diagram of an example optical system 2300 according to still other aspects of the subject disclosure. Optical system 2300 can comprise a set of optical elements 2302, as depicted. In at least one aspect of the subject disclosure, optical elements 2302 can comprise a set of lenses substantially similar to optical elements 1802 and 1902 of Figures 18 and 19, *supra,* but having a different focus position. Specifically, a subset of optical elements 2302 can be positioned in a manner suitable to focus an image of a near-field object at an image plane of optical elements 2302. As depicted, the near-field object position for optical elements 2302 is 12.8cm. By repositioning the subset of optical elements 2302 between the position depicted by Figure 23 and that of optical elements 1902 of Figure 19, optical system 2300 can focus different object distances between the near-field object and an object at infinity.

**[00106]** Optical system 2300 illustrates a set of ray fans representing light incident upon optical elements 2302 at discrete field angles. A field angle of zero is depicted by rays of light that converge at an optical axis of optical system 2300 at an image plane of optical elements 2302. Light converging at points on the image plane at increasing distances from the optical axis represent rays of light encountering optical elements 2302 at correspondingly larger field angles.

**[00107]** Figure 24 depicts a diagram of an example optical system 2400 according to still other aspects of the subject disclosure. Optical system 2400 delineates optical lenses and associated optical surfaces of optical system 2300 of Figure 23. Further, in at least one aspect, the optical lenses and associated optical surfaces of optical system 2300 can be substantially similar to the optical lenses and optical surfaces of optical systems 1800 and 1900 of Figures 18 and 19, *supra.* Optical system 2400 can differ from optical systems 1800 and 1900 in that optical elements 2402 can be configured to focus an image of an object located at substantially 12.8cm at a sensor 2408. Other aspects of optical system 2400 and optical elements 2402, including optical surfaces R1 and R2 of lens LI, R3 and R4 of lens L2, R5 and R6 of lens L3, R7 and R8 of lens L4, and R9 and R10 of lens L5. Further, sensor 2408 and cover glass 2406 can be substantially similar to sensor 1906 and cover glass 1908 of optical system 1900.

**[00108]** According to a particular aspect of the subject disclosure, optical elements 2402 comprise an object lens, lens LI, which is connected to an actuator *(e.g.,* MEMS actuator, ...) to facilitate auto-focusing for optical system 2400. In the arrangement of optical elements 2402 depicted by Figure 24, and in particular an air distance $distance_{nea}r$ between lens LI and lens L2, optical elements 2402 are configured to focus a real image of an object at an object distance of 12.8cm onto sensor 2408. By moving lens LI into a position depicted by optical elements 1902 of Figure 19, where the air distance between lens LI and lens L2 is a distance^, optical system 2400 can be configured to focus an image of an object at infinity, instead. In at least one alternative or additional aspect of the subject disclosure, lens LI can be repositioned to change the air distance between $distance_{nea}r$ and distance^, thereby focusing an image of an object located at points between 12.8cm and infinity at sensor 2408. Optical elements 2402 can have image characteristics as described by the optical characteristics of Tables 28 - 31A.

| Parameter Description | Value |
|---|---|



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| | |
|---|---|
| Effective Focal Length (in air at system temperature and pressure) | 4.673877 |
| Effective Focal Length (in image space) | 4.673877 |
| Back Focal Length | -0.05732965 |
| Total Track Length (TTL) | 5.668093 |
| Image Space F/# | 2.596598 |
| Paraxial Working F/# | 2.7471 79 |
| Working F/# | 2.738746 |
| Image Space NA | 0.1 790633 |
| Object Space NA | 0.007028331 |
| Stop Radius | 0.9 |
| Paraxial Image Height | 3.492 |
| Paraxial Magnification | -0.03861 7 11 |
| Entrance Pupil Diameter | 1.8 |
| Entrance Pupil Position | 0.05 |
| Exit Pupil Diameter | 1.1 98642 |
| Exit Pupil Position | -3.269722 |
| Maximum Radial Field | 3.492 |
| Lens Units | Millimeters (mm) |
| Angular Magnification | 1.501698 |

**Table 28: General Optical Properties (Object in Focus at ~12.8cm)**

| Field / # | VDX | VDY | VCX | VCY | VAN |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | -0.00588 | 0.000003 | 0.005875 | 0 |
| 8 | 0 | -0.02139 | 0.000058 | 0.021397 | 0 |
| 9 | 0 | -0.0355 | 0.00023 | 0.035498 | 0 |
| 10 | 0 | -0.06623 | 0.000798 | 0.066238 | 0 |
| 11 | 0 | -0.16868 | 0.006487 | 0.1687 | 0 |
| 12 | 0 | -0.24396 | 0.016135 | 0.243989 | 0 |

**Table 29: Vignetting Factors for Fields of Table 20**



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| Surface | Type | Radius | Thickness | Material | Diameter | Conic | Notes |
|---|---|---|---|---|---|---|---|
| Object | Standard | Infinity | 128 | | 179.1413 | 0 | |
| 1 | Standard | Infinity | 0.05 | | 2.060591 | 0 | Stopl |
| Stop | Standard | Infinity | -0.176644 | | 1.8 | 0 | A1 |
| 3 | EvenAsph | 2.024203 | 0.721 | ZEONF52R | 1.872 | -1 | R1 |
| 4 | EvenAsph | -11.8344 | 0.08 | | 1.89 | 0 | R2 |
| 5 | Standard | Infinity | 0.1656548 | | 2.015092 | 0 | Stop 2 |
| 6 | EvenAsph | -250 | 0.32 | EP5000 | 1.91 | 0 | R3 |
| 7 | EvenAsph | 2.745619 | 0.3434152 | | 2.093864 | 0 | R4 |
| 8 | Standard | Infinity | 0.00302399 | | 2.284414 | 0 | Stop 3 |
| 9 | EvenAsph | 2.970147 | 0.3494011 | EP5000 | 2.456709 | 0 | R5 |
| 10 | EvenAsph | 3.958667 | 0.1844251 | | 2.735497 | 0 | R6 |
| 11 | Standard | Infinity | 0.3353069 | | 2.905287 | 0 | Stop 4 |
| 12 | EvenAsph | -4.5388 | 0.5144013 | ZEONF52R | 3.007844 | 0 | R7 |
| 13 | EvenAsph | -1.56458 | 0.2719004 | | 3.349097 | -1 | R8 |
| 14 | Standard | Infinity | 0.421506 | | 5.039133 | 0 | Stop 5 |
| 15 | EvenAsph | -3.33374 | 0.908 | ZEONF52R | 5.142131 | 0 | R9 |
| 16 | EvenAsph | 3.980869 | 0.6500583 | | 6.098372 | 0 | R10 |
| 17 | Standard | Infinity | 0.3 | | 6.852322 | 0 | CG 1908 |
| 18 | Standard | Infinity | 0.1 | | 7.029509 | 0 | |
| Image | Standard | Infinity | | | 7.027898 | 0 | |

**Table 30: Surface Data Summary**

| | | Wavelengths (μm): | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.4358 | | 0.4861 | | 0.5461 | |
| Number | Field (mm) | Tan | Sag | Tan | Sag | Tan | Sag |
| 1 | 0 | 2.7277 | 2.7277 | 2.7317 | 2.7317 | 2.7387 | 2.7387 |
| 2 | 0.339 | 2.7368 | 2.7372 | 2.7406 | 2.741 | 2.7475 | 2.7479 |
| 3 | 0.678 | 2.7568 | 2.7652 | 2.7602 | 2.7683 | 2.7668 | 2.7746 |
| 4 | 1.018 | 2.7759 | 2.8091 | 2.7796 | 2.8111 | 2.7862 | 2.8166 |
| 5 | 1.357 | 2.8003 | 2.8645 | 2.8054 | 2.8651 | 2.8128 | 2.8695 |
| 6 | 1.696 | 2.8707 | 2.929 | 2.8781 | 2.9282 | 2.8869 | 2.9315 |
| 7 | 2.035 | 3.0426 | 3.0048 | 3.0514 | 3.0027 | 3.0608 | 3.0049 |
| 8 | 2.375 | 3.3173 | 3.0938 | 3.3236 | 3.0904 | 3.33 | 3.0916 |
| 9 | 2.714 | 3.7043 | 3.1909 | 3.7032 | 3.1866 | 3.7021 | 3.1868 |
| 10 | 3.053 | 4.4104 | 3.2987 | 4.3944 | 3.2936 | 4.3798 | 3.2932 |
| 11 | 3.392 | 5.6482 | 3.4392 | 5.6174 | 3.4339 | 5.587 | 3.4329 |
| 12 | 3.492 | 6.4939 | 3.5062 | 6.4341 | 3.5014 | 6.3828 | 3.5006 |

**Table 31: F/Number Data**

| | | Wavelengths (μm) | | | |
|---|---|---|---|---|---|
| | | 0.5876 | | 0.6563 | |
| Number | Field (mm) | Tan | Sag | Tan | Sag |

| | | | | | |
|---|---|---|---|---|---|
| 1 | 0 | 2.7437 | 2.7437 | 2.751 4 | 2.751 4 |
| 2 | 0.339 | 2.7524 | 2.7528 | 2.7599 | 2.7603 |
| 3 | 0.678 | 2.771 6 | 2.7793 | 2.7789 | 2.7865 |
| 4 | 1.01 8 | 2.7909 | 2.8208 | 2.7981 | 2.8276 |
| 5 | 1.357 | 2.81 77 | 2.8733 | 2.8251 | 2.8794 |
| 6 | 1.696 | 2.8924 | 2.9347 | 2.9003 | 2.9401 |
| 7 | 2.035 | 3.0664 | 3.0075 | 3.0742 | 3.01 22 |
| 8 | 2.375 | 3.3337 | 3.0937 | 3.339 | 3.0977 |
| 9 | 2.71 4 | 3.701 6 | 3.1884 | 3.701 | 3.1 9 17 |
| 10 | 3.053 | 4.372 | 3.2943 | 4.361 8 | 3.2971 |
| 11 | 3.392 | 5.5698 | 3.4337 | 5.5469 | 3.436 |
| 12 | 3.492 | 6.3558 | 3.501 4 | 6.321 1 | 3.5037 |

**Table 31A: F/Number Data (Continued)**

**[00109]** Tables 28 - 3 1A comprise optical characteristics and image characteristics of optical system 2400 that differ from the configuration of optical system 1900. Table 28 provides general optical information for the embodiment of optical system 2400. Table 29 includes vignetting data for the set of optical fields of Table 20. Table 30 provides a summary of general optical characteristics for lenses of optical elements 2402, including surface type, radius of curvature, thickness, material (from standard glass and plastic catalogues, including a fictitious material for cover glass 2408), diameter, conic constant and applicable notes. Tables 3 1 and 3 1A provide F/# data for identified wavelengths and optical fields.

**[00110]** Figure 25 illustrates a diagram of field curvature and distortion for the optical system 2400 of Figure 24, *supra.* Wavelengths employed for the field curvature and distortion graphs include 0.436, 0.486, 0.546, 0.588 and 0.656 μιη. Rays traced to generate these graphs have units in field angle with a maximum field of 34.188 degrees. The field curvature for both tangential and sagittal rays are generally positive and less than about 0.05 mm for all field angles. Distortion is less than about 1% for mid to low field angles, and increases to about 1.6% at high field angles.

**[00111]** Figure 26 illustrates a diagram of longitudinal aberration for optical system 2400. The longitudinal aberration graph is provided for five wavelengths, including 0.436, 0.486, 0.546, 0.588 and 0.656 μιη. The graph charts longitudinal aberration in millimeters for increasing field angles, and with pupil radius of 0.9mm. At low field angles the longitudinal aberration is generally positive and less than about 0.04 millimeters. At higher field angles, the longitudinal aberration ranges positive to negative for different field angles, and is generally between positive 0.03 millimeters and about negative 0.035 millimeters.



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**[00112]** Figure 27 depicts a graph of lateral color for optical elements 2402 of Figure 24, *supra.* The graph of lateral color relates to optical elements 2402 configured to focus an image of an object located at about 12.8cm onto sensor 2406. The maximum field for the lateral color graph is 3.3920 millimeters, and wavelengths employed for the graph range from 0.4358 through 0.6563_μιη. In addition, data is referenced to 0.546100 μιη. For all field angles the lateral color is less than about +3 microns and greater than about -1 microns. At low and mid field angles, the lateral color ranges between about +1 micron and about -0.25 microns.

**[00113]** Figures 28A - 28D illustrate an example optical system according to one or more additional aspects of the subject disclosure. The optical system is depicted at Figure 28A on the upper left in a configuration to focus an image of an object at infinity onto a sensor of the optical system. Figures 29A - 29D illustrate the example optical system in a configuration to focus an image of a near-field object onto the sensor of the optical system. The latter configuration can be achieved, for instance, by decreasing an air distance between the first left-most lens closest to the object side of the optical system, closer to the second lens on the object side of the optical system.

**[00114]** Generally, the optical system comprises five lenses, from an object side to image side, including lens LI (also referred to as an objective lens), lens L2, lens L3, lens L4 and lens L5 (referred to collectively as lenses LI - L5). Moreover, the optical system of Figures 28A - 28D can comprise two or more lens groups, defined at least in part on an on-axis inter-lens air distance between respective lenses of the two or more lens groups. As an example, the five lenses of the optical system can be arranged into two lens groups, a first of the lens groups comprising a first lens, second lens and third lens from the object side of the optical system, and where the second of the lens groups comprising a fourth lens and fifth lens from the object side of the optical system. The lens groups can be constrained to have on-axis air distances between lenses that is smaller than an on-axis air distance between the first and the second lens groups.

**[00115]** Figures 28B - 28D illustrate image characteristics for the optical system of Figure 28A configured to focus an image of an object at infinity on a sensor of the optical system (far field focus configuration). Figures 29B - 29D illustrate image characteristics for the optical system of Figure 29A configured to focus a near-field object on the sensor (near field focus configuration). Figure 28B depicts a graph of field curvature and distortion for the far field focus configuration, with a maximum field greater than about 32 degrees for wavelengths between about 0.47 and about 0.65

microns. Figure 28C illustrates a graph of longitudinal aberration for the far field configuration at the above wavelengths, and for a pupil radius of about 0.991mm, and Figure 28D depicts a graph of lateral color for this configuration having a maximum field of about 2.956 millimeters having data referenced to wavelength of about 0.555 microns.

**[00116]** Figure 29B illustrates field curvature and distortion for the near field configuration of the optical system, depicted at Figure 29A. The field curvature and distortion has a maximum field of about 34.51 degrees for wavelengths between about 0.470 and about 0.650 microns. Figure 29C depicts longitudinal aberration for the near field configuration with pupil radius of about 0.991 millimeters and wavelengths of about 0.470, 0.510, 0.555, 0.610 and 0.650 microns. Figure 29D illustrates a graph of lateral color for the near field configuration, with a maximum field of about 2.9560 millimeters and with data referenced to wavelength of 0.555 microns. The optical system of Figures 28A and 29A are described by the optical and image characteristics provided by Tables 32 - 40A, below.

| Parameter Description | Value |
|---|---|
| Effective Focal Length (in air at system temperature and pressure) | 4.309199 |
| Effective Focal Length (in image space) | 4.309199 |
| Back Focal Length | 0.528864 |
| Total Track Length (TTL) | 5.348668 |
| Image Space F/# | 2.44563 |
| Paraxial Working F/# | 2.44563 |
| Working F/# | 2.468005 |
| Image Space NA | 0.200303 |
| Object Space NA | 8.81E-11 |
| Stop Radius | 0.881 |
| Paraxial Image Height | 2.956 |
| Paraxial Magnification | 0 |
| Entrance Pupil Diameter | 1.762 |
| Entrance Pupil Position | 0 |
| Exit Pupil Diameter | 1.257817 |
| Exit Pupil Position | -3.09729 |



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| | |
|---|---|
| Maximum Radial Field | 2.956 |
| Lens Units | Millimeters (mm) |
| Angular Magnification | 1.400838 |

**Table 32: General Optical Properties (Object in Focus at Infinity)**

| Field # | X-Value | Y-Value | Weight |
|---|---|---|---|
| 1 | 0 | 0 | 1 |
| 2 | 0 | 0.571 | 1 |
| 3 | 0 | 1.142 | 1 |
| 4 | 0 | 1.714 | 1 |
| 5 | 0 | 2.285 | 1 |
| 6 | 0 | 2.57 | 1 |
| 7 | 0 | 2.856 | 0.2 |
| 8 | 0 | 2.956 | 0.2 |

**Table 33: Field Type v. Real Image Height (in mm)**

| Field / # | VDX | VDY | VCX | VCY | VAN |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0.003903 | 0.00001 | 0.003903 | 0 |
| 3 | 0 | 0.007781 | 0.000035 | 0.007783 | 0 |
| 4 | 0 | 0.01172 | 0.000106 | 0.011721 | 0 |
| 5 | 0 | -0.00257 | 0.000337 | 0.034007 | 0 |
| 6 | 0 | -0.04564 | 0.001626 | 0.08102 | 0 |
| 7 | 0 | -0.09687 | 0.005447 | 0.136263 | 0 |
| 8 | 0 | -0.14243 | 0.009529 | 0.183383 | 0 |

**Table 34: Vignetting Factors for Fields of Table 20**

| Wavelength # | Value (in μm) | Weight |
|---|---|---|
| 1 | 0.47 | 91 |
| 2 | 0.51 | 503 |
| 3 | 0.555 | 1000 |
| 4 | 0.61 | 503 |
| 5 | 0.65 | 107 |

**Table 35: Wavelengths Used for Raytracing**

| Surface | Type | Radius | Thickness | Material | Diameter | Conic | Notes |
|---|---|---|---|---|---|---|---|
| Object | Standard | Infinity | Infinity | | 0 | 0 | |
| Stop | Standard | Infinity | -0.05 | | 1.762 | 0 | Stop |
| 2 | Standard | Infinity | -0.05 | | 1.762 | 0 | Vig |
| 3 | EvenAsph | 1.9541 12 | 0.658876 | APEL551 4ML | 1.8681 1 | 0 | L1 |
| 4 | EvenAsph | -16.4984 | 0.12381 2 | | 1.900083 | 0 | |
| 5 | EvenAsph | 28.78283 | 0.537232 | EP5000-F | 1.936491 | 0 | L2 |
| 6 | EvenAsph | 2.751 3 | 0.242475 | | 2.0091 9 | 0 | |
| 7 | Standard | Infinity | 0.05 | | 2.05 | 0 | |
| 8 | Standard | Infinity | 0.08601 6 | | 2.05 | 0 | |
| 9 | EvenAsph | -34.5053 | 0.862679 | APEL551 4ML | 2.120461 | 0 | L3 |
| 10 | EvenAsph | -6. 1921 6 | 0.424308 | | 2.71 6502 | 0 | |
| 11 | EvenAsph | 2.722564 | 0.5091 04 | APEL551 4ML | 3.355454 | 0 | L4 |
| 12 | EvenAsph | -4.26721 | -0. 19 | | 4.009626 | 0 | |
| 13 | Standard | Infinity | 0.05 | | 4.16 | 0 | |
| 14 | Standard | Infinity | 0.389066 | | 4.16 | 0 | |
| 15 | EvenAsph | -2.51 369 | 0.4261 01 | APEL551 4ML | 4.449728 | 0 | L5 |
| 16 | EvenAsph | 2.608397 | 0.329 | | 4.87851 7 | 0 | |
| 17 | Standard | Infinity | 0.3 | N-BK7 | 5.233205 | 0 | CG 1908 |
| 18 | Standard | Infinity | 0.55 | | 5.402932 | 0 | |
| Image | Standard | Infinity | | | 5.91 7565 | 0 | |

**Table 36: Surface Data Summary**

| Surface | Parameter Description | Value |
|---|---|---|
| R1 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.00386 |
| | Coefficient on r 6 | 0.009055 |
| | Coefficient on r 8 | -0.01604 |
| | Coefficient on r 10 | 0.006453 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R2 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | 0.014879 |
| | Coefficient on r 6 | -0.02489 |
| | Coefficient on r 8 | 0.011334 |
| | Coefficient on r 10 | 0.003758 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |



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| | | |
|---|---|---|
| R3 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | 0.001774 |
| | Coefficient on r 6 | -0.03857 |
| | Coefficient on r 8 | 0.035738 |
| | Coefficient on r 10 | -0.00277 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R4 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.00027 |
| | Coefficient on r 6 | 0.001123 |
| | Coefficient on r 8 | 0.000761 |
| | Coefficient on r 10 | 0.006183 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R5 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.04891 |
| | Coefficient on r 6 | 0.029453 |
| | Coefficient on r 8 | -0.01911 |
| | Coefficient on r 10 | 0.004124 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R6 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.13503 |
| | Coefficient on r 6 | 0.048368 |
| | Coefficient on r 8 | 0.001742 |
| | Coefficient on r 10 | -0.00582 |
| | Coefficient on r 12 | 0.00078 |
| | Coefficient on r 14 | 5.79E-05 |

| | | |
|---|---|---|
| | Coefficient on r 16 | 0.000106 |
| R7 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.1187 |
| | Coefficient on r 6 | 0.031933 |
| | Coefficient on r 8 | -0.0214 |
| | Coefficient on r 10 | 0.008804 |
| | Coefficient on r 12 | -0.0012 |
| | Coefficient on r 14 | -0.00074 |
| | Coefficient on r 16 | 0.00021 6 |
| R8 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | 0.070788 |
| | Coefficient on r 6 | -0.01663 |
| | Coefficient on r 8 | -0.00017 |
| | Coefficient on r 10 | -0.00047 |
| | Coefficient on r 12 | 0.000282 |
| | Coefficient on r 14 | -1.50E-05 |
| | Coefficient on r 16 | -2.54E-06 |
| R9 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | 0.019234 |
| | Coefficient on r 6 | 0.011958 |
| | Coefficient on r 8 | -0.00178 |
| | Coefficient on r 10 | 1.79E-05 |
| | Coefficient on r 12 | 5.79E-06 |
| | Coefficient on r 14 | 9.92E-07 |
| | Coefficient on r 16 | 4.90E-08 |
| R1O | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.10214 |
| | Coefficient on r 6 | 0.027793 |
| | Coefficient on r 8 | -0.0071 |
| | Coefficient on r 10 | 0.000868 |
| | Coefficient on r 12 | 1.66E-05 |



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| | | |
|---|---|---|
| | Coefficient on r 14 | -1.31 E-05 |
| | Coefficient on r 16 | 7.35E-07 |

**Table 37: Surface Aspheric Coefficients**

| Surface | Edge |
|---|---|
| Stop | -0.05 |
| 2 | 0.184732 |
| 3 | 0.400359 |
| 4 | 0.15927 |
| 5 | 0.723662 |
| 6 | 0.044372 |
| 7 | 0.05 |
| 8 | 0.026648 |
| 9 | 0.560283 |
| 10 | 0.571295 |
| 11 | 0.51101 |
| 12 | 0.022871 |
| 13 | 0.05 |
| 14 | 0.126282 |
| 15 | 0.613075 |
| 16 | 0.40481 |
| 17 | 0.3 |
| 18 | 0.55 |
| Image | 0 |

**Table 38: Edge Thickness Data**

| Temperature (Temp) in degrees Celsius and pressure (Press) in atmospheres | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Surface | Material | Temp | Press | 0.4358 | 0.4861 | 0.5461 | 0.5876 | 0.6563 |
| 0 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 3 | APEL5514ML | 20 | 1 | 1.552896 | 1.549574 | 1.546504 | 1.543579 | 1.541977 |
| 4 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 5 | EP5000-F | 20 | 1 | 1.657924 | 1.647547 | 1.638966 | 1.631351 | 1.627143 |
| 6 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 7 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 8 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 9 | APEL5514ML | 20 | 1 | 1.552896 | 1.549574 | 1.546504 | 1.543579 | 1.541977 |
| 10 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 11 | APEL5514ML | 20 | 1 | 1.552896 | 1.549574 | 1.546504 | 1.543579 | 1.541977 |
| 12 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 13 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 14 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |



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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 15 | APEL 551 4 ML | 20 | 1 | 1.552896 | 1.549574 | 1.546504 | 1.543579 | 1.541 977 |
| 16 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 17 | N-BK7 | 20 | 1 | 1.523605 | 1.520769 | 1.51 8274 | 1.51 5909 | 1.51 452 |
| 18 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 19 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |

**Table 39: Index of Refraction Data**

| | | Wavelengths (μm): | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.4358 | | 0.4861 | | 0.5461 | |
| Number | Field (mm) | Tan | Sag | Tan | Sag | Tan | Sag |
| 1 | 0 | 2.4671 | 2.4671 | 2.4655 | 2.4655 | 2.468 | 2.468 |
| 2 | 0.571 | 2.5183 | 2.4954 | 2.516 | 2.4934 | 2.5179 | 2.4954 |
| 3 | 1.142 | 2.5939 | 2.5672 | 2.5915 | 2.564 | 2.5931 | 2.5651 |
| 4 | 1.714 | 2.7124 | 2.6738 | 2.7134 | 2.6698 | 2.717 | 2.6702 |
| 5 | 2.285 | 3.1321 | 2.8097 | 3.1364 | 2.8053 | 3.1424 | 2.8052 |
| 6 | 2.57 | 3.6079 | 2.8988 | 3.613 | 2.8941 | 3.6195 | 2.8939 |
| 7 | 2.856 | 3.8132 | 3.003 | 3.8209 | 2.9987 | 3.8222 | 2.9987 |
| 8 | 2.956 | 4.0285 | 3.0378 | 4.0284 | 3.0345 | 4.0233 | 3.0351 |

**Table 40: F/Number Data**

| | | Wavelengths (μm) | | | |
|---|---|---|---|---|---|
| | | 0.5876 | | 0.6563 | |
| Number | Field (mm) | Tan | Sag | Tan | Sag |
| 1 | 0 | 2.4725 | 2.4725 | 2.4748 | 2.4748 |
| 2 | 0.571 | 2.522 | 2.4996 | 2.524 | 2.5017 |
| 3 | 1.142 | 2.5966 | 2.5685 | 2.5984 | 2.5702 |
| 4 | 1.714 | 2.7219 | 2.6729 | 2.7244 | 2.6742 |
| 5 | 2.285 | 3.1492 | 2.8075 | 3.1529 | 2.8085 |
| 6 | 2.57 | 3.6267 | 2.896 | 3.6307 | 2.8969 |
| 7 | 2.856 | 3.8203 | 3.0009 | 3.8197 | 3.0019 |
| 8 | 2.956 | 4.0151 | 3.0376 | 4.0105 | 3.0389 |

**Table 40A: F/Number Data (Continued)**

**[00117]** Tables 32 - 40A provides optical and image characteristics for the optical system of Figure 28A, having a far field focus configuration. Table 32 provides general optical information for this optical system. Table 33 provides image heights in the y axis, measured at an image sensor of the optical system, for a set of optical fields and respective weights for the respective optical fields. Table 34 includes vignetting data for the set of optical fields of Table 33. Table 35 depicts wavelengths of respective rays traced in the optical imaging system of Figure 28. Table 36 provides a summary of general optical surface characteristics for lenses of this optical system, including surface type, radius of curvature, thickness, material (from standard glass and plastic catalogues), diameter, conic constant and applicable notes. Table 37 describes aspheric coefficients for the surfaces of Table 35, whereas Table 38 provides edge thickness information for those surfaces. Table 39 provides index of refraction data for multiple wavelengths and listed optical fields. Tables 40 and 40A provide F/# data for those same wavelengths and optical fields.

**[00118]** As utilized herein, the word "exemplary" is intended to mean serving as an example, instance, or illustration. Any aspect or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects or designs. Rather, use of the word exemplary is intended to present concepts in a concrete fashion. As used in this application, the term "or" is intended to mean an inclusive "or" rather than an exclusive "or". That is, unless specified otherwise, or clear from context, "X employs A or B" is intended to mean any of the natural inclusive permutations. That is, if X employs A; X employs B; or X employs both A and B, then "X employs A or B" is satisfied under any of the foregoing instances. In addition, the articles "a" and "an" as used in this application and the appended claims should generally be construed to mean "one or more" unless specified otherwise or clear from context to be directed to a singular form.

**[00119]** Furthermore, various portions of electronic systems associated with disclosed optical systems described herein may include or consist of artificial intelligence or knowledge or rule based components, sub-components, processes, means, methodologies, or mechanisms *(e.g.,* support vector machines, neural networks, expert systems, Bayesian belief networks, fuzzy logic, data fusion engines, classifiers...). Such components, *inter alia,* and in addition to that already described herein, can automate certain mechanisms or processes performed thereby to make portions of the systems and methods more adaptive as well as efficient and intelligent. For instance, such components can automate optimization of image quality of an optical system, as described above *(e.g.,* see electronic device 500 of Figure 5, *supra).*

**[00120]** What has been described above includes examples of aspects of the claimed subject matter. It is, of course, not possible to describe every conceivable



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combination of components or methodologies for purposes of describing the claimed subject matter, but one of ordinary skill in the art can recognize that many further combinations and permutations of the disclosed subject matter are possible. Accordingly, the disclosed subject matter is intended to embrace all such alterations, modifications and variations that fall within the spirit and scope of the appended claims. Furthermore, to the extent that the terms "includes," "has" or "having" are used in either the detailed description or the claims, such terms are intended to be inclusive in a manner similar to the term "comprising" as "comprising" is interpreted when employed as a transitional word in a claim.

# CLAIMS

What is Claimed is:

1. An optical imaging system arranged along an optical axis, comprising:

a set of optical lenses including a first lens group and a second lens group, wherein the second lens group is fixed in position along the optical axis;

a micro electromechanical system (MEMS) actuator mechanically connected to the first lens group and configured to adjust a position of the first lens group along the optical axis, wherein a first adjusted position is configured to focus an image of an object positioned far from the optical imaging system onto an image plane associated with the optical imaging system, and wherein a second adjusted position is configured to focus an image of an object positioned near to the optical imaging system onto the image plane;

wherein:

the set of optical lenses comprising five lenses;

the MEMS actuator is configured to adjust a position of the first lens group along the optical axis up to between 50 and 150 micrometers;

the first optical lens group comprising a biconvex object-side lens; and

a ratio of the focal length of the biconvex object-side lens to a combined focal length of the five lenses is greater than one half.

2. The optical imaging system of claim 1, further comprising an aperture stop positioned at an object-side of the biconvex object-side lens.

3. The optical imaging system of claim 2, wherein the aperture stop is fixed in position along the optical axis.

4. The optical imaging system of claim 2, wherein the aperture stop is fixed in position relative to the first lens group.

5. The optical imaging system of claim 4, wherein the MEMS actuator is configured to reposition the first lens group and the aperture stop along the optical axis and maintain the fixed position between the aperture stop and the first lens group at least at the first adjusted position and at the second adjusted position.

6. The optical imaging system of claim 1, the second lens group comprising four lens elements, including a second lens, a third lens, a fourth lens and a fifth lens.

7. The optical imaging system of claim 6, the second lens having a concave image-side surface and a flat or a weak convex curvature on an object-side surface.

8. The optical imaging system of claim 7, the second lens having a negative optical power, and formed of an OKP4HT plastic.

9. The optical imaging system of claim 6, the third lens having a concave object-side surface and a convex image-side surface, a positive optical power, and formed of an APEL5514ML glass.

10. The optical imaging system of claim 6, the fourth lens having an object-side surface that is convex near the optical axis and transitions to concave away from the optical axis, and an image-side surface having convex curvature.

11. The optical imaging system of claim 10, the fourth lens having positive optical power near the optical axis, and having small negative optical power, small positive optical power, or no optical power away from the optical axis, and the fourth lens is formed of an APEL55 14ML plastic.

12. The optical imaging system of claim 6, the fifth lens having an object-side surface that is concave near the optical axis and that transitions to convex away from the optical axis, and an image-side surface that is concave near the optical axis and transitions to convex away from the optical axis.

13. The optical imaging system of claim 12, the fifth lens having large negative optical power near the optical axis, and positive optical power away from the optical axis, and the fifth lens is formed of an APEL5514ML plastic.

14. The optical imaging system of claim 1, the biconvex object-side lens is formed of an APEL55 14ML plastic.

15. The optical imaging system of claim 1, wherein an optical power of the biconvex object-side lens is at least in part a function of a distance along the optical axis between the first adjusted position and the second adjusted position.

16. The optical imaging system of claim 1, wherein the ratio of the focal length of the biconvex object-side lens to a combined focal length of the five lenses is about three quarters.

17. The optical imaging system of claim 1, wherein the ratio of the optical power of the biconvex object-side lens to a combined optical power of the five lenses is at least in part a function of a distance along the optical axis between the first adjusted position and the second adjusted position.

18. The optical imaging system of claim 1, wherein the object positioned far from the optical system is positioned substantially at infinity, and wherein the object positioned near to the optical system is positioned at substantially 10cm from an aperture stop of the optical imaging system.

19. An optical system comprising:

a plurality of optical elements arranged along a common optical axis for forming a real image of an object, said optical elements including:

a first lens having a positive refractive power, with both surfaces, one facing an object side and another facing an image side, having convex shape;

a second lens having negative refractive power and a meniscus shape, with the surface facing the object side having a convex shape and the surface facing the image side having a concave shape;

a third lens having positive refractive power, and a biconvex shape near the optical axis, and the surface facing the object side is concave away from the optical axis;

a fourth lens, with the surface facing the object side having a concave shape, and the surface facing the image side having a convex shape; and

a fifth lens having a meniscus shape with the surface facing the object side having a convex shape and the surface facing the image side having a concave shape near the optical axis and a convex shape away from the optical axis; and

an actuator configured to move the first lens along the optical axis.

20. The optical system of claim 19, wherein the motor is a microelectromechanical system.

21. The optical system of claim 19, wherein the second lens performs a majority of chromatic correction for the optical system.

22. The optical system of claim 19, further comprising an aperture that is embedded into the first lens and moves with the first lens, wherein the aperture having a depth of 50μιη.

23. The optical system of claim 19, wherein the F-number of the optical system is approximately 2.4.

24. The optical system of claim 19, wherein one or more of the lenses are made of plastic.

25. The optical system of claim 19, wherein the surfaces of the lenses are aspheric.

26. The optical system of claim 19, wherein the refractive index of the lenses is within a range of about 1.5 to about 1.66.

27. The optical system of claim 19, wherein the range of movement for the first lens is between about Oμιη and about IOOμιη.

28. The optical system of claim 19, wherein an amount of movement to focus an image of an object is inversely proportional to the positive refractive power of the first lens.

29. The optical system of claim 19, wherein the primary lateral color range for the optical system focused on an object at infinity is equal to or less than approximately Iμιη.

30. The optical system of claim 19, wherein the primary lateral color range for the optical system focused on an object at 10cm is equal to or less than approximately 4μιη.

31. An optical imaging system arranged along an optical axis, comprising:

a set of optical lenses including a first lens group and a second lens group, wherein the second lens group is fixed in position along the optical axis and comprises a majority of the optical lenses of the set of optical lenses; and

an actuator mechanically connected to the first lens group and configured to adjust a position of the first lens group along the optical axis, wherein a first adjusted position is configured to focus an image of an object positioned far from the optical imaging system onto an image plane associated with the optical imaging system, and wherein a second adjusted position is configured to focus an image of an object positioned near to the optical imaging system onto the image plane;

wherein:

the set of optical lenses comprising five lenses;

the actuator is configured to adjust a position of the first lens group along the optical axis up to between 50 and 150 micrometers;

the second optical lens group comprising a third lens of the set of optical lenses that is third in sequence from an object side of the set of optical lenses, the third lens having a meniscus shape that is convex toward the object side of the set of optical lenses.

32. The optical imaging system of claim 31, wherein the actuator comprises a micro electromechanical system (MEMS) actuator.

33. The optical imaging system of claim 31, the first optical lens group comprising a biconvex objective lens that provides a majority of the positive optical power of the set of optical lenses.

34. The optical imaging system of claim 33, wherein the biconvex objective lens has greater positive refractive power than a combined refractive power of the set of optical lenses.

35. The optical imaging system of claim 31, wherein an effective focal length of the set of optical lenses is between about 4.5 and about 5.0 millimeters.

36. The optical imaging system of claim 31, wherein a ratio of total track length to effective focal length of the optical system is between about 1.1 and about 1.2.

37. The optical imaging system of claim 31, wherein the first lens group comprises a single lens of the set of optical lenses.

38. The optical imaging system of claim 37, wherein the single lens is an objective lens of the optical system.

39. The optical imaging system of claim 37, wherein the second adjusted position focuses an image of an object at an object distance of about 12.8 centimeters onto the image plane.

40. The optical imaging system of claim 31, wherein an air distance between a third lens and a fourth lens of the set of optical lenses, numbered from an object side of the set of optical lenses, is a largest of air distances between respective ones of the set of optical lenses.

41. The optical imaging system of claim 31, wherein an air distance between a fourth lens and a fifth lens of the set of optical lenses, numbered from an object side of the set of optical lenses, is a largest of air distances between respective ones of the set of optical lenses.

42. The optical imaging system of claim 31, further comprising an aperture stop about an object side surface of a first lens of the set of optical lenses, numbered from an object side of the set of optical lenses.

43. The optical imaging system of claim 42, further comprising a stop between a second and third lens of the set of optical lenses, numbered from an object side of the set of optical lenses.

44. The optical imaging system of claim 43, further comprising a second stop between the third lens and a fourth lens of the set of optical lenses.

45. The optical imaging system of claim 44, further comprising a third stop between the fourth lens and a fifth lens of the set of optical lenses.

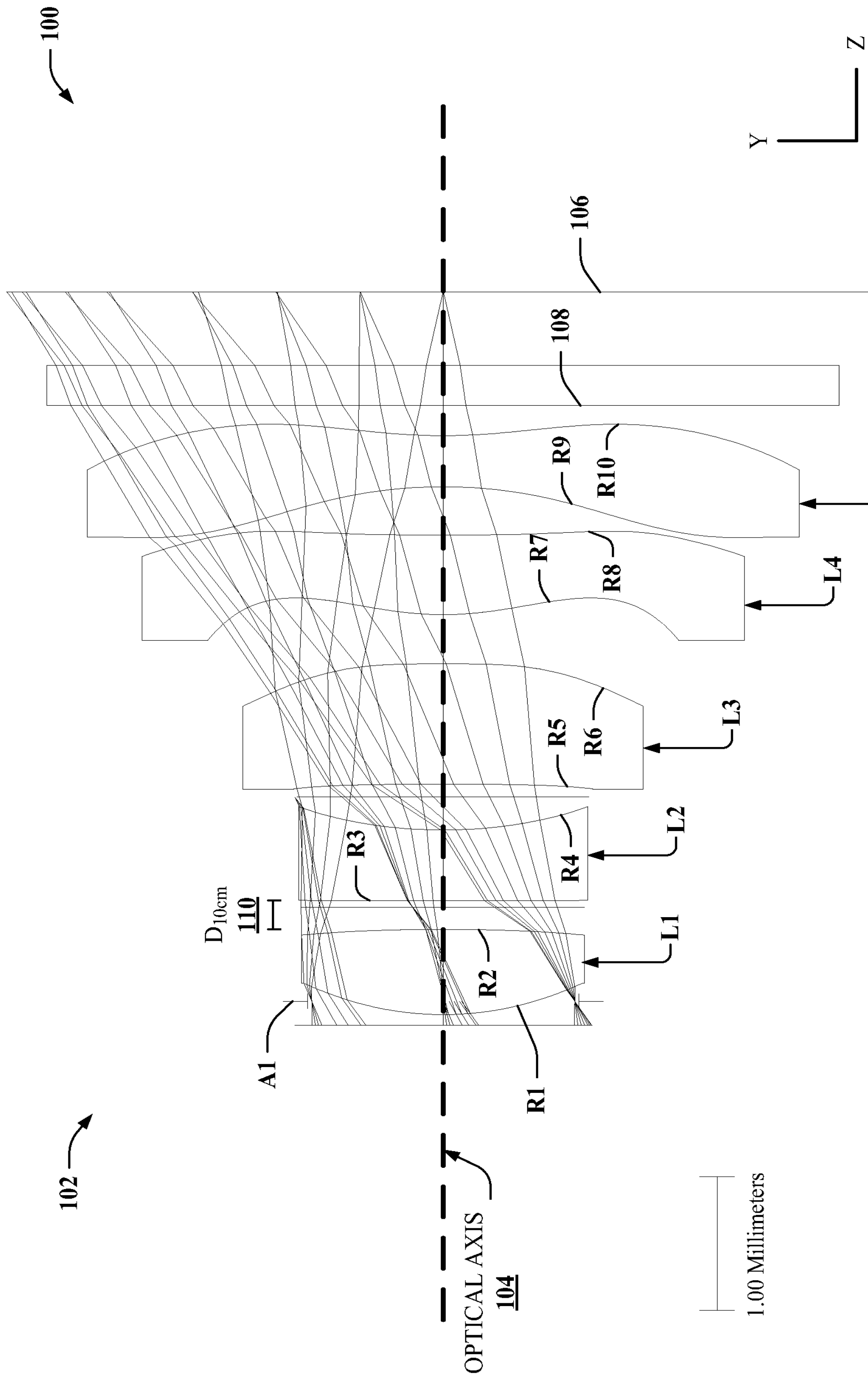



FIG. 1

OPTICAL LAYOUT; OBJECT FOCUSED AT 10CM

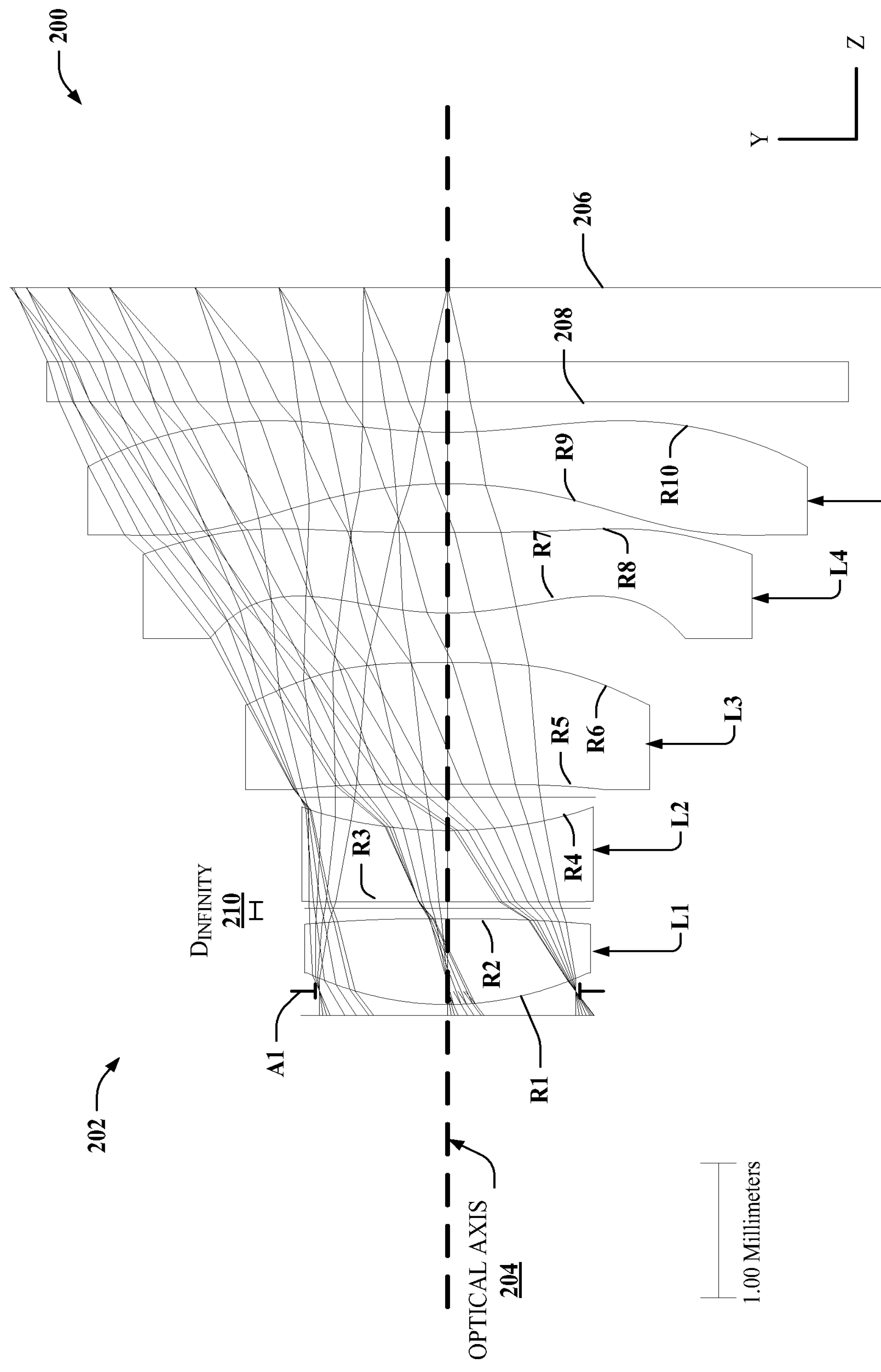



FIG. 2

OPTICAL LAYOUT; OBJECT FOCUSED AT INFINITY

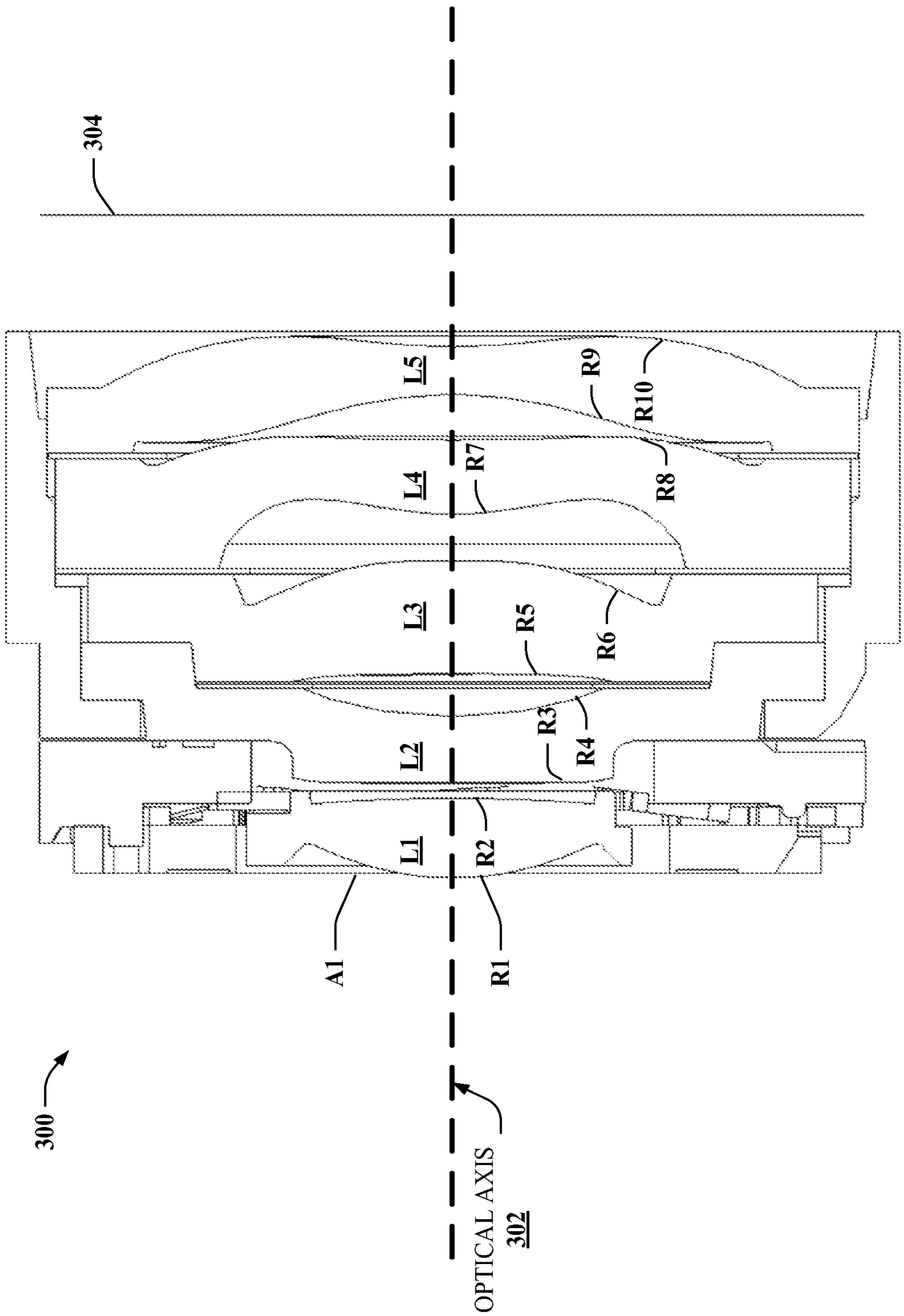

304
L5
R9
R10
R7
L4
R8
L3
R5
R6
R3
R4
L2
L1
R2
A1
R1
300
OPTICAL AXIS
302

FIG. 3

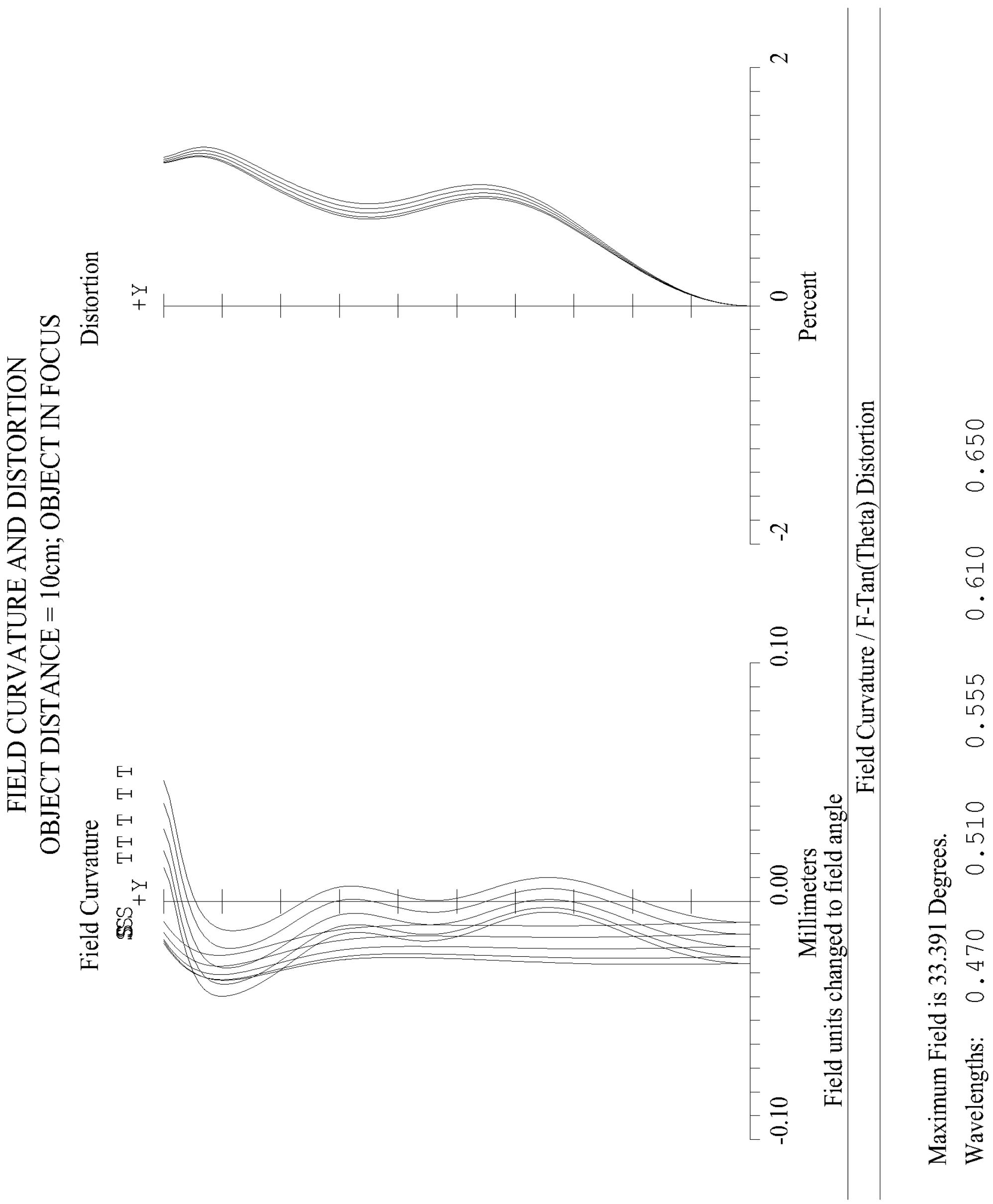

FIELD CURVATURE AND DISTORTION
OBJECT DISTANCE = 10cm; OBJECT IN FOCUS
Field Curvature
Distortion
S S S T T T T T
+Y
+Y
-0.10
0.00
0.10
Millimeters
Field units changed to field angle
-2
0
2
Percent
Field Curvature / F-Tan(Theta) Distortion
Maximum Field is 33.391 Degrees.
Wavelengths: 0.470 0.510 0.555 0.610 0.650

FIG. 4

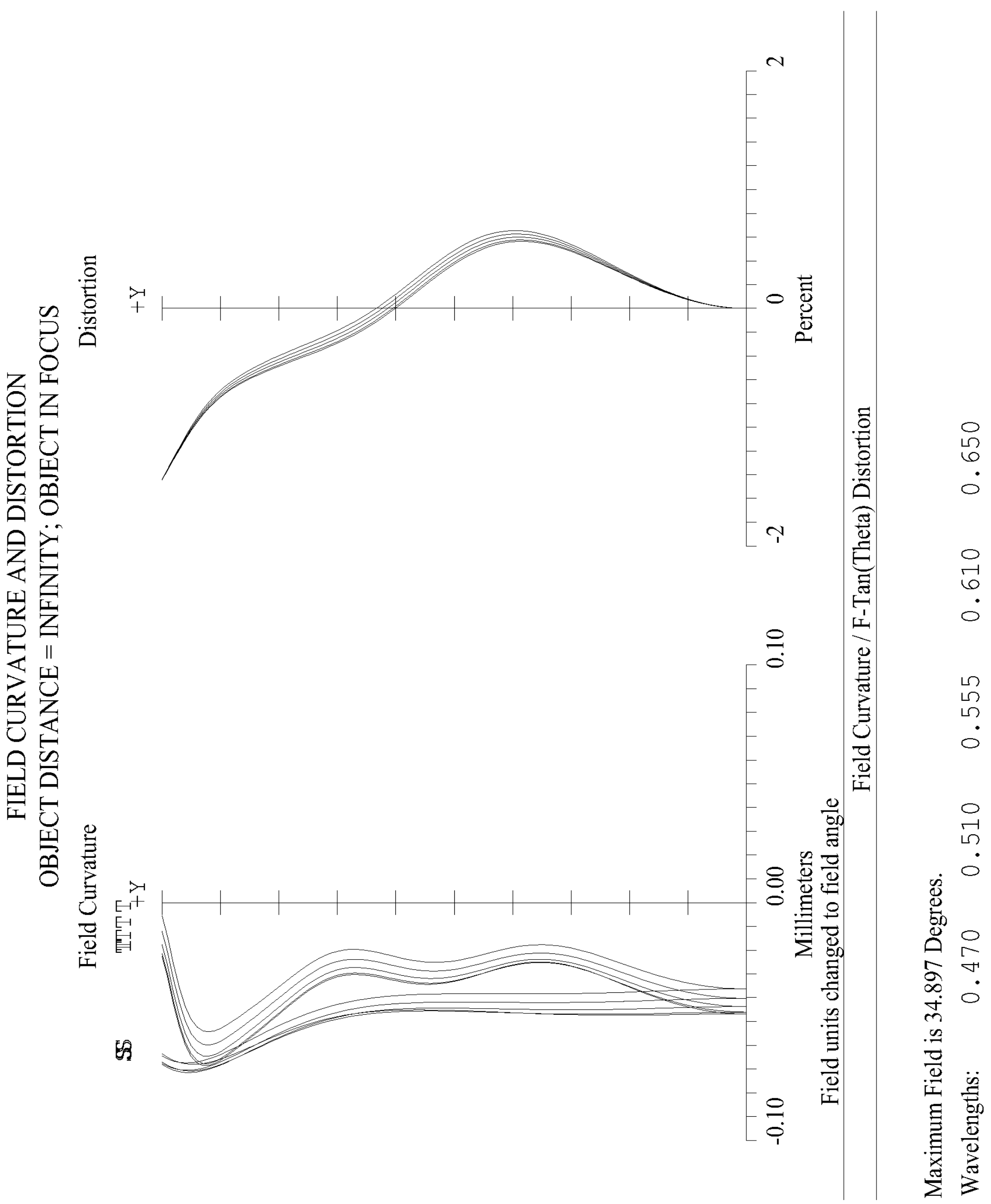

FIELD CURVATURE AND DISTORTION
OBJECT DISTANCE = INFINITY; OBJECT IN FOCUS
Field Curvature
Distortion
+Y
S
T
-0.10
0.00
0.10
Millimeters
Field units changed to field angle
-2
0
2
Percent
Field Curvature / F-Tan(Theta) Distortion
Maximum Field is 34.897 Degrees.
Wavelengths: 0.470 0.510 0.555 0.610 0.650

**FIG. 5**

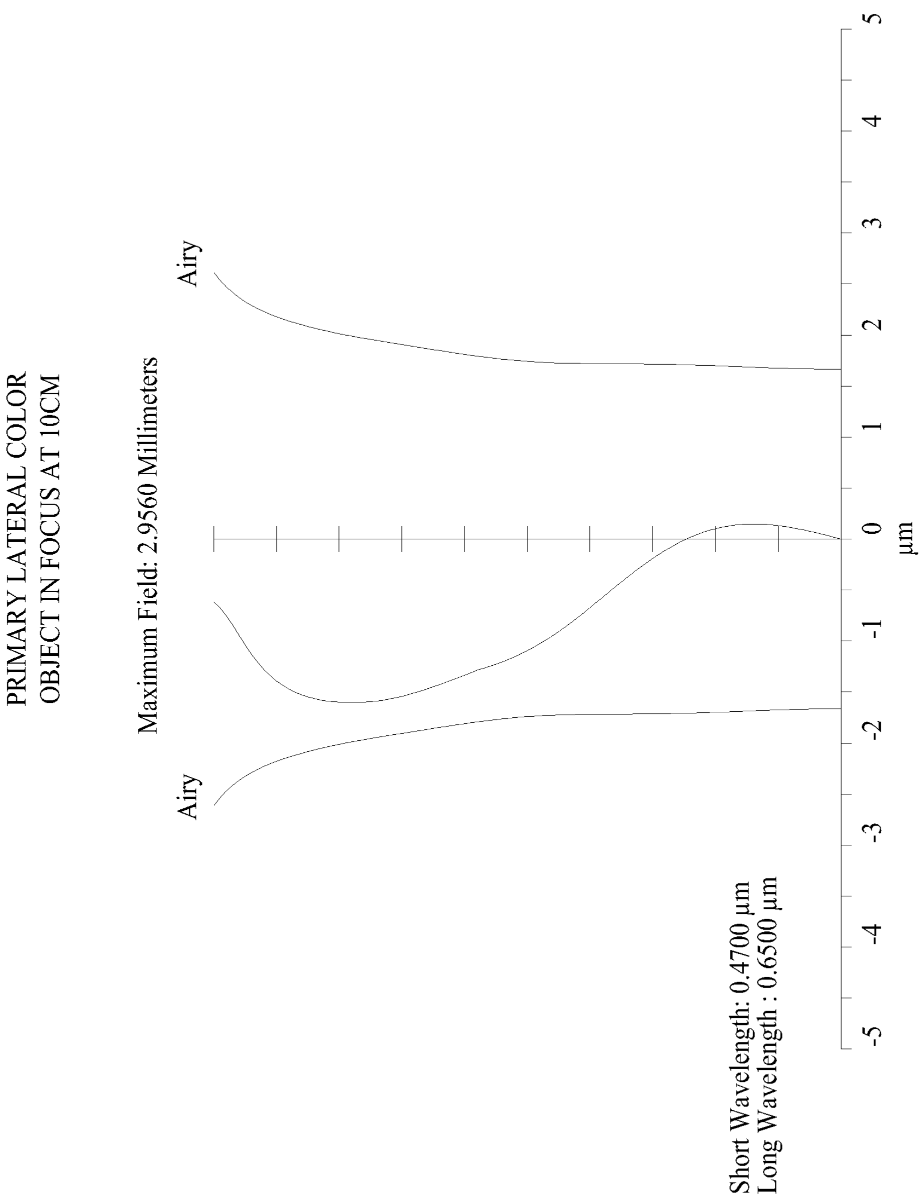

PRIMARY LATERAL COLOR
OBJECT IN FOCUS AT 10CM
Maximum Field: 2.9560 Millimeters
Airy
Airy
-5
-4
-3
-2
-1
0
1
2
3
4
5
µm
Short Wavelength: 0.4700 µm
Long Wavelength : 0.6500 µm

**FIG. 6**

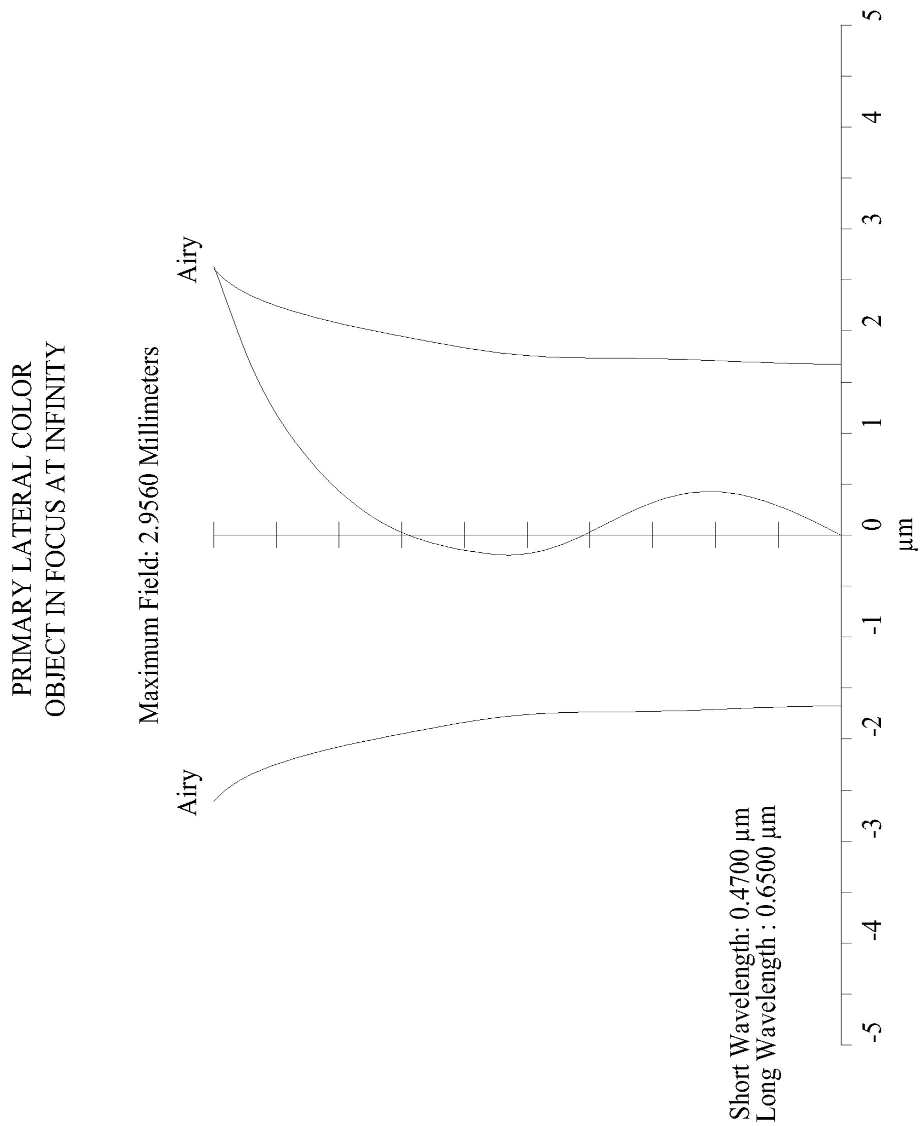

PRIMARY LATERAL COLOR
OBJECT IN FOCUS AT INFINITY
Maximum Field: 2.9560 Millimeters
Airy
Airy
-5 -4 -3 -2 -1 0 1 2 3 4 5
μm
Short Wavelength: 0.4700 μm
Long Wavelength : 0.6500 μm

**FIG. 7**

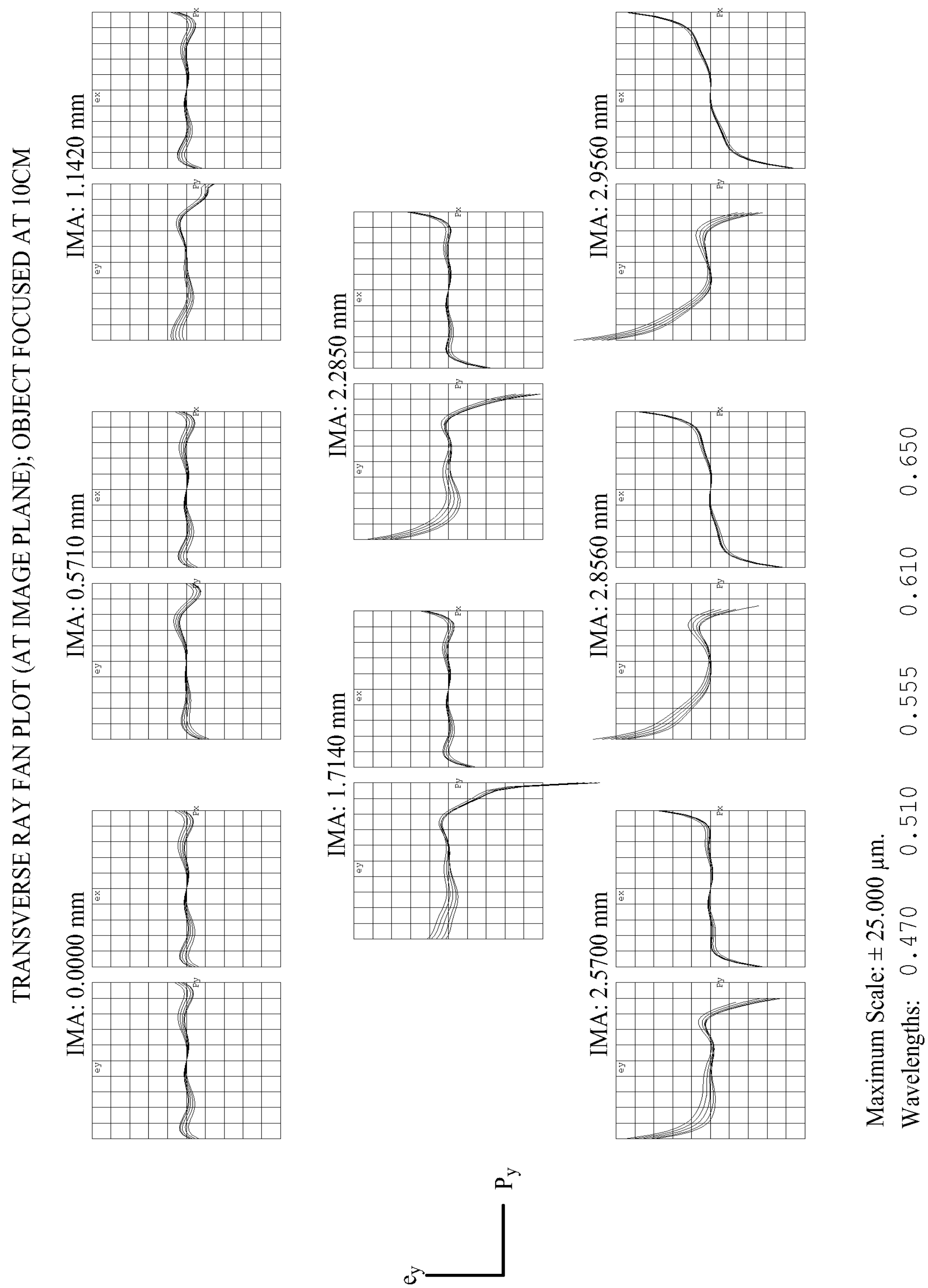

TRANSVERSE RAY FAN PLOT (AT IMAGE PLANE); OBJECT FOCUSED AT 10CM
IMA: 0.0000 mm
IMA: 0.5710 mm
IMA: 1.1420 mm
IMA: 1.7140 mm
IMA: 2.2850 mm
IMA: 2.5700 mm
IMA: 2.8560 mm
IMA: 2.9560 mm
Maximum Scale: ± 25.000 µm.
Wavelengths: 0.470 0.510 0.555 0.610 0.650
ey
Py

**FIG. 8**

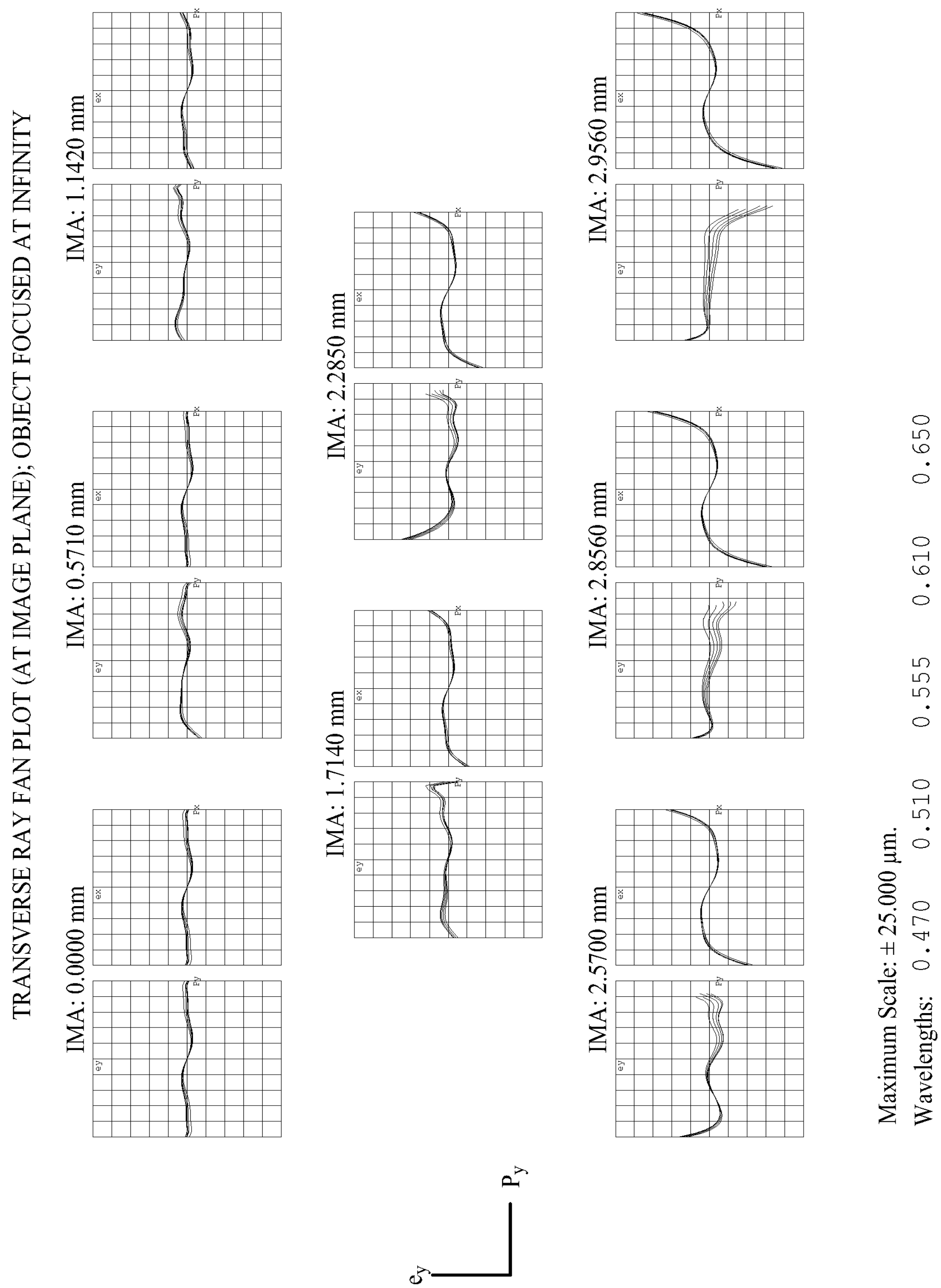

TRANSVERSE RAY FAN PLOT (AT IMAGE PLANE); OBJECT FOCUSED AT INFINITY
IMA: 0.0000 mm
IMA: 0.5710 mm
IMA: 1.1420 mm
IMA: 1.7140 mm
IMA: 2.2850 mm
IMA: 2.5700 mm
IMA: 2.8560 mm
IMA: 2.9560 mm
ey
ex
Py
Px
Maximum Scale: ± 25.000 µm.
Wavelengths: 0.470 0.510 0.555 0.610 0.650
$e_y$
$P_y$

FIG. 9

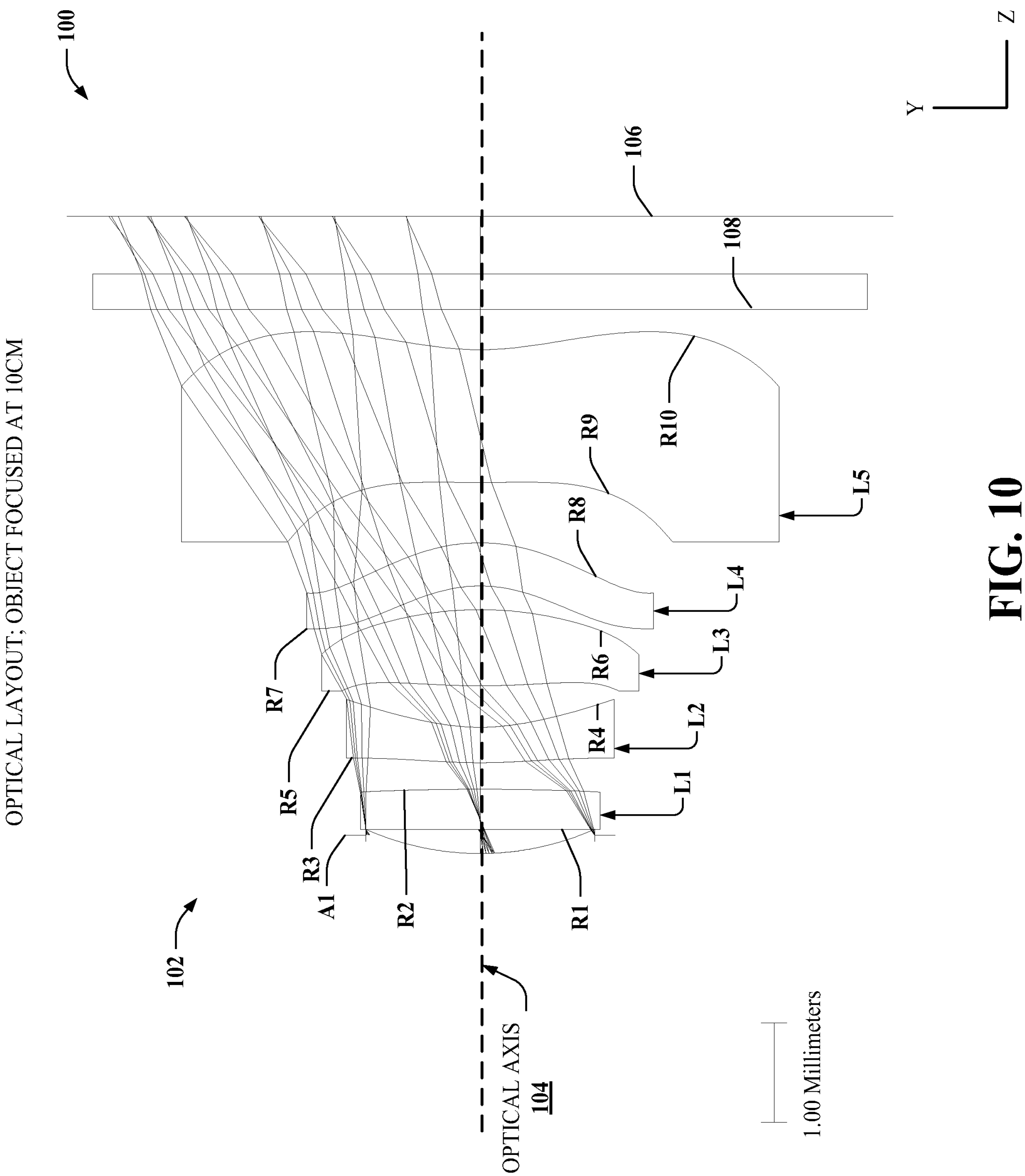

OPTICAL LAYOUT; OBJECT FOCUSED AT 10CM
100
102
106
108
R1
R2
R3
A1
R4
R5
R6
R7
R8
R9
R10
L1
L2
L3
L4
L5
OPTICAL AXIS
104
1.00 Millimeters
Y
Z

FIG. 10

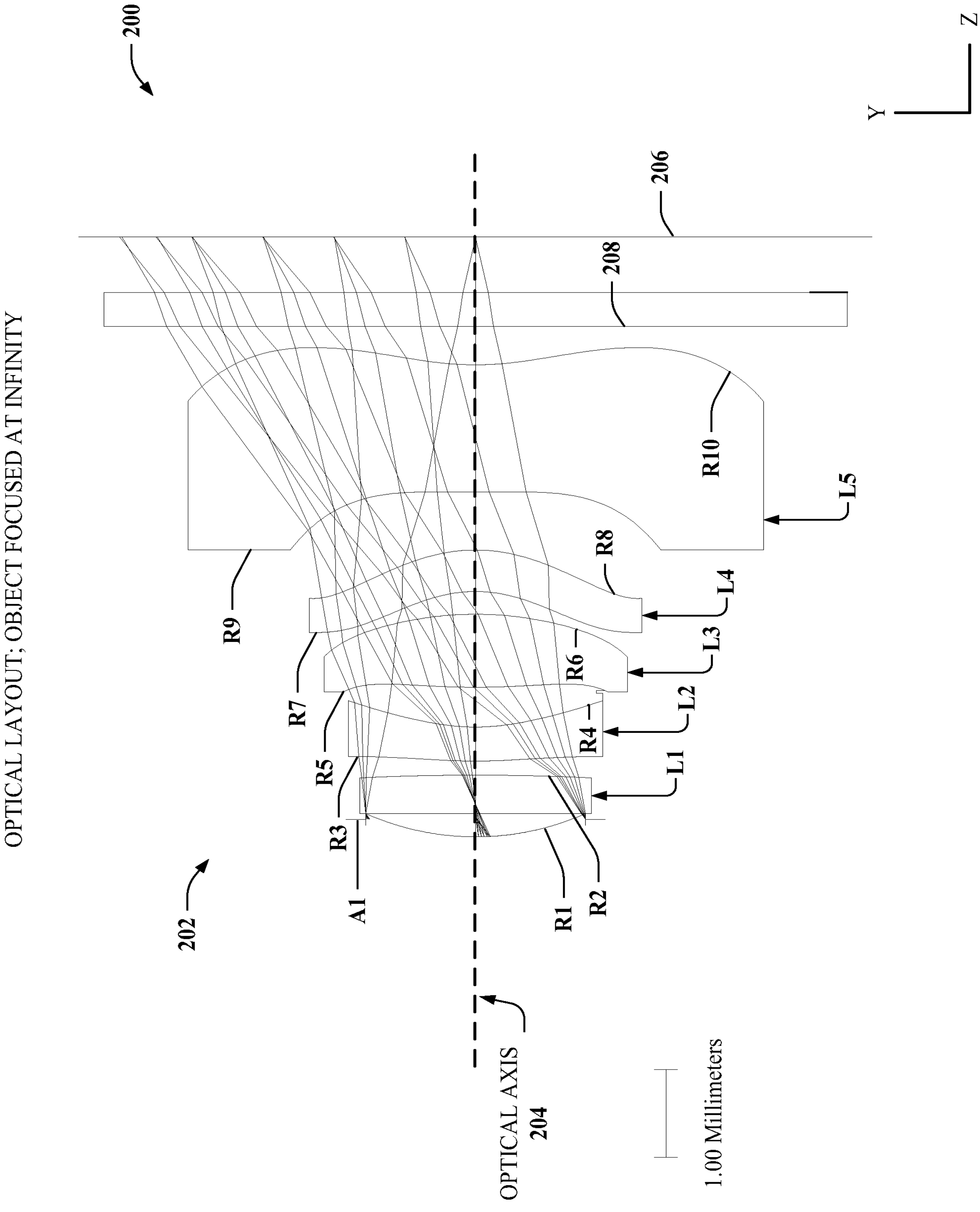
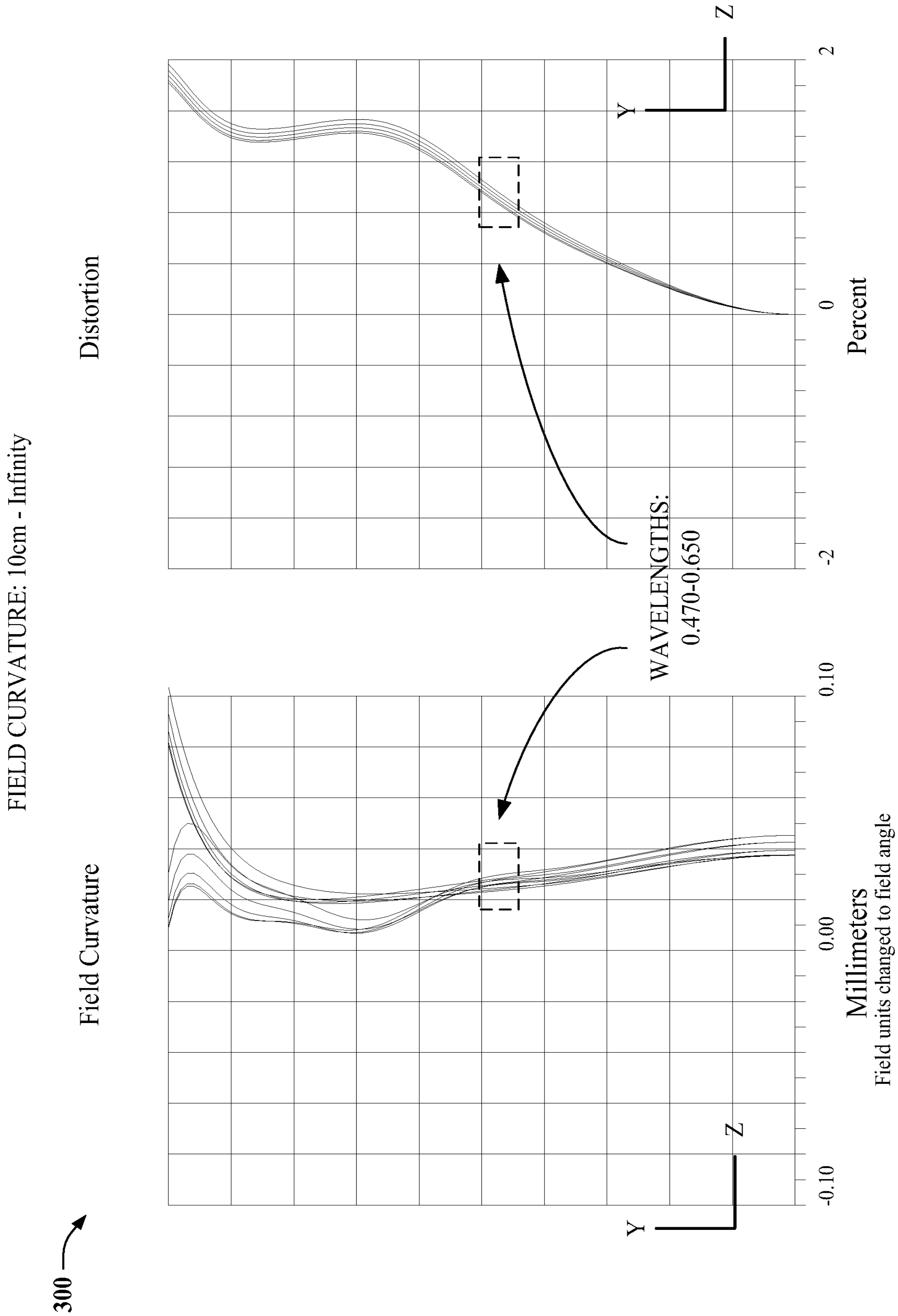

OPTICAL LAYOUT; OBJECT FOCUSED AT INFINITY
200
202
206
208
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
A1
L1
L2
L3
L4
L5
OPTICAL AXIS
204
1.00 Millimeters
Y
Z

FIG. 11



300
FIELD CURVATURE: 10cm - Infinity
Field Curvature
Distortion
WAVELENGTHS:
0.470-0.650
-0.10
0.00
0.10
Millimeters
Field units changed to field angle
-2
0
2
Percent
Y
Z
Y
Z


FIG. 12

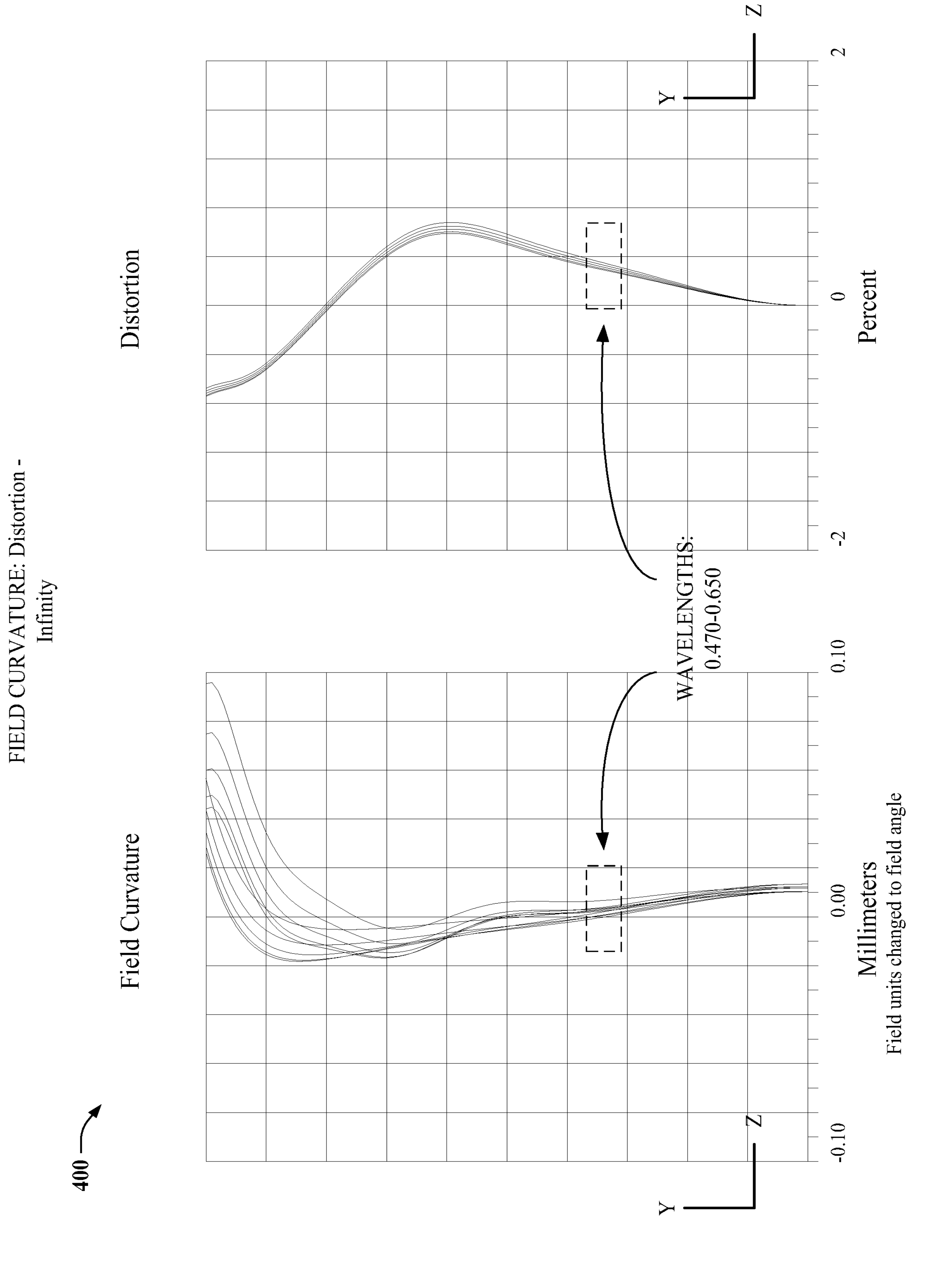

400
FIELD CURVATURE: Distortion - Infinity
Field Curvature
Distortion
Y
Z
-0.10
0.00
0.10
Millimeters
Field units changed to field angle
WAVELENGTHS:
0.470-0.650
-2
0
2
Percent

FIG. 13

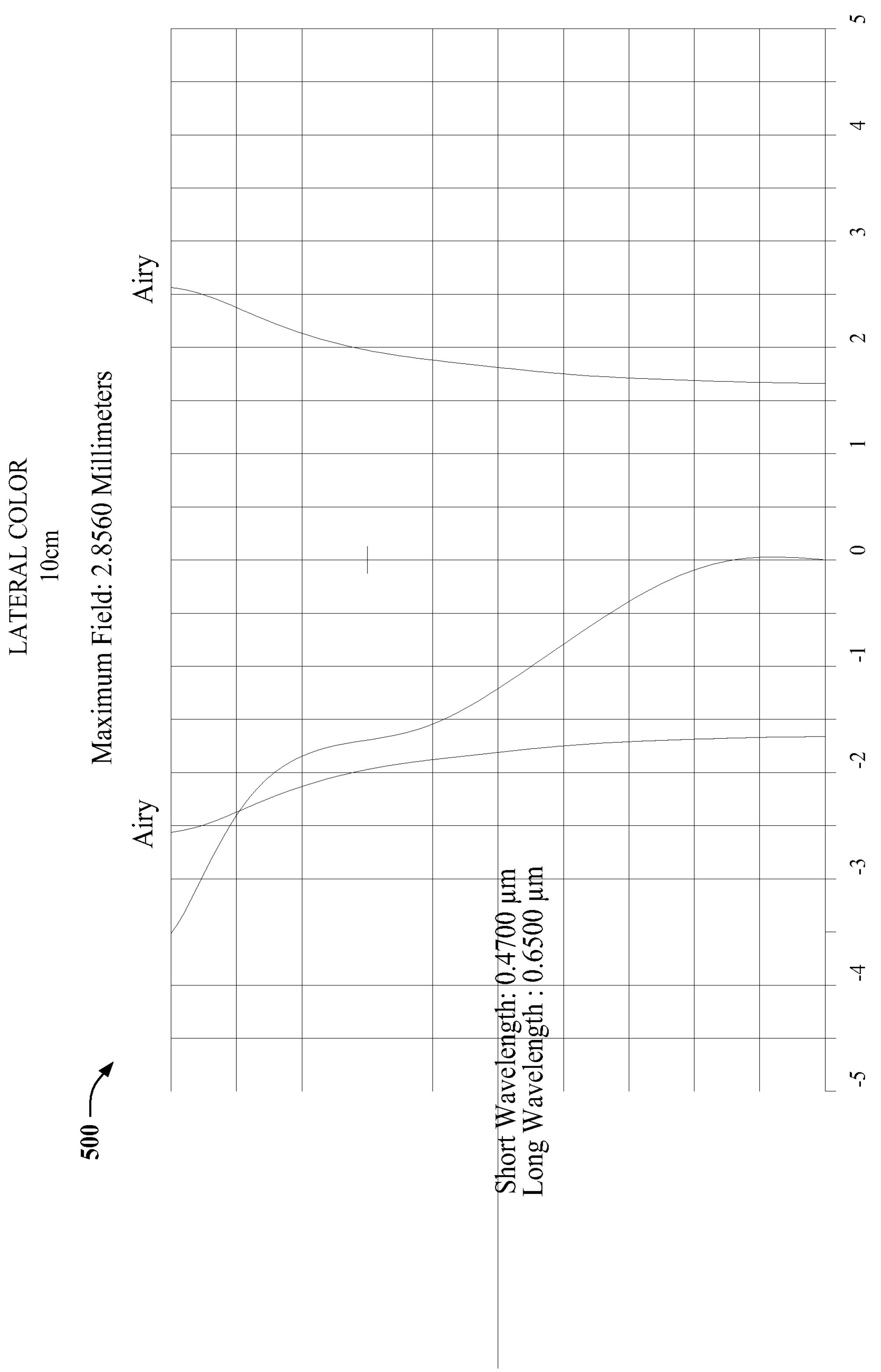

500
LATERAL COLOR
10cm
Maximum Field: 2.8560 Millimeters
Airy
Airy
Short Wavelength: 0.4700 µm
Long Wavelength : 0.6500 µm
-5
-4
-3
-2
-1
0
1
2
3
4
5
µm

**FIG. 14**

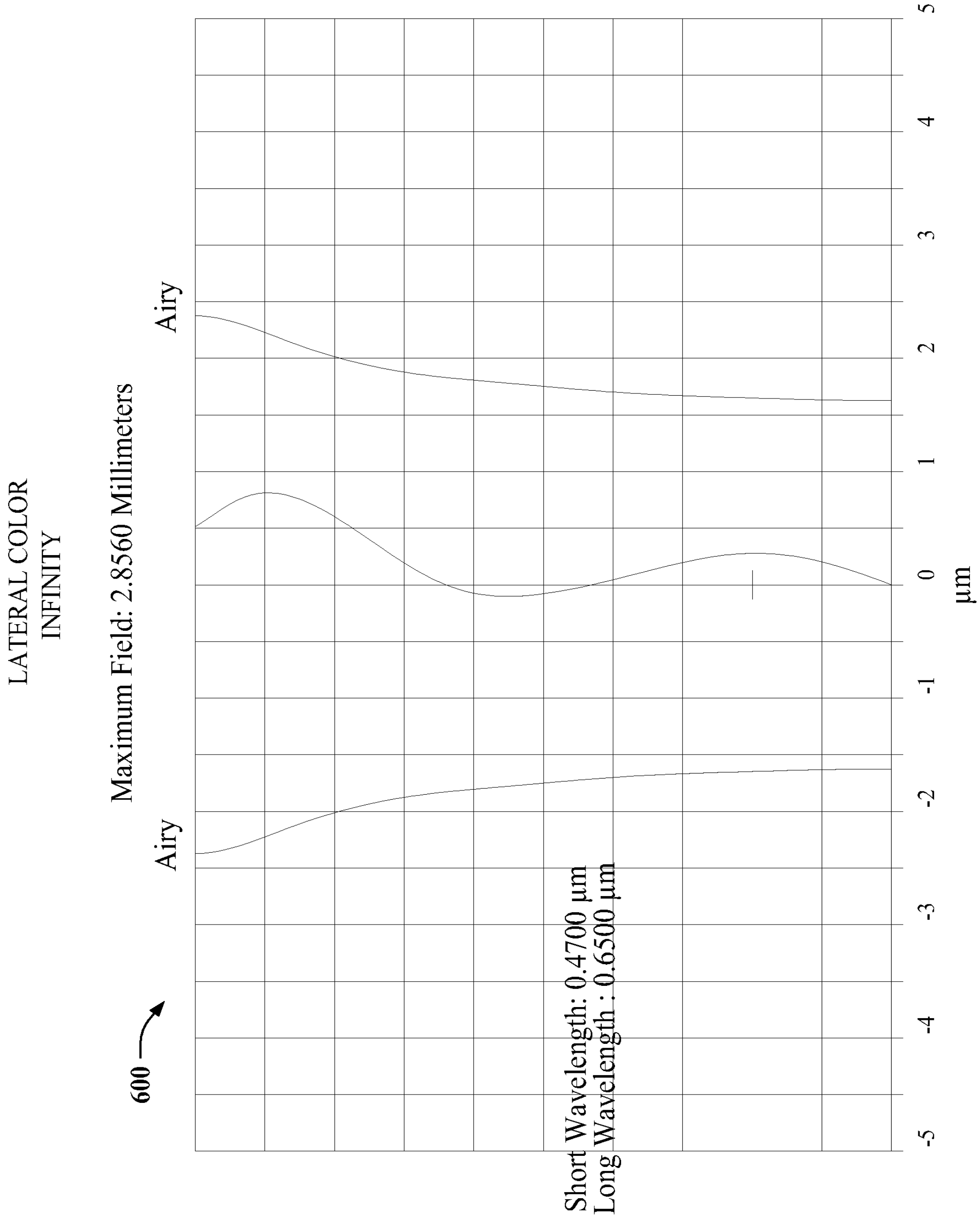

LATERAL COLOR
INFINITY
Maximum Field: 2.8560 Millimeters
Airy
Airy
600
Short Wavelength: 0.4700 µm
Long Wavelength : 0.6500 µm
-5
-4
-3
-2
-1
0
1
2
3
4
5
µm

FIG. 15

TRANSVERSE RAY FAN PLOT 10cm

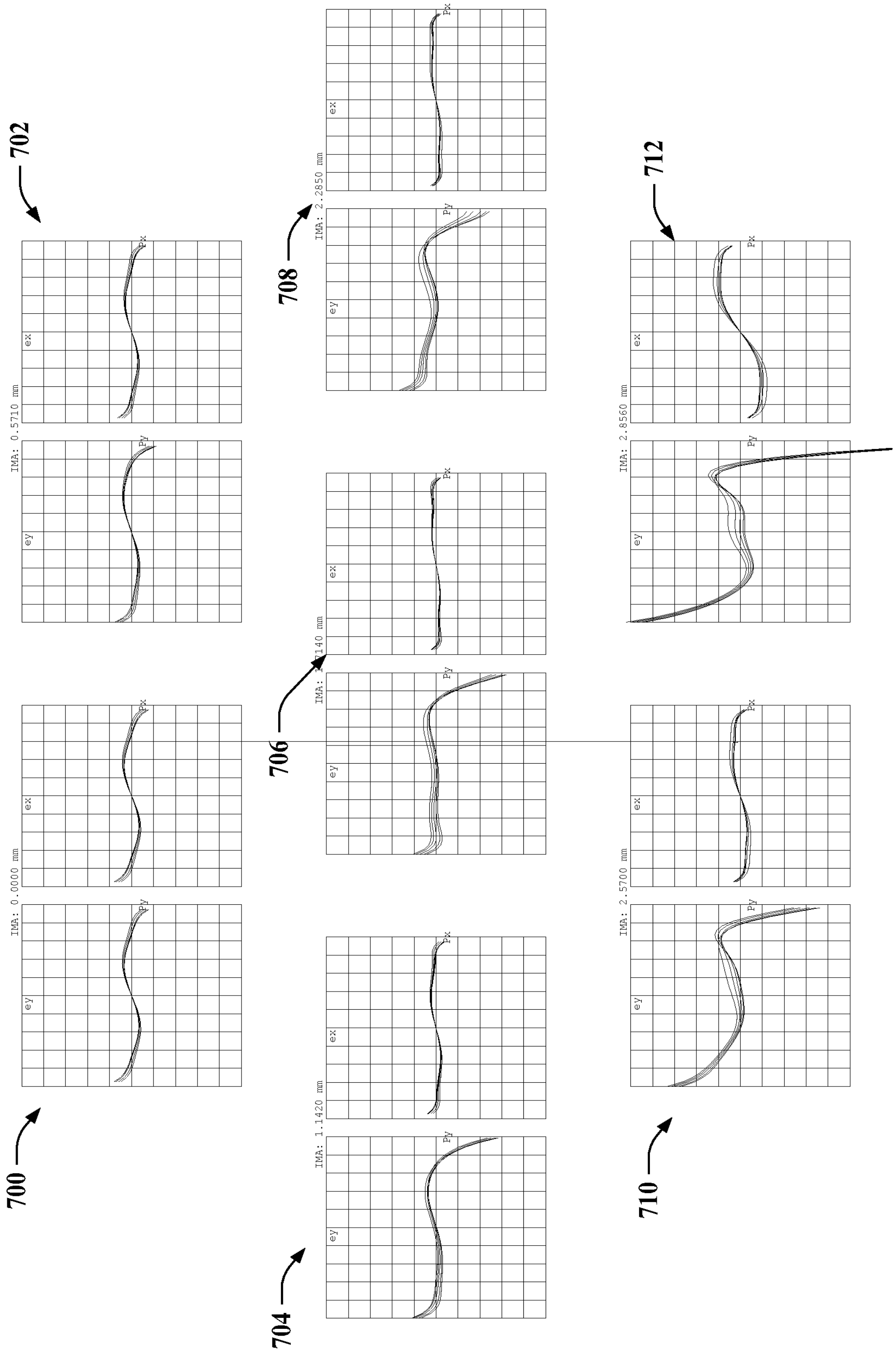



FIG. 16

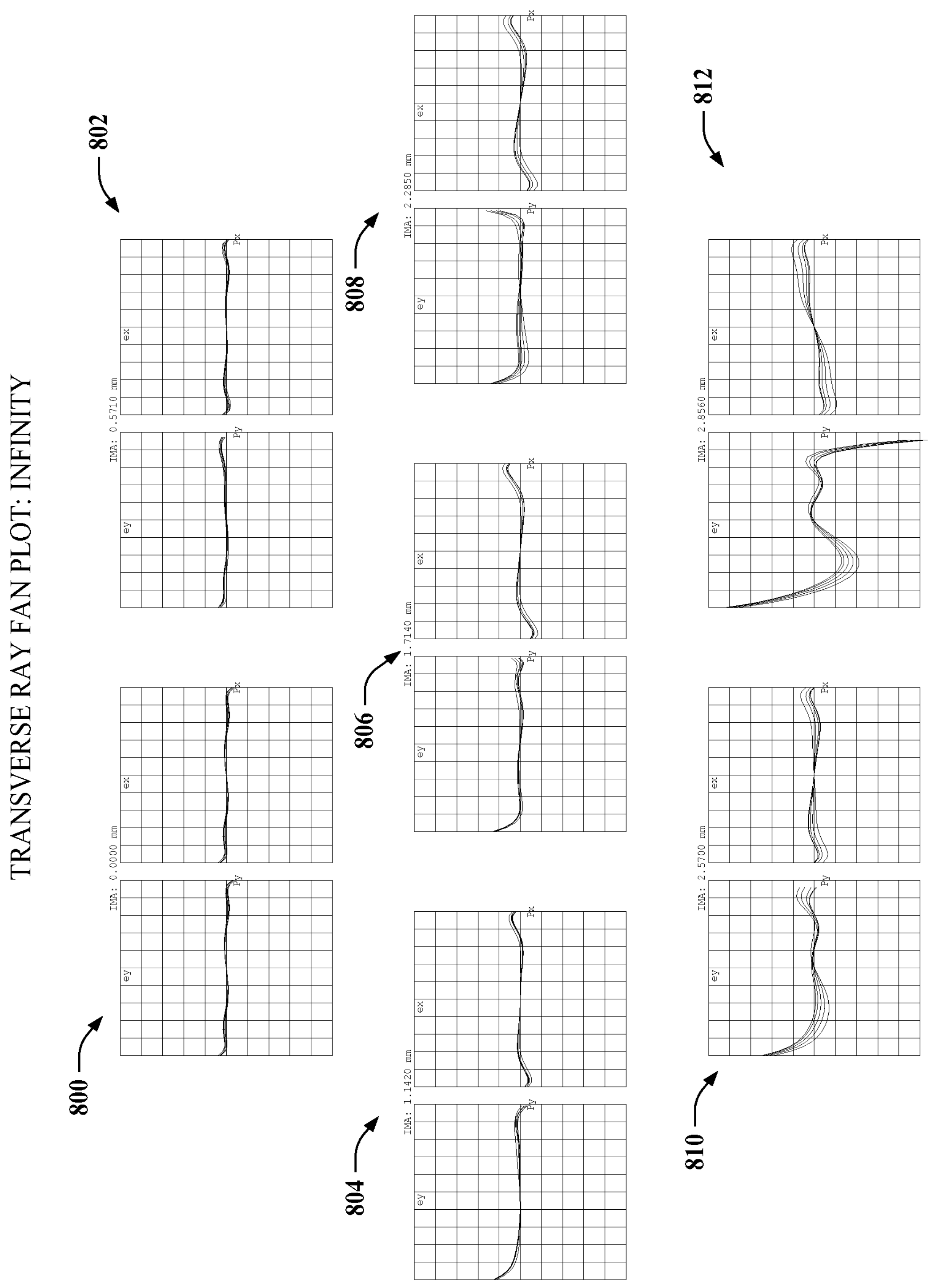

TRANSVERSE RAY FAN PLOT: INFINITY
800
802
804
806
808
810
812
IMA: 0.0000 mm
IMA: 0.5710 mm
IMA: 1.1420 mm
IMA: 1.7140 mm
IMA: 2.2850 mm
IMA: 2.5700 mm
IMA: 2.8560 mm
ey
ex
Py
Px

FIG. 17

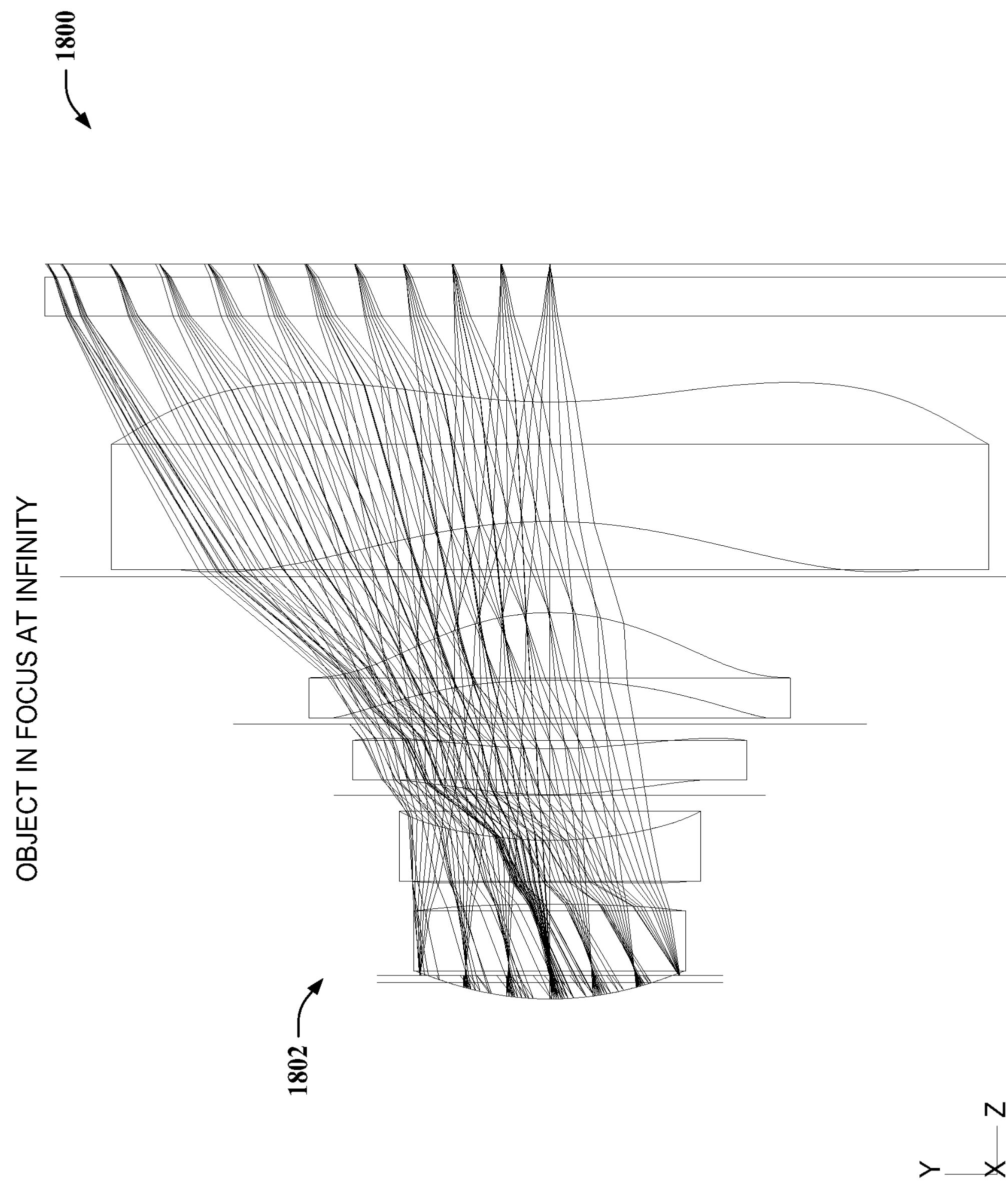



FIG. 18

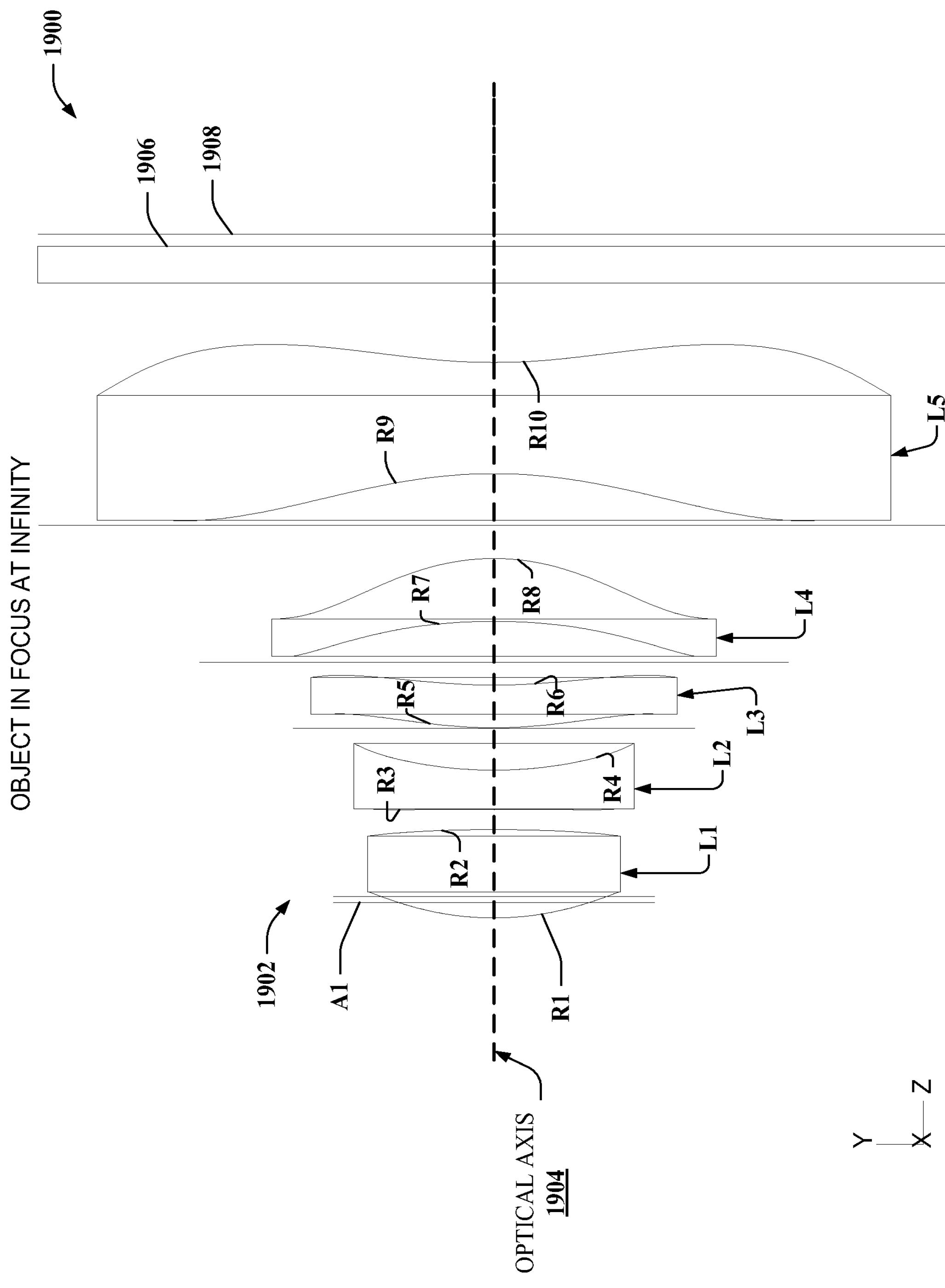

1900
1906
1908
OBJECT IN FOCUS AT INFINITY
R9
R10
L5
R7
R8
L4
R5
R6
L3
R3
R4
L2
R2
L1
1902
A1
R1
OPTICAL AXIS
1904
Y
X
Z

FIG. 19

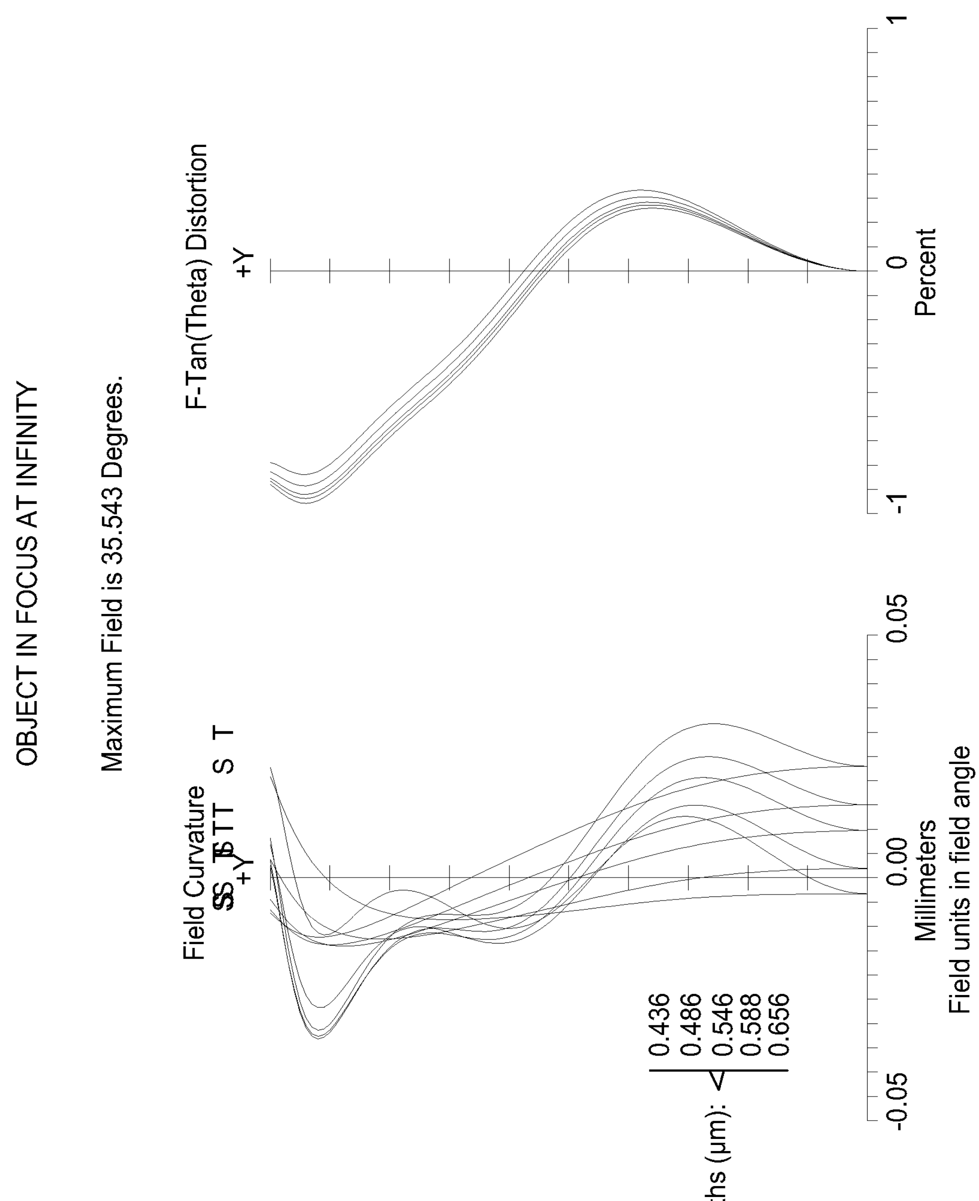

OBJECT IN FOCUS AT INFINITY
Maximum Field is 35.543 Degrees.
Field Curvature
S T
+Y
F-Tan(Theta) Distortion
+Y
-0.05
0.00
0.05
Millimeters
Field units in field angle
-1
0
1
Percent
Wavelengths (µm):
0.436
0.486
0.546
0.588
0.656

**FIG. 20**

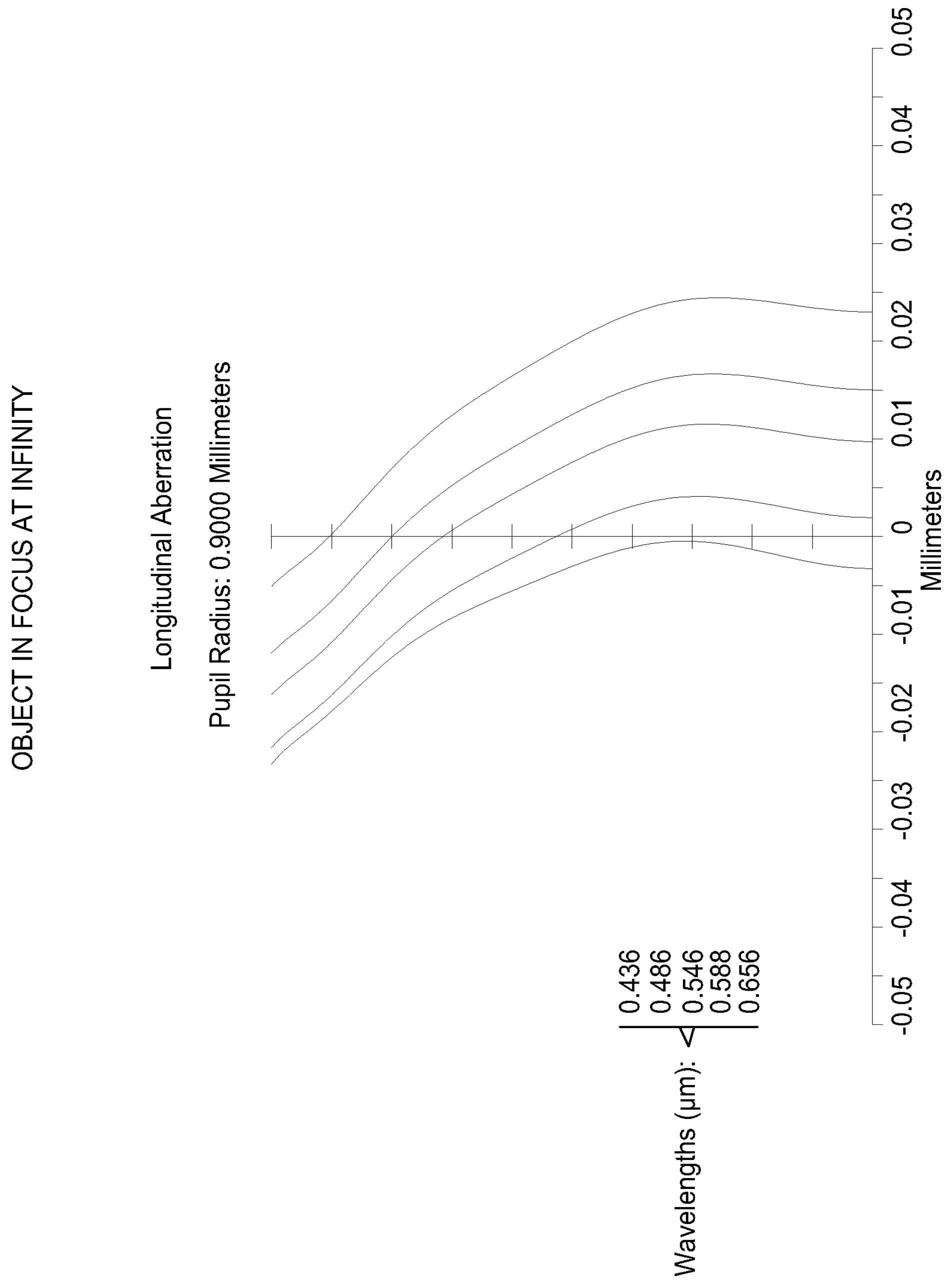

OBJECT IN FOCUS AT INFINITY
Longitudinal Aberration
Pupil Radius: 0.9000 Millimeters
-0.05
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05
Millimeters
Wavelengths (μm):
0.436
0.486
0.546
0.588
0.656

FIG. 21

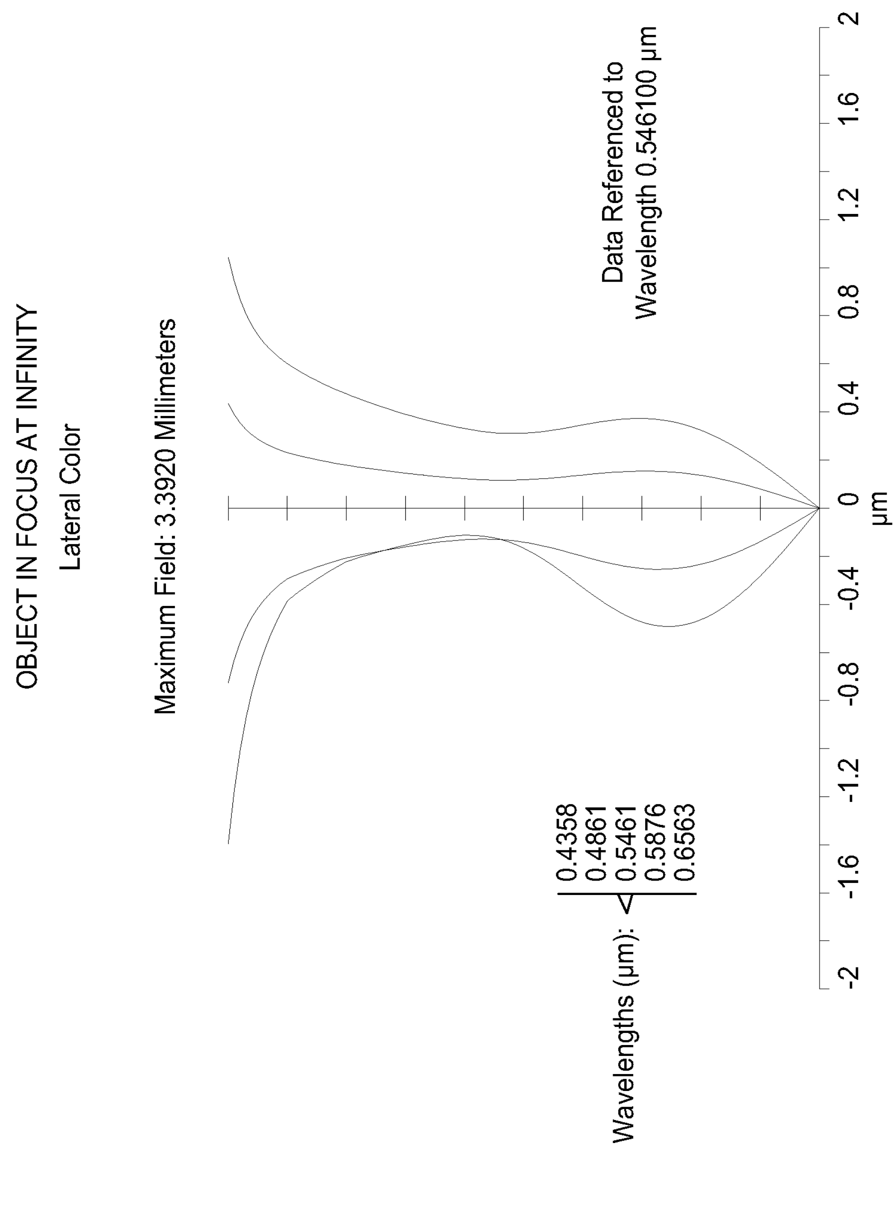

OBJECT IN FOCUS AT INFINITY
Lateral Color
Maximum Field: 3.3920 Millimeters
Data Referenced to
Wavelength 0.546100 µm
Wavelengths (µm):
0.4358
0.4861
0.5461
0.5876
0.6563
-2
-1.6
-1.2
-0.8
-0.4
0
0.4
0.8
1.2
1.6
2
µm

FIG. 22

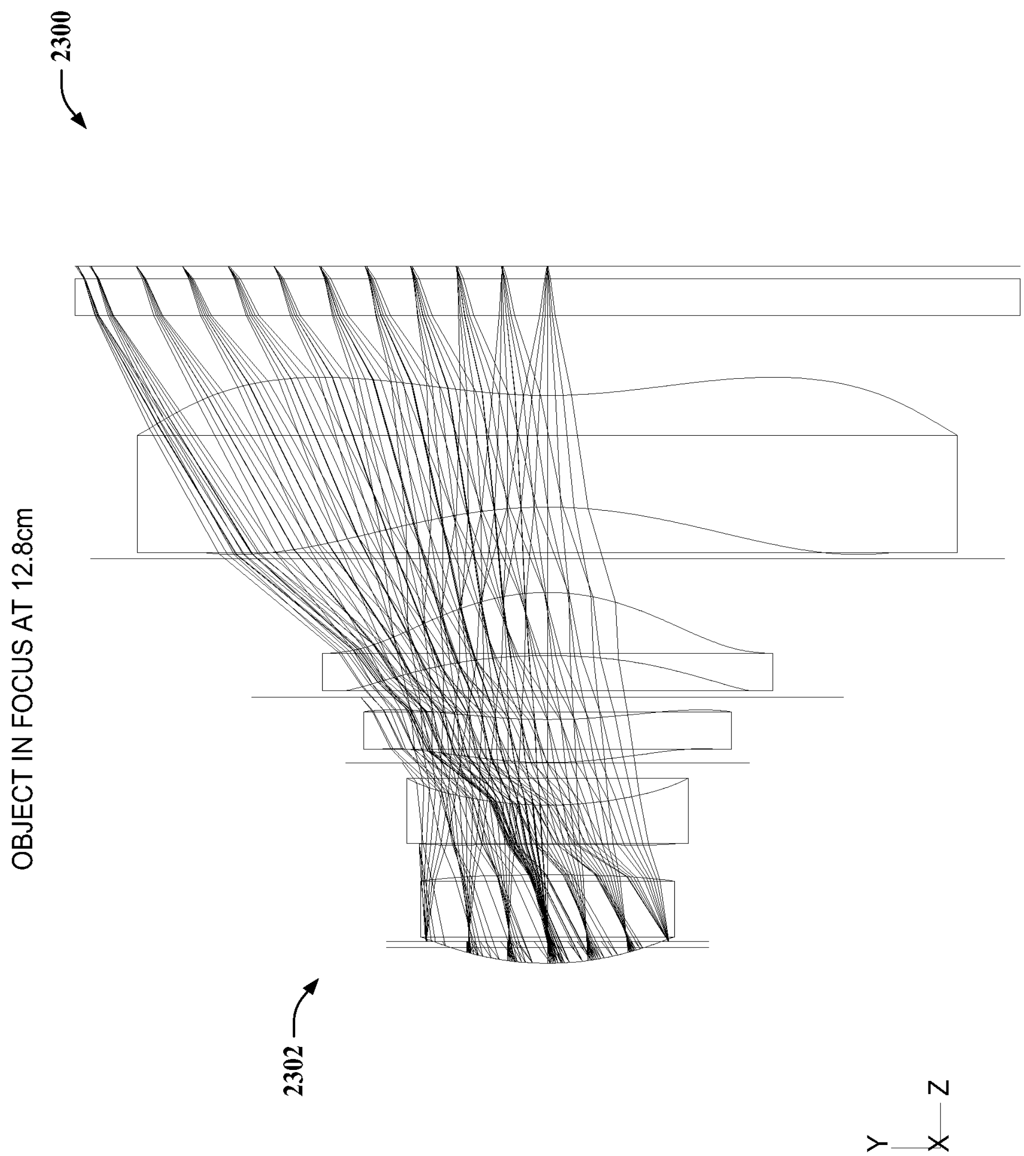



FIG. 23

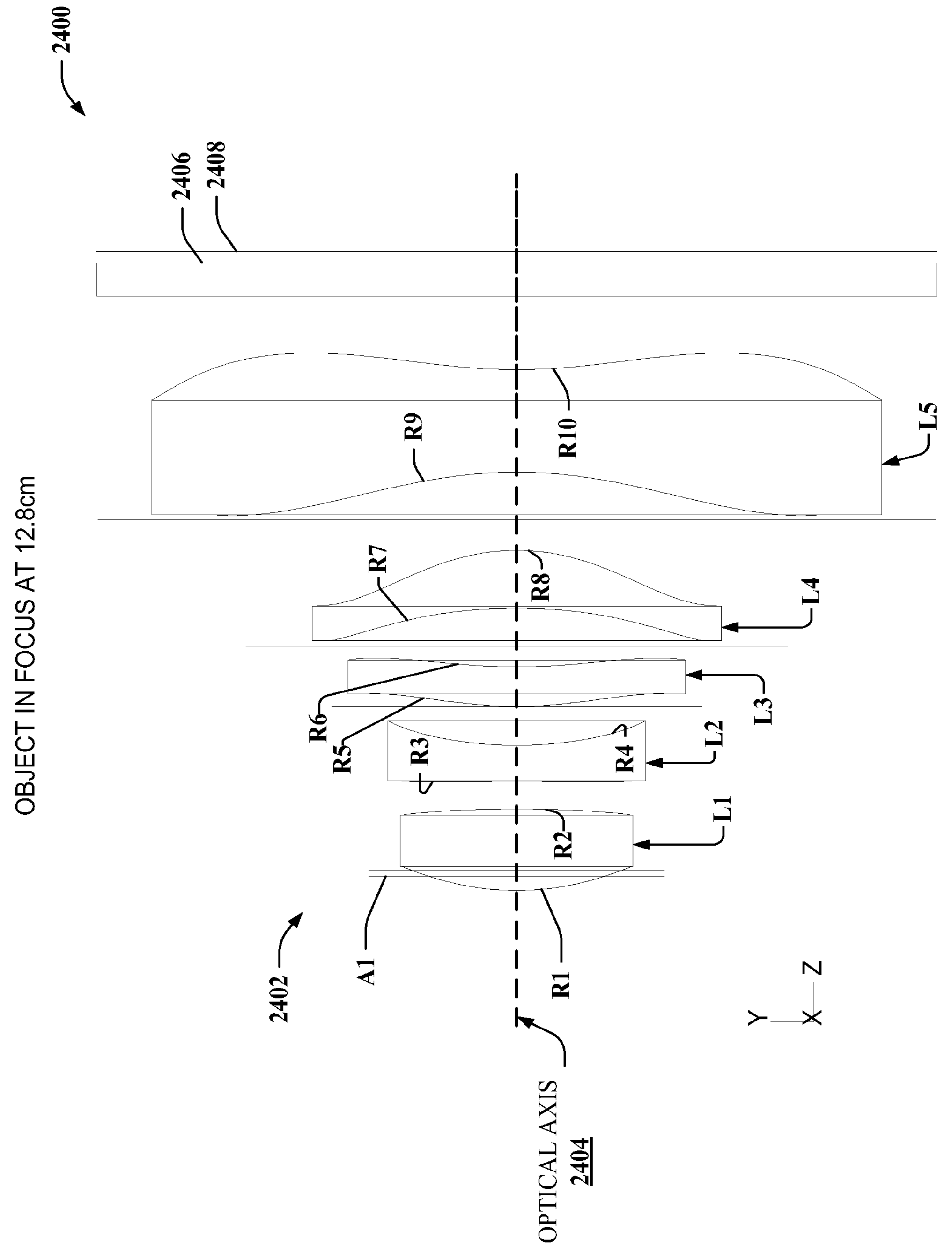

2400
2406
2408
OBJECT IN FOCUS AT 12.8cm
R9
R10
L5
R7
R8
L4
R6
R5
L3
R3
R4
L2
R2
L1
2402
A1
R1
Y
X
Z
OPTICAL AXIS
2404

FIG. 24

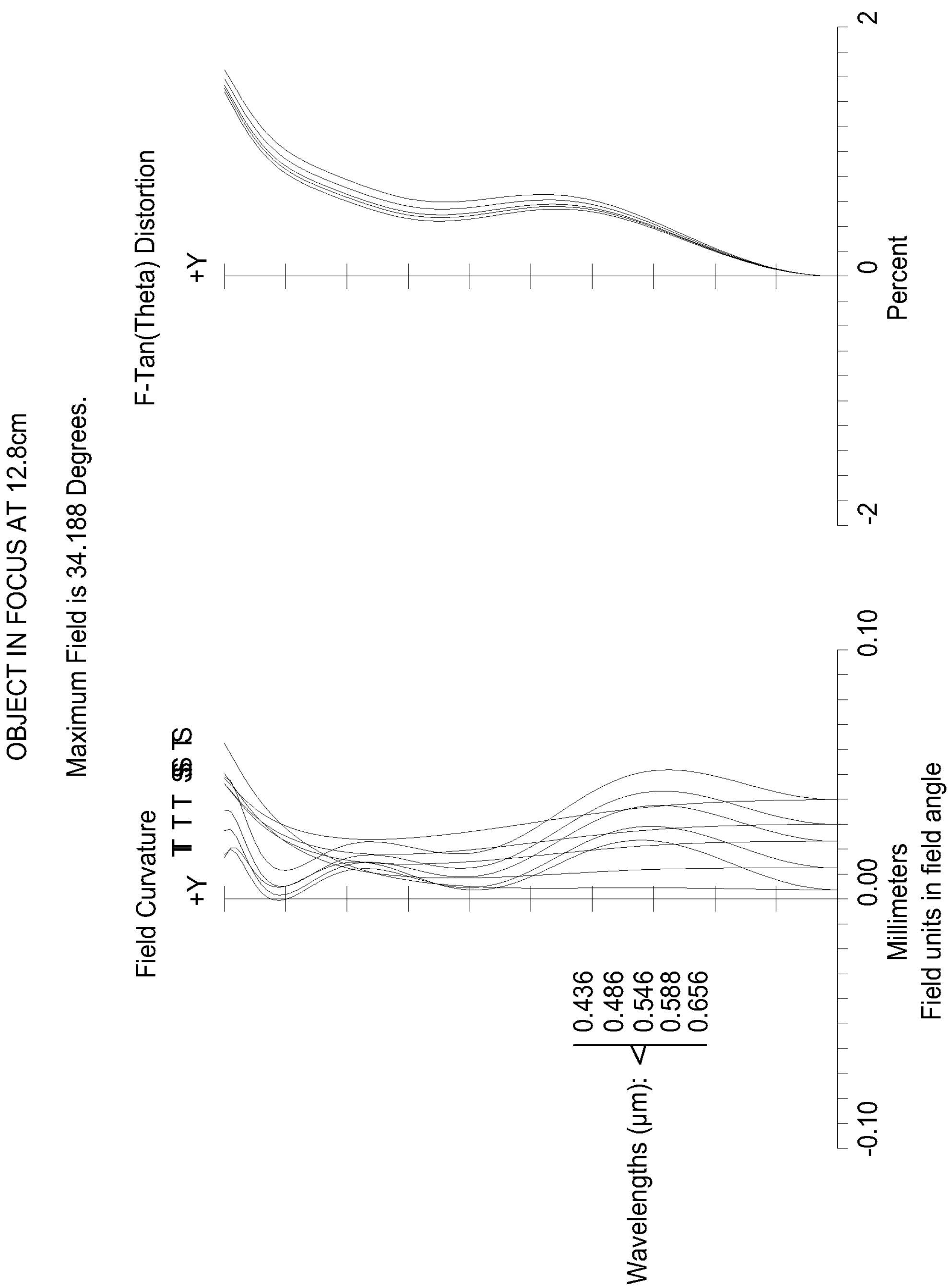

OBJECT IN FOCUS AT 12.8cm
Maximum Field is 34.188 Degrees.
Field Curvature
+Y
T T T S S S
-0.10
0.00
0.10
Millimeters
Field units in field angle
Wavelengths (μm):
0.436
0.486
0.546
0.588
0.656
F-Tan(Theta) Distortion
+Y
-2
0
2
Percent

FIG. 25

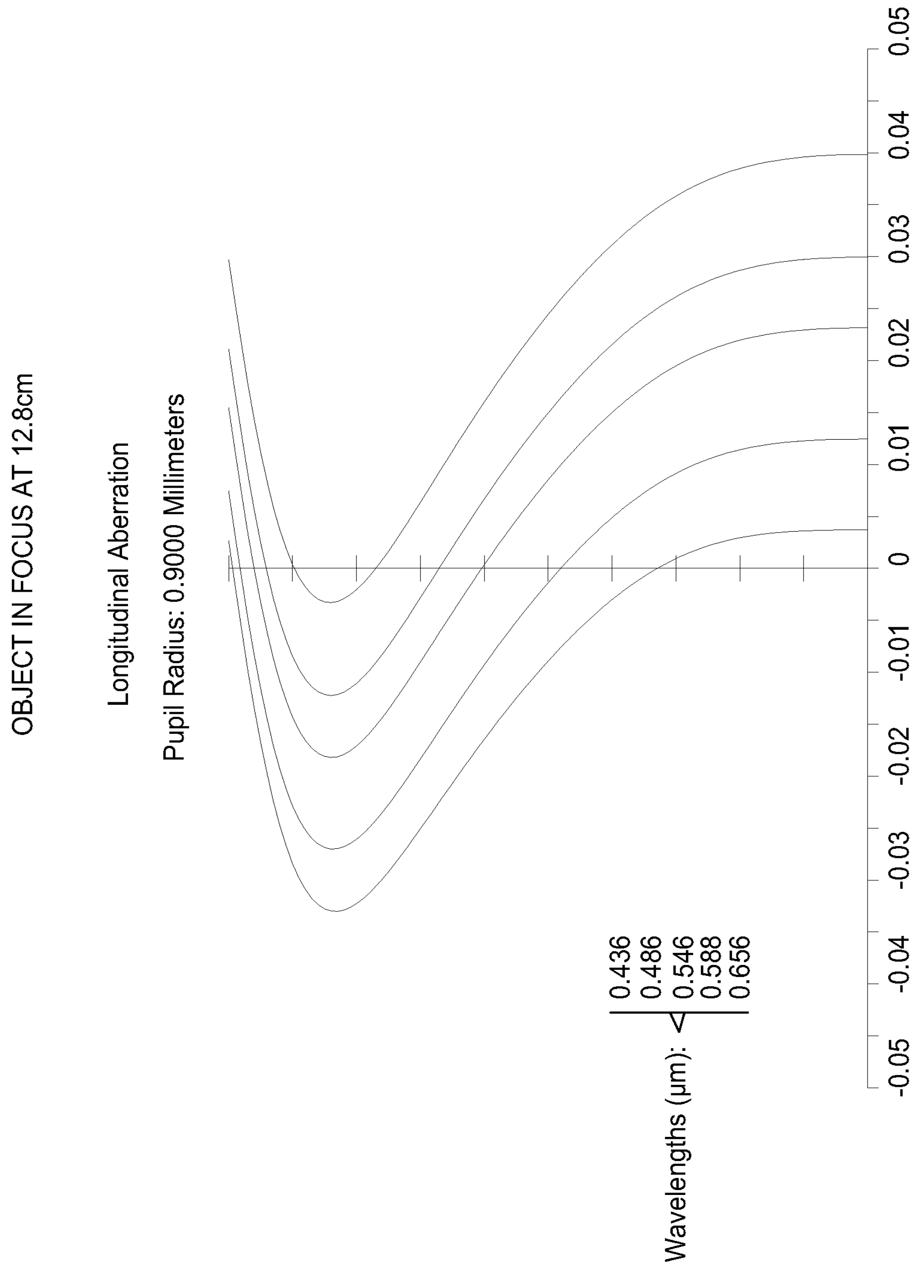

OBJECT IN FOCUS AT 12.8cm
Longitudinal Aberration
Pupil Radius: 0.9000 Millimeters
Wavelengths (µm):
0.436
0.486
0.546
0.588
0.656
-0.05
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05
Millimeters

FIG. 26

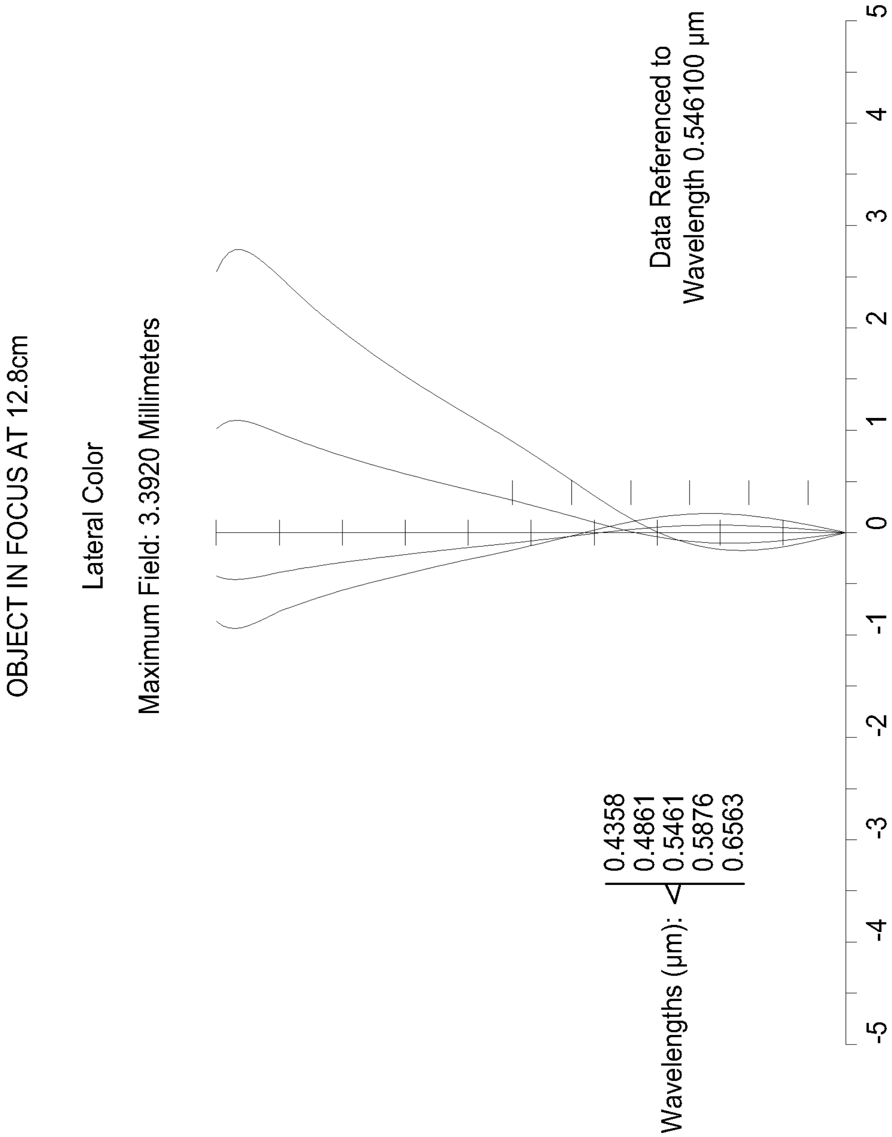

OBJECT IN FOCUS AT 12.8cm
Lateral Color
Maximum Field: 3.3920 Millimeters
Data Referenced to
Wavelength 0.546100 µm
Wavelengths (µm):
0.4358
0.4861
0.5461
0.5876
0.6563
-5
-4
-3
-2
-1
0
1
2
3
4
5
µm

FIG. 27

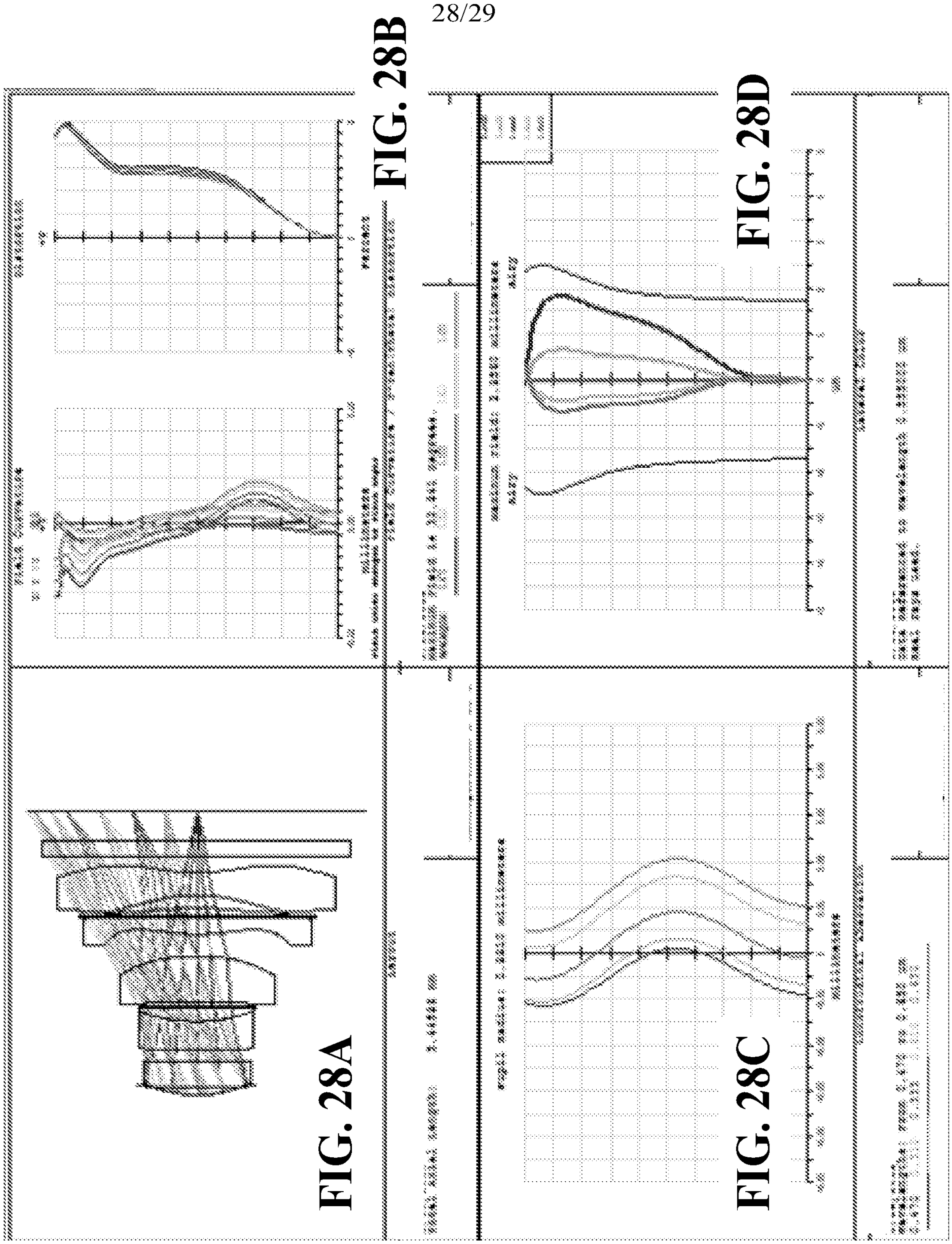


FIG. 28A

FIG. 28B

FIG. 28C

FIG. 28D

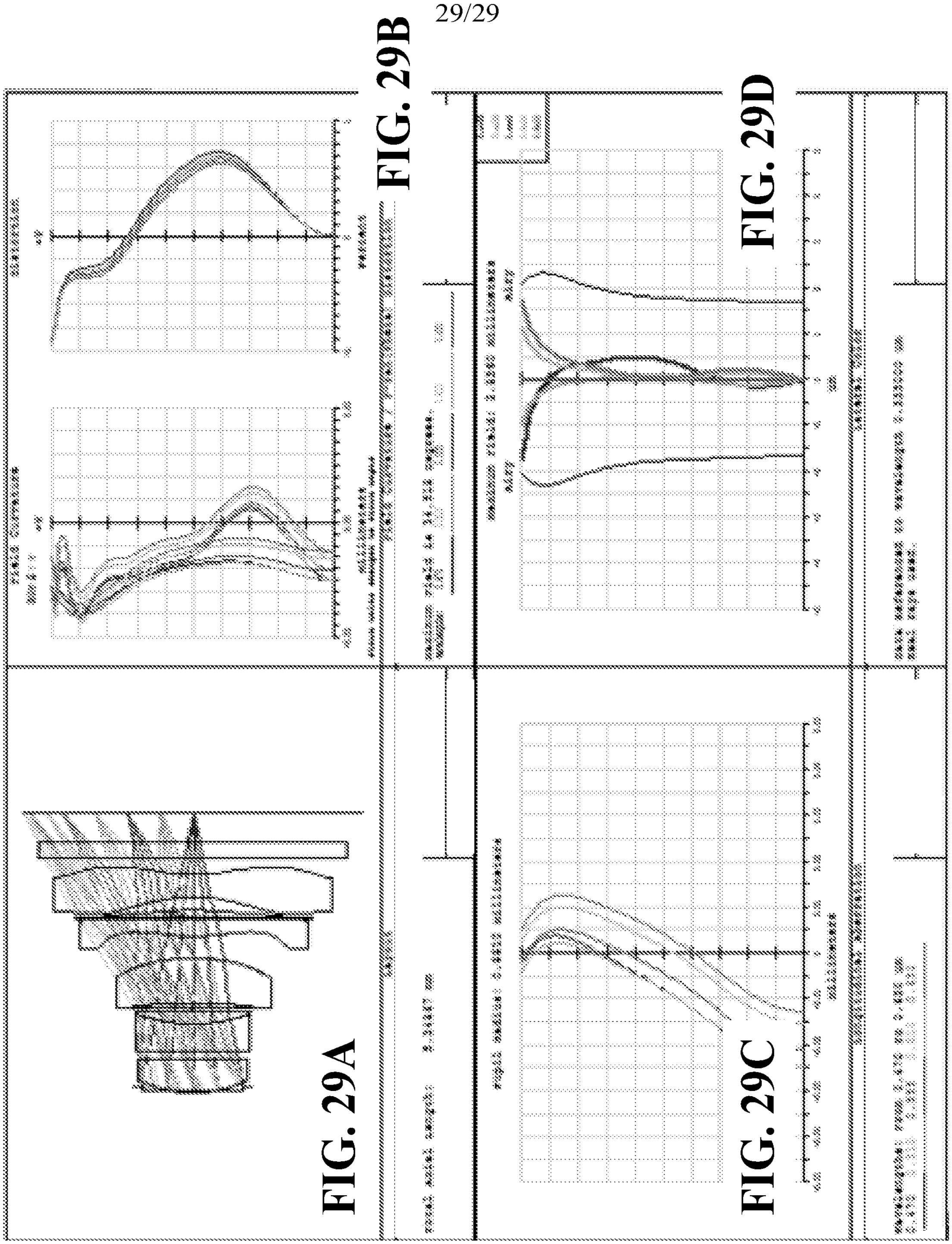


FIG. 29A

FIG. 29B

FIG. 29C

FIG. 29D

# INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/061668

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B13/00 H04N5/232
ADD.

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)
G02B H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | JP 2010 224521 A (KONICA MINOLTA OPTO INC) 7 October 2010 (2010-10-07) | 1,14-18 |
| Y | abstract; figure 5 | 6-13 |
| Y | US 5 598 299 A (HAYAKAWA) 28 January 1997 (1997-01-28) figure 1 | 6-13 |
| A | JP 2011 209554 A (Y. SHINOHARA) 20 October 2011 (2011-10-20) figures 4,11; tables 7,19 | 19-30 |
| X | JP 7 181389 A (MINOLTA CO LTD) 21 July 1995 (1995-07-21) abstract; figure 1 paragraph [0023] ; table 1 | 31-35, 40-42 |

☐ 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" documentwhich may throw doubts on priority claim(s) orwhich 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 |
|---|---|
| 14 March 2013 | 21/03/2013 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Michel , Alain |

4

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/061668

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos. :

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos. :

**Remark on Protest**

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

**FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210**

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-18

Claim 1 relates to an imaging system having two lens groups, five lenses and front-focusing carried out by a MEMS actuator. Claims 2-18 depend on claim 1.
The underlying problem to be solved is how to enable a small lens displacement during focusing.
The special feature is the first lens group comprising a biconvex object-side lens, the focal length of which being greater than half of the focal length of the whole imaging system.

---

2. claims: 19-30

Independent claim 19 relates to an optical system having five lenses, focusing being carried out by moving the first lens. Claims 20-30 depend on claim 19.
The underlying problem to be solved is how to reduce field curvature and distortion.
The special feature is the lens constitution of the optical system, the first and the fourth lenses being biconvex, the second and the fifth lenses being menisci and the third lens being concave-convex.

---

3. claims: 31-45

Independent claim 31 relates to an imaging system having two lens groups, the first lens group for focusing and consisting of two lenses and the second lens group having three lenses. Claims 32-45 depend on claim 31.
The underlying problem to be solved is how to reduce primary lateral colour.
The special feature is the second lens group comprising a fore-front lens being a meniscus that has a convex surface towards the object side.

---

# INTERNATIONAL SEARCH REPORT

**Information on patent family members**

**International application No**
PCT/US2012/061668

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| JP 2010224521 A | 07-10-2010 | CN 101819315 A | 01-09-2010 |
| | | JP 2010224521 A | 07-10-2010 |
| | | JP 2011138175 A | 14-07-2011 |
| | | US 2010220229 A1 | 02-09-2010 |
| US 5598299 A | 28-01-1997 | JP 3141681 B2 | 05-03-2001 |
| | | JP 7294853 A | 10-11-1995 |
| | | US 5598299 A | 28-01-1997 |
| JP 2011209554 A | 20-10-2011 | NONE | |
| JP 7181389 A | 21-07-1995 | NONE | |

Form PCT/ISA/210 (patent family annex) (April 2005)

# Optical lens


## Abstract

The invention relates to an optical lens which sequentially comprises a front lens group with positive focal power, a diaphragm element and a rear lens group with positive focal power from the object space to the image space. The front lens group sequentially comprises a first lens and a second lens from the object space to the image space. The first lens is a biconcave lens with negative focal power. The second lens is a biconvex lens with positive focal power. The rear lens group sequentially comprises a third lens, a fourth lens and a fifth lens from the object space to the image space. A gluing lens is formed by the third lens and the fourth lens. The fifth lens is an aspheric surface lens with positive focal power, and two concave faces of the fifth lens are in the same-direction crescent shape. According to the optical lens, high pixels, small deformation and large apertures can be achieved under the condition that the requirements for low cost and miniaturization are met, a perfect image can still be kept within the temperature range of -40 DEG C to 85 DEG C, and the optical lens is particularly suitable for monitors and vehicle-mounted camera systems which work in the day and at night or under a poor illumination condition.



CN104297906A

CN Application

Download PDF Find Prior Art Similar

**Other languages:** Chinese

**Inventor:** Yao Bo, Xie Qiansen, Yan Wenwei

**Original Assignee:** Ningbo Haoyu Vehicle Optical Technology Co., Ltd.

**Priority date :** 2014-10-20

Family: CN (3)

| Date | App/Pub Number | Status |
|---|---|---|
| 2014-10-20 | CN 201410559069 | |
| 2015-01-21 | CN104297906A | Application |
| 2015 | CN 201520812120 | |
| 2015 | CN 201510679740 | |

# Electronic Acknowledgement Receipt

| | |
|---|---|
| **EFS ID:** | 33783787 |
| **Application Number:** | 15976391 |
| **International Application Number:** | |
| **Confirmation Number:** | 1858 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Customer Number:** | 92342 |
| **Filer:** | Menachem Nathan |
| **Filer Authorized By:** | |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |
| **Receipt Date:** | 20-SEP-2018 |
| **Filing Date:** | 10-MAY-2018 |
| **Time Stamp:** | 16:55:57 |
| **Application Type:** | Utility under 35 USC 111(a) |

## Payment information:

| | |
|---|---|
| Submitted with Payment | no |

## File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 1 | Information Disclosure Statement (IDS) Form (SB08) | IDS_Lens.pdf | 615177<br>5970eff4807e59cc87a95eb3699716bbd461ed8e | no | 12 |

**Warnings:**

| | | | | | |
|---|---|---|---|---|---|
| **Information:** | | | | | |
| 2 | Transmittal Letter | IDS_TF.pdf | 277371<br>4a0ca72968a3700e4cf8cf920c96a16cda8d3cba | no | 2 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 3 | Foreign Reference | Lens_FR.pdf | 2602347<br>a3ba49b7753b9e70b0353fc6e285bb9106fab23c | no | 110 |
| **Warnings:** | | | | | |
| The page size in the PDF is too large. The pages should be 8.5 x 11 or A4. If this PDF is submitted, the pages will be resized upon entry into the Image File Wrapper and may affect subsequent processing | | | | | |
| **Information:** | | | | | |
| 4 | Non Patent Literature | Lens_Papers.pdf | 4681685<br>c8a8ad8853971fe9772d8b90d079b6f7005a1b30 | no | 48 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| **Total Files Size (in bytes):** | | | 8176580 | | |

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**<u>New Applications Under 35 U.S.C. 111</u>**
**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.**
**<u>National Stage of an International Application under 35 U.S.C. 371</u>**
**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.**
**<u>New International Application Filed with the USPTO as a Receiving Office</u>**
**If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.**

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

| | |
|---|---|
| In re Applicant: | § Confirmation No. 1858 |
| | § |
| Michael Dror | § |
| | § |
| Serial No.: 15/976,391 | |
| Title: MINIATURE TELEPHOTO LENS ASSEMBLY | |
| | § |
| Filed: 05/10/2018 | § |
| | § Attorney Docket: Coreph-0080 US CON4 |

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

PRELIMINARY AMENDMENT

Sir/Madam

Before substantive examination, Applicant respectfully requests the application be amended as follows:

IN THE CLAIMS:

Please amend the claims as follows:

1. (Original) A lens assembly, comprising: a plurality of lens elements arranged along an optical axis and spaced apart by respective spaces, wherein the lens assembly has an effective focal length (EFL), a total track length (TTL) of 6.5 millimeters or less and a ratio TTL/EFL < 1.0, wherein the plurality of lens elements includes, in order from an object side to an image side, a first group comprising lens elements $L_{1\_1}$, $L_{1\_2}$ and $L_{1\_3}$ with respective focal lengths $f_{1\_1}$, $f_{1\_2}$ and $f_{1\_3}$ and a second group comprising lens elements $L_{2\_1}$ and $L_{2\_2}$, wherein the first and second groups of lens elements are separated by a gap that is larger than twice any other gap between lens elements, wherein lens element $L_{1\_1}$ has positive refractive power and lens element $L_{1\_2}$ has negative refractive power and wherein lens elements $L_{2\_1}$ and $L_{2\_2}$ have opposite refractive powers.

2. (Original) The lens assembly of claim 1, wherein the TTL is equal or smaller than 6.0mm and wherein the lens assembly has a f-number F# < 2.9

3. (Original) The lens assembly of claim 1, wherein the TTL is equal or smaller than 6.0mm and wherein lens element $L_{1\_1}$ has an image-side surface diameter between 2.3mm and 2.5mm.

4. (Original) (Original) The lens assembly of claim 1, wherein $f_{1\_1}$<TTL/2.

5. (Original) The lens assembly of claim 1, wherein the lens assembly has a f-number F# < 2.9.

6. (Original) The lens assembly of claim 5, wherein lens element $L_{1\_1}$ has a concave image-side surface.

7. (Original) The lens assembly of claim 1, wherein the lens assembly has a f-number F# = 2.8

8. (Original) The lens assembly of claim 5, wherein lens element $L_{1\_1}$ has a convex image-side surface.

9. (Original) The lens assembly of claim 1, wherein $1.2x|f_{1\_3}| > 1.5xf_{1\_1}$.

10. (Original) The lens assembly of claim 1, wherein $1.2x|f_{1\_3}| > |f_{1\_2}| > 1.5xf_{1\_1}$.

11. (Original) The lens assembly of claim 1, wherein a combined power of lens elements $L_{1\_2}$ and $L_{1\_3}$ is negative.

12. (Original) The lens assembly of claim 1, wherein $L_{1\_3}$ has negative refractive power.

13. (Original) The lens assembly of claim 1, wherein the gap between lens elements $L_{2\_1}$ and $L_{2\_2}$ is smaller than $1.5xd_{2\_2}$, where $d_{2\_2}$ is a thickness of lens element $L_{2\_2}$ along the optical axis.

14. (Original) The lens assembly of claim 1, wherein lens elements $L_{2\_1}$ and $L_{2\_2}$ are separated by a gap smaller than TTL/20.

15. (Original) The lens assembly of claim 1, wherein $L_{2\_1}$ and $L_{2\_2}$ are made of different lens materials having different Abbe numbers, such that one lens element has Abbe number that is smaller than 30 and the other lens element has an Abbe number that is larger than 50.

16. (Original) The lens assembly of claim 2, wherein the lens assembly further includes a ratio between a largest optical axis thickness L11 and a circumferential edge thickness L1e of lens element $L_{1\_1}$ of L11/L1e < 3.

17. (Currently amended) A lens assembly, comprising a plurality of lens elements arranged along an optical axis and spaced apart by respective spaces, wherein the lens assembly has an effective focal length (EFL), wherein a lens system that includes the lens assembly plus a window positioned between the fifth lens element and an image plane has a total track length (TTL) of 6.5 millimeters or less, ~~and~~ wherein a ratio TTL/EFL < 1.0, wherein the plurality of lens elements includes, in order from an object side to an image side, a first group comprising lens elements $L_{1\_1}$, $L_{1\_2}$ and $L_{1\_3}$ with respective focal lengths $f_{1\_1}$,

$f_{1\_2}$ and $f_{1\_3}$, and a second group comprising lens elements $L_{2\_1}$ and $L_{2\_2}$, wherein lens element $L_{1\_1}$ has positive refractive power and lens element $L_{1\_2}$ has negative refractive power, wherein $1.2x|f_{1\_3}|>|f_{1\_2}|>1.5xf_{1\_1}$ and wherein lens elements $L_{2\_1}$ and $L_{2\_2}$ have opposite refractive powers.

18. (Original) The lens assembly of claim 17, wherein the TTL is equal or smaller than 6.0mm and wherein the lens assembly has a f-number F# < 2.9

19. (Original) The lens assembly of claim 17, wherein the TTL is equal or smaller than 6.0mm and wherein lens element $L_{1\_1}$ has an image-side surface diameter between 2.3mm and 2.5mm

20. (Original) The lens assembly of claim 17, wherein $f_{1\_1}$ < TTL/2.

21. (Original) The lens assembly of claim 17, wherein the lens assembly has a f-number F# < 2.9.

22. (Original) The lens assembly of claim 21, wherein lens element $L_{1\_1}$ has a concave image-side surface.

23. (Original) The lens assembly of claim 17, wherein the lens assembly has a f-number F# = 2.8

24. (Original) The lens assembly of claim 21, wherein lens element $L_{1\_1}$ has a convex image-side surface.

25. (Original) The lens assembly of claim 17, wherein a combined power of lens elements $L_{1\_2}$ and $L_{1\_3}$ is negative.

26. (Original) The lens assembly of claim 17, wherein $L_{1\_3}$ has negative refractive power.

27. (Original) The lens assembly of claim 17, wherein a gap between lens elements $L_{2\_1}$ and $L_{2\_2}$ is smaller than $1.5xd_5$, where $d_5$ is a thickness of lens element $L_{2\_2}$ along the optical axis.

28. (Original) The lens assembly of claim 17, wherein lens elements $L_{2\_1}$ and $L_{2\_2}$ are separated by a gap smaller than TTL/20.

29. (Original) The lens assembly of claim 17, wherein $L_{2\_1}$ and $L_{2\_2}$ are made of different lens materials having different Abbe numbers, such that one lens element has an Abbe number that is smaller than 30 and the other lens element has an Abbe number that is larger than 50.

30. (Original) The lens assembly of claim 18, wherein the lens assembly further includes a ratio between a largest optical axis thickness L11 and a circumferential edge thickness L1e of lens element $L_{1\_1}$ of $L11/L1e < 3$.

## REMARKS

This preliminary amendment amends independent claim 17 to better reflect the claimed subject matter. Support for the amendment may be found in FIGS. 1A, 2A and 3A that show the added recited "window" between the lens and an image plane, and in their description.

It is respectfully submitted that claims 1-30 are in condition for allowance. Prompt notice of allowance is respectfully and earnestly solicited.

Respectfully submitted,

/ Menachem Nathan /
Menachem Nathan
Agent for Applicant
Registration No. 65392

Date: August 3, 2018

# Electronic Acknowledgement Receipt

| | |
|---|---|
| **EFS ID:** | 33364569 |
| **Application Number:** | 15976391 |
| **International Application Number:** | |
| **Confirmation Number:** | 1858 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Customer Number:** | 92342 |
| **Filer:** | Menachem Nathan |
| **Filer Authorized By:** | |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |
| **Receipt Date:** | 03-AUG-2018 |
| **Filing Date:** | 10-MAY-2018 |
| **Time Stamp:** | 09:31:18 |
| **Application Type:** | Utility under 35 USC 111(a) |

## Payment information:

| | |
|---|---|
| Submitted with Payment | no |

## File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 1 | Preliminary Amendment | Preliminary_Amendment.pdf | 82048<br>e5ac896c64fc8fcbd76fb7e06f547c7026eb7760 | no | 6 |

**Warnings:**

| Information: | |
|---|---|
| Total Files Size (in bytes): | 82048 |

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

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

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

PTO/SB/06 (09-11)
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**PATENT APPLICATION FEE DETERMINATION RECORD**
Substitute for Form PTO-875

Application or Docket Number: 15/976,391
Filing Date: 05/10/2018
☐ To be Mailed

**ENTITY:** ☐ LARGE ☒ SMALL ☐ MICRO

## APPLICATION AS FILED – PART I

| FOR | NUMBER FILED (Column 1) | NUMBER EXTRA (Column 2) | 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 $ = | |
| INDEPENDENT CLAIMS (37 CFR 1.16(h)) | minus 3 = | * | X $ = | |
| ☐ 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

| AMENDMENT 08/03/2018 | CLAIMS REMAINING AFTER AMENDMENT (Column 1) | | HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2) | PRESENT EXTRA (Column 3) | RATE ($) | ADDITIONAL FEE ($) |
|---|---|---|---|---|---|---|
| Total (37 CFR 1.16(i)) | * 30 | Minus | ** 30 | = 0 | x $50 = | 0 |
| Independent (37 CFR 1.16(h)) | * 2 | Minus | ***3 | = 0 | x $230 = | 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** |

| AMENDMENT | CLAIMS REMAINING AFTER AMENDMENT (Column 1) | | HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2) | PRESENT EXTRA (Column 3) | RATE ($) | ADDITIONAL FEE ($) |
|---|---|---|---|---|---|---|
| Total (37 CFR 1.16(i)) | * | Minus | ** | = | X $ = | |
| Independent (37 CFR 1.16(h)) | * | Minus | *** | = | X $ = | |
| ☐ 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.
** 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 number found in the appropriate box in column 1.

LDRC
ANDREW JAMES JR

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.*

PTO/SB/08a (02-18)
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| **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** ( **Not for submission under 37 CFR 1.99)** | | |
|---|---|---|
| | Application Number | 15976391 |
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-0080 US CON4 |

## 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 | 3388956 | A | 1968-06-18 | Eggert et al. | |

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

## 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 |
|---|---|---|---|---|---|---|
| | 1 | | | | | |

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

## FOREIGN PATENT DOCUMENTS

| Examiner Initial* | Cite No | Foreign Document Number[3] | Country Code[2] i | Kind Code[4] | Publication Date | Name of Patentee or Applicant of cited Document | Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear | T[5] |
|---|---|---|---|---|---|---|---|---|
| | 1 | 1979003617 | JP | A | 1979-01-01 | Tsuji | | ☐ |

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## 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, pages(s), volume-issue number(s), publisher, city and/or country where published. | T[5] |
|---|---|---|---|

| INFORMATION DISCLOSURE STATEMENT BY APPLICANT ( Not for submission under 37 CFR 1.99) | Application Number | 15976391 |
|---|---|---|
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-0080 US CON4 |

| | | | |
|---|---|---|---|
| | 1 | | ☐ |

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**EXAMINER SIGNATURE**

| Examiner Signature | | Date Considered | |
|---|---|---|---|

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

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

| **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** ( **Not for submission under 37 CFR 1.99)** | Application Number | 15976391 |
|---|---|---|
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-0080 US CON4 |

**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 | /Menachem Nathan/ | Date (YYYY-MM-DD) | 2018-07-09 |
|---|---|---|---|
| Name/Print | MENACHEM NATHAN | Registration Number | 65392 |

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.**

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

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

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

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

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

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

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

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

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

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

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

PTO/AIA/15 (03-13)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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# UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

| | |
|---|---|
| Attorney Docket No. | COREPH-0080 US CON4 |
| First Named Inventor | Michael Dror |
| Title | MINIATURE TELEPHOTO LENS ASSEMBLY |
| Express Mail Label No. | |

## APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: **Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450**

1. ☐ **Fee Transmittal Form** (PTO/SB/17 or equivalent)
2. ☐ **Applicant asserts small entity status.** See 37 CFR 1.27
3. ☐ **Applicant certifies micro entity status.** See 37 CFR 1.29. Applicant must attach form PTO/SB/15A or B or equivalent.
4. ☐ **Specification** [Total Pages ______]
   Both the claims and abstract must start on a new page.
   *(See MPEP § 608.01(a) for information on the preferred arrangement)*
5. ☐ **Drawing(s)** (35 U.S.C. 113) [Total Sheets ______]
6. **Inventor's Oath or Declaration** [Total Pages ______]
   *(including substitute statements under 37 CFR 1.64 and assignments serving as an oath or declaration under 37 CFR 1.63(e))*
   a. ☐ Newly executed (original or copy)
   b. ☐ A copy from a prior application (37 CFR 1.63(d))
7. ☐ **Application Data Sheet** ** See note below.*
   See 37 CFR 1.76 (PTO/AIA/14 or equivalent)
8. **CD-ROM or CD-R**
   in duplicate, large table, or Computer Program (*Appendix*)
   ☐ Landscape Table on CD
9. **Nucleotide and/or Amino Acid Sequence Submission**
   (*if applicable, items a. – c. are required*)
   a. ☐ Computer Readable Form (CRF)
   b. ☐ Specification Sequence Listing on:
      i. ☐ CD-ROM or CD-R (2 copies); or
      ii. ☐ Paper
   c. ☐ Statements verifying identity of above copies

## ACCOMPANYING APPLICATION PAPERS

10. ☐ **Assignment Papers**
    (cover sheet & document(s))
    Name of Assignee ______
11. ☐ **37 CFR 3.73(c) Statement** (*when there is an assignee*) ☐ **Power of Attorney**
12. ☐ **English Translation Document** (*if applicable*)
13. ☑ **Information Disclosure Statement**
    (PTO/SB/08 or PTO-1449)
    ☑ Copies of citations attached
14. ☐ **Preliminary Amendment**
15. ☐ **Return Receipt Postcard**
    (*MPEP § 503*) (*Should be specifically itemized*)
16. ☐ **Certified Copy of Priority Document(s)**
    (*if foreign priority is claimed*)
17. ☐ **Nonpublication Request**
    Under 35 U.S.C. 122(b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent.
18. ☑ **Other:** Remarks - This is a supplemental IDS. Citation or identification of any reference in this IDS shall not be construed as an admission that such reference is available as prior art.

***Note**: (1) Benefit claims under 37 CFR 1.78 and foreign priority claims under 1.55 **must** be included in an Application Data Sheet (ADS).
(2) For applications filed under 35 U.S.C. 111, the application must contain an ADS specifying the applicant if the applicant is an assignee, person to whom the inventor is under an obligation to assign, or person who otherwise shows sufficient proprietary interest in the matter. See 37 CFR 1.46(b).

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| Name (Print/Type) | MENACHEM NATHAN | Registration No. (Attorney/Agent) | 65,392 |

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**JP,54-003617,B**

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## DETAILED DESCRIPTION

** The telephotographic objective ** Japanese-Patent-Application-No. 46-11866 [phase] application 46 [ Showa ]. (1971) March 8 public-presentation closed 47-22725@ Showa -- 47 (1972) October 9 @ inventor Sadahiko Tsuji -- Kawasaki ** hotel 80 ****** @ applicant CANON KABUSHIKI KAISHA 3-30-2, Shimo-maruko, Ota-ku, Tokyo [phase] representative patent attorney Katsuo Ando ** -- a scope of the claim -- 15 group composition -- the 1st group -- curvature -- size -- a convex. The 2nd group is a converging lens towards the object side, and a convergence meniscus lens which has separated and arranged slight air spacing to the 1st group. It is the diverging meniscus lens which turned to the object side the concave surface which the 3rd group received the divergent lens, and the 4th group received the 3rd group, and has separated and arranged big air spacing. The 5th group slight air spacing to the 4th group. separating to make the arranged converging lens -- focal distance [ of f:whole system ] r: -- in turn -- curvature-radius [ of each refracting interface ] d: -- in turn -- the axis top thickness of each lens, or air spacing N: -- refractive-index V: [ as opposed to d line of each lens constitution glass in turn ] -- in turn -- Abbe number [ of each lens constitution glass ] psi:, if it is the refracting power to the 3rd group from the 1st group. coming -- (1) O185 / 1.2/of f<psi f(2) 0.25 f<rl<f<dl[ 0.4f(3) 0.1 ] (4) O -- < -- a '/<1/2f(5) 0.15f field and +d2+d3+d4+d -- 5< 0.3f (6) -- 0<1/r -- The telephotographic objective with which it is satisfied of the terms and conditions of <1/2f(7)1-47<N1-N2<1.65<N3<1.75(8)50<**1.V2 <=61.27<V3<35.

the detailed description of the invention -- the present invention is the Seki SU ** at a compact telephotographic objective with a short overall length.

This kind of lens is increase of a zona-orbicularis spherical aberration and a zona-orbicularis coma aberration, when it is going to miniaturize. It is accompanied by defects, such as aggravation etc. of generating of the positive distortion aberration based on the spherical aberration correction excessive to short wavelength light, the **** curvature correction excessive on which a Petzval sum is based too little, and asymmetric structure, the aberration variation by object distance, especially astigmatism.

if an overall length is lengthened and it has symmetrical type composition, it can protect substantially, but these defects are spread good 1 as an interchangeable lens for miniature cameras -- there is nothing.

The present invention improves these points, is carried out without lengthening an overall length, corrects several aberration satisfactorily, makes change of the aberration by object distance small extremely, and is field angle 24degree' and a thing which aims to obtain an about F2.8 and about [ looking-far ratio 0.93 ] telephotographic objective, In the place by which it is characterized [ the ], the 1st group is [ size ] the converging lens which turned the becoming convex to the object side by 5 group composition. The 2nd group is a convergence NONISU dregs lens which has separated and arranged slight air spacing to the 1st group. As for the 3rd group, the 4th group is a divergent lens and the diverging meniscus lens which turned to the object side the concave surface which has separated and arranged big air spacing to the 3rd group. The 5th group considers it as the converging lens which has separated and arranged slight air spacing to the 4th group, f: focal distance [ of the whole system ] r: -- in turn -- curvature-radius [ of each refracting interface ] d: -- in turn -- the axis top thickness of each lens, or air spacing N: -- refractive-index **= [ as opposed to d line of each lens constitution glass in turn ] -- in turn -- Abbe number [ of each lens constitution glass ] psi:, if it is the refracting power to the 3rd group from the 1st group. Come and (1) 0.85/f<psi <1.2/f(2) 0.25 f<rl<0.4f(3) 0.1 f<dl(4) 0 ** 1/and 5<1/2f(5) 0.15 f<d1+d2+d3+d, + d5< 0.3f(6) O<1/<'/2f (7) The terms and conditions of 1.47<N1 and N2<1.65<N3<1.75(8)50<Vl and v2 <=61.27<V3<35 are satisfied.

In the present invention, the above-mentioned conditions (1), (2), and (3) are conditions of overall-length shortening.

(1) When the lower limit of a formula is exceeded, there is no overall-length shortening effect, if upper limit is exceeded, shortening of an overall length can be performed, but asymmetry becomes remarkable and it becomes difficult to correct it of several aberration.

If the lower limit of (2) types is exceeded, a spherical aberration and a coma aberration will enlarge, correction with a rear group will become difficult, and if upper limit is exceeded, the overall-length shortening effect will not be acquired.

(3) If this lower limit is exceeded although a formula is effective also in correction of the chromatic aberration of magnification, it cannot perform shortening of an overall length.

(4) A formula is a range which can correct a spherical aberration and a coma aberration, and it will become insufficient correcting it, if upper limit is exceeded and a spherical aberration will exceed a correction excessive next door and a lower limit.

(5) The conditions of a formula are useless conditions which keep a Petzval sum suitable on the basis of the conditions of (1), if the lower limit of this condition is exceeded, a Petzval sum will become excessive, and if upper limit is exceeded, they will become [ too little ].

(6) Formulas are the conditions of coma aberration correction of a distortion aberration and a pupil, if a lower limit is exceeded, a distortion aberration cannot be corrected, but when a lower limit is exceeded, change of the astigmatism at the time of the short-distance photographing by

the coma aberration of a pupil enlarges them.

(7) a formula -- the above -- terms and conditions -- imposing -- if -- a lens system -- setting -- a Petzval sum -- too little -- becoming -- a thing -- protecting -- uselessness -- a convex lens -- a refractive index -- a concave lens -- a refractive index -- low -- carrying out -- things -- the range -- limiting -- a thing -- it is -- this -- the range -- deviating -- if -- a Petzval sum -- too little -- becoming .

(8) Formulas are the conditions of the achromatism in this lens system, and if it deviates from this condition, achromatism will become difficult, and especially the lower limit of a second formula is important for preventing increase of a secondary chromatic aberration.

Next, the example of 1 numerical value of present invention enforcement is shown.

f=11:2.82 w= 240 overall length = 0.93 rl:o, 31245 d, =

0.12459N1=1.62041V1.-60.2r2=24.05484d2=0.004r3=0.30835d3=0.03099N221.58913V2=

61.0r4=Q -- 53555d4=0.03400r, =-3, 21278W1111111d, =

0.03485N5=1.71736V3=29.5r6=0.24769d6=0.27499r7=0.18235d7=0.03000N4=1.58913V4

=61.0r81:0.31186d8=0.00200r, = The Di Dell aberration coefficient of the above-mentioned

Example is shown in 3.31487d9-0.03650N5-1.72342V5=37.9r1o=-0, 53436psi20.91d1+d2+d,

and +d4+d the 5= 0.2284th table.

l11111IPV7.7465-0.90490.10571.2254-0.15553.8057-3.61723.4380-0.0159-3.2525-0.2662-

0.3294-0.40761.20230.98332.9940-3.27383.

5797-0.5833-3.2764-12.23338.8352-6.3809-0.13004.7023-0.0044-0.0037-0.0031-1.6864-1 .4109-3.2031-0.2973-0.0276-2.0331-0.19120.

5282-0.26020.12821.1888-0.64891.00980.0712-0.51680.12662.83070.8348-0.26910.08680 .7855-0.28120.1923-0.04920.00240.0799-0. 7003 Fig. 2 and Fig. 3 are aberration figures in the above-mentioned Example, and each aberration is especially corrected satisfactorily and is understood [ in / Fig. 2 can be set in infinite distance distance, and / in Fig. 3 / a 10-f short distance ] that the amounts of aberration variations are very few also in a short distance.

Easy description Fig. 1 of Drawings is set to the configuration diagram of one Example of a present invention lens, Fig. 2 is set in the Example same as the above, and the ****** figure in infinite distance distance and Fig. 3 are aberration figures in the short distance of]Of in an Example same as the above.

[Phase] Cited document JP,44-13678,B JP,45-35742,B rl111111

| Electronic Acknowledgement Receipt | |
|---|---|
| **EFS ID:** | 33117417 |
| **Application Number:** | 15976391 |
| **International Application Number:** | |
| **Confirmation Number:** | 1858 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Customer Number:** | 92342 |
| **Filer:** | Menachem Nathan |
| **Filer Authorized By:** | |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |
| **Receipt Date:** | 09-JUL-2018 |
| **Filing Date:** | 10-MAY-2018 |
| **Time Stamp:** | 11:34:26 |
| **Application Type:** | Utility under 35 USC 111(a) |

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| | Application Number | 15976391 |
| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-080 US CON4 |

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| | Filing Date | | 2018-05-10 |
| | First Named Inventor | Michael Dror | |
| | Art Unit | | |
| | Examiner Name | | |
| | Attorney Docket Number | | COREPH-080 US CON4 |

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| **INFORMATION DISCLOSURE STATEMENT BY APPLICANT**<br>**( Not for submission under 37 CFR 1.99)** | Application Number: 15976391<br>Filing Date: 2018-05-10<br>First Named Inventor: Michael Dror<br>Art Unit:<br>Examiner Name:<br>Attorney Docket Number: COREPH-080 US CON4 |

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| | Filing Date | 2018-05-10 |
| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-080 US CON4 |

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|---|---|---|
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| | First Named Inventor | Michael Dror |
| | Art Unit | |
| | Examiner Name | |
| | Attorney Docket Number | COREPH-080 US CON4 |

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| | Application Number | 15976391 |
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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 | /Menachem Nathan/ | Date (YYYY-MM-DD) | 2018-06-28 |
|---|---|---|---|
| Name/Print | MENACHEM NATHAN | Registration Number | 65392 |

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

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

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

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

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

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

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

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PTO/AIA/15 (03-13)
Approved for use through 01/31/2014. OMB 0651-0032
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# UTILITY PATENT APPLICATION TRANSMITTAL

*(Only for new nonprovisional applications under 37 CFR 1.53(b))*

| | |
|---|---|
| *Attorney Docket No.* | COREPH-0080 US CON4 |
| *First Named Inventor* | Michael Dror |
| *Title* | MINIATURE TELEPHOTO LENS ASSEMBLY |
| *Express Mail Label No.* | |

## APPLICATION ELEMENTS

*See MPEP chapter 600 concerning utility patent application contents.*

*ADDRESS TO:* **Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450**

1. ☐ **Fee Transmittal Form** (PTO/SB/17 or equivalent)
2. ☐ **Applicant asserts small entity status.** See 37 CFR 1.27
3. ☐ **Applicant certifies micro entity status.** See 37 CFR 1.29. Applicant must attach form PTO/SB/15A or B or equivalent.
4. ☐ **Specification** [*Total Pages* ______] Both the claims and abstract must start on a new page. *(See MPEP § 608.01(a) for information on the preferred arrangement)*
5. ☐ **Drawing(s)** (35 U.S.C. 113) [*Total Sheets* ______]
6. **Inventor's Oath or Declaration** [*Total Pages* ______] *(including substitute statements under 37 CFR 1.64 and assignments serving as an oath or declaration under 37 CFR 1.63(e))*
   a. ☐ Newly executed (original or copy)
   b. ☐ A copy from a prior application (37 CFR 1.63(d))
7. ☐ **Application Data Sheet** ** See note below.* See 37 CFR 1.76 (PTO/AIA/14 or equivalent)
8. **CD-ROM or CD-R** in duplicate, large table, or Computer Program (*Appendix*)
   ☐ Landscape Table on CD
9. **Nucleotide and/or Amino Acid Sequence Submission** (*if applicable, items a. – c. are required*)
   a. ☐ Computer Readable Form (CRF)
   b. ☐ Specification Sequence Listing on:
      i. ☐ CD-ROM or CD-R (2 copies); or
      ii. ☐ Paper
   c. ☐ Statements verifying identity of above copies

## ACCOMPANYING APPLICATION PAPERS

10. ☐ **Assignment Papers** (cover sheet & document(s)) Name of Assignee ______
11. ☐ **37 CFR 3.73(c) Statement** (*when there is an assignee*) ☐ **Power of Attorney**
12. ☐ **English Translation Document** (*if applicable*)
13. ☑ **Information Disclosure Statement** (PTO/SB/08 or PTO-1449)
    ☑ Copies of citations attached
14. ☐ **Preliminary Amendment**
15. ☐ **Return Receipt Postcard** (*MPEP § 503*) (*Should be specifically itemized*)
16. ☐ **Certified Copy of Priority Document(s)** (*if foreign priority is claimed*)
17. ☐ **Nonpublication Request** Under 35 U.S.C. 122(b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent.
18. ☑ **Other:** Remarks - This is an IDS. Citation or identification of any reference in this IDS shall not be construed as an admission that such reference is available as prior art.

***Note**: (1) Benefit claims under 37 CFR 1.78 and foreign priority claims under 1.55 **must** be included in an Application Data Sheet (ADS).
(2) For applications filed under 35 U.S.C. 111, the application must contain an ADS specifying the applicant if the applicant is an assignee, person to whom the inventor is under an obligation to assign, or person who otherwise shows sufficient proprietary interest in the matter. See 37 CFR 1.46(b).

## 19. CORRESPONDENCE ADDRESS

☑ The address associated with Customer Number: 92342 **OR** ☐ Correspondence address below

| | | | | | |
|---|---|---|---|---|---|
| Name | | | | | |
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| City | | State | | Zip Code | |
| Country | | Telephone | | Email | |

| | | | |
|---|---|---|---|
| Signature | /Menachem Nathan/ | Date | 07-03-2018 |
| Name (Print/Type) | MENACHEM NATHAN | Registration No. (Attorney/Agent) | 65,392 |

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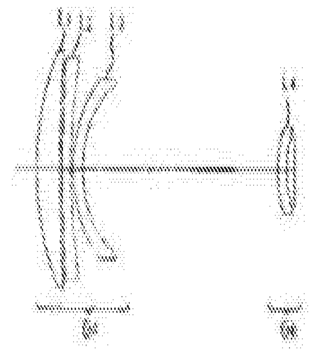
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

(11)Publication number : 07-113952
(43)Date of publication of application : 02.05.1995
(51)Int.Cl. : G02B 13/14

(21)Application number : 05-260573
(22)Date of filing : 19.10.1993
(71)Applicant : NIKON CORP
(72)Inventor : KOYAMA MOTOO
KODAMA NAOKO



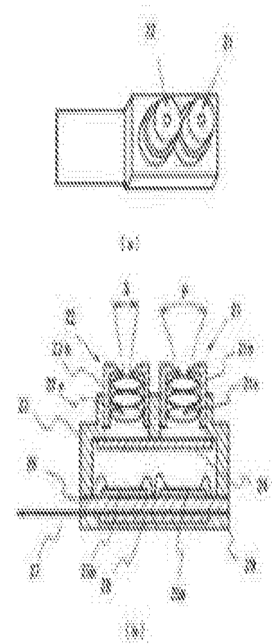
## (54)OPTICAL SYSTEM FOR INFRARED RAY


### (57)Abstract

PURPOSE: To excellently compensate chromatic aberration over almost the whole regions of infrared wavelengths below 3μm, to have large aperture ratio and to excellently compensate aberrations over the whole screen.
CONSTITUTION: Looking from the object side, the system has a front group GF and a rear group GR of positive refractive powers, the front group GF has a first lens component L1 of positive refractive power, a second lens component L2 of negative refractive power and a third lens component L3 of negative refractive power. By representing the focal distance of the whole system by (f), the focal distance of the third lens component L3 by f3, the refractive index of glass composing the third lens component L3 by n2, the conditions -8f<f3<-3f, n3<1.8 and v3<50 are satisfied, where, v3 is a value defined by n3=(ny-1)/(nz-nx) when the refractive indice for 3μm, 2μm and 1μm are represented by nx, ny nz, respectively.

(11)Publication number : 2007-306282
(43)Date of publication of application : 22.11.2007
(51)Int.Cl. : H04N 5/225 (2006.01)
H04N 5/335 (2006.01)
H01L 27/14 (2006.01)
G03B 19/06 (2006.01)
G03B 19/07 (2006.01)
G03B 17/12 (2006.01)

(21)Application number : 2006-132321
(22)Date of filing : 11.05.2006
(71)Applicant : CITIZEN ELECTRONICS CO LTD
(72)Inventor : KAYANUMA YASUAKI



# (54)CAMERA MODULE


## (57)Abstract

PROBLEM TO BE SOLVED: To provide a thin camera module that can selectively obtain images of different magnifications, and is suitable to portable equipment.

SOLUTION: The camera module comprises a plurality of lens units 21, 22 having different focal lengths, image sensor chips 25a and 25b which process imaging signals based upon light made incident through the lens units, and a selecting means of selecting the light made incident through the plurality of lens units and imaging signals based upon the light. This selecting means is operative to select light made incident through one of the plurality of lens units or an imaging signal based upon the light.

(11)Publication number : 2008-064884

(43)Date of publication of application : 21.03.2008

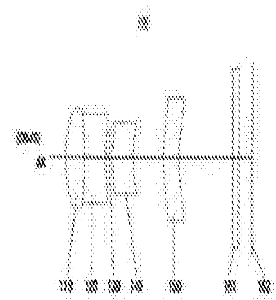
(51)Int.Cl. : G02B 13/18 (2006.01)

(21)Application number : 2006-240631

(22)Date of filing : 05.09.2006

(71)Applicant : KYOCERA CORP

(72)Inventor : KOISHI TOMOFUMI
OHARA NAOTO



## (54)IMAGING LENS

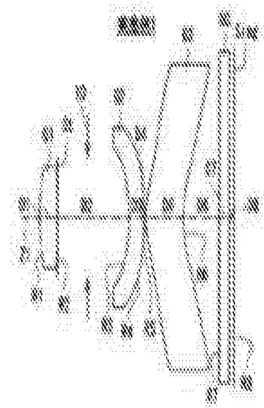

(57)Abstract

PROBLEM TO BE SOLVED: To provide an imaging lens designed so that an aberration is satisfactorily corrected and an optical characteristic is excellent in an optical system that has a small size and a narrow view angle.

SOLUTION: The imaging lens includes, in order from the object side: a first lens group having main refractive power; an aperture diaphragm; and a second lens group having refractive power lower than the first lens group. The imaging lens satisfies following conditional formulas: (1) $|f/fi|<0.50$; and (2) $0.85<TL/f<1.1$, wherein f represents the focal distance of the entire system; fi (i=1, 2, and so on) represents the focal distance of i-th lens from the object side; and TL represents the entire length of a lens system from the aperture diaphragm to an image face.

(11)Publication number : 2008-122900
(43)Date of publication of application : 29.05.2008
(51)Int.Cl. : G02B 13/00 (2006.01)
G02B 13/18 (2006.01)

(21)Application number : 2007-068160
(22)Date of filing : 16.03.2007
(71)Applicant : FUJINON CORP
(72)Inventor : SATO KENICHI
TANIYAMA MINORU



(30)Priority

| | | | | | |
|---|---|---|---|---|---|
| Priority number : | 2006094540 | Priority date : | 30.03.2006 | Priority country : | JP |
| | 2006285908 | | 20.10.2006 | | JP |

# (54)IMAGING LENS

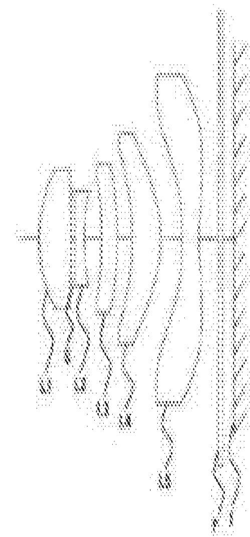

## (57)Abstract

PROBLEM TO BE SOLVED: To provide a compact and high-performance imaging lens where an internal space for arranging a shutter mechanism is sufficiently secured while maintaining high aberration performance coping with high pixelation.

SOLUTION: The imaging lens includes: a first lens G1 which has a biconvex shape in a vicinity of an optical axis; a second lens G2 which has a concave surface facing an object side and has negative refractive power; and a third lens G3 which has a positive or negative meniscus shape containing, in the vicinity of the optical axis, a convex surface facing the object side in order from the object side. The following conditional expressions are satisfied. (1) $0.7<f1/f<1.3$, (2) $0.2\leq D2/f<0.5$, where f denotes the focal length of the entire system, f1 denotes the focal length of the first lens G1 and D2 denotes an interval on the optical axis Z1 between the first lens G1 and the second lens G2.

(11)Publication number : 2011-138175
(43)Date of publication of application : 14.07.2011
(51)Int.Cl. : G02B 13/00 (2006.01)
G02B 13/18 (2006.01)

(21)Application number : 2011-089935
(22)Date of filing : 14.04.2011
(71)Applicant : KONICA MINOLTA OPTO INC
(72)Inventor : SANO EIGO



(30)Priority

| | | |
|---|---|---|
| Priority number : 2009045802 | Priority date : 27.02.2009 | Priority country : JP |

# (54)IMAGE PICKUP LENS, IMAGE PICKUP DEVICE AND MOBILE TERMINAL


(57)Abstract

PROBLEM TO BE SOLVED: To provide an image pickup lens composed of five lenses of which various aberrations are favorably corrected though being smaller than past types, an image pickup device including the image pickup lens, and also to provide a mobile terminal.

SOLUTION: As the value of a conditional expression (1) is smaller than the upper limit, the refractive power of the first lens is maintained at a moderate level, the synthetic main points of the first to fourth lenses are arranged to an object side, and the total length of the image pickup lens is reduced. Meanwhile, as the value is larger than the lower limit, the refractive power of the first lens is prevented from becoming larger than necessary, and the high-order spherical aberration or coma aberration generated in the first lens are suppressed.

Espacenet

# Bibliographic data: JP2013106289 (A) — 2013-05-30

## IMAGING APPARATUS

| | |
|---|---|
| **Inventor(s):** | KONNO KENJI; MATSUZAKA KEIJI; YAMADA KEIKO + (KONNO KENJI, ; MATSUZAKA KEIJI, ; YAMADA KEIKO) |
| **Applicant(s):** | KONICA MINOLTA ADVANCED LAYERS + (KONICA MINOLTA ADVANCED LAYERS INC) |
| **Classification:** | **- international:** ***G02B13/00; G02B13/18; G02B15/00; G03B19/07; H04N5/225; H04N5/228; H04N5/232*** <br> **- cooperative:** |
| **Application number:** | JP20110250322 20111116 Global Dossier |
| **Priority number (s):** | JP20110250322 20111116 |
| **Also published as:** | JP5741395 (B2) |


**Abstract of JP2013106289 (A)**

PROBLEM TO BE SOLVED: To provide high image quality with high resolution for an entire wide variable power region. ;SOLUTION: An imaging apparatus includes first and second imaging optical systems LN1 and LN2 with single focus, which look the same direction. A focal length of the second imaging optical system LN2 is longer than that of the first imaging optical system LN1. Zooming is performed from a wide angle end to an intermediate focal length state with an electronic zoom by segmentation of an image obtained in the first imaging optical system LN1, and zooming is performed from the intermediate focal length state to a telescopic end with an electronic zoom by segmentation of an image obtained in the second imaging optical system. Thus, zooming from the wide angle end to the telescopic end is performed as a whole.; Both the first and second imaging optical systems LN1 and LN2 consist of four or more lenses of first lenses of positive power and second lenses of negative power in order from an object side, the lenses nearest to the image side are negative lenses, composite focal lengths of the first lenses and the second lenses are positive and they satisfy a conditional expression :1.0<fFw/fFm<1.5. ;COPYRIGHT: (C) 2013,JPO&INPIT;PROBLEM TO BE SOLVED: To provide high image quality with high resolution for an entire wide variable power region.SOLUTION: An imaging apparatus includes first and second imaging optical systems LN1 and LN2 with single focus, which look the same direction. A focal length of the second imaging optical system LN2 is longer than that of the first imaging optical system LN1. Zooming is performed from a wide angle end to an intermediate focal length state with an electronic zoom by segmentation of an image obtained in the first imaging optical system LN1, and zooming is performed from the intermediate focal length state to a telescopic end with

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an electronic zoom by segmentation of an image obtained in the second imaging optical system. Thus, zooming from the wide angle end to the telescopic end is performed as a whole.; Both the first and second imaging optical systems LN1 and LN2 consist of four or more lenses of first lenses of positive power and second lenses of negative power in order from an object side, the lenses nearest to the image side are negative lenses, composite focal lengths of the first lenses and the second lenses are positive and they satisfy a conditional expression :$1.0 < fFw/fFm < 1.5$.



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(19)日本国特許庁(JP)　(12)**公開特許公報(A)**　(11)特許出願公開番号
**特開2013-106289**
**(P2013-106289A)**
(43)公開日　**平成25年5月30日(2013.5.30)**

| (51) Int.Cl. | | | F I | | | テーマコード（参考） |
|---|---|---|---|---|---|---|
| ***H04N*** | ***5/228*** | ***(2006.01)*** | H04N | 5/228 | Z | 2H054 |
| ***H04N*** | ***5/225*** | ***(2006.01)*** | H04N | 5/225 | Z | 2H087 |
| ***G02B*** | ***13/00*** | ***(2006.01)*** | G02B | 13/00 | | 5C122 |
| ***G02B*** | ***15/00*** | ***(2006.01)*** | G02B | 15/00 | | |
| ***G02B*** | ***13/18*** | ***(2006.01)*** | G02B | 13/18 | | |

審査請求 未請求　請求項の数 10　ＯＬ　（全 26 頁）　最終頁に続く

(21) 出願番号　特願2011-250322 (P2011-250322)
(22) 出願日　平成23年11月16日 (2011.11.16)

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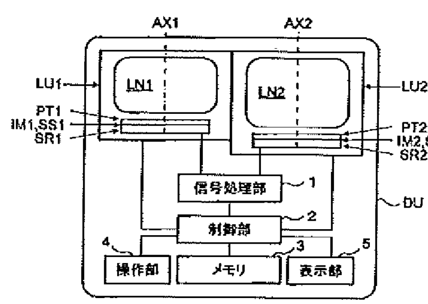
最終頁に続く

(54) 【発明の名称】撮像装置

(57) 【要約】　（修正有）
【課題】広変倍域すべてにわたって高解像度で高画質の画像を得る。
【解決手段】同一方向を向いた単焦点の第１，第２撮像光学系ＬＮ１，ＬＮ２を有し、第２撮像光学系ＬＮ２の焦点距離が第１撮像光学系ＬＮ１の焦点距離よりも長く、第１撮像光学系ＬＮ１で得られた画像の切り出しによる電子ズームで広角端から中間焦点距離状態までのズーミングを行い、前記第２撮像光学系で得られた画像の切り出しによる電子ズームで中間焦点距離状態から望遠端までのズーミングを行うことにより、全体として広角端から望遠端までのズーミングを行う。第１，第２撮像光学系ＬＮ１，ＬＮ２のいずれもが、物体側から順に、正パワーの第１レンズと、負パワーの第２レンズと、を有する４枚以上のレンズから成るとともに、最も像側のレンズが負レンズであり、第１レンズと第２レンズの合成焦点距離が正であり、条件式：１．０＜ｆＦｗ／ｆＦｍ＜１．５を満足する。
【選択図】図２１



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## Imaging Lens and Camera Moudule including the same
촬상 렌즈 및 이를 포함하는 카메라 모듈

Unexam. Full Text | Publ. Full Text | Regist. Details | Administrative

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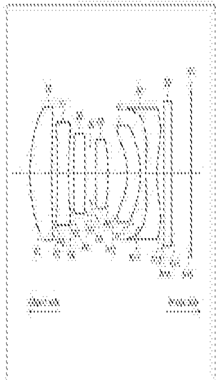

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|---|---|
| (51) Int. Cl. | G02B 9/62(2006.01.01) G02B 13/18(2006.01.01) G02B 1/04(2006.01.01) |
| (52) CPC | G02B 9/62(2013.01) G02B 13/0045(2013.01) G02B 13/18(2013.01) G02B 1/041(2013.01) G02B 5/28(2013.01) |
| (21) Application No.(Date) | 1020080099407 (2008.10.10) |
| (71) Applicant | LG INNOTEK CO., LTD. |
| (11) Registration No.(Date) | 1014999690000 (2015.03.02) |
| (65) Unex. Pub. No.(Date) | 1020100040357 (2010.04.20) |
| (11) Publication No.(Date) | (2015.03.13) |
| (86) Int'l Application No.(Date) | |
| (87) Int'l Unex. Pub. No.(Date) | |
| (30) Priority info (Country / No. / Date) | |
| Legal Status | Registered |
| Examination Status | Decision to grant (General) |
| Trial Info | |
| Kind/Right of Org. Application | New Application / |
| Right of Org. Application No.(Date) | |
| Related Application No. | 1020140163368 |
| Request for an examination(Date) | Y(2013.10.04) |
| Number of examination claims | 14 |

PURPOSE: An imaging lens is provided to improve aberration property by using a sixth lens having more than one point of inflection of aspherical curved plane. CONSTITUTION: A pick-up lens a first lens(10), a second lens(20), a third lens(30), a fourth lens(40), a fifth lens(50), and a sixth lens(60). The first lens has a positive power. A second lens has a negative power. The third lens has a positive power. The fourth lens has a positive power. The fifth lens has a negative power. The sixth lens has a negative power. An iris(35) is interposed between the third lens and the fourth lens.
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Photographic lens optical system
촬영 렌즈 광학계

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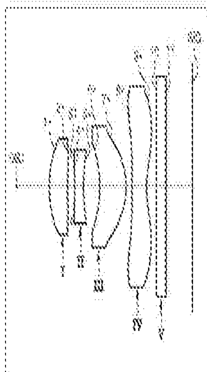

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|---|---|
| (51) Int. CL. | G02B 9/34(2006.01.01) G02B 13/18(2006.01.01) G02B 5/00(2006.01.01) G02B 1/04(2006.01.01) |
| (52) CPC | G02B 9/34(2013.01) G02B 13/004(2013.01) G02B 13/18(2013.01) G03B 9/02(2013.01) G02B 1/041(2013.01) H04N 5/2254(2013.01) |
| (21) Application No.(Date) | 1020090038791 (2009.05.01) |
| (71) Applicant | KOLEN CO., LTD. |
| (11) Registration No.(Date) | 1010578300000 (2011.09.20) |
| (65) Unex. Pub. No.(Date) | 1020100119373 (2010.11.10) |
| (11) Publication No.(Date) | (2011.09.26) |
| (86) Int'l Application No.(Date) | |
| (87) Int'l Unex. Pub. No.(Date) | |
| (30) Priority Info.(Country / No. / Date) | |
| Legal Status | Registered |
| Examination Status | Decision to grant (General) |
| Trial Info | |
| Kind/Right of Org. Application | New Application / |
| Right of Org. Application No.(Date) | |
| Related Application No. | |
| Request for an examination(Date) | Y(2009.05.01) |
| Number of examination claims | 10 |

PURPOSE: A photographic lens optical system is implement excellent performance while being compact CONSTITUTION: A lens optical system comprises four lenses which are arranged to an image sensor from a subject in order. A first lens(I) is convex to a subject. A second lens(II) has both concave sides. A third lens(III) is convex to the image sensor. A fourth lens(IV) has light incidence face or light emitting face which is aspheric COPYRIGHT KIPO 2011

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
2 May 2013 (02.05.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/063097 A1

(51) International Patent Classification:
*G02B 13/00* (2006.01) *H04N 5/232* (2006.01)

(21) International Application Number:
PCT/US2012/061668

(22) International Filing Date:
24 October 2012 (24.10.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/550,789 24 October 2011 (24.10.2011) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: 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) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (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).

**Declarations under Rule 4.17**:

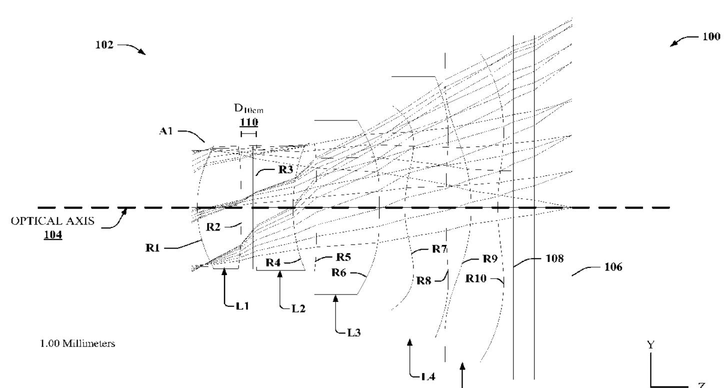
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

**Published**:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

**(54) Title**: OPTICAL OBJECTIVE HAVING FIVE LENSES WITH FRONT FOCUSING




OPTICAL LAYOUT; OBJECT FOCUSED AT 10CM

**FIG. 1**

**(57) Abstract**: Optical system comprising five lenses, a front pupil and achieving focus for objects from close to infinity by adjusting, via a MEMS actuator, the position of a subset of lenses located on the object-side of the optical system. The most object-side, biconvex, lens provides a substantial amount of the system's optical power for achieving focus from an object as close as 10 cm away from the aperture stop.

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# OPTICAL OBJECTIVE HAVING FIVE LENSES WITH FRONT FOCUSING

## CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims the benefit of U. S. Provisional Patent Application Serial No. 61/550,789 entitled "OPTICAL SYSTEM WITH MICROELECTROMECHANICAL SYSTEM IMAGE FOCUS ACTUATOR" filed October 24, 2011. The entirety of the above-noted application is incorporated by reference herein.

## TECHNICAL FIELD

**[0002]** The following relates generally to imaging optics, and more particularly to a compact optical lens system with micro electromechanical system (MEMS) actuator for focusing the optical lens system.

## BACKGROUND

**[0003]** Applications for optics and optical devices have become numerous in conjunction with advances in optical fabrication technology. One interesting advancement in optical technology is fabrication of micro lenses, and other optical components on a millimeter or micrometer scale, or less. Compared with traditional optical elements typically on the scale of centimeters or larger, micro optics have made optical systems compatible with smaller devices than traditional telescopes, microscopes, cameras, and so on.

**[0004]** One mechanism facilitating the fabrication of micro optics is wafer-level optics. Wafer-level optics is a fabrication technology that enables design and manufacture of optical components using techniques similar to semiconductor manufacturing. The technology is generally scalable with different size scales (e.g., millimeter, micrometer, etc.). Moreover, wafer-level optics can produce single-element as well as multi-element optical structures, yielding precision aligned stacks of lens elements. The end result of wafer-level optics provide cost effective, miniaturized optical components that enable reduced form factor for optical systems. These optical systems can be employed in a wide range of small or miniature devices, including camera modules for mobile phones, surveillance equipment, miniature video cameras, and the like.

**[0005]** Although wafer-level optics is one relatively recent technology for fabricating small optical components, some traditional fabrication techniques have been adapted to small-scale optical fabrication as well. For instance, plastic fabrication techniques including injection molding, and others can be employed for manufacturing small-scale optical components. Further, glass fabrication techniques have been adapted for miniaturized optical components, providing high quality optical surfaces for small-scale devices.

**[0006]** In addition to optical elements, the miniaturization of digital imaging sensors has also facilitated the continuing miniaturization of image capture and recording devices. Improvements in image sensors have provided high resolution image detectors utilizing micro-scale pixilation, and at high signal to noise ratio and increasingly lower cost. In conjunction with micro optics, such as wafer-level optical components, small, relatively inexpensive digital capture and recording devices can match or exceed the capabilities of relatively expensive, yet very high quality camera systems utilizing traditional optics of just a decade ago. Although quality is very high for modern micro optical devices, one persistent limitation has been zoom capability for miniature optical systems. One solution has been the introduction of digital zoom, which sacrifices optical resolution to enlarge an image. For high resolution sensors, this often provides a suitable alternative to traditional optical zoom capability. However, optical zoom provides advantages that digital zoom cannot achieve.

**[0007]** For example, the inventors of the disclosed subject matter suggest it would be desirable to have a miniature optical system with optical auto-focus capability. Such an optical system that achieves close focus would be additionally desirable.

## SUMMARY

**[0008]** The following presents a simplified summary of one or more aspects in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated aspects, and is intended to neither identify key or critical elements of all aspects nor delineate the scope of any or all aspects. Its sole purpose is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.

**[0009]** Particular aspects of the subject disclosure provide a miniaturized optical system. In some aspects, the miniaturized optical system can comprise an injection



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molded optical system. In further aspects, the miniaturized optical system can be an auto-focus optical system comprising five optical components. In still other aspects, the miniaturized optical system can be an auto-focus optical system employing a micro electromechanical system (MEMS) actuator to achieve focusing of the optical system.

**[0010]** In one or more other aspects of the subject disclosure, provided is an optical system that employs a MEMS actuator to achieve close focus. In one such aspect, the close focus can comprise a substantially 10cm object distance. Further, according to other aspects, the optical system can be configured to achieve close focus and infinity focus by adjusting position of a subset of optical components of the optical system. In particular aspects, the subset of optical components can comprise a single optical component of the optical system. In at least one such aspect, the single optical component can be a lens closest along an optical axis of the optical system to an object being imaged by the optical system (referred to as an object-side lens). In such aspect(s), the MEMS actuator can be configured to displace the object-side lens of the optical system a first distance configured to focus an object at infinity onto an image sensor associated with the optical system, and to displace the object-side lens a second distance configured to focus a close object (*e.g.*, an object substantially 10cm from the object-side lens) onto the image sensor.

**[0011]** According to one or more additional aspects, an auto-focus optical system disclosed herein can be configured to include an aperture stop. In a particular aspect, the auto-focus optical system can comprise injection molded plastic lenses, whereas in other aspects, the auto-focus optical system can comprise wafer-level optical lenses, glass lenses, or a suitable combination thereof. In another aspect, the aperture stop can be positioned on an object side of the object–side lens of the optical system. In one alternative aspect, a MEMS actuator can be configured to move a subset of optical components of the optical system to focus an object, while maintaining the aperture stop in a fixed position along an optical axis of the optical system. In another alternative aspect, the MEMS actuator can instead be configured to move both the subset of optical components and the aperture stop relative to the optical axis, to focus the object.

**[0012]** According to still other aspects, disclosed is an auto-focus optical system comprising a plurality of optical components. The plurality of optical components can, in some such aspects, comprise an object-side lens providing a substantial amount of optical power to the optical system. In at least one such aspect, the object-side lens can comprise substantially half or greater than half of the combined focal length of the



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optical system. In another aspect, the object-side lens can comprise substantially three-quarters or more of the combined focal length of the optical system. In a particular aspect, a MEMS actuator is connected to the object-side lens, and is configured to displace the object-side lens a first distance configured to focus an object at infinity, and a second distance configured to focus an object close to the optical system. According to one specific embodiment, a ratio of the focal length of the object-side lens and of a combined focal length of the optical system can be a function of a difference in magnitude of the first distance and the second distance along an optical axis of the optical system.

**[0013]** According to additional aspects, the subject disclosure provides a micro-optical system comprising five optical lenses. In one such aspect, an objective lens of the five optical lenses can be configured to supply all positive refractive power of the five optical lenses. In this aspect, the remaining four lenses have a combined net negative refractive power. In at least one particular aspect, the remaining four lenses can have respective negative refractive powers, with a combined net negative refractive power. According to an alternative or additional aspect, a third lens of the five optical lenses can a convex object side surface and a concave image side surface. As yet another alternative or additional aspect, a spacing between a fourth of the five optical lenses and a fifth of the five optical lenses can be a largest spacing between lenses of the optical system. In another aspect, the micro-optical system can be an auto-focus system in which a subset of the five optical lenses are movable along an optical axis to refine a focus of the optical system. In one specific aspect, the subset of the five optical lenses can comprise the objective lens, and the subset being movable by a MEMS actuator.

**[0014]** In further aspects of the subject disclosure, provided is a micro-optical system comprising five optical lenses. The five optical lenses can be arranged into a plurality of lens groups, each lens group comprising respective subsets of the five optical lenses. Each group comprises inter-lens distances equal to or less than a distance(s) between the plurality of optical groups. In a further aspect, each lens within at least one of the plurality of lens groups comprises at least one optical surface having both a concave portion and a convex portion. In a particular aspect, an effective focal length of the micro-optical system varies in response to a change in position along an optical axis of a first lens of the five optical lenses, and in an alternative or additional aspect, a back focal length of the micro-optical system remains substantially the same in response to the change in position along the optical axis of the first lens.

**[0015]** To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative aspects of the one or more aspects. These aspects are indicative, however, of but a few of the various ways in which the principles of various aspects can be employed and the described aspects are intended to include all such aspects and their equivalents.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0016]** Figure 1 illustrates a diagram of an example optical imaging system configured to focus a relatively close object, according to various aspects of the subject disclosure.

**[0017]** Figure 2 illustrates a diagram of a sample optical imaging system configured to focus an object substantially at infinity, according to other disclosed aspects.

**[0018]** Figure 3 depicts a diagram of an example optical imaging system comprising a plurality of injection molded optical components.

**[0019]** Figure 4 illustrates a diagram of example field curvature and distortion graphs for a sample optical imaging system focusing a relatively close object.

**[0020]** Figure 5 illustrates a diagram of example field curvature and distortion graphs for the sample optical imaging system of Figure 4, focusing an object substantially at infinity.

**[0021]** Figure 6 depicts a diagram of a sample lateral color graph for an example optical imaging system focusing a relatively close object, according to further aspects.

**[0022]** Figure 7 illustrates a diagram of a sample lateral color graph for the example optical imaging system of Figure 6 focusing an object substantially at infinity, according other aspects.

**[0023]** Figure 8 depicts a diagram of transverse ray fan plots for a disclosed optical imaging system with an object focused at 10cm.

**[0024]** Figure 9 illustrates a diagram of transverse ray fan plots for the disclosed optical imaging system of Figure 8, with an object focused substantially at infinity.

**[0001]** Figure 10 illustrates a cross-section of a sample optical system for focusing an image of an object at 10cm according to aspects of the subject disclosure.



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**[0002]** Figure 11 illustrates a cross-section of a sample optical system for focusing an image of an object at infinity according to aspects of the subject disclosure.

**[0003]** Figure 12 illustrates an example graph of field curvature and distortion for an object at 10cm according to aspects of the subject disclosure.

**[0004]** Figure 13 illustrates an example graph of field curvature and distortion for an object at infinity in other aspects of the subject disclosure.

**[0005]** Figure 14 illustrates an example graph of primary lateral color for an object at 10cm according to an aspect(s).

**[0006]** Figure 15 illustrates an example graph of primary lateral color for an object at infinity according to one or more other aspects.

**[0007]** Figure 16 illustrates an example transverse ray fan plot for various image heights for an object at 10cm according to still other aspects.

**[0025]** Figure 17 illustrates an example transverse ray fan plot for various image heights for an object at infinity according to at least one other aspect.

**[0026]** Figure 18 depicts a transverse ray fan plot for a range of field angles for an example micro-optical system according to additional disclosed aspects.

**[0027]** Figure 19 illustrates a sample diagram of the micro-optical system of Figure 18 including lenses and optical surfaces.

**[0028]** Figure 20 depicts an example graph of field curvature and distortion for an object focused by the micro-optical system of Figure 18.

**[0029]** Figure 21 illustrates a sample graph of longitudinal aberration for a pupil radius of 0.90 millimeters in an aspect.

**[0030]** Figure 22 depicts an example graph of lateral color for a disclosed micro-optical system according to further aspects.

**[0031]** Figure 23 illustrates a transverse ray fan plot for a range of field angles for a micro-optical system focused in the near-field according to disclosed aspects.

**[0032]** Figure 24 depicts a sample diagram of the micro-optical system of Figure 23 including lenses and optical surfaces.

**[0033]** Figure 25 illustrates an example diagram of field curvature and distortion for a near-field object focused by the micro-optical system of Figure 23.

**[0034]** Figure 26 depicts a sample diagram of longitudinal aberration for pupil radius of 0.90 millimeters for a disclosed micro-optical system, in an aspect.

**[0035]** Figure 27 illustrates an example diagram of lateral color for a disclosed micro-optical system according to still other disclosed aspects.



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**[0036]** Figures 28A, 28B, 28C and 28D illustrate diagrams of an example micro-optical system focused at infinity according to further aspects, and related optical performance graphs.

**[0037]** Figures 29A, 29B, 29C and 29D depict the micro-optical system of Figure 28 focused in the near-field and related optical performance graphs.

## DETAILED DESCRIPTION

**[0038]** Various aspects are now described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more aspects. It will be evident, however, that such aspect(s) can be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to facilitate describing one or more aspects.

**[0039]** In addition, it should be apparent that the teaching herein can be embodied in a wide variety of forms and that the specific structures or functions disclosed herein are merely representative. Based on the teachings herein one skilled in the art should appreciate that the disclosed aspects can be implemented independently of other aspects, and that two or more of these aspects can be combined in various ways. For example, an apparatus can be implemented and/or a method practiced using any number of the aspects set forth herein. In addition, an apparatus can be implemented and/or a method practiced using other structure and/or functionality in addition to or other than one or more of the aspects set forth herein. As an example, many of the apparatuses and lens systems disclosed herein are described in the context of providing high resolution optical imaging *via* compact fixed position optical lens arrangements. One skilled in the art should appreciate that similar techniques could apply to other optical lens architectures. For example, the lens arrangements used herein may be used in mechanical focus or auto-focus systems whereby the optical arrangement is automatically or manually displaced relative to the image plane.

**[0040]** In at least one aspect of the subject disclosure, an optical imaging system is provided. The optical imaging system can comprise a first group of lenses and a second group of lenses. The optical imaging system can be focused by repositioning the first group of lenses relative to the second group of lenses along an optical axis of the optical imaging system. In at least one aspect of the subject disclosure, the second



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group of lenses includes an image sensor for the optical imaging system. In particular aspects of the subject disclosure, the first group of lenses can comprise a single lens. For instance, the single lens can include an object-side lens, which is an optical element closes to an object side of the optical imaging system.

**[0041]** Referring now to the drawings, Figure 1 depicts a block diagram of an example optical system 100 according to aspects of the subject disclosure. System 100 comprises an arrangement of optical elements 102 positioned transverse to an optical axis 104. As utilized herein, an optical element refers to a single piece of refractive or reflective material at least partially transparent to electromagnetic radiation at least partially within the visible spectrum (*e.g.*, including wavelengths approximately 400 to 700 nanometers [nm]). Examples of suitable material include ground and polished glass, molded glass or glass formed from a replication molding process, wafer-level optics (WLO), injection-molded plastic, etched micro optics formed on an optical substrate, or the like. Additionally, an optical element will have at least one refractive or reflective surface. One example of an optical element utilized herein is an optical lens. An optical lens is an optical element comprising two opposing refractive surfaces, and an edge between the opposing surfaces that defines an outer diameter (for a circular lens) or perimeter of the lens, and an edge thickness of the lens. A typical arrangement of optical lenses includes a series of lenses 102 at least generally transverse to an axis (optical axis 104). It should be appreciated, however, that other possible arrangements can exist consistent with the subject disclosure. A "lens component" is defined herein as (A) a single lens element spaced so far from any adjacent lens element that the spacing cannot be neglected in computing the image forming properties of the respective lens elements, or (B) two or more lens elements that have adjacent lens surfaces either in full overall contact or so close together that any spacing between the adjacent lens surfaces are so small that the spacing(s) can be neglected in computing image forming properties of the two or more lens elements. Thus, some lens elements can also be lens components, and the terms "lens element" and "lens component" are not mutually exclusive terms. In addition, it should be appreciated that the term "optical component" is utilized herein to refer to a superset of items having significant properties related to imaging optical systems, and includes optical elements such as lens elements and lens components, as well as various optical stops including but not limited to aperture stops, but can also include various other items such as a thin film, a bandpass filter, a lowpass or highpass filter, a polarizing filter, a mirror, *etc.*



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**[0042]** Light entering the left side, or object side, of optical elements 102 can interact sequentially with respective elements (102) and exit the right side, or image side, of the elements 102, toward an optical sensor 106. It should be appreciated that not all light interacting with the left side of the optical elements 102 will be transmitted to the sensor 106; some light can be reflected off of respective elements (102), some light can be scattered away from the optical axis 104 and absorbed (*e.g.*, by an optical stop – not depicted), and so forth. However, in general, the optical elements 102 will receive light from an object on one side of the elements (*e.g.*, the left side) and form a real image of the object on an opposite side of the elements (*e.g.*, on the right side). The real image will be formed along the optical axis 104 a certain distance from the optical elements 102, called an image distance (ID). Notably, the ID depends primarily on a corresponding object distance (OD – distance between the object and the optical elements 102 along the optical axis 104) and a refractive power, or optical power, of the combined optical elements 102.

**[0043]** Sensor 106 can be a digital device comprising a multi-dimensional array (*e.g.*, a two dimensional array) of electro-optical sensors, or pixels. Examples of such a device can include a charge-coupled device (CCD) array, or a complementary metal-oxide semiconductor (CMOS) array, or some other suitable array of optical sensors. Each electro-optical sensor, or pixel, of such array is configured to output an electric signal when irradiated with light. Furthermore, an amount of electric current for the electric signal is directly related to energy density of light irradiating the pixel. Accordingly, by collecting output current levels from each pixel of the array, sensor 106 can digitally reproduce a two dimensional radiant energy pattern of light irradiating the sensor 106. Additionally, where the pixel surface or sensor plane of sensor 106 is placed at the above-mentioned ID, the two dimensional radiant energy pattern that is produced is that of a real optical image generated by optical elements 102. Accordingly, sensor 106 can be utilized to digitally reproduce that image. Resolution of a digital image generated by sensor 106 depends on a number of pixels within an active array of sensor 106. In addition, optical system 100 can comprise a cover plate 108 between the optical elements 102 and image sensor 106, as depicted by Figure 1.

**[0044]** As depicted by optical system 100, optical elements 102 can comprise five optical lenses, including lens L1, lens L2, lens L3, lens L4 and lens L5, from the object-side of optical elements 102 to an image-side of optical elements 102. As depicted, lens L1 is a biconvex lens having positive optical power, having convex object-side and convex image-side surfaces, R1 and R2, respectively. Additionally, lens L1 can have a relatively strong positive optical power, relative to lenses L2, L3, L4 and L5. In at least one aspect, lens L1 can have a relatively strong positive optical power relative to a combination of lenses L2, L3, L4 and L5. In a particular aspect, lens L1 can provide at least about half or more of the combined focal length of optical elements 102. In an alternative aspect, lens L1 can provide substantially about three-quarters or more of the combined focal length of optical elements 102. In related aspects, the optical power of the object-side lens ($L1_{power}$) can be about 1.25x the combined optical power of optical elements 102 (*e.g.*, $L1_{power} \leq 1.25*(L1_{power} + L2_{power} + L3_{power} + L4_{power} + L5_{power})$). In a particular aspect, an aperture stop A1 can be positioned at or in front of an object-side of lens L1. Aperture stop A1 is described in more detail below.

**[0045]** Lens L2 can have an overall negative optical power. Further, lens L2, in one aspect, can have a mildly concave object-side surface R3. In an alternative aspect, object-side surface R3 can be flat, with no optical power. As yet another alternative aspect, object-side surface R3 can be mildly convex. An image-side surface R4 of lens L2 can have concave curvature. Moreover, lens L2 can be configured to provide chromatic aberration correction for optical system 100. In at least one aspect, lens L2 can provide a majority of chromatic aberration correction for optical system 100.

**[0046]** Lens L3 comprises an object-side surface R5 and an image-side surface R6. Object-side surface R5 can be mildly concave, in particular aspects. Moreover, image-side surface R6 can be convex. In a particular aspect, lens L3 can have a positive optical power.

**[0047]** Lens L4 comprises an object-side surface R7 and an image-side surface R8. Object-side surface R7 can have convex curvature near optical axis 104. Moreover, in at least one aspect of the subject disclosure, object-side surface R7 can transition to concave further from optical axis 104. Moreover, image-side surface R8 can be substantially flat with little or no optical power near optical axis 104, and transition to convex curvature away from optical axis 104. In an alternative aspect, image-side surface R8 can be convex near optical axis 104 having significant optical power for low to mid field angles, as well as convex away from optical axis 104. In a particular aspect, lens L4 can have positive power for low field angles (*e.g.*, field angles between zero and about 12 to 15 degrees). In another aspect, lens L4 can have small positive, small negative, or substantially zero optical power for medium field angles (*e.g.*, field angles between about 12 to 15 degrees and about 22 to 25 degrees). In yet another aspect, lens L4 can have small positive, small negative, or substantially zero optical power for for high field angles (*e.g.*, field angles between about 22 to 25 degrees and about 33 or more degrees, up to a maximum accepted field angle of optical system 100).

**[0048]** Lens L5 comprises an object-side surface R9 and an image-side surface R10. Object-side surface R9 can have concave curvature for low and medium field angles. In at least one aspect, object-side surface R9 can transition to mildly concave or no curvature for high field angles. Image-side surface R10 can be concave near optical axis 104. Moreover, image-side surface R10 can transition from concave to convex for medium and high field angles, as depicted.

**[0049]** As depicted, optical elements 102 can have respective spaces (*e.g.*, air spacing) between respective lenses L1, L2, L3, L4 and L5. In at least one disclosed embodiment, a first on-axis distance between lens L1 and L2 can be substantially small compared with a third on-axis distance between lens L3 and lens L4. In another embodiment, the first on-axis distance can be substantially small compared to a second on-axis distance between lens L2 and L3, and a fourth on-axis distance between lens L4 and L5, in addition to the third on-axis distance. In at least one embodiment, the second, third and fourth on-axis distances can be substantially similar in magnitude, at least in comparison with the first on-axis distance. In other embodiments, these relations between the first, second, third and fourth on-axis distances need not exist. For instance, other relationships between the first, second, third and fourth on-axis distances may exist instead.

**[0050]** In at least one aspect of the subject disclosure, a MEMS actuator can be connected at least to lens L1. The MEMS actuator can be configured to reposition lens L1 along optical axis 104 to focus objects at different object distances. As one example, the MEMS actuator can change the first distance between lens L1 and lens L2 to focus objects at differing object distances. In at least one aspect, the MEMS actuator can position lens L1 a distance $D_{10cm}$ 110 from lens L2 to focus onto sensor 106 an image of an object that is substantially 10 centimeters (cm) from a position of aperture stop A1 on optical axis 104.

**[0051]** According to further aspects, aperture stop A1 can be fixed relative to optical axis 104. In another aspect, aperture stop A1 can be fixed relative to a position of lens L1. In the latter aspect, aperture stop A1 can be moved by a MEMS actuator in conjunction with lens L1 when focusing an image of an object. According to still other aspects, the MEMS actuator can be configured to move lens L1, either alone or in conjunction with aperture stop A1, a total distance along optical axis 104. The total distance can, in a particular aspect, at one end thereof focus an image of an object at infinity, and at an opposite end thereof, focus an image of an object substantially at 10cm from aperture stop A1. As utilized herein, an object at infinity includes an object distance that satisfies the paraxial approximation known in the art of optical imaging science. The paraxial approximation, broadly stated, refers to an object at such a distance that an angle - subtending a first optical ray that is parallel with optical axis 104 and a second optical ray that originates at a point on the object farthest from the optical axis and passes through optical axis 104 at aperture stop A1 – is substantially zero degrees. In yet another aspect, lens L1 can have a focal length that is at least in part a function of a magnitude of the total distance. In still other aspects, a ratio of the focal length of lens L1 and a combined focal length of optical elements 102 can at least in part be a function of the magnitude of the total distance.

**[0052]** Because the pixel array of sensor 106 generates an electronic reproduction of a real image, data generated by sensor 106 (and other sensors disclosed herein) in the form of electric signals can be saved to memory, projected to a display for viewing (*e.g.*, digital display screen), edited in software, and so on. Thus, at least one application of optical system 100 is in conjunction with a digital camera or video camera comprising a digital display. Furthermore, optical system 100 and other optical systems included in the subject disclosure can be implemented in conjunction with a camera module of an electronic device. Such an electronic device can include a wide array of consumer, commercial or industrial devices. Examples include consumer electronics, including a cell phone, smart phone, laptop computer, net-book, PDA, computer monitor, television, flat-screen television, and so forth, surveillance or monitoring equipment, including commercial equipment (*e.g.*, ATM cameras, bank teller window cameras, convenience store cameras, warehouse cameras and so on), personal surveillance equipment (*e.g.*, pen camera, eyeglass camera, button camera, *etc.*), or industrial surveillance equipment (*e.g.*, airfield cameras, freight yard cameras, rail yard camera, and so on). For instance in consumer electronics, because optical system 100 can comprise optical components having physical dimensions on the order of a few millimeters or less, and because at least some of optical elements 102 can have a fixed position, system 100 and other disclosed systems are well suited for various



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types of mini or micro camera modules. It is to be appreciated, however, that the disclosed systems are not limited to this particular application; rather, other applications known to those of skill in the art or made known by way of the context provided herein, are included within the scope of the subject disclosure.

**[0053]** Figure 2 illustrates a diagram of an example optical imaging system 200 according to additional aspects of the subject disclosure. Optical imaging system 200 can comprise a set of optical elements 202 arranged transverse to an optical axis 204. Furthermore, optical elements 202 can be configured to focus an image onto an image plane 206 of an object located substantially at infinity from an aperture stop A1 of optical imaging system 200. In at least one aspect, optical elements 202 can be substantially similar to optical elements 102 of Figure 1, *supra*, except for the first distance between lens L1 and lens L2. Particularly, this first distance in optical imaging system 200 can be a distance $D_{INFINITY}$ 210 configured to focus the object located substantially at infinity, discussed above. Furthermore, as described at Figure 1, *supra*, aperture stop A1 can, in one aspect, be fixed in position relative to optical axis 204. In an alternative aspect, aperture stop A1 can be fixed in position relative to lens L1, and move along optical axis 204 with lens L2.

**[0054]** It should be appreciated that surfaces R1 through R10 of lenses L1 through L5 of optical elements 102 and 202 (as well as other optical surfaces described throughout the subject disclosure) can be of varying shapes. In one aspect, one or more of the surfaces can be spherical surfaces. In other aspects, one or more of the surfaces can be conic surfaces. In yet other aspects, one or more of the surfaces can be aspheric surfaces, according to a suitable aspheric equation, such as the even aspheric equation:

(1) $z = [\frac{CY^2}{\{1 + (1 - (1+K)C^2Y^2)^{1/2}\}}] + \sum_i (A_i * Y^i)$, where z is the sag height (in mm) of a line drawn from a point on the aspheric lens surface at a radial distance, Y from the optical axis to the tangential plane of the aspheric surface vertex, C is the curvature of the aspheric lens surface on the optical axis, Y is the radial distance (in mm) from the optical axis, K is the conic constant, and $A_i$ is the $i^{th}$ aspheric coefficient, with the summation over even number i. However, these aspects are not to be construed as limiting the scope of the subject disclosure. Rather, various surfaces can be odd aspheric, or of an aspheric equation comprising even and odd coefficients.

**[0055]** Further to the above, it should be appreciated that lenses of optical elements 102 and 202 (and optical lenses of various other optical systems provided throughout the subject disclosure) can be made of various suitable types of transparent material, and formed according to various suitable processes for generating an optical quality surface. In one aspect, lenses L1 through L5 can be ground and polished glass, where the glass is selected to have an index of refraction resulting in a desired effective focal length for the combined lenses L1 through L5. In another aspect, the lenses can be an optical-quality injected molded plastic (or plastic of optical quality formed by another suitable method), wherein the plastic has an index of refraction suitable to provide the desired effective focal length. In at least one other aspect, the lenses L1 through L5 can be etched from a transparent glass, crystalline or other suitable structure (*e.g.*, silicon dioxide – $SiO_2$ wafer) with a lithographic etching process similar to that used to etch semiconductor chips (*e.g.*, solid state memory chip, data processing chip). In a particular aspect, optical elements 102 and optical elements 202 can be described according to the optical prescription of Tables 1 – 9, below.

| Parameter Description | Value |
|---|---|
| Effective Focal Length (in air at system temperature and pressure) | 4.131396 |
| Effective Focal Length (in image space) | 4.131396 |
| Back Focal Length | 0.349633 |
| Total Track Length (TTL) | 5.49089 |
| Image Space F/# | 2.293412 |
| Paraxial Working F/# | 2.44 |
| Working F/# | 2.857105 |
| Image Space NA | 0.1752143 |
| Object Space NA | 0.008991 |
| Stop Radius | 0.90071 |
| Paraxial Image Height | 2.956 |
| Paraxial Magnification | -0.04388 |
| Entrance Pupil Diameter | 1.801419 |
| Entrance Pupil Position | 0.18 |
| Exit Pupil Diameter | 1.236574 |
| Exit Pupil Position | -3.03634 |
| Maximum Radial Field | 2.956 |

| Lens Units | Millimeters (mm) |
|---|---|
| Angular Magnification | 1.183246 |

**Table 1: General Optical Properties**

| Field # | X-Value | Y-Value | Weight |
|---|---|---|---|
| 1 | 0 | 0 | 1 |
| 2 | 0 | 0.571 | 1 |
| 3 | 0 | 1.142 | 1 |
| 4 | 0 | 1.714 | 1 |
| 5 | 0 | 2.285 | 1 |
| 6 | 0 | 2.57 | 1 |
| 7 | 0 | 2.856 | 0.2 |
| 8 | 0 | 2.956 | 0.2 |

**Table 2: Field Type v. Real Image Height (in mm)**

| Field / # | VDX | VDY | VCX | VCY | VAN |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | -0.04364 | 0.000234 | 0.043642 | 0 |
| 6 | 0 | -0.081 | 0.001432 | 0.081006 | 0 |
| 7 | 0 | -0.1227 | 0.004184 | 0.122713 | 0 |
| 8 | 0 | -0.13916 | 0.006035 | 0.139171 | 0 |

**Table 3: Vignetting Factors for Fields of Table 2**

| Wavelength # | Value (in µm) | Weight |
|---|---|---|
| 1 | 0.47 | 91 |
| 2 | 0.51 | 503 |
| 3 | 0.555 | 1000 |
| 4 | 0.61 | 503 |
| 5 | 0.65 | 107 |

**Table 4: Wavelengths Used for Raytracing**



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| Surface | Type | Radius | Thickness | Material | Diameter | Conic | Notes |
|---|---|---|---|---|---|---|---|
| Object | Standard | Infinity | 100 | | 132.3188 | 0 | |
| 1 | Standard | Infinity | 0.18 | | 2.036472 | 0 | |
| Stop | Standard | Infinity | -0.1 | | 1.85939 | 0 | |
| 3 | EvenAsph | 1.974507 | 0.637634 | APEL5514ML | 1.907153 | 0 | |
| 4 | EvenAsph | -13.5665 | 0.166808 | | 1.939212 | 0 | |
| 5 | Standard | Infinity | 0.049504 | | 1.939212 | 0 | not vignetting |
| 6 | EvenAsph | 68.79989 | 0.528506 | OKP4HT | 1.951274 | 0 | |
| 7 | EvenAsph | 2.992822 | 0.247886 | | 1.977445 | 0 | |
| 8 | Standard | Infinity | 0.09498 | | 2 | 0 | Vignetting at 1.000 |
| 9 | EvenAsph | 143.3822 | 0.902332 | APEL5514ML | 2.122436 | 0 | |
| 10 | EvenAsph | -24.6284 | 0.367969 | | 2.741479 | 0 | |
| 11 | EvenAsph | 1.97917 | 0.596974 | APEL5514ML | 3.225637 | 0 | |
| 12 | EvenAsph | 91.68886 | 0.360983 | | 4.127183 | 0 | |
| 13 | EvenAsph | -3.10061 | 0.382215 | APEL5514ML | 4.395569 | 0 | |
| 14 | EvenAsph | 3.497914 | 0.2251 | | 4.876466 | 0 | |
| 15 | EvenAsph | Infinity | 0.3 | N-BK7 | 5.271775 | 0 | |
| 16 | Standard | Infinity | 0.55 | | 5.427336 | 0 | |
| Image | Standard | | | | 0 | 0 | |

**Table 5: Surface Data Summary**

| Surface | Parameter Description | Value |
|---|---|---|
| R1 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.01328 |
| | Coefficient on r 6 | 0.020358 |
| | Coefficient on r 8 | -0.03418 |
| | Coefficient on r 10 | 0.012665 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R2 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.0043 |
| | Coefficient on r 6 | 0.001395 |
| | Coefficient on r 8 | -0.02717 |
| | Coefficient on r 10 | 0.022646 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |



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| | | |
|---|---|---|
| | Coefficient on r 16 | 0 |
| R3 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.01683 |
| | Coefficient on r 6 | 0.019474 |
| | Coefficient on r 8 | -0.03875 |
| | Coefficient on r 10 | 0.034171 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R4 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.01678 |
| | Coefficient on r 6 | 0.057631 |
| | Coefficient on r 8 | -0.06199 |
| | Coefficient on r 10 | 0.029185 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R5 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.07378 |
| | Coefficient on r 6 | 0.078871 |
| | Coefficient on r 8 | -0.04834 |
| | Coefficient on r 10 | 0.007991 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R6 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.20739 |
| | Coefficient on r 6 | 0.12271 |
| | Coefficient on r 8 | -0.04163 |
| | Coefficient on r 10 | 0.006751 |
| | Coefficient on r 12 | 0 |

| | | |
|---|---|---|
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R7 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.15706 |
| | Coefficient on r 6 | 0.019487 |
| | Coefficient on r 8 | -0.00924 |
| | Coefficient on r 10 | 0.001005 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R8 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | 0.054595 |
| | Coefficient on r 6 | -0.04501 |
| | Coefficient on r 8 | 0.010689 |
| | Coefficient on r 10 | -0.00087 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R9 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.01701 |
| | Coefficient on r 6 | 0.02087 |
| | Coefficient on r 8 | -0.00363 |
| | Coefficient on r 10 | 0.000212 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R10 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.07822 |
| | Coefficient on r 6 | 0.013989 |
| | Coefficient on r 8 | -0.00152 |
| | Coefficient on r 10 | 6.37E-05 |

| | | |
|---|---|---|
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |

**Table 6: Surface Aspheric Coefficients**

| Surface | Edge |
|---|---|
| Object | 100 |
| 1 | 0.18 |
| Stop | 0.13436 |
| 3 | 0.361345 |
| 4 | 0.208736 |
| 5 | 0.052866 |
| 6 | 0.700429 |
| 7 | 0.0726 |
| 8 | 0.054707 |
| 9 | 0.625532 |
| 10 | 0.494114 |
| 11 | 0.625166 |
| 12 | 0.144313 |
| 13 | 0.505743 |
| 14 | 0.480978 |
| 15 | 0.3 |
| 16 | 0.55 |
| Image | 0 |

**Table 7: Edge Thickness Data**

| Temperature (Temp) in degrees Celsius and pressure (Press) in atmospheres | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Surface | Material | Temp | Press | 0.47 | 0.51 | 0.555 | 0.61 | 0.65 |
| 0 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 1 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 2 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 3 | APEL55 14ML | 20 | 1 | 1.552896 | 1.549574 | 1.546504 | 1.543579 | 1.541977 |
| 4 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 5 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 6 | OKP4HT | 20 | 1 | 1.65642 | 1.646281 | 1.637383 | 1.62927 | 1.625419 |
| 7 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 8 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 9 | APEL55 14ML | 20 | 1 | 1.552896 | 1.549574 | 1.546504 | 1.543579 | 1.541977 |
| 10 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 11 | APEL55 14ML | 20 | 1 | 1.552896 | 1.549574 | 1.546504 | 1.543579 | 1.541977 |
| 12 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 13 | APEL55 | 20 | 1 | 1.552896 | 1.549574 | 1.546504 | 1.543579 | 1.541977 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 14ML | | | | | | | |
| 14 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 15 | N-BK7 | 20 | 1 | 1.523605 | 1.520769 | 1.518274 | 1.515909 | 1.51452 |
| 16 | | 20 | 1 | 1 | 1 | 1 | 1 | |
| 17 | | 20 | 1 | 1 | 1 | 1 | 1 | |

**Table 8: Index of Refraction Data**

| | | Wavelengths (μm): | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.47 | | 0.51 | | 0.555 | |
| Number | Field (mm) | Tan | Sag | Tan | Sag | Tan | Sag |
| 1 | 0 | 2.4569 | 2.4569 | 2.4571 | 2.4571 | 2.4591 | 2.4591 |
| 2 | 0.571 | 2.5045 | 2.4888 | 2.5043 | 2.4886 | 2.506 | 2.4902 |
| 3 | 1.142 | 2.5363 | 2.5666 | 2.5363 | 2.5654 | 2.538 | 2.5662 |
| 4 | 1.714 | 2.6412 | 2.6707 | 2.644 | 2.6687 | 2.6478 | 2.6688 |
| 5 | 2.285 | 3.1763 | 2.8179 | 3.1806 | 2.8155 | 3.1856 | 2.8152 |
| 6 | 2.57 | 3.6191 | 2.9098 | 3.6212 | 2.9074 | 3.6236 | 2.907 |
| 7 | 2.856 | 4.1799 | 3.0168 | 4.1688 | 3.0144 | 4.1575 | 3.014 |
| 8 | 2.956 | 4.4668 | 3.0594 | 4.4391 | 3.0571 | 4.4113 | 3.0567 |

**Table 9: F/Number Data**

| | | Wavelengths (μm) | | | |
|---|---|---|---|---|---|
| | | 0.61 | | 0.65 | |
| Number | Field (mm) | Tan | Sag | Tan | Sag |
| 1 | 0 | 2.4624 | 2.4624 | 2.4666 | 2.4666 |
| 2 | 0.571 | 2.509 | 2.4932 | 2.5132 | 2.4973 |
| 3 | 1.142 | 2.5408 | 2.5684 | 2.5444 | 2.5721 |
| 4 | 1.714 | 2.6522 | 2.6703 | 2.656 | 2.6736 |
| 5 | 2.285 | 3.1911 | 2.8164 | 3.1952 | 2.8194 |
| 6 | 2.57 | 3.6263 | 2.908 | 3.6281 | 2.911 |
| 7 | 2.856 | 4.1459 | 3.0151 | 4.1376 | 3.018 |
| 8 | 2.956 | 4.3835 | 3.0578 | 4.3641 | 3.0606 |

**Table 9A: F/Number Data (Continued)**

**[0056]** Table 1 provides general optical information for an embodiment of optical imaging systems 100 and 200. Table 2 provides image heights in the y axis, measured at the image sensor 106 or image sensor 206, for eight different optical fields, and provides weights for the respective fields. Table 3 includes vignetting data for the eight fields indicated in Table 2. Table 4 depicts wavelengths of respective rays traced



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in optical imaging systems 100 and 200, depicted at Figures 1 and 2. Table 5 provides a summary of general optical surface characteristics for the lenses of optical elements 102 and optical elements 202, including surface type, radius of curvature, thickness, material (from standard glass and plastic catalogues), diameter, conic constant, and notes regarding vignetting. Table 6 describes even aspheric coefficients for the surfaces of Table 5, whereas Table 7 provides edge thickness information for those surfaces. Table 8 provides index of refraction data for multiple wavelengths for the optical fields identified at Table 2. Tables 9 and 9A provide F/# data for those same wavelengths and optical fields.

**[0057]** Figure 3 illustrates a diagram of an example injection molded plastic optical system 300 (also referred to as system 300) according to further aspects of the subject disclosure. System 300 can be formed from multiple injection molded plastic components. In one embodiment, two or more of lenses L1, L2, L3, L4 and L5 can be formed from a single mold. In other embodiments, respective lenses can be formed from separate molds and assembled, as depicted, after molding. In other aspects, formation of lenses L1, L2, L3, L4 and L5 can result from another optical fabrication technique, such as wafer-level optic fabrication. In at least one disclosed aspect, system 300 can be substantially similar to optical imaging system 100. In another aspect, system 300 can be substantially similar to optical imaging system 200. According to yet other aspects, system 300 can comprise MEMS hardware configured to displace lens L1 along optical axis 302 to achieve focusing at an image plane 304 of system 300. In a particular embodiment, system 300 can comprise lens surfaces R1 and R2 of lens L1, surfaces R3 and R4 of lens L2, surfaces R5 and R6 of lens L3, surfaces R7 and R8 of lens L4, and surfaces R9 and R10 of lens L5, that are substantially similar to surfaces R1 – R10 described at Figure 1, *supra*.

**[0058]** Figure 4 illustrates a diagram of field curvature and F-Tan(Theta) Distortion (referred to hereinafter as distortion) for an optical imaging system as described herein. Particularly, Figure 4 illustrates field curvature and distortion for an object distance of 10cm, which can correspond with optical imaging system 100 of Figure 1, *supra*. The field curvature and distortion graphs utilize five wavelengths, having wavelengths of 0.470, 0.510, 0.555, 0.610 and 0.650 μm, respectively, and have a maximum field angle of 33.391 degrees. The left-hand graph depicts field curvature in millimeters along a y-axis at an image plane of an optical imaging system. Field curvature data is depicted for Sagittal rays (delineated as ‘S’ on Figure 4) and Tangential rays (delineated as 'T' on Figure 4). As is clear from the graph, field curvature is minimal for sagittal rays over most of the image plane, and field curvature is within a few microns for tangential rays for most of the image plane, and several microns at the outer edge of the image plane (high y values).

**[0059]** The distortion graph on the right hand side also includes curves for the above five wavelengths. The distortion data is normalized to 0% at the optical axis. Throughout the image plane, distortion is less than about 1.5%, and less than one percent for low field angles.

**[0060]** Figure 5 depicts a diagram of field curvature and distortion for an optical imaging system focusing an object at infinity. Thus, the graphs of Figure 5 can correspond with optical imaging system 200 of Figure 2, *supra*. The field curvature and distortion graphs of Figure 5 employ graphs for the same wavelengths as for Figure 4, for a maximum field angle of 34.897 degrees. Field curvature includes lines for sagittal rays (S) for the indicated wavelengths, as well as transverse rays (T) for those same wavelengths. As depicted, field curvature for an object in focus at 10cm is within about +/- 50 microns.

**[0061]** Distortion at infinity varies a bit more than for the 10cm graph of Figure 4. Distortion is again normalized to 0% on the optical axis. The distortion ranges from about a half percent at medium field angles to about negative one and a half percent at the edge of the image plane. Total distortion for all field angles is about two percent.

**[0062]** Figure 6 illustrates a graph of primary lateral color for an optical imaging system as described herein. Particularly, the primary lateral color graph of Figure 6 is for an object in focus at 10cm object distance, and therefore can correspond with optical imaging system 100 of Figure 1, *supra*. The maximum field for the primary lateral color graph is 2.9560 mm, and ranges in wavelengths between 0.4700 and 0.6500 μm. As depicted, lateral color variation is well within a half a micron for small field angles, varies to just over negative one microns for medium field angles, and becomes as large as about negative one and a half microns for higher field angles. Overall distortion remains below two microns for the image plane.

**[0063]** Figure 7 illustrates a graph of primary lateral color for an object in focus at infinity. Accordingly, Figure 7 can correspond with optical imaging system 200 of Figure 2, *supra*. Similar to Figure 6, the maximum field is 2.9560 mm for wavelengths between 0.4700 and 0.6500 μm. For low and medium field angles, primary lateral color remains at or below about one half a micron. Only at larger field angles does the



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primary lateral color exceed half a micron, reaching a peak at just over about two microns at an edge of the image plane.

**[0064]** Figure 8 illustrates several transverse ray fan plots at an image plane of an optical imaging system described herein. Particularly, the transverse ray fan plots of Figure 8 correspond with an object in focus at 10cm object distance, and therefore can correspond with optical imaging system 100 of Figure 1, *supra*. The transverse ray fan plots depict transverse ray error ($e_y$) along a vertical axis, and pupil diameter ($P_y$) along the horizontal axis, for various image heights. Flatter plots indicate optimal performance and minimal error, whereas greater deviations along the vertical axis indicate greater transverse ray error. As is depicted by Figure 8, transverse ray error is minimal for near the optical axis (small image height), and generally increases with image height. The scale ranges from positive 25 microns to negative 25 microns along the x and y axis, respectively. The transverse ray fan plots include wavelengths between 0.470 and 0.650 wavelengths.

**[0065]** Figure 9 depicts several transverse ray fan plots for an object in focus at infinity, and therefore can correspond with optical imaging system 200 of Figure 2, *supra*. Similar to Figure 8, the plots exhibit minimal error near the optical axis, and generally low error for small pupil diameters at all field angles. At higher field angles and particularly higher pupil diameters, the transverse ray error increases. Generally, transverse ray error for the object at infinity is less than for the object at 10cm.

**[0066]** Referring now to the drawings, Figure 10 depicts a cross sectional view of an optical system 1000 for an object at 10cm comprising an arrangement of optical elements 1002 positioned in a like manner relative to an optical axis 1004. Light entering the left side, or object side, of optical elements 1002 can interact sequentially with respective elements 1002 and exit the right side, or image side, of the elements 1002, toward an image sensor 1006. The real image will be formed along the optical axis 1004 a certain distance from the optical elements 1002, called an image distance (ID). Notably, the ID depends primarily on a corresponding object distance (OD – distance between the object and the optical elements 1002 along the optical axis 1004) and a refractive power, or optical power, of the combined optical elements 102.

**[0067]** Sensor 1006 can be a digital device comprising a multi-dimensional array (*e.g.*, a two dimensional array) of electro-optical sensors, or pixels, which can include a CCD array, or a CMOS array, *etc*. Resolution of a digital image generated by sensor 1006 depends on a number of pixels within the sensor plane array 1008, which in turn is dependent on pixel area and total array area. Thus, for example, for relatively square pixels approximately 1.4 microns per side (1.96 square microns), a 0.4 cm square sensor array can comprise as many as 8.1 megapixels (Mp). Said differently, such a sensor would have resolution of about 8Mp. Because the pixel array generates an electronic reproduction of a real image, data generated by sensor 1006 in the form of electric signals can be saved to memory, projected to a display for viewing (*e.g.*, digital display screen), edited in software, and so on.

**[0068]** It should be appreciated that the optical imaging arrangement 1000 depicted in Figure 10 (and other optical imaging systems disclosed herein) is not intended to be drawn to scale. For instance, lens thicknesses, positions and heights are not necessarily depicted in proper proportion with actual sizes. Rather, arrangement 1002 is intended to provide a visual context of an imaging system to aid conceptual understanding of other aspects disclosed herein.

**[0069]** Optical system 1000 comprises a first lens L1, a second lens L2, a third lens L3, a fourth lens L4, and a fifth lens L5 centered upon an optical axis 104. The lenses are numbered starting from the object side to the image side. Thus, lens L1 is closest to the object, and lens L5 is closest to the image. Aperture A1 can be embedded into lens L1, or can be fixed to L1 physically. Accordingly, in this embodiment, aperture A1 does not move relative to lens L1. In certain aspects of the disclosure, the aperture A1 can have a 50μm depth.

**[0070]** Lenses L1 through L5 each have two opposed refracting surfaces. A radius of curvature for the respective surfaces is denoted by the letter "R" followed by a surface number, starting with the object side surface of lens L1. Thus, the surfaces in order from object side to image side are object side surface R1 and image side surface R2 of lens L1, object side surface R3 and image side surface R4 of lens L2, object side surface R5 and image side surface R6 of lens L3, object side surface R7 and image side surface R8 of lens L4, and object side surface R9 and image side surface R10 of lens L5. The respective surface identifiers (R1, R2, R3, …, R10) are also utilized to represent the radius of curvature for the respective surfaces. Additionally, refractive index $n_i$ denotes the refractive index of the lens medium associated with the $i^{th}$ surface, and v_di is the Abbe number of the lens medium associated with the $i^{th}$ surface.

**[0071]** Lens L1 can have a large positive refractive power, with both optical surfaces, R1 and R2, being convex. As utilized herein, the terms large or small refractive power (whether positive or negative) are intended to be relative to other lenses of a particular optical system. Thus, for instance, referring to lens L1 as having large positive refractive power implies that lens L1 has greater than average positive refractive power as compared with other positive power lenses of optical system 1000. Conversely, a lens having small positive refractive power for optical system 1000 will have less than the average positive refractive power.

**[0072]** In an embodiment, L1 can be moveable relative to lenses L2-L5 and the sensor plane 1008. Movement can be achieved using MEMS or other appropriate actuators. In this embodiment, L2-L5 remain fixed relative to the image sensor plane 1008 and image sensor 1006. In some aspects of the disclosure, the range of movement of L1 is around 100μm. The movement of L1 allows optical system 1000 to maintain focus on objects at various distances. In Figure 10, the optical system 1000 is focused on an object at a distance of 10cm from the optical system. In Figure 2, the optical system 1100 is focused on an object at optical infinity.

**[0073]** In certain embodiments, there is an inverse relationship between the refractive power of L1 and the range of motion required to focus on objects at various distances. An L1 with a higher power requires a shorter range of movement to focus on objects at various distances and vice versa. According to some aspects of the disclosure, the axial gap, or distance between lenses L1 and L2 at the optical axis is around 125μm, with a gap of about 170 μm at the clear aperture.

**[0074]** L2 can have a meniscus shape (having smaller thickness near the optical axis than away from the optical axis), with optical surface R3 being convex, and optical surface R4 being concave. In some aspects of the disclosure, lens L2 provides most of the chromatic correction for optical system 1000 and has negative refractive power. Lens L3 can be biconvex near the optical axis 1004 as optical surface R5 is convex near the optical axis 1004 and concave away from the optical axis 1004 and image side optical surface R6 is convex. According to some aspects of the disclosure, lens L3 can have a positive refractive power. In certain embodiments, L2 can be mounted on to L3, such that L2 is fixed to L3, and L2 does not touch an optical barrel that arranges lenses L1 – L5 of optical system 1000 along optical axis 1004.

**[0075]** Lens L4 has a concave object side optical surface R7, and a convex shaped image side optical surface R8. Lens L5 can be meniscus shaped with a convex optical surface R9 near optical axis 1004 and optical surface R10 that is concave near the optical axis 104.

**[0076]** It should be appreciated that surfaces R1-R10 (as well as other optical surfaces described throughout the subject disclosure, including optical surfaces for system 200 can be of varying shapes. In one aspect, one or more of the surfaces can be spherical surfaces. In other aspects, one or more of the surfaces can be conic surfaces. In yet other aspects, one or more of the surfaces can be aspheric surfaces, according to a suitable aspheric equation, such as the even aspheric equation:

**[0077]** (1) $z = [\frac{CY^2}{\{1+(1-(1+K)C^2Y^2)^{1/2}\}}] + \sum_i (A_i * Y^i)$, where z is the sag height (in mm) of a line drawn from a point on the aspheric lens surface at a radial distance, Y from the optical axis to the tangential plane of the aspheric surface vertex, C is the curvature of the aspheric lens surface on the optical axis, Y is the radial distance (in mm) from the optical axis, K is the conic constant, and $A_i$ is the $i^{th}$ aspheric coefficient, with the summation over even number i. However, these aspects are not to be construed as limiting the scope of the subject disclosure. Rather, various surfaces can be odd aspheric, or of an aspheric equation comprising even and odd coefficients.

**[0078]** Further to the above, it should be appreciated that lenses L1-L5 of optical system 1000 (and the optical lenses of optical system 1100) can be made of various suitable types of transparent material, formed according to various suitable processes for generating an optical quality surface. In one aspect, the lenses L1-L5 can be ground and polished glass, where the glass is selected to have an index of refraction resulting in a desired effective focal length for the combined lenses L1-L5. In another aspect, the lenses can be an optical-quality injected molded plastic (or plastic of optical quality formed by another suitable method), wherein the plastic has an index of refraction suitable to provide the desired effective focal length. In at least one other aspect, the lenses L1-L5 can be etched from a transparent glass, crystalline or other suitable structure (*e.g.*, silicon dioxide – $SiO_2$ wafer) with a lithographic etching process similar to that used to etch semiconductor chips (*e.g.*, solid state memory chip, data processing chip).

**[0079]** According to various aspects, the lenses L1, L2, L3, L4 and L5 can be made of plastic (*e.g.*, APL5014, OKP4HT, or ZE-330R or another suitable plastic having similar refractive index and Abbe number, or a suitable combination thereof). In one specific aspect, lenses L1, L3, and L5 are made of one plastic (*e.g.*, APL5014) while lenses L2 and L4 are made of different plastics (*e.g.*, OKP4HT and ZE-330R



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respectively). It should be appreciated, however, that in other aspects the lenses can be of other materials having similar Abbe numbers or refractive indices instead.

**[0080]** Turning now to Figure 11, a cross-section of a sample optical system focused at infinity according to aspects of the subject disclosure is shown. The optical system 1100 of Figure 11 is similar to optical system 100, although optical system 1100 is focused on an object at infinity as opposed to at 10 cm. A difference between optical system 1100 and optical system 1000 is that L1 is positioned at a different distance from the sensor 1106 relative to lenses L2-L5.

**[0081]** According to one specific aspect of the subject disclosure, a prescription for the respective lenses L1, L2, L3, L4 and L5 is provided in Tables 10-13, below. Table 10 lists general lens data for the respective lenses, and Table 11 lists surface data including radius of curvature (R) (in mm) near the optical axis, distance between surfaces, diameter of the respective lenses, and material of the respective lenses. Furthermore, Table 12 provides aspheric constants $A_i$ for i = 2, 4, 6, 8, 10, 12, 14, 16 of equation (1), *supra*, for aspheric surfaces of Table 11, where the index "i" is denoted by "r" (*e.g.*, as generated in the optical design software program ZEMAX, available from ZEMAX Development Corporation). Table 13 provides refractive index $n_i$ of the $i^{th}$ lens for a set of wavelengths. Table 14 provides a range of fields versus image height, Table 15 provides vignetting information for optical systems 1000 and 1100, Table 16 provides wavelength and weights used for the raytracing of Figures 10 and 11, Table 17 provides surface data for optical systems 1000 and 1100, including radius, thickness, material, diameter, and conic constant. Additionally, Table 18 provides edge thickness information for optical systems 1000 and 1100.

| | |
|---|---|
| Surfaces (including apertures) | 15 |
| Stops | 1 |
| System Aperture | Float by stop size = 0.886727 |
| Apodization | Uniform Factor = 0.00000E+000 |
| Temperature (C) | 2.00000E+001 |
| Pressure (ATM) | 1.00000E+000 |
| Effective Focal Length | 4.28412 (in air at system temp & pressure) |
| Effective Focal Length | 4.28412 (in image space) |

| | |
|---|---|
| Back Focal Length | 0.5015793 |
| TTL | 5.299934 |
| Image Space F/# | 2.415692 |
| Paraxial Working F/# | 2.415692 |
| Working F/# | 2.40149 |
| Image Space NA | 0.202684 |
| Object Space NA | 8.867272e-011 |
| Stop Radius | 0.8867272 |
| Paraxial Image Height | 2.856 |
| Paraxial Magnification | 0 |
| Entrance Pupil Diameter | 1.773454 |
| Entrance Pupil Position | 0 |
| Field Type | Real Image height in mm |
| Maximum Radial Field | 2.856 |
| Primary Wavelength | 0.555µm |
| Lens Units | mm |
| Angular Magnification | 1.39828 |

**Table 10: General Properties for Optical Systems 1000 and 1100**

(Optical Properties defined in Optical Design Software Zemax)

| Surface | Type | Radius (mm) | Thickness (mm) | Medium | Diameter (mm) |
|---|---|---|---|---|---|
| OBJ | Standard | Infinity | Infinity | | 0 |
| A1 | Standard | Infinity | 0.05 | | 1.773454 |
| R1 | Even_Asph | 2.031962 | 0.545 | APL5014 | 1.774436 |
| R2 | Even_Asph | -17.60993 | 0.1242087 | | 1.867362 |
| R3 | Even_Asph | 4.178319 | 0.3 | OKP4-HT | 1.941112 |
| R4 | Even_Asph | 1.60308 | 0.3519566 | | 2.054041 |
| R5 | Even_Asph | 5.790688 | 0.6445624 | APL5014 | 2.132792 |
| R6 | Even_Asph | -2.417954 | 0.2002186 | | 2.449247 |
| R7 | Even_Asph | -0.9919052 | 0.3658935 | ZE-330R | 2.5699 |
| R8 | Even_Asph | -1.223582 | 0.5116968 | | 2.686087 |
| R9 | Even_Asph | 12.46394 | 1.123586 | APL5014 | 2.987795 |
| R10 | Even_Asph | 2.132428 | 0.3415114 | | 4.646312 |
| 14 | Standard | Infinity | 0.3 | D263T | 6 |



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| | | | | | |
|---|---|---|---|---|---|
| 15 | Standard | Infinity | 0.4913 | | 6 |
| IMA | Standard | Infinity | | | 6.4 |

**Table 11: Surface Data for Lens Elements for Optical System 1000 and 1100**

| Surface | Conic | Note |
|---|---|---|
| OBJ | 0 | |
| A1 | 0 | stop1 |
| R1 | -1 | L1-1 |
| R2 | -1 | L1-2 |
| R3 | -1 | L2-1 |
| R4 | -1 | L2-2 |
| R5 | -1 | L3-1 |
| R6 | -1 | L3-2 |
| R7 | -1 | L4-1 |
| R8 | -1 | L4-2 |
| R9 | -1 | L5-1 |
| R10 | -1 | L5-2 |
| 14 | 0 | Ir cut-off (D263T) |
| 15 | 0 | |
| IMA | | |

**Table 11: Continued**

| Surface | R1 | |
|---|---|---|
| | Coeff on r2 | 0 |
| | Coeff on r4 | 0.021400101 |
| | Coeff on r6 | -0.0044229854 |
| | Coeff on r8 | -0.00018162551 |
| | Coeff on r10 | 0 |
| | Coeff on r12 | 0 |
| | Coeff on r14 | 0 |
| | Coeff on r16 | 0 |
| Surface | R2 | |
| | Coeff on r2 | 0 |
| | Coeff on r4 | 0.0013366226 |
| | Coeff on r6 | 0.0044675095 |

| | | |
|---|---|---|
| | Coeff on r8 | -0.0065254167 |
| | Coeff on r10 | 0 |
| | Coeff on r12 | 0 |
| | Coeff on r14 | 0 |
| | Coeff on r16 | 0 |
| Surface | R3 | |
| | Coeff on r2 | 0 |
| | Coeff on r4 | -0.15575931 |
| | Coeff on r6 | 0.11775238 |
| | Coeff on r8 | -0.040496241 |
| | Coeff on r10 | 0 |
| | Coeff on r12 | 0 |
| | Coeff on r14 | 0 |
| | Coeff on r16 | 0 |
| Surface | R4 | |
| | Coeff on r2 | 0 |
| | Coeff on r4 | -0.17899613 |
| | Coeff on r6 | 0.13165259 |
| | Coeff on r8 | -0.041877243 |
| | Coeff on r10 | 0 |
| | Coeff on r12 | 0 |
| | Coeff on r14 | 0 |
| | Coeff on r16 | 0 |
| Surface | R5 | |
| | Coeff on r2 | 0 |
| | Coeff on r4 | -0.034806957 |
| | Coeff on r6 | -0.055196853 |
| | Coeff on r8 | -0.0076170308 |
| | Coeff on r10 | 0 |
| | Coeff on r12 | 0 |
| | Coeff on r14 | 0 |
| | Coeff on r16 | 0 |
| Surface | R6 | |
| | Coeff on r2 | 0 |
| | Coeff on r4 | 0.020581236 |
| | Coeff on r6 | -0.0065040866 |
| | Coeff on r8 | -0.018006387 |
| | Coeff on r10 | 0 |
| | Coeff on r12 | 0 |
| | Coeff on r14 | 0 |
| | Coeff on r16 | 0 |
| Surface | R7 | |

| | | |
|---|---|---|
| | Coeff on r2 | 0 |
| | Coeff on r4 | 0.17752822 |
| | Coeff on r6 | 0.0025820117 |
| | Coeff on r8 | 0.0073104429 |
| | Coeff on r10 | -0.0065708267 |
| | Coeff on r12 | 0 |
| | Coeff on r14 | 0 |
| | Coeff on r16 | 0 |
| Surface | R8 | |
| | Coeff on r2 | 0 |
| | Coeff on r4 | 0.03288338 |
| | Coeff on r6 | 0.076502466 |
| | Coeff on r8 | -0.06842281 |
| | Coeff on r10 | 0.038984099 |
| | Coeff on r12 | -0.0076836467 |
| | Coeff on r14 | 0 |
| | Coeff on r16 | 0 |
| Surface | R9 | |
| | Coeff on r2 | 0 |
| | Coeff on r4 | -0.1830718 |
| | Coeff on r6 | 0.075510932 |
| | Coeff on r8 | -0.034603365 |
| | Coeff on r10 | 0.0066539539 |
| | Coeff on r12 | -0.00029016159 |
| | Coeff on r14 | 0 |
| | Coeff on r16 | 0 |
| Surface | R10 | |
| | Coeff on r2 | 0 |
| | Coeff on r4 | -0.15124446 |
| | Coeff on r6 | 0.071176496 |
| | Coeff on r8 | -0.029255744 |
| | Coeff on r10 | 0.0080879291 |
| | Coeff on r12 | -0.0014220241 |
| | Coeff on r14 | 0.00014276636 |
| | Coeff on r16 | -6.2275295e-006 |

**Table 12: Aspheric Coefficients for Optical System 1000 and 1100**

| | | | | **Index** (for given wavelength in μm) | | | | |
|---|---|---|---|---|---|---|---|---|
| **Surface** | **Medium** | **Temp** | **Pressure** | 0.47 | 0.41 | 0.555 | 0.61 | 0.65 |
| L1 | APL5014 | 20 | 1 | 1.5518 | 1.5483 | 1.5452 | 1.5424 | 1.5408 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| L2 | OKP4-HT | 20 | 1 | 1.6564 | 1.6458 | 1.6369 | 1.6291 | 1.6248 |
| L3 | APL5014 | 20 | 1 | 1.5518 | 1.5483 | 1.5452 | 1.5424 | 1.5408 |
| L4 | ZE-330R | 20 | 1 | 1.5172 | 1.5139 | 1.5111 | 1.5084 | 1.5069 |
| L5 | APL5014 | 20 | 1 | 1.5518 | 1.5483 | 1.5452 | 1.5424 | 1.5408 |

**Table 13: Index of Refraction for Optical Systems 1000 and 1100**

| Field # | X-Value | Y-Value | Weight |
|---|---|---|---|
| 1 | 0 | 0 | 1 |
| 2 | 0 | 0.571 | 1 |
| 3 | 0 | 1.142 | 1 |
| 4 | 0 | 1.714 | 1 |
| 5 | 0 | 2.285 | 1 |
| 6 | 0 | 2.57 | 1 |
| 7 | 0 | 2.856 | 1 |

**Table 14: Field Type v. Real Image Height (in mm)**

| Field / # | VDX | VDY | VCX | VCY | VAN |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | -0.00376 | 0.00001 | 0.003764 | 0 |
| 3 | 0 | -0.00751 | 0.00003 | 0.007509 | 0 |
| 4 | 0 | -0.01125 | 0.000093 | 0.011253 | 0 |
| 5 | 0 | -0.01512 | 0.00015 | 0.015117 | 0 |
| 6 | 0 | -0.01707 | 0.000226 | 0.017069 | 0 |
| 7 | 0 | -0.019 | 0.000251 | 0.018997 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 |

**Table 15: Vignetting Factors for Fields of Table 2**

| Wavelength # | Value (in µm) | Weight |
|---|---|---|
| 1 | 0.47 | 91 |
| 2 | 0.51 | 503 |
| 3 | 0.555 | 1000 |
| 4 | 0.61 | 503 |
| 5 | 0.65 | 107 |

**Table 16: Wavelengths Used for Raytracing**

| Surface | Type | Radius | Thickness | Material | Diameter | Conic | Notes |
|---|---|---|---|---|---|---|---|



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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Object | Standard | Infinity | Infinity | | 0 | 0 | |
| Stop | Standard | Infinity | 0.05 | | 1.773454 | 0 | |
| 2 | Standard | Infinity | -0.204 | | 1.773454 | 0 | |
| 3 | EvenAsph | 2.031962 | 0.545 | APL5014 | 1.774436 | -1 | L1 |
| 4 | EvenAsph | -17.6099 | 0.124209 | | 1.867362 | -1 | |
| 5 | EvenAsph | 4.178319 | 0.3 | OKP4HT | 1.941112 | -1 | L2 |
| 6 | EvenAsph | 1.60308 | 0.351957 | | 2.054041 | -1 | |
| 7 | EvenAsph | 5.790688 | 0.644562 | APL5014 | 2.132792 | -1 | L3 |
| 8 | EvenAsph | -2.41795 | 0.200219 | | 2.449247 | -1 | |
| 9 | EvenAsph | -0.99191 | 0.365894 | ZE-330R | 2.5699 | -1 | L4 |
| 10 | EvenAsph | -1.22358 | 0.511697 | | 2.686087 | -1 | |
| 11 | EvenAsph | 12.46394 | 1.123586 | APL5014 | 2.987795 | -1 | L5 |
| 12 | EvenAsph | 2.132428 | 0.341511 | | 4.646312 | -1 | |
| 13 | Standard | Infinity | 0.3 | D263T | 6 | 0 | IRCF |
| 14 | Standard | Infinity | 0.4913 | N-BK7 | 6 | 0 | |
| Image | Standard | Infinity | 6.4 | | 0 | 0 | |

**Table 17: Surface Data Summary**

| Surface | Edge |
|---|---|
| Stop | 0.05 |
| 2 | 0.000726 |
| 3 | 0.315728 |
| 4 | 0.189805 |
| 5 | 0.491449 |
| 6 | 0.078721 |
| 7 | 0.308446 |
| 8 | 0.214072 |
| 9 | 0.303193 |
| 10 | 0.428579 |
| 11 | 1.31122 |
| 12 | 0.662695 |
| 13 | 0.3 |
| 14 | 0.4913 |
| Image | 0 |

**Table 18: Edge Thickness Data**

**[0082]** Figure 12 illustrates a graph of field curvature and distortion for optical configuration 1002. Further, the field curvature and distortion values are displayed for several wavelengths ranging from 0.470μm to 0.650μm. Field curvature is within about 10 microns for these wavelengths for low field angles, and is less than 100 microns even at the perimeter of the image plane. Further, distortion is well within the range of two and negative two percent. As would be clear to one of skill in the art, aberrations are well compensated for by the subject optical arrangement 1002.

**[0083]** Figure 13 illustrates a graph of field curvature and distortion for optical configuration 1102. Further, the field curvature and distortion values are displayed for



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several wavelengths ranging from 0.470μm to 0.650μm. Field curvature is well within the range of +/- 100 microns, and distortion is well within the range of two and negative two percent. As would be clear to one of skill in the art, aberrations are well compensated for by the subject optical arrangement 1102.

**[0084]** Figure 14 depicts a graph of lateral color for optical arrangement 1002. A maximum field for the graph is 2.8560mm. Additionally, the lateral color curve is over a range of wavelengths from 0.470μm to 0.650μm. The primary lateral color for an object in focus at 10cm is about -3.5μm as depicted by the graph.

**[0085]** Figure 15 depicts a graph of lateral color for optical arrangement 1102 for an object in focus at infinity. A maximum field for the graph is 2.8560mm. Additionally, the lateral color curve is over a range of wavelengths from 0.470μm to 0.650μm. The primary lateral color for the object in focus at infinity is about +0.8 microns.

**[0086]** Figure 16 and Figure 17 depict transverse ray fan plots for optical arrangements 1002 and 1102 respectively. The transverse ray fan plots depict transverse aberration ($e_y$ and $e_x$) along the y and x axis for pupil diameters $P_y$ and $P_x$. The transverse ray fan plots are made at image heights 0.000mm (1600 and 1700), 0.5710mm (1602 and 1702), 1.1420mm (1604 and 1704), 1.7140mm (1606 and 1706), 2.2850mm (1608 and 1708), 2.5700mm (1610 and 1710), and 2.8560mm (1612 and 1712). The plots are generally within acceptable ranges for optical imaging and accordingly, the optical arrangements 1002 and 1102 have good imaging quality.

**[0087]** Figure 18 illustrates a diagram of an example ray plot diagram for an optical system 1800 according to alternative aspects of the subject disclosure. System 1800 comprises an arrangement of optical elements 1802. Optical rays are depicted intersecting optical elements 1802 within a field of view of optical system 1800. On-axis rays are focused onto the optical axis at an image plane or focal plane associated with optical elements 1802, and rays originating at larger field angles are depicted as converging at farther distances from the optical axis at the image plane.

**[0088]** A left-most side of optical elements 1802 is an object side of optical system 1800, and a right-most side of optical elements 1802 is an image side of optical system 1800. A real image of the object is formed at the image plane of optical elements 1802 when optical elements 1802 are properly in focus. In at least one aspect of the subject disclosure, optical system 1800 can comprise a variable focus optical system, in which a subset of optical elements 1802 can be moved along the optical axis to bring an image of an object into focus at the image plane. In particular aspects, a set of positions of the subset of optical elements 1802 can correspond with a set of object distances having respective images in focus at the image plane. In other words, when the subset of optical elements 1802 is positioned at one of the set of positions, an object at a corresponding one of the set of object distances will be in focus at the image plane. A position of optical elements 1802 as depicted by Figure 18 and Figure 19, *infra*, illustrate an example arrangement in which optical elements of system 1800 are in a position to focus an object located at infinity onto the image plane. A position of optical elements 1802 as depicted by Figures 23 and 24, *infra*, illustrate an example arrangement in which the optical elements are in a position to focus a near-field object onto the image plane.

**[0089]** Figure 19 depicts a diagram of an example optical system 1900 comprising optical elements and optical surfaces according to additional aspects of the subject disclosure. Optical system 1900 can be substantially similar to optical system 1800. As indicated, optical system 1900 is configured to focus an image of an object located in the far-field (*e.g.*, at infinity).

**[0090]** Optical system 1900 can comprise a set of optical elements 1902 centered along an optical axis 1904. Optical elements 1902 can be configured to focus an image that can be captured by a sensor 1908. Sensor 1908 can comprise a multi-dimensional array of optical-sensitive pixels located at an image plane of sensor 1908. The optical-sensitive pixels can output electrical signals in response to electro-magnetic energy (*e.g.*, light) focused by optical elements 1902 upon sensor 1908. Moreover, the electrical signals can have characteristics related to optical characteristics of the electro-magnetic energy. These electrical signals can be utilized to re-produce the image focused by optical elements 1902 and captured by sensor 1908, as described herein or known in the art. Optical system 1900 can also comprise a cover plate 1906 for sensor 1908. Cover plate can protect the optical-sensitive pixels of sensor 1908 from dust or other particles that might otherwise absorb or scatter electro-magnetic energy focused by optical elements 1902, thereby distorting the image.

**[0091]** Optical elements 1902 can comprise five optical lenses, including lens L1, lens L2, lens L3, lens L4 and lens L5 (referred to collectively as lenses L1 – L5). The optical lenses are numbered from left – the object side of optical system 1900 – to right – the image side of optical system 1900. The left-most lens, L1, is therefore also referred to herein as the object-side lens. Alternatively, lens L1 can be referred to as an objective lens of optical system 1900.

**[0092]** As depicted, lens L1 is a bi-convex lens having positive optical power, and having a convex object-side surface R1 and convex image-side surface R2. Furthermore, lens L1 can have a strong optical power relative to lenses L2, L3, L4 and L5 of optical elements 1902. In particular aspects, lens L1 can have greater positive optical power than either of lenses L2, L3, L4 or L5. In a further aspect, L1 can have greater positive optical power than any subset of lenses L2, L3, L4 and L5. In at least one alternative or additional aspect, lens L1 can have greater positive optical power than the combination of lenses L2, L3, L4 and L5. As depicted, an aperture stop A1 can be located about the object side surface R1 of lens L1.

**[0093]** Lens 2 can be a lens having a negative optical power. Lens L2 can have an object-side surface R3 and an image-side surface R4. Surface R3 can be mildly convex, in some aspects of the subject disclosure. In other aspects, surface R3 can be substantially flat with no significant optical power. In still other aspects of the subject disclosure, surface R3 can have a complex curvature that is convex for a subset of pupil radii (*e.g.*, a range of distances from optical axis 1904) of surface R3, and concave for a different subset of pupil radii of surface R3. As an example, surface R3 can have a concave curvature from the optical axis 1904 to a first pupil radius, and can have a convex curvature from the first pupil radius to a second pupil radius, where the second pupil radius is larger than the first pupil radius. An image side surface R4 can have a concave curvature, providing the majority of negative optical power of lens L2.

**[0094]** Lens L3 can be a meniscus lens having a convex curvature toward the object side of lens L3. As depicted, lens L3 comprises an object side surface R5 and image side surface R6. Object side surface R5 can have convex curvature. In particular aspects, convexity of object side surface R5 can be stronger near optical axis 1904 than near a perimeter of lens L3. Said differently, a radius of curvature of object side surface R5 can increase with increasing pupil radius of object side surface R5, and in at least one aspect become infinite near the perimeter of lens L3. Image side surface R6 can have concave curvature. In at least one aspect, a radius of curvature of image side surface R6 can increase with increasing pupil radius of lens L3. In an alternative or additional aspect, image side surface R6 can be convex near the perimeter of lens L3.

**[0095]** Lens L4 comprises an object side surface R7 and an image side surface R8. Lens L4 can be a meniscus lens toward the image side of optical elements 1902.



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Additionally, lens L4 can have mild positive optical power. In one alternative or additional aspect, positive power of lens L4 can be greater near optical axis 1904 as compared with a periphery of lens L4, whereas in other aspects the positive power can be substantially constant over the surface of image side surface R8.

**[0096]** Lens L5 comprises an object side surface R9 and image side surface R10. Object side surface R9 can have concave curvature for low and medium field angles, and reduced curvature at higher field angles. Image side surface R10 can be concave near optical axis 1904. Further, image side surface R10 can transition from concave to convex for medium and high field angles.

**[0097]** Optical elements 1902 can have respective spaces (air gaps) between respective lenses L1, L2, L3, L4 and L5. In a particular aspect, an on-axis air distance between lens L4 and lens L5 can be a largest of a set of air distances among lenses L1 – L5. In an alternative or additional aspect, an air distance between lens L3 and lens L4 can be a second largest of the set of air distances among lenses L1 – L5.

**[0098]** In a further aspect of the subject disclosure, an actuator can be connected to a subset of optical elements 1902. In one example, the actuator can be a MEMS actuator, whereas in other aspects the actuator can be another type of actuator known in the art. The actuator can be configured to reposition the subset of optical lenses along optical axis 1904. Repositioning the subset of optical lenses can cause images of objects at different object distances to come into focus at sensor 1908 of optical system 1900. In particular aspects, optical lenses 1902 can be configured to focus an image of an object located in the far field (*e.g.*, infinity, …) onto sensor 1908. According to further aspects, the subset of optical elements 1902 can be repositioned to focus an object in the near field at sensor 1908. In a specific aspect, the subset of optical elements can include lens L1, and lens L1 can be positioned as depicted by Figure 19 by the MEMS actuator to bring an object located at infinity into focus at sensor 1908, and can be positioned as depicted by Figure 23 by the MEMS actuator to bring an object at an object distance of substantially 12.8 centimeters (cm) into focus at sensor 1908.

**[0099]** In a further aspect, aperture stop A1 can be fixed relative to optical axis 1904. In another aspect, aperture stop A1 can be fixed relative to a position of lens L1. In the latter aspect, aperture stop A1 can be moved by a MEMS actuator in conjunction with lens L1 when focusing an image of an object onto sensor 1908. According to still other aspects, the MEMS actuator can be configured to move lens L1, either alone or in conjunction with aperture stop A1, a total distance along optical axis 1904. The total distance can, at one end thereof, focus an image of an object at infinity on sensor 1908, and at another end thereof, focus an image of an object at an object distance of substantially 12.8cm at sensor 1908.

**[00100]** Lenses L1 – L5 can be of various suitable types of suitable optically transparent material, and formed according to a suitable method(s) for generating an optical quality surface. In one aspect, lenses L1 – L5 can be ground or polished glass, where the glass is selected to have an index of refraction resulting in a desired effective focal length for the combined lenses L1 – L5. In another aspect, the lenses can be an optical-quality injection molded plastic (or plastic of optical quality formed by another suitable fabrication method), wherein the plastic has an index of refraction suitable to provide the desired focal length. In another aspect(s), the lenses L1 – L5 can be etched from a transparent glass, crystalline or other suitable structure with a lithographic etching process similar to that used to etch semiconductor chips. In a specific aspect(s), lenses L1 – L5 can be of differing glasses, plastics or suitable optical-transparent medium, by one or more of the above or similar suitable fabrication techniques (note that cover 1908 is a fictional material). In a further aspect, optical elements 1902 can have be described according to the optical prescription of Tables 19 – 27A.

| Parameter Description | Value |
|---|---|
| Effective Focal Length (in air at system temperature and pressure) | 4.803702 |
| Effective Focal Length (in image space) | 4.803702 |
| Back Focal Length | 0.1097044 |
| Total Track Length (TTL) | 5.588093 |
| Image Space F/# | 2.668723 |
| Paraxial Working F/# | 2.668742 |
| Working F/# | 2.647852 |
| Image Space NA | 0.1841501 |
| Object Space NA | 9e-007 |
| Stop Radius | 0.9 |
| Paraxial Image Height | 3.492 |
| Paraxial Magnification | -4.803736e-006 |
| Entrance Pupil Diameter | 1.8 |
| Entrance Pupil Position | 0.05 |

| | |
|---|---|
| Exit Pupil Diameter | 1.214476 |
| Exit Pupil Position | -3.231397 |
| Maximum Radial Field | 3.492 |
| Lens Units | Millimeters (mm) |
| Angular Magnification | 1.482119 |

**Table 1: General Optical Properties (Object in Focus at Infinity)**

| Field # | X-Value | Y-Value | Weight |
|---|---|---|---|
| 1 | 0 | 0 | 1 |
| 2 | 0 | 0.339 | 1 |
| 3 | 0 | 0.678 | 1 |
| 4 | 0 | 1.018 | 1 |
| 5 | 0 | 1.357 | 1 |
| 6 | 0 | 1.696 | 1 |
| 7 | 0 | 2.035 | 1 |
| 8 | 0 | 2.375 | 1 |
| 9 | 0 | 2.714 | 1 |
| 10 | 0 | 3.053 | 1 |
| 11 | 0 | 3.392 | 1 |
| 12 | 0 | 3.492 | 1 |

**Table 20: Field Type v. Real Image Height (in mm)**

| Field / # | VDX | VDY | VCX | VCY | VAN |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | -0.005032 | 0.000003 | 0.005032 | 0 |
| 8 | 0 | -0.018773 | 0.000041 | 0.018775 | 0 |
| 9 | 0 | -0.031175 | 0.000230 | 0.031178 | 0 |
| 10 | 0 | -0.062274 | 0.000739 | 0.062281 | 0 |
| 11 | 0 | -0.154303 | 0.005254 | 0.154319 | 0 |
| 12 | 0 | -0.218933 | 0.013148 | 0.218954 | 0 |

**Table 21: Vignetting Factors for Fields of Table 20**

| Wavelength # | Value (in µm) | Weight |
|---|---|---|
| 1 | 0.4358 | 0.15 |
| 2 | 0.4861 | 0.45 |
| 3 | 0.5461 | 1.00 |



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| | | |
|---|---|---|
| 4 | 0.5876 | 0.80 |
| 5 | 0.6563 | 0.10 |

**Table 22: Wavelengths Used for Raytracing**

| Surface | Type | Radius | Thickness | Material | Diameter | Conic | Notes |
|---|---|---|---|---|---|---|---|
| Object | Standard | Infinity | 1000000 | | 1471328 | 0 | |
| 1 | Standard | Infinity | 0.05 | | 2.054093 | 0 | Stop1 |
| Stop | Standard | Infinity | -0.176644 | | 1.8 | 0 | A1 |
| 3 | EvenAsph | 2.024203 | 0.721 | ZEONF52R | 1.872 | -1 | R1 |
| 4 | EvenAsph | -11.83444 | 0 | | 1.89 | 0 | R2 |
| 5 | Standard | Infinity | 0.1656548 | | 2.013514 | 0 | Stop 2 |
| 6 | EvenAsph | -250 | 0.32 | EP5000 | 1.91 | 0 | R3 |
| 7 | EvenAsph | 2.745619 | 0.3434152 | | 2.093864 | 0 | R4 |
| 8 | Standard | Infinity | 0.0030239 | | 2.284004 | 0 | Stop 3 |
| 9 | EvenAsph | 2.970147 | 0.3494011 | EP5000 | 2.456709 | 0 | R5 |
| 10 | EvenAsph | 3.958667 | 0.1844251 | | 2.735497 | 0 | R6 |
| 11 | Standard | Infinity | 0.3353069 | | 2.904996 | 0 | Stop 4 |
| 12 | EvenAsph | -4.538803 | 0.5144013 | ZEONF52R | 3.007844 | 0 | R7 |
| 13 | EvenAsph | -1.564577 | 0.2719004 | | 3.349097 | -1 | R8 |
| 14 | Standard | Infinity | 0.421506 | | 5.022903 | 0 | Stop 5 |
| 15 | EvenAsph | -3.333743 | 0.908 | ZEONF52R | 5.142131 | 0 | R9 |
| 16 | EvenAsph | 3.980869 | 0.6500583 | | 6.098372 | 0 | R10 |
| 17 | Standard | Infinity | 0.3 | | 6.850686 | 0 | CG 1908 |
| 18 | Standard | Infinity | 0.1 | | 7.016723 | 0 | |
| Image | Standard | Infinity | | | 7.009976 | 0 | |

**Table 23: Surface Data Summary**

| Surface | Parameter Description | Value |
|---|---|---|
| R1 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | 0.0072492627 |
| | Coefficient on r 6 | -0.0011425636 |
| | Coefficient on r 8 | -0.026147557 |
| | Coefficient on r 10 | 0.02892707 |
| | Coefficient on r 12 | -0.015728565 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |



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| | | |
|---|---|---|
| R2 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.018496708 |
| | Coefficient on r 6 | 0.041017657 |
| | Coefficient on r 8 | -0.14989043 |
| | Coefficient on r 10 | 0.18705355 |
| | Coefficient on r 12 | -0.081043198 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R3 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.04452888 |
| | Coefficient on r 6 | 0.1590456 |
| | Coefficient on r 8 | -0.32756888 |
| | Coefficient on r 10 | 0.38155806 |
| | Coefficient on r 12 | -0.15580658 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R4 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.067461498 |
| | Coefficient on r 6 | 0.16544449 |
| | Coefficient on r 8 | -0.23156178 |
| | Coefficient on r 10 | 0.20660588 |
| | Coefficient on r 12 | -0.067541427 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R5 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.10351059 |
| | Coefficient on r 6 | 0.083284677 |
| | Coefficient on r 8 | -0.073446626 |
| | Coefficient on r 10 | 0.031355945 |
| | Coefficient on r 12 | -0.005953706 |
| | Coefficient on r 14 | 0 |

| | | |
|---|---|---|
| | Coefficient on r 16 | 0 |
| R6 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.080839736 |
| | Coefficient on r 6 | 0.05806703 |
| | Coefficient on r 8 | -0.042396061 |
| | Coefficient on r 10 | 0.013117216 |
| | Coefficient on r 12 | -0.001392345 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R7 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.061283862 |
| | Coefficient on r 6 | 0.056005953 |
| | Coefficient on r 8 | -0.023784572 |
| | Coefficient on r 10 | 0.004382924 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R8 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | 0.005176523 |
| | Coefficient on r 6 | 0.02067126 |
| | Coefficient on r 8 | 0.001625502 |
| | Coefficient on r 10 | -0.001134584 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R9 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | 0.019100544 |
| | Coefficient on r 6 | -0.000208483 |
| | Coefficient on r 8 | 5.84E-05 |
| | Coefficient on r 10 | -3.36E-06 |
| | Coefficient on r 12 | 0 |

| | | |
|---|---|---|
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R10 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.038366245 |
| | Coefficient on r 6 | 0.004903112 |
| | Coefficient on r 8 | -0.000509017 |
| | Coefficient on r 10 | 1.88E-05 |
| | Coefficient on r 12 | 1.99E-07 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |

**Table 24: Surface Aspheric Coefficients**

| Surface | Edge |
|---|---|
| Object | 1000000 |
| 1 | 0.05 |
| Stop | 0.036971 |
| 3 | 0.45386 |
| 4 | 0.053525 |
| 5 | 0.17191 |
| 6 | 0.53351 |
| 7 | 0.123651 |
| 8 | 0.113652 |
| 9 | 0.301427 |
| 10 | 0.121772 |
| 11 | 0.050401 |
| 12 | 0.30346 |
| 13 | 0.767748 |
| 14 | 0.053483 |
| 15 | 0.953242 |
| 16 | 0.972839 |
| 17 | 0.3 |
| 18 | 0.1 |
| Image | 0 |

**Table 25: Edge Thickness Data**

| Temperature (Temp) in degrees Celsius and pressure (Press) in atmospheres | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Surface | Material | Temp | Press | 0.4358 | 0.4861 | 0.5461 | 0.5876 | 0.6563 |
| 0 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 3 | ZEONF5 | 20 | 1 | 1.5467026 | 1.54130926 | 1.53688 | 1.53462 | 1.531786 |



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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2R | | | | | | | |
| 4 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 5 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 6 | EP5000 | 20 | 1 | 1.67140227 | 1.65459312 | 1.641717 | 1.635484 | 1.628005 |
| 7 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 8 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 9 | EP5000 | 20 | 1 | 1.67140227 | 1.65459312 | 1.641717 | 1.635484 | 1.628005 |
| 10 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 11 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 12 | ZEONF5 2R | 20 | 1 | 1.5467026 | 1.54130926 | 1.53688 | 1.53462 | 1.531786 |
| 13 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 14 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 15 | ZEON F52R | 20 | 1 | 1.5467026 | 1.541309 26 | 1.53688 | 1.53462 | 1.531786 |
| 16 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 17 | MODE L | 20 | 1 | 1.5267041 6 | 1.522378 72 | 1.518719 | 1.516798 | 1.514329 |
| 18 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 19 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |

**Table 26: Index of Refraction Data**

| | | Wavelengths (µm): | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.4358 | | 0.4861 | | 0.5461 | |
| Number | Field (mm) | Tan | Sag | Tan | Sag | Tan | Sag |
| 1 | 0 | 2.6405 | 2.6405 | 2.6425 | 2.6425 | 2.6479 | 2.6479 |
| 2 | 0.339 | 2.6528 | 2.6499 | 2.6546 | 2.6517 | 2.6597 | 2.6568 |
| 3 | 0.678 | 2.681 | 2.6772 | 2.6823 | 2.6783 | 2.6871 | 2.683 |
| 4 | 1.018 | 2.7091 | 2.7201 | 2.7106 | 2.7201 | 2.7153 | 2.7239 |
| 5 | 1.357 | 2.7373 | 2.7739 | 2.7401 | 2.7726 | 2.7455 | 2.7753 |
| 6 | 1.696 | 2.8006 | 2.8361 | 2.8059 | 2.8335 | 2.8128 | 2.8352 |
| 7 | 2.035 | 2.9489 | 2.9083 | 2.9563 | 2.9045 | 2.9645 | 2.9052 |
| 8 | 2.375 | 3.1818 | 2.9917 | 3.1891 | 2.9868 | 3.196 | 2.9866 |
| 9 | 2.714 | 3.5028 | 3.0817 | 3.5075 | 3.076 | 3.5109 | 3.075 |
| 10 | 3.053 | 4.1133 | 3.1794 | 4.1121 | 3.1732 | 4.109 | 3.1717 |
| 11 | 3.392 | 5.1478 | 3.3011 | 5.1473 | 3.2949 | 5.1404 | 3.2931 |
| 12 | 3.492 | 5.7808 | 3.3568 | 5.7754 | 3.3511 | 5.7637 | 3.3495 |

**Table 27: F/Number Data**

| | | Wavelengths (µm) | | | |
|---|---|---|---|---|---|
| | | 0.5876 | | 0.6563 | |
| Number | Field (mm) | Tan | Sag | Tan | Sag |
| 1 | 0 | 2.6519 | 2.6519 | 2.6583 | 2.6583 |
| 2 | 0.339 | 2.6637 | 2.6608 | 2.67 | 2.6671 |
| 3 | 0.678 | 2.6909 | 2.6867 | 2.697 | 2.6927 |
| 4 | 1.018 | 2.719 | 2.7272 | 2.7249 | 2.7327 |



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| | | | | | |
|---|---|---|---|---|---|
| 5 | 1.357 | 2.7494 | 2.7781 | 2.7555 | 2.7831 |
| 6 | 1.696 | 2.8173 | 2.8375 | 2.824 | 2.8417 |
| 7 | 2.035 | 2.9694 | 2.907 | 2.9763 | 2.9106 |
| 8 | 2.375 | 3.2 | 2.9879 | 3.2054 | 2.9909 |
| 9 | 2.714 | 3.5125 | 3.0759 | 3.5143 | 3.0782 |
| 10 | 3.053 | 4.1067 | 3.1722 | 4.1033 | 3.1741 |
| 11 | 3.392 | 5.1347 | 3.2934 | 5.1255 | 3.295 |
| 12 | 3.492 | 5.7553 | 3.3499 | 5.7426 | 3.3515 |

**Table 27A: F/Number Data (Continued)**

**[00101]** Table 19 provides general optical information for an embodiment of optical systems 1800, 1900 of Figures 18 and 19, respectively. Table 20 provides image heights in the y axis, measured at the image sensor 1906 for a set of optical fields, and respective weights for the respective fields. Table 21 includes vignetting data for the set of optical fields of Table 20. Table 22 depicts wavelengths of respective rays traced in optical imaging system 1800, depicted at Figure 18. Table 23 provides a summary of general optical surface characteristics for lenses of optical elements 1902, including surface type, radius of curvature, thickness, material (from standard glass and plastic catalogues; not that a fictitious material is used for cover glass 1908), diameter, conic constant and applicable notes. Table 24 describes aspheric coefficients for the surfaces of Table 23, whereas Table 25 provides edge thickness information for those surfaces. Table 26 provides index of refraction data for multiple wavelengths for the optical fields identified at Table 20. Tables 27 and 27A provide F/# data for those same wavelengths and optical fields.

**[00102]** Figure 20 depicts a diagram of field curvature and distortion for the optical systems 1800, 1900 of Figures 18 and 19, *supra*. Particularly, the field curvature and distortion depicted in Figure 20 correspond with the optical elements 1902 configured to focus an image of an object at infinity onto sensor 1906. The field curvature and distortion graphs utilize five wavelengths, including 0.436, 0.486, 0.546, 0.588 and 0.656 μm respectively. Moreover, the rays are traced with a maximum field of 35.543 degrees. The left-hand graph depicts field curvature in millimeters along a y axis at an image plane of an optical imaging system. Field curvature curves are depicted for Sagittal rays (delineated by an ‘S’) and Tangential rays (delineated by a ‘T’). The range of field curvature over the utilized wavelengths is within a few microns for sagittal and tangential rays. The distortion graphs on the right-hand side of Figure 20 also includes curves for the above five wavelengths. The distortion data is normalized to 0% at the optical axis. Throughout the image plane, distortion is less than about -1%, and for mid to low field angles below about + / - one half a percent.

**[00103]** Figure 21 illustrates a diagram of longitudinal aberration for a set of wavelengths. Longitudinal aberration of Figure 21 relates to optical elements 1902, configured to image an object located at infinity onto sensor 1906. The listed wavelengths include 0.436, 0.486, 0.546, 0.588 and 0.656 μm. The graph charts longitudinal aberration in millimeters for increasing field angles, for a pupil radius of 0.9mm. At low field angles the longitudinal aberration is generally positive and less than about 0.02 millimeters. At high field angles, the longitudinal aberration is more negative and generally less than about 0.03 millimeters. The longitudinal aberration graph of Figure 21 indicates optical elements 1902 provide reasonably good aberration correction for the identified wavelengths.

**[00104]** Figure 22 depicts a graph of lateral color for optical elements 1902 of Figure 19, *supra*. Accordingly, the graph of lateral color relates to optical elements 1902 configured to focus an image of an object located at infinity onto sensor 1906. The maximum field for the lateral color graph is 3.3920 millimeters, and wavelengths for the lateral color graph range from 0.4358 through 0.6563 μm. In addition, data is referenced to 0.546100 μm. For most field angles the lateral color is within about + / - 0.5 microns. At high field angles, lower wavelengths exhibit lateral color about -1 micron or greater, and higher wavelengths exhibit lateral color about 1 micron.

**[00105]** Figure 23 illustrates a diagram of an example optical system 2300 according to still other aspects of the subject disclosure. Optical system 2300 can comprise a set of optical elements 2302, as depicted. In at least one aspect of the subject disclosure, optical elements 2302 can comprise a set of lenses substantially similar to optical elements 1802 and 1902 of Figures 18 and 19, *supra*, but having a different focus position. Specifically, a subset of optical elements 2302 can be positioned in a manner suitable to focus an image of a near-field object at an image plane of optical elements 2302. As depicted, the near-field object position for optical elements 2302 is 12.8cm. By repositioning the subset of optical elements 2302 between the position depicted by Figure 23 and that of optical elements 1902 of Figure 19, optical system 2300 can focus different object distances between the near-field object and an object at infinity.

**[00106]** Optical system 2300 illustrates a set of ray fans representing light incident upon optical elements 2302 at discrete field angles. A field angle of zero is depicted by rays of light that converge at an optical axis of optical system 2300 at an image plane of optical elements 2302. Light converging at points on the image plane at increasing distances from the optical axis represent rays of light encountering optical elements 2302 at correspondingly larger field angles.

**[00107]** Figure 24 depicts a diagram of an example optical system 2400 according to still other aspects of the subject disclosure. Optical system 2400 delineates optical lenses and associated optical surfaces of optical system 2300 of Figure 23. Further, in at least one aspect, the optical lenses and associated optical surfaces of optical system 2300 can be substantially similar to the optical lenses and optical surfaces of optical systems 1800 and 1900 of Figures 18 and 19, *supra*. Optical system 2400 can differ from optical systems 1800 and 1900 in that optical elements 2402 can be configured to focus an image of an object located at substantially 12.8cm at a sensor 2408. Other aspects of optical system 2400 and optical elements 2402, including optical surfaces R1 and R2 of lens L1, R3 and R4 of lens L2, R5 and R6 of lens L3, R7 and R8 of lens L4, and R9 and R10 of lens L5. Further, sensor 2408 and cover glass 2406 can be substantially similar to sensor 1906 and cover glass 1908 of optical system 1900.

**[00108]** According to a particular aspect of the subject disclosure, optical elements 2402 comprise an object lens, lens L1, which is connected to an actuator (*e.g.*, MEMS actuator, …) to facilitate auto-focusing for optical system 2400. In the arrangement of optical elements 2402 depicted by Figure 24, and in particular an air distance $\text{distance}_{\text{near}}$ between lens L1 and lens L2, optical elements 2402 are configured to focus a real image of an object at an object distance of 12.8cm onto sensor 2408. By moving lens L1 into a position depicted by optical elements 1902 of Figure 19, where the air distance between lens L1 and lens L2 is a $\text{distance}_{\text{far}}$, optical system 2400 can be configured to focus an image of an object at infinity, instead. In at least one alternative or additional aspect of the subject disclosure, lens L1 can be repositioned to change the air distance between $\text{distance}_{\text{near}}$ and $\text{distance}_{\text{far}}$, thereby focusing an image of an object located at points between 12.8cm and infinity at sensor 2408. Optical elements 2402 can have image characteristics as described by the optical characteristics of Tables 28 – 31A.

| Parameter Description | Value |
|---|---|



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| | |
|---|---|
| Effective Focal Length (in air at system temperature and pressure) | 4.673877 |
| Effective Focal Length (in image space) | 4.673877 |
| Back Focal Length | -0.05732965 |
| Total Track Length (TTL) | 5.668093 |
| Image Space F/# | 2.596598 |
| Paraxial Working F/# | 2.747179 |
| Working F/# | 2.738746 |
| Image Space NA | 0.1790633 |
| Object Space NA | 0.007028331 |
| Stop Radius | 0.9 |
| Paraxial Image Height | 3.492 |
| Paraxial Magnification | -0.03861711 |
| Entrance Pupil Diameter | 1.8 |
| Entrance Pupil Position | 0.05 |
| Exit Pupil Diameter | 1.198642 |
| Exit Pupil Position | -3.269722 |
| Maximum Radial Field | 3.492 |
| Lens Units | Millimeters (mm) |
| Angular Magnification | 1.501698 |

**Table 28: General Optical Properties (Object in Focus at ~12.8cm)**

| Field / # | VDX | VDY | VCX | VCY | VAN |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | -0.00588 | 0.000003 | 0.005875 | 0 |
| 8 | 0 | -0.02139 | 0.000058 | 0.021397 | 0 |
| 9 | 0 | -0.0355 | 0.00023 | 0.035498 | 0 |
| 10 | 0 | -0.06623 | 0.000798 | 0.066238 | 0 |
| 11 | 0 | -0.16868 | 0.006487 | 0.1687 | 0 |
| 12 | 0 | -0.24396 | 0.016135 | 0.243989 | 0 |

**Table 29: Vignetting Factors for Fields of Table 20**



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| Surface | Type | Radius | Thickness | Material | Diameter | Conic | Notes |
|---|---|---|---|---|---|---|---|
| Object | Standard | Infinity | 128 | | 179.1413 | 0 | |
| 1 | Standard | Infinity | 0.05 | | 2.060591 | 0 | Stop1 |
| Stop | Standard | Infinity | -0.176644 | | 1.8 | 0 | A1 |
| 3 | EvenAsph | 2.024203 | 0.721 | ZEONF52R | 1.872 | -1 | R1 |
| 4 | EvenAsph | -11.8344 | 0.08 | | 1.89 | 0 | R2 |
| 5 | Standard | Infinity | 0.1656548 | | 2.015092 | 0 | Stop 2 |
| 6 | EvenAsph | -250 | 0.32 | EP5000 | 1.91 | 0 | R3 |
| 7 | EvenAsph | 2.745619 | 0.3434152 | | 2.093864 | 0 | R4 |
| 8 | Standard | Infinity | 0.00302399 | | 2.284414 | 0 | Stop 3 |
| 9 | EvenAsph | 2.970147 | 0.3494011 | EP5000 | 2.456709 | 0 | R5 |
| 10 | EvenAsph | 3.958667 | 0.1844251 | | 2.735497 | 0 | R6 |
| 11 | Standard | Infinity | 0.3353069 | | 2.905287 | 0 | Stop 4 |
| 12 | EvenAsph | -4.5388 | 0.5144013 | ZEONF52R | 3.007844 | 0 | R7 |
| 13 | EvenAsph | -1.56458 | 0.2719004 | | 3.349097 | -1 | R8 |
| 14 | Standard | Infinity | 0.421506 | | 5.039133 | 0 | Stop 5 |
| 15 | EvenAsph | -3.33374 | 0.908 | ZEONF52R | 5.142131 | 0 | R9 |
| 16 | EvenAsph | 3.980869 | 0.6500583 | | 6.098372 | 0 | R10 |
| 17 | Standard | Infinity | 0.3 | | 6.852322 | 0 | CG 1908 |
| 18 | Standard | Infinity | 0.1 | | 7.029509 | 0 | |
| Image | Standard | Infinity | | | 7.027898 | 0 | |

**Table 30: Surface Data Summary**

| | | Wavelengths (μm): | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.4358 | | 0.4861 | | 0.5461 | |
| Number | Field (mm) | Tan | Sag | Tan | Sag | Tan | Sag |
| 1 | 0 | 2.7277 | 2.7277 | 2.7317 | 2.7317 | 2.7387 | 2.7387 |
| 2 | 0.339 | 2.7368 | 2.7372 | 2.7406 | 2.741 | 2.7475 | 2.7479 |
| 3 | 0.678 | 2.7568 | 2.7652 | 2.7602 | 2.7683 | 2.7668 | 2.7746 |
| 4 | 1.018 | 2.7759 | 2.8091 | 2.7796 | 2.8111 | 2.7862 | 2.8166 |
| 5 | 1.357 | 2.8003 | 2.8645 | 2.8054 | 2.8651 | 2.8128 | 2.8695 |
| 6 | 1.696 | 2.8707 | 2.929 | 2.8781 | 2.9282 | 2.8869 | 2.9315 |
| 7 | 2.035 | 3.0426 | 3.0048 | 3.0514 | 3.0027 | 3.0608 | 3.0049 |
| 8 | 2.375 | 3.3173 | 3.0938 | 3.3236 | 3.0904 | 3.33 | 3.0916 |
| 9 | 2.714 | 3.7043 | 3.1909 | 3.7032 | 3.1866 | 3.7021 | 3.1868 |
| 10 | 3.053 | 4.4104 | 3.2987 | 4.3944 | 3.2936 | 4.3798 | 3.2932 |
| 11 | 3.392 | 5.6482 | 3.4392 | 5.6174 | 3.4339 | 5.587 | 3.4329 |
| 12 | 3.492 | 6.4939 | 3.5062 | 6.4341 | 3.5014 | 6.3828 | 3.5006 |

**Table 31: F/Number Data**

| | | Wavelengths (μm) | | | |
|---|---|---|---|---|---|
| | | 0.5876 | | 0.6563 | |
| Number | Field (mm) | Tan | Sag | Tan | Sag |



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| | | | | | |
|---|---|---|---|---|---|
| 1 | 0 | 2.7437 | 2.7437 | 2.7514 | 2.7514 |
| 2 | 0.339 | 2.7524 | 2.7528 | 2.7599 | 2.7603 |
| 3 | 0.678 | 2.7716 | 2.7793 | 2.7789 | 2.7865 |
| 4 | 1.018 | 2.7909 | 2.8208 | 2.7981 | 2.8276 |
| 5 | 1.357 | 2.8177 | 2.8733 | 2.8251 | 2.8794 |
| 6 | 1.696 | 2.8924 | 2.9347 | 2.9003 | 2.9401 |
| 7 | 2.035 | 3.0664 | 3.0075 | 3.0742 | 3.0122 |
| 8 | 2.375 | 3.3337 | 3.0937 | 3.339 | 3.0977 |
| 9 | 2.714 | 3.7016 | 3.1884 | 3.701 | 3.1917 |
| 10 | 3.053 | 4.372 | 3.2943 | 4.3618 | 3.2971 |
| 11 | 3.392 | 5.5698 | 3.4337 | 5.5469 | 3.436 |
| 12 | 3.492 | 6.3558 | 3.5014 | 6.3211 | 3.5037 |

**Table 31A: F/Number Data (Continued)**

**[00109]** Tables 28 – 31A comprise optical characteristics and image characteristics of optical system 2400 that differ from the configuration of optical system 1900. Table 28 provides general optical information for the embodiment of optical system 2400. Table 29 includes vignetting data for the set of optical fields of Table 20. Table 30 provides a summary of general optical characteristics for lenses of optical elements 2402, including surface type, radius of curvature, thickness, material (from standard glass and plastic catalogues, including a fictitious material for cover glass 2408), diameter, conic constant and applicable notes. Tables 31 and 31A provide F/# data for identified wavelengths and optical fields.

**[00110]** Figure 25 illustrates a diagram of field curvature and distortion for the optical system 2400 of Figure 24, *supra*. Wavelengths employed for the field curvature and distortion graphs include 0.436, 0.486, 0.546, 0.588 and 0.656 μm. Rays traced to generate these graphs have units in field angle with a maximum field of 34.188 degrees. The field curvature for both tangential and sagittal rays are generally positive and less than about 0.05 mm for all field angles. Distortion is less than about 1% for mid to low field angles, and increases to about 1.6% at high field angles.

**[00111]** Figure 26 illustrates a diagram of longitudinal aberration for optical system 2400. The longitudinal aberration graph is provided for five wavelengths, including 0.436, 0.486, 0.546, 0.588 and 0.656 μm. The graph charts longitudinal aberration in millimeters for increasing field angles, and with pupil radius of 0.9mm. At low field angles the longitudinal aberration is generally positive and less than about 0.04 millimeters. At higher field angles, the longitudinal aberration ranges positive to negative for different field angles, and is generally between positive 0.03 millimeters and about negative 0.035 millimeters.



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**[00112]** Figure 27 depicts a graph of lateral color for optical elements 2402 of Figure 24, *supra*. The graph of lateral color relates to optical elements 2402 configured to focus an image of an object located at about 12.8cm onto sensor 2406. The maximum field for the lateral color graph is 3.3920 millimeters, and wavelengths employed for the graph range from 0.4358 through 0.6563 µm. In addition, data is referenced to 0.546100 µm. For all field angles the lateral color is less than about +3 microns and greater than about -1 microns. At low and mid field angles, the lateral color ranges between about +1 micron and about -0.25 microns.

**[00113]** Figures 28A – 28D illustrate an example optical system according to one or more additional aspects of the subject disclosure. The optical system is depicted at Figure 28A on the upper left in a configuration to focus an image of an object at infinity onto a sensor of the optical system. Figures 29A – 29D illustrate the example optical system in a configuration to focus an image of a near-field object onto the sensor of the optical system. The latter configuration can be achieved, for instance, by decreasing an air distance between the first left-most lens closest to the object side of the optical system, closer to the second lens on the object side of the optical system.

**[00114]** Generally, the optical system comprises five lenses, from an object side to image side, including lens L1 (also referred to as an objective lens), lens L2, lens L3, lens L4 and lens L5 (referred to collectively as lenses L1 – L5). Moreover, the optical system of Figures 28A – 28D can comprise two or more lens groups, defined at least in part on an on-axis inter-lens air distance between respective lenses of the two or more lens groups. As an example, the five lenses of the optical system can be arranged into two lens groups, a first of the lens groups comprising a first lens, second lens and third lens from the object side of the optical system, and where the second of the lens groups comprising a fourth lens and fifth lens from the object side of the optical system. The lens groups can be constrained to have on-axis air distances between lenses that is smaller than an on-axis air distance between the first and the second lens groups.

**[00115]** Figures 28B – 28D illustrate image characteristics for the optical system of Figure 28A configured to focus an image of an object at infinity on a sensor of the optical system (far field focus configuration). Figures 29B – 29D illustrate image characteristics for the optical system of Figure 29A configured to focus a near-field object on the sensor (near field focus configuration). Figure 28B depicts a graph of field curvature and distortion for the far field focus configuration, with a maximum field greater than about 32 degrees for wavelengths between about 0.47 and about 0.65



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microns. Figure 28C illustrates a graph of longitudinal aberration for the far field configuration at the above wavelengths, and for a pupil radius of about 0.991mm, and Figure 28D depicts a graph of lateral color for this configuration having a maximum field of about 2.956 millimeters having data referenced to wavelength of about 0.555 microns.

**[00116]** Figure 29B illustrates field curvature and distortion for the near field configuration of the optical system, depicted at Figure 29A. The field curvature and distortion has a maximum field of about 34.51 degrees for wavelengths between about 0.470 and about 0.650 microns. Figure 29C depicts longitudinal aberration for the near field configuration with pupil radius of about 0.991 millimeters and wavelengths of about 0.470, 0.510, 0.555, 0.610 and 0.650 microns. Figure 29D illustrates a graph of lateral color for the near field configuration, with a maximum field of about 2.9560 millimeters and with data referenced to wavelength of 0.555 microns. The optical system of Figures 28A and 29A are described by the optical and image characteristics provided by Tables 32 – 40A, below.

| Parameter Description | Value |
|---|---|
| Effective Focal Length (in air at system temperature and pressure) | 4.309199 |
| Effective Focal Length (in image space) | 4.309199 |
| Back Focal Length | 0.528864 |
| Total Track Length (TTL) | 5.348668 |
| Image Space F/# | 2.44563 |
| Paraxial Working F/# | 2.44563 |
| Working F/# | 2.468005 |
| Image Space NA | 0.200303 |
| Object Space NA | 8.81E-11 |
| Stop Radius | 0.881 |
| Paraxial Image Height | 2.956 |
| Paraxial Magnification | 0 |
| Entrance Pupil Diameter | 1.762 |
| Entrance Pupil Position | 0 |
| Exit Pupil Diameter | 1.257817 |
| Exit Pupil Position | -3.09729 |



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| | |
|---|---|
| Maximum Radial Field | 2.956 |
| Lens Units | Millimeters (mm) |
| Angular Magnification | 1.400838 |

**Table 32: General Optical Properties (Object in Focus at Infinity)**

| Field # | X-Value | Y-Value | Weight |
|---|---|---|---|
| 1 | 0 | 0 | 1 |
| 2 | 0 | 0.571 | 1 |
| 3 | 0 | 1.142 | 1 |
| 4 | 0 | 1.714 | 1 |
| 5 | 0 | 2.285 | 1 |
| 6 | 0 | 2.57 | 1 |
| 7 | 0 | 2.856 | 0.2 |
| 8 | 0 | 2.956 | 0.2 |

**Table 33: Field Type v. Real Image Height (in mm)**

| Field / # | VDX | VDY | VCX | VCY | VAN |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0.003903 | 0.00001 | 0.003903 | 0 |
| 3 | 0 | 0.007781 | 0.000035 | 0.007783 | 0 |
| 4 | 0 | 0.01172 | 0.000106 | 0.011721 | 0 |
| 5 | 0 | -0.00257 | 0.000337 | 0.034007 | 0 |
| 6 | 0 | -0.04564 | 0.001626 | 0.08102 | 0 |
| 7 | 0 | -0.09687 | 0.005447 | 0.136263 | 0 |
| 8 | 0 | -0.14243 | 0.009529 | 0.183383 | 0 |

**Table 34: Vignetting Factors for Fields of Table 20**

| Wavelength # | Value (in µm) | Weight |
|---|---|---|
| 1 | 0.47 | 91 |
| 2 | 0.51 | 503 |
| 3 | 0.555 | 1000 |
| 4 | 0.61 | 503 |
| 5 | 0.65 | 107 |

**Table 35: Wavelengths Used for Raytracing**



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| Surface | Type | Radius | Thickness | Material | Diameter | Conic | Notes |
|---|---|---|---|---|---|---|---|
| Object | Standard | Infinity | Infinity | | 0 | 0 | |
| Stop | Standard | Infinity | -0.05 | | 1.762 | 0 | Stop |
| 2 | Standard | Infinity | -0.05 | | 1.762 | 0 | Vig |
| 3 | EvenAsph | 1.954112 | 0.658876 | APEL5514ML | 1.86811 | 0 | L1 |
| 4 | EvenAsph | -16.4984 | 0.123812 | | 1.900083 | 0 | |
| 5 | EvenAsph | 28.78283 | 0.537232 | EP5000-F | 1.936491 | 0 | L2 |
| 6 | EvenAsph | 2.7513 | 0.242475 | | 2.00919 | 0 | |
| 7 | Standard | Infinity | 0.05 | | 2.05 | 0 | |
| 8 | Standard | Infinity | 0.086016 | | 2.05 | 0 | |
| 9 | EvenAsph | -34.5053 | 0.862679 | APEL5514ML | 2.120461 | 0 | L3 |
| 10 | EvenAsph | -6.19216 | 0.424308 | | 2.716502 | 0 | |
| 11 | EvenAsph | 2.722564 | 0.509104 | APEL5514ML | 3.355454 | 0 | L4 |
| 12 | EvenAsph | -4.26721 | -0.19 | | 4.009626 | 0 | |
| 13 | Standard | Infinity | 0.05 | | 4.16 | 0 | |
| 14 | Standard | Infinity | 0.389066 | | 4.16 | 0 | |
| 15 | EvenAsph | -2.51369 | 0.426101 | APEL5514ML | 4.449728 | 0 | L5 |
| 16 | EvenAsph | 2.608397 | 0.329 | | 4.878517 | 0 | |
| 17 | Standard | Infinity | 0.3 | N-BK7 | 5.233205 | 0 | CG 1908 |
| 18 | Standard | Infinity | 0.55 | | 5.402932 | 0 | |
| Image | Standard | Infinity | | | 5.917565 | 0 | |

**Table 36: Surface Data Summary**

| Surface | Parameter Description | Value |
|---|---|---|
| R1 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.00386 |
| | Coefficient on r 6 | 0.009055 |
| | Coefficient on r 8 | -0.01604 |
| | Coefficient on r 10 | 0.006453 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R2 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | 0.014879 |
| | Coefficient on r 6 | -0.02489 |
| | Coefficient on r 8 | 0.011334 |
| | Coefficient on r 10 | 0.003758 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |



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| | | |
|---|---|---|
| R3 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | 0.001774 |
| | Coefficient on r 6 | -0.03857 |
| | Coefficient on r 8 | 0.035738 |
| | Coefficient on r 10 | -0.00277 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R4 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.00027 |
| | Coefficient on r 6 | 0.001123 |
| | Coefficient on r 8 | 0.000761 |
| | Coefficient on r 10 | 0.006183 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R5 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.04891 |
| | Coefficient on r 6 | 0.029453 |
| | Coefficient on r 8 | -0.01911 |
| | Coefficient on r 10 | 0.004124 |
| | Coefficient on r 12 | 0 |
| | Coefficient on r 14 | 0 |
| | Coefficient on r 16 | 0 |
| R6 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.13503 |
| | Coefficient on r 6 | 0.048368 |
| | Coefficient on r 8 | 0.001742 |
| | Coefficient on r 10 | -0.00582 |
| | Coefficient on r 12 | 0.00078 |
| | Coefficient on r 14 | 5.79E-05 |



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| | | |
|---|---|---|
| | Coefficient on r 16 | 0.000106 |
| R7 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.1187 |
| | Coefficient on r 6 | 0.031933 |
| | Coefficient on r 8 | -0.0214 |
| | Coefficient on r 10 | 0.008804 |
| | Coefficient on r 12 | -0.0012 |
| | Coefficient on r 14 | -0.00074 |
| | Coefficient on r 16 | 0.000216 |
| R8 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | 0.070788 |
| | Coefficient on r 6 | -0.01663 |
| | Coefficient on r 8 | -0.00017 |
| | Coefficient on r 10 | -0.00047 |
| | Coefficient on r 12 | 0.000282 |
| | Coefficient on r 14 | -1.50E-05 |
| | Coefficient on r 16 | -2.54E-06 |
| R9 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | 0.019234 |
| | Coefficient on r 6 | 0.011958 |
| | Coefficient on r 8 | -0.00178 |
| | Coefficient on r 10 | 1.79E-05 |
| | Coefficient on r 12 | 5.79E-06 |
| | Coefficient on r 14 | 9.92E-07 |
| | Coefficient on r 16 | 4.90E-08 |
| R10 | Even Asphere | |
| | Coefficient on r 2 | 0 |
| | Coefficient on r 4 | -0.10214 |
| | Coefficient on r 6 | 0.027793 |
| | Coefficient on r 8 | -0.0071 |
| | Coefficient on r 10 | 0.000868 |
| | Coefficient on r 12 | 1.66E-05 |



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| | | |
|---|---|---|
| | Coefficient on r 14 | -1.31E-05 |
| | Coefficient on r 16 | 7.35E-07 |

**Table 37: Surface Aspheric Coefficients**

| Surface | Edge |
|---|---|
| Stop | -0.05 |
| 2 | 0.184732 |
| 3 | 0.400359 |
| 4 | 0.15927 |
| 5 | 0.723662 |
| 6 | 0.044372 |
| 7 | 0.05 |
| 8 | 0.026648 |
| 9 | 0.560283 |
| 10 | 0.571295 |
| 11 | 0.51101 |
| 12 | 0.022871 |
| 13 | 0.05 |
| 14 | 0.126282 |
| 15 | 0.613075 |
| 16 | 0.40481 |
| 17 | 0.3 |
| 18 | 0.55 |
| Image | 0 |

**Table 38: Edge Thickness Data**

| Temperature (Temp) in degrees Celsius and pressure (Press) in atmospheres | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Surface | Material | Temp | Press | 0.4358 | 0.4861 | 0.5461 | 0.5876 | 0.6563 |
| 0 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 3 | APEL5514ML | 20 | 1 | 1.552896 | 1.549574 | 1.546504 | 1.543579 | 1.541977 |
| 4 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 5 | EP5000-F | 20 | 1 | 1.657924 | 1.647547 | 1.638966 | 1.631351 | 1.627143 |
| 6 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 7 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 8 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 9 | APEL5514ML | 20 | 1 | 1.552896 | 1.549574 | 1.546504 | 1.543579 | 1.541977 |
| 10 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 11 | APEL5514ML | 20 | 1 | 1.552896 | 1.549574 | 1.546504 | 1.543579 | 1.541977 |
| 12 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 13 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 14 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 15 | APEL 5514 ML | 20 | 1 | 1.552896 | 1.549574 | 1.546504 | 1.543579 | 1.541977 |
| 16 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 17 | N-BK7 | 20 | 1 | 1.523605 | 1.520769 | 1.518274 | 1.515909 | 1.51452 |
| 18 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 19 | | 20 | 1 | 1 | 1 | 1 | 1 | 1 |

**Table 39: Index of Refraction Data**

| | | Wavelengths (µm): | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.4358 | | 0.4861 | | 0.5461 | |
| Number | Field (mm) | Tan | Sag | Tan | Sag | Tan | Sag |
| 1 | 0 | 2.4671 | 2.4671 | 2.4655 | 2.4655 | 2.468 | 2.468 |
| 2 | 0.571 | 2.5183 | 2.4954 | 2.516 | 2.4934 | 2.5179 | 2.4954 |
| 3 | 1.142 | 2.5939 | 2.5672 | 2.5915 | 2.564 | 2.5931 | 2.5651 |
| 4 | 1.714 | 2.7124 | 2.6738 | 2.7134 | 2.6698 | 2.717 | 2.6702 |
| 5 | 2.285 | 3.1321 | 2.8097 | 3.1364 | 2.8053 | 3.1424 | 2.8052 |
| 6 | 2.57 | 3.6079 | 2.8988 | 3.613 | 2.8941 | 3.6195 | 2.8939 |
| 7 | 2.856 | 3.8132 | 3.003 | 3.8209 | 2.9987 | 3.8222 | 2.9987 |
| 8 | 2.956 | 4.0285 | 3.0378 | 4.0284 | 3.0345 | 4.0233 | 3.0351 |

**Table 40: F/Number Data**

| | | Wavelengths (µm) | | | |
|---|---|---|---|---|---|
| | | 0.5876 | | 0.6563 | |
| Number | Field (mm) | Tan | Sag | Tan | Sag |
| 1 | 0 | 2.4725 | 2.4725 | 2.4748 | 2.4748 |
| 2 | 0.571 | 2.522 | 2.4996 | 2.524 | 2.5017 |
| 3 | 1.142 | 2.5966 | 2.5685 | 2.5984 | 2.5702 |
| 4 | 1.714 | 2.7219 | 2.6729 | 2.7244 | 2.6742 |
| 5 | 2.285 | 3.1492 | 2.8075 | 3.1529 | 2.8085 |
| 6 | 2.57 | 3.6267 | 2.896 | 3.6307 | 2.8969 |
| 7 | 2.856 | 3.8203 | 3.0009 | 3.8197 | 3.0019 |
| 8 | 2.956 | 4.0151 | 3.0376 | 4.0105 | 3.0389 |

**Table 40A: F/Number Data (Continued)**

**[00117]** Tables 32 – 40A provides optical and image characteristics for the optical system of Figure 28A, having a far field focus configuration. Table 32 provides general optical information for this optical system. Table 33 provides image heights in the y axis, measured at an image sensor of the optical system, for a set of optical fields and respective weights for the respective optical fields. Table 34 includes vignetting data for the set of optical fields of Table 33. Table 35 depicts wavelengths of respective rays traced in the optical imaging system of Figure 28. Table 36 provides a summary of general optical surface characteristics for lenses of this optical system, including surface type, radius of curvature, thickness, material (from standard glass and plastic catalogues), diameter, conic constant and applicable notes. Table 37 describes aspheric coefficients for the surfaces of Table 35, whereas Table 38 provides edge thickness information for those surfaces. Table 39 provides index of refraction data for multiple wavelengths and listed optical fields. Tables 40 and 40A provide F/# data for those same wavelengths and optical fields.

**[00118]** As utilized herein, the word "exemplary" is intended to mean serving as an example, instance, or illustration. Any aspect or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects or designs. Rather, use of the word exemplary is intended to present concepts in a concrete fashion. As used in this application, the term "or" is intended to mean an inclusive "or" rather than an exclusive "or". That is, unless specified otherwise, or clear from context, "X employs A or B" is intended to mean any of the natural inclusive permutations. That is, if X employs A; X employs B; or X employs both A and B, then "X employs A or B" is satisfied under any of the foregoing instances. In addition, the articles "a" and "an" as used in this application and the appended claims should generally be construed to mean "one or more" unless specified otherwise or clear from context to be directed to a singular form.

**[00119]** Furthermore, various portions of electronic systems associated with disclosed optical systems described herein may include or consist of artificial intelligence or knowledge or rule based components, sub-components, processes, means, methodologies, or mechanisms (*e.g.*, support vector machines, neural networks, expert systems, Bayesian belief networks, fuzzy logic, data fusion engines, classifiers…). Such components, *inter alia*, and in addition to that already described herein, can automate certain mechanisms or processes performed thereby to make portions of the systems and methods more adaptive as well as efficient and intelligent. For instance, such components can automate optimization of image quality of an optical system, as described above (*e.g.*, see electronic device 500 of Figure 5, *supra*).

**[00120]** What has been described above includes examples of aspects of the claimed subject matter. It is, of course, not possible to describe every conceivable combination of components or methodologies for purposes of describing the claimed subject matter, but one of ordinary skill in the art can recognize that many further combinations and permutations of the disclosed subject matter are possible. Accordingly, the disclosed subject matter is intended to embrace all such alterations, modifications and variations that fall within the spirit and scope of the appended claims. Furthermore, to the extent that the terms “includes,” “has” or “having” are used in either the detailed description or the claims, such terms are intended to be inclusive in a manner similar to the term “comprising” as “comprising” is interpreted when employed as a transitional word in a claim.

CLAIMS

What is Claimed is:

1. An optical imaging system arranged along an optical axis, comprising:

a set of optical lenses including a first lens group and a second lens group, wherein the second lens group is fixed in position along the optical axis;

a micro electromechanical system (MEMS) actuator mechanically connected to the first lens group and configured to adjust a position of the first lens group along the optical axis, wherein a first adjusted position is configured to focus an image of an object positioned far from the optical imaging system onto an image plane associated with the optical imaging system, and wherein a second adjusted position is configured to focus an image of an object positioned near to the optical imaging system onto the image plane;

wherein:

the set of optical lenses comprising five lenses;

the MEMS actuator is configured to adjust a position of the first lens group along the optical axis up to between 50 and 150 micrometers;

the first optical lens group comprising a biconvex object-side lens; and

a ratio of the focal length of the biconvex object-side lens to a combined focal length of the five lenses is greater than one half.

2. The optical imaging system of claim 1, further comprising an aperture stop positioned at an object-side of the biconvex object-side lens.

3. The optical imaging system of claim 2, wherein the aperture stop is fixed in position along the optical axis.

4. The optical imaging system of claim 2, wherein the aperture stop is fixed in position relative to the first lens group.

5. The optical imaging system of claim 4, wherein the MEMS actuator is configured to reposition the first lens group and the aperture stop along the optical axis and maintain the fixed position between the aperture stop and the first lens group at least at the first adjusted position and at the second adjusted position.

6. The optical imaging system of claim 1, the second lens group comprising four lens elements, including a second lens, a third lens, a fourth lens and a fifth lens.

7. The optical imaging system of claim 6, the second lens having a concave image-side surface and a flat or a weak convex curvature on an object-side surface.

8. The optical imaging system of claim 7, the second lens having a negative optical power, and formed of an OKP4HT plastic.

9. The optical imaging system of claim 6, the third lens having a concave object-side surface and a convex image-side surface, a positive optical power, and formed of an APEL5514ML glass.

10. The optical imaging system of claim 6, the fourth lens having an object-side surface that is convex near the optical axis and transitions to concave away from the optical axis, and an image-side surface having convex curvature.

11. The optical imaging system of claim 10, the fourth lens having positive optical power near the optical axis, and having small negative optical power, small positive optical power, or no optical power away from the optical axis, and the fourth lens is formed of an APEL5514ML plastic.

12. The optical imaging system of claim 6, the fifth lens having an object-side surface that is concave near the optical axis and that transitions to convex away from the optical axis, and an image-side surface that is concave near the optical axis and transitions to convex away from the optical axis.



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13. The optical imaging system of claim 12, the fifth lens having large negative optical power near the optical axis, and positive optical power away from the optical axis, and the fifth lens is formed of an APEL5514ML plastic.

14. The optical imaging system of claim 1, the biconvex object-side lens is formed of an APEL5514ML plastic.

15. The optical imaging system of claim 1, wherein an optical power of the biconvex object-side lens is at least in part a function of a distance along the optical axis between the first adjusted position and the second adjusted position.

16. The optical imaging system of claim 1, wherein the ratio of the focal length of the biconvex object-side lens to a combined focal length of the five lenses is about three quarters.

17. The optical imaging system of claim 1, wherein the ratio of the optical power of the biconvex object-side lens to a combined optical power of the five lenses is at least in part a function of a distance along the optical axis between the first adjusted position and the second adjusted position.

18. The optical imaging system of claim 1, wherein the object positioned far from the optical system is positioned substantially at infinity, and wherein the object positioned near to the optical system is positioned at substantially 10cm from an aperture stop of the optical imaging system.

19. An optical system comprising:

a plurality of optical elements arranged along a common optical axis for forming a real image of an object, said optical elements including:

a first lens having a positive refractive power, with both surfaces, one facing an object side and another facing an image side, having convex shape;

a second lens having negative refractive power and a meniscus shape, with the surface facing the object side having a convex shape and the surface facing the image side having a concave shape;

a third lens having positive refractive power, and a biconvex shape near the optical axis, and the surface facing the object side is concave away from the optical axis;

a fourth lens, with the surface facing the object side having a concave shape, and the surface facing the image side having a convex shape; and

a fifth lens having a meniscus shape with the surface facing the object side having a convex shape and the surface facing the image side having a concave shape near the optical axis and a convex shape away from the optical axis; and

an actuator configured to move the first lens along the optical axis.

20. The optical system of claim 19, wherein the motor is a microelectromechanical system.

21. The optical system of claim 19, wherein the second lens performs a majority of chromatic correction for the optical system.

22. The optical system of claim 19, further comprising an aperture that is embedded into the first lens and moves with the first lens, wherein the aperture having a depth of 50μm.

23. The optical system of claim 19, wherein the F-number of the optical system is approximately 2.4.

24. The optical system of claim 19, wherein one or more of the lenses are made of plastic.

25. The optical system of claim 19, wherein the surfaces of the lenses are aspheric.

26. The optical system of claim 19, wherein the refractive index of the lenses is within a range of about 1.5 to about 1.66.

27. The optical system of claim 19, wherein the range of movement for the first lens is between about 0μm and about 100μm.

28. The optical system of claim 19, wherein an amount of movement to focus an image of an object is inversely proportional to the positive refractive power of the first lens.

29. The optical system of claim 19, wherein the primary lateral color range for the optical system focused on an object at infinity is equal to or less than approximately 1μm.

30. The optical system of claim 19, wherein the primary lateral color range for the optical system focused on an object at 10cm is equal to or less than approximately 4μm.

31. An optical imaging system arranged along an optical axis, comprising:

a set of optical lenses including a first lens group and a second lens group, wherein the second lens group is fixed in position along the optical axis and comprises a majority of the optical lenses of the set of optical lenses; and

an actuator mechanically connected to the first lens group and configured to adjust a position of the first lens group along the optical axis, wherein a first adjusted position is configured to focus an image of an object positioned far from the optical imaging system onto an image plane associated with the optical imaging system, and wherein a second adjusted position is configured to focus an image of an object positioned near to the optical imaging system onto the image plane;

wherein:

the set of optical lenses comprising five lenses;

the actuator is configured to adjust a position of the first lens group along the optical axis up to between 50 and 150 micrometers;

the second optical lens group comprising a third lens of the set of optical lenses that is third in sequence from an object side of the set of optical lenses, the third lens having a meniscus shape that is convex toward the object side of the set of optical lenses.

32. The optical imaging system of claim 31, wherein the actuator comprises a micro electromechanical system (MEMS) actuator.

33. The optical imaging system of claim 31, the first optical lens group comprising a biconvex objective lens that provides a majority of the positive optical power of the set of optical lenses.

34. The optical imaging system of claim 33, wherein the biconvex objective lens has greater positive refractive power than a combined refractive power of the set of optical lenses.

35. The optical imaging system of claim 31, wherein an effective focal length of the set of optical lenses is between about 4.5 and about 5.0 millimeters.

36. The optical imaging system of claim 31, wherein a ratio of total track length to effective focal length of the optical system is between about 1.1 and about 1.2.

37. The optical imaging system of claim 31, wherein the first lens group comprises a single lens of the set of optical lenses.

38. The optical imaging system of claim 37, wherein the single lens is an objective lens of the optical system.

39. The optical imaging system of claim 37, wherein the second adjusted position focuses an image of an object at an object distance of about 12.8 centimeters onto the image plane.

40. The optical imaging system of claim 31, wherein an air distance between a third lens and a fourth lens of the set of optical lenses, numbered from an object side of the set of optical lenses, is a largest of air distances between respective ones of the set of optical lenses.

41. The optical imaging system of claim 31, wherein an air distance between a fourth lens and a fifth lens of the set of optical lenses, numbered from an object side of the set of optical lenses, is a largest of air distances between respective ones of the set of optical lenses.

42. The optical imaging system of claim 31, further comprising an aperture stop about an object side surface of a first lens of the set of optical lenses, numbered from an object side of the set of optical lenses.

43. The optical imaging system of claim 42, further comprising a stop between a second and third lens of the set of optical lenses, numbered from an object side of the set of optical lenses.

44. The optical imaging system of claim 43, further comprising a second stop between the third lens and a fourth lens of the set of optical lenses.

45. The optical imaging system of claim 44, further comprising a third stop between the fourth lens and a fifth lens of the set of optical lenses.

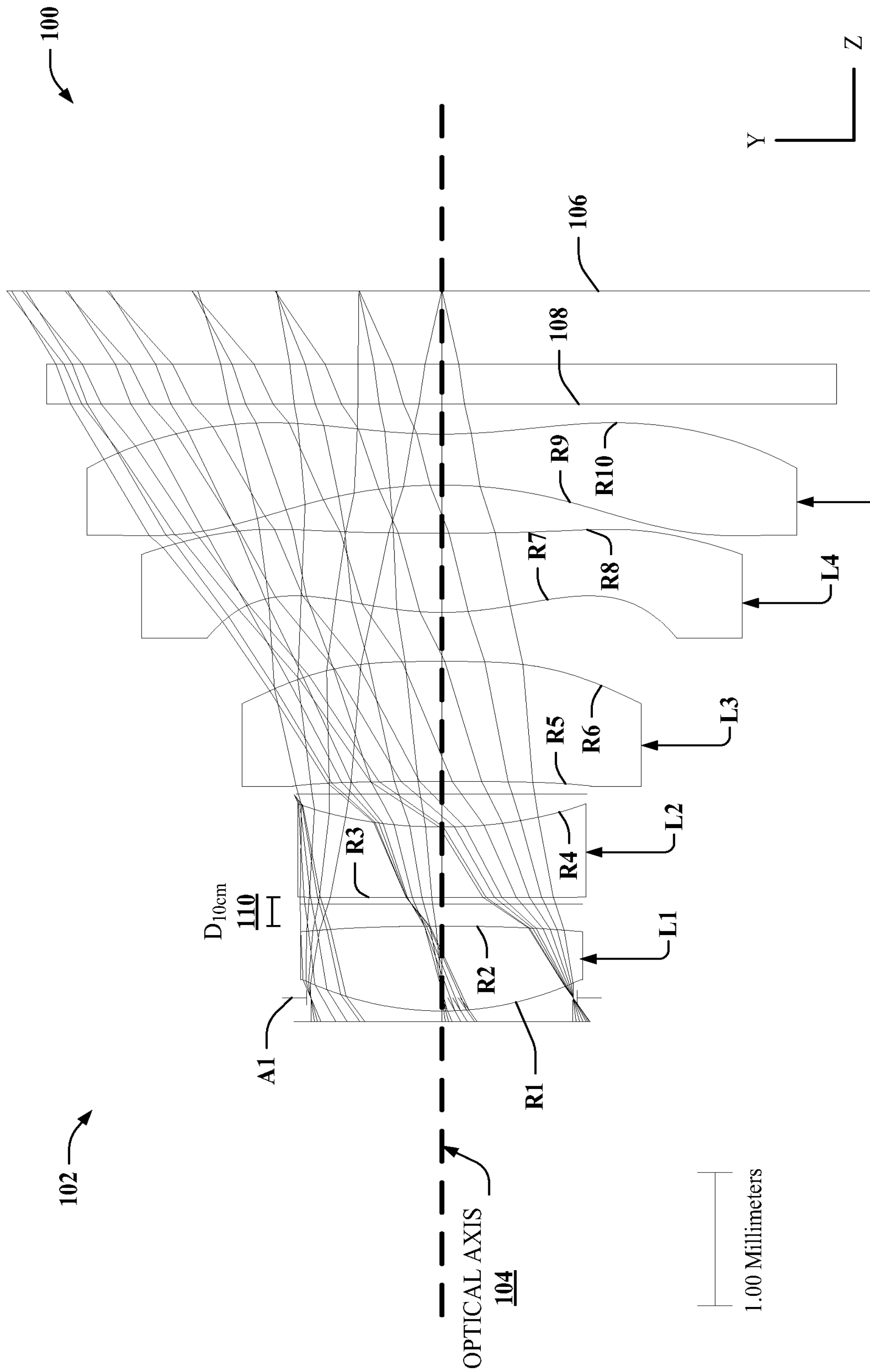


FIG. 1

OPTICAL LAYOUT; OBJECT FOCUSED AT 10CM

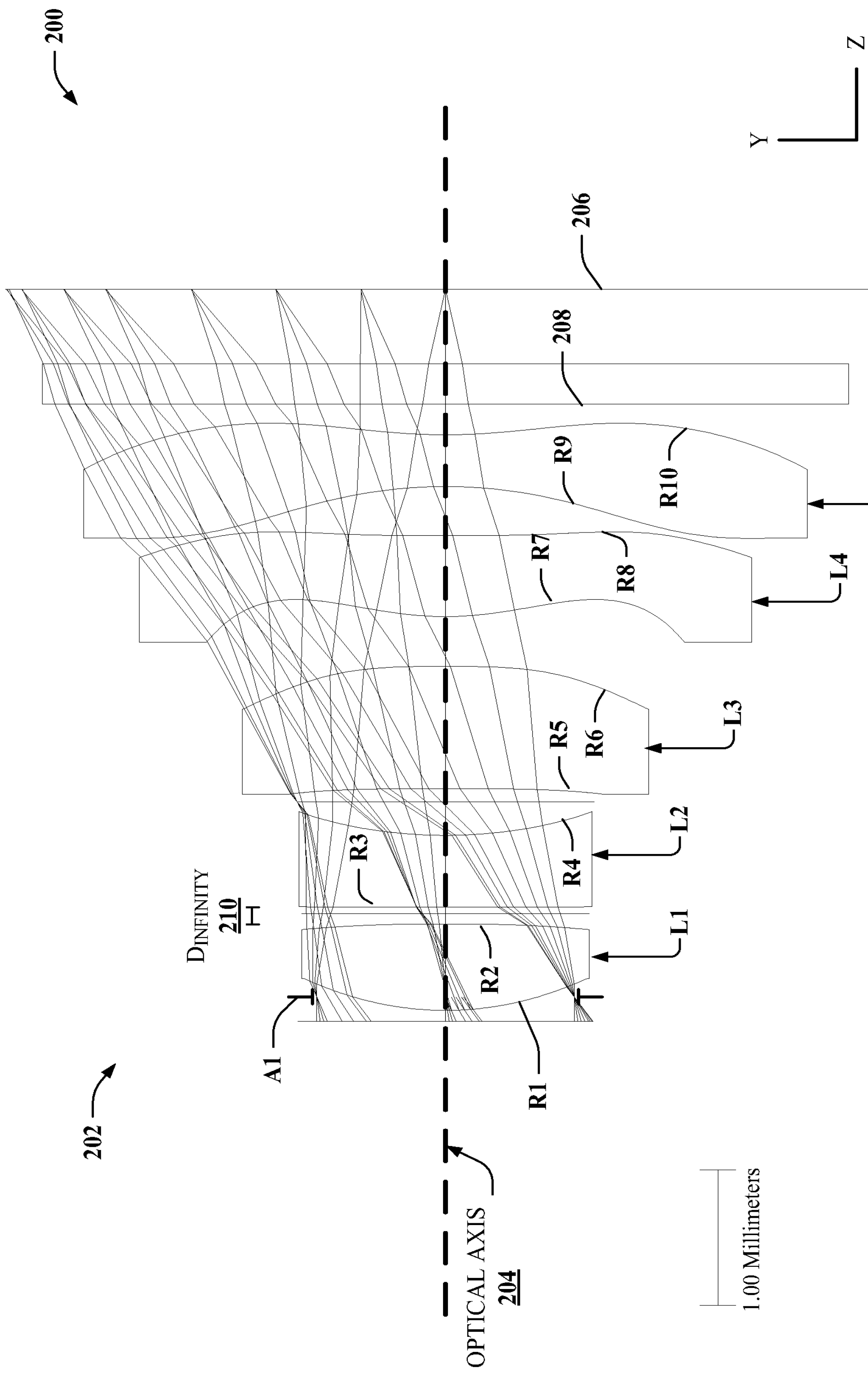


FIG. 2

OPTICAL LAYOUT; OBJECT FOCUSED AT INFINITY

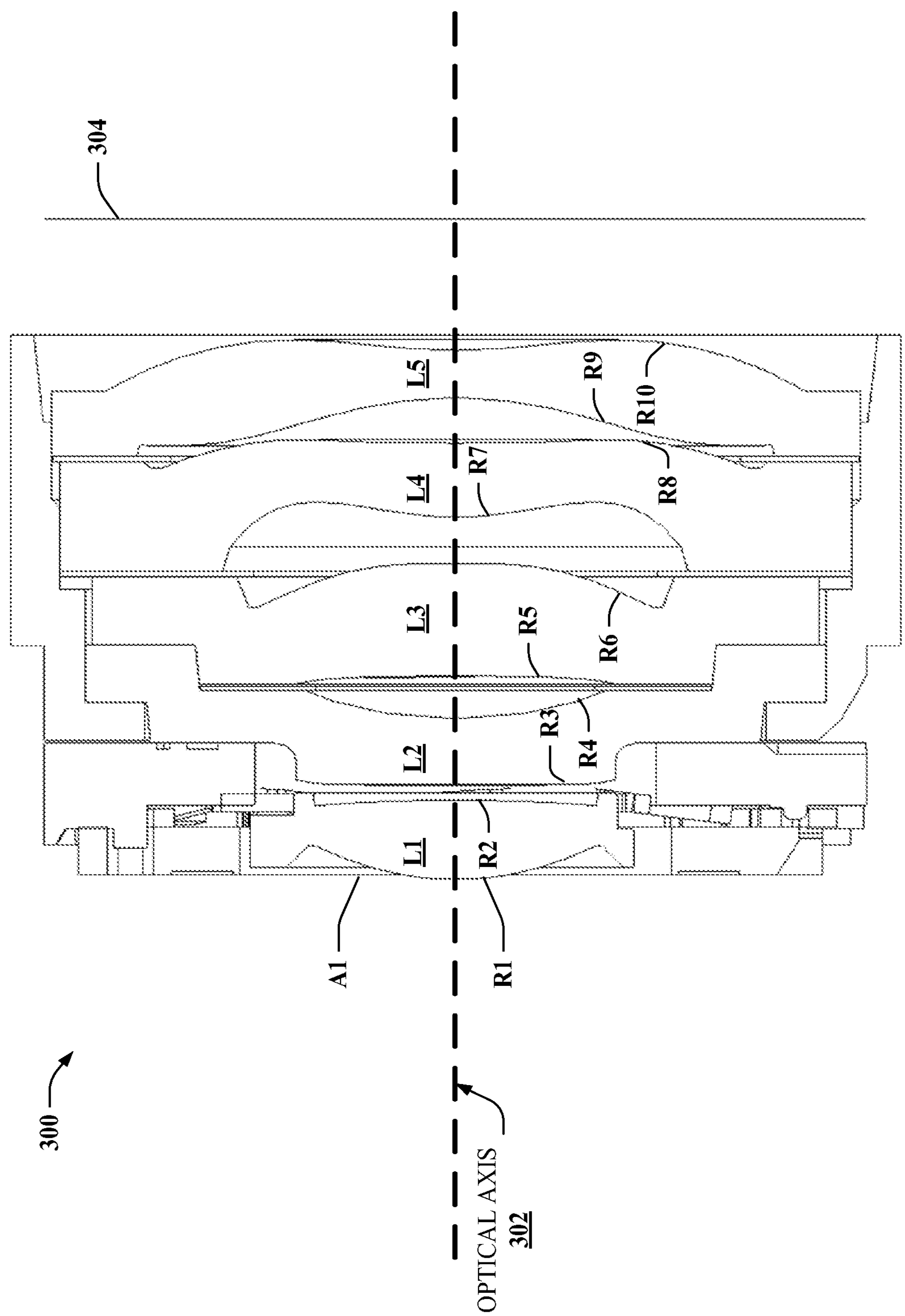
304
L5
R9
R10
L4
R7
R8
L3
R5
R6
L2
R3
R4
L1
R2
A1
R1
300
OPTICAL AXIS
302

FIG. 3

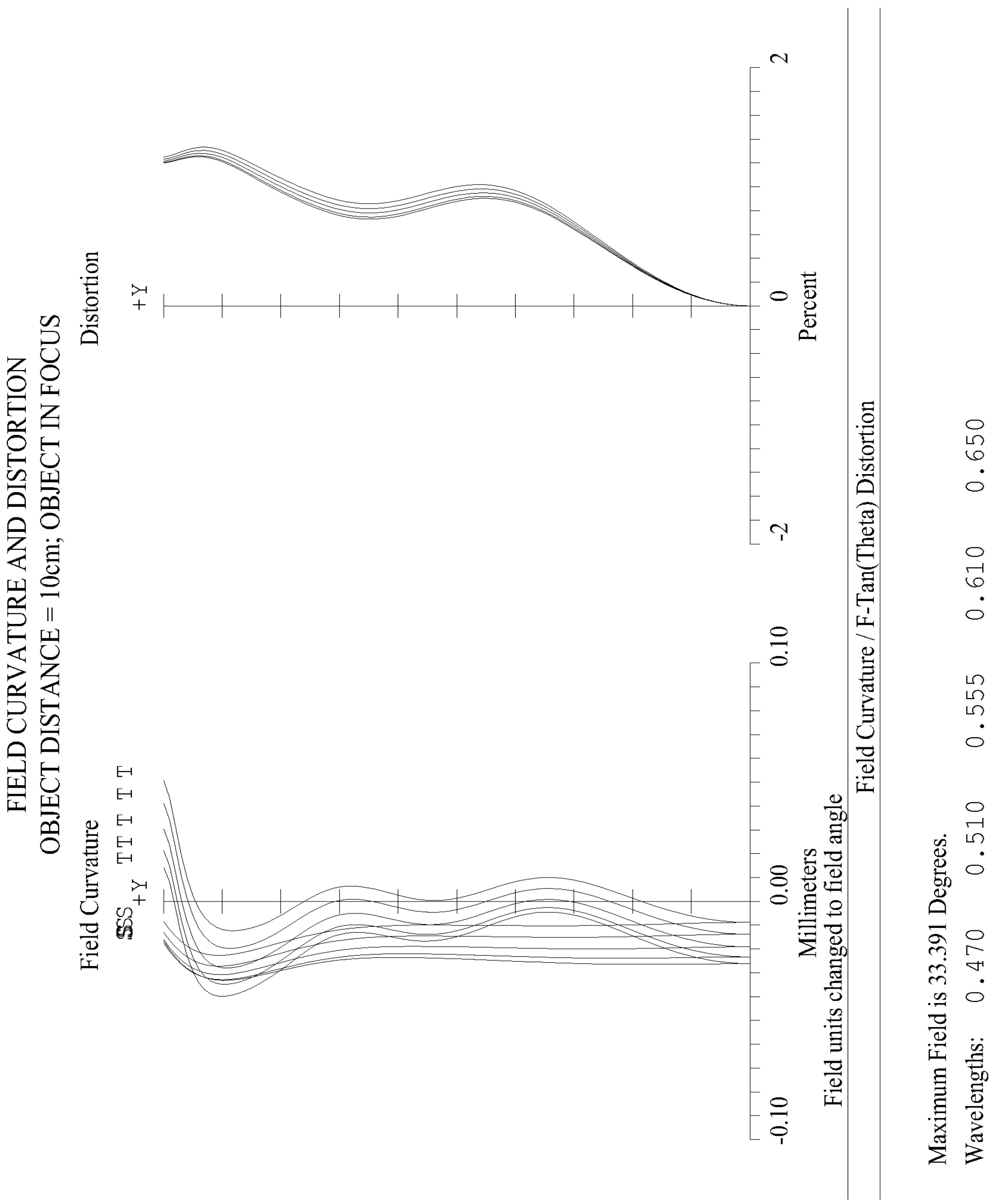
FIELD CURVATURE AND DISTORTION
OBJECT DISTANCE = 10cm; OBJECT IN FOCUS
Field Curvature
+Y
S S S T T T T T
Distortion
+Y
-0.10
0.00
0.10
Millimeters
Field units changed to field angle
-2
0
2
Percent
Field Curvature / F-Tan(Theta) Distortion
Maximum Field is 33.391 Degrees.
Wavelengths: 0.470 0.510 0.555 0.610 0.650

FIG. 4

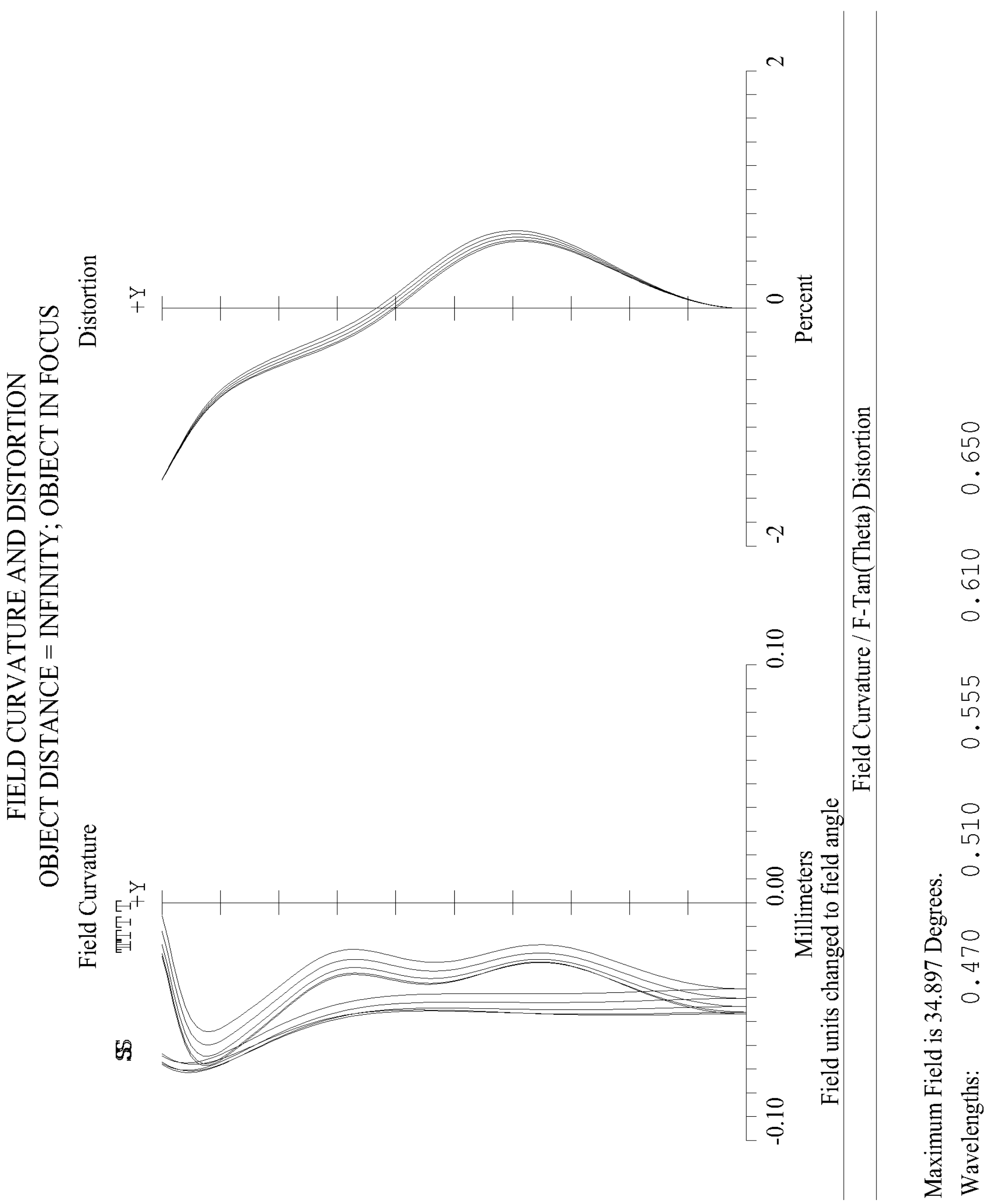
FIELD CURVATURE AND DISTORTION
OBJECT DISTANCE = INFINITY; OBJECT IN FOCUS
Field Curvature
Distortion
+Y
+Y
S
T
-0.10
0.00
0.10
Millimeters
Field units changed to field angle
-2
0
2
Percent
Field Curvature / F-Tan(Theta) Distortion
Maximum Field is 34.897 Degrees.
Wavelengths: 0.470 0.510 0.555 0.610 0.650

FIG. 5

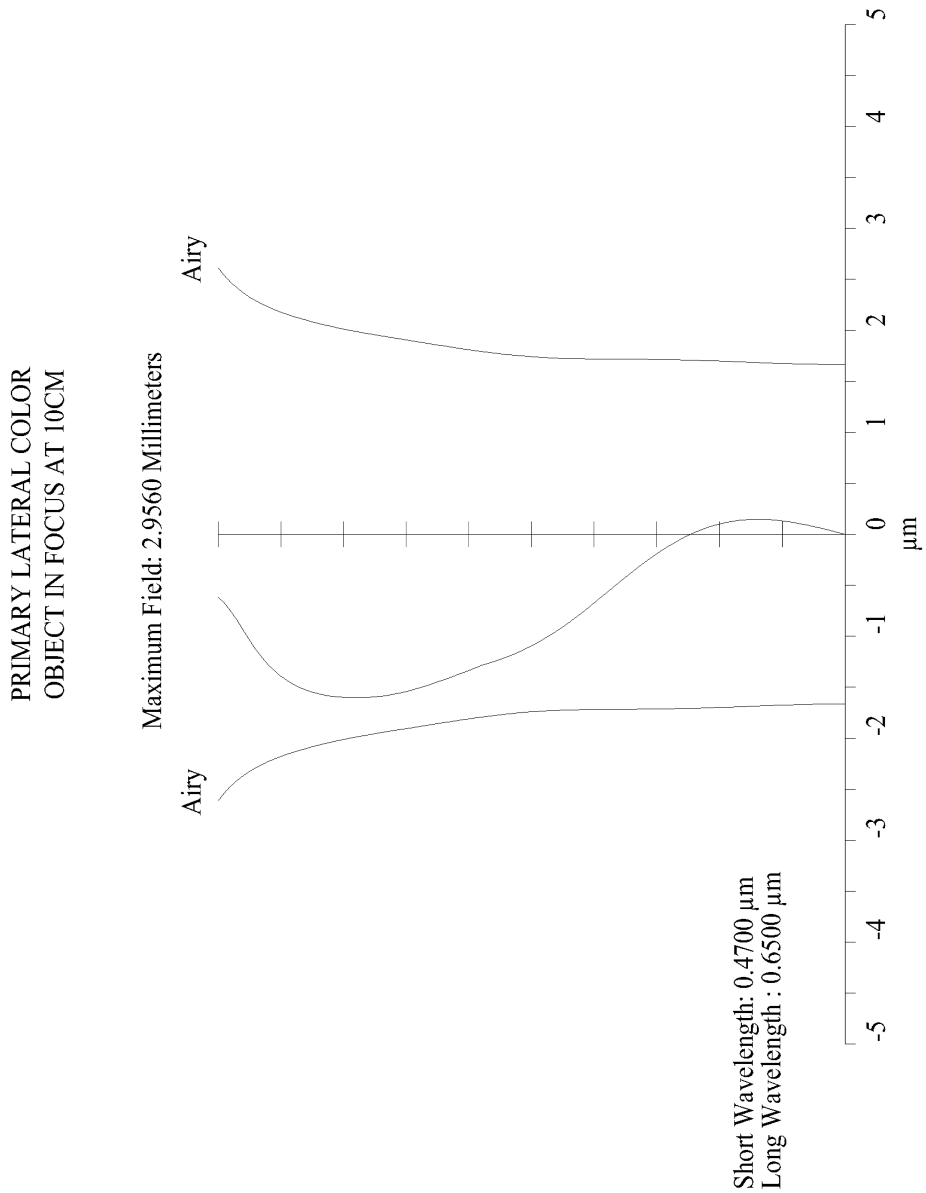
PRIMARY LATERAL COLOR
OBJECT IN FOCUS AT 10CM
Maximum Field: 2.9560 Millimeters
Airy
Airy
-5
-4
-3
-2
-1
0
1
2
3
4
5
µm
Short Wavelength: 0.4700 µm
Long Wavelength : 0.6500 µm

**FIG. 6**

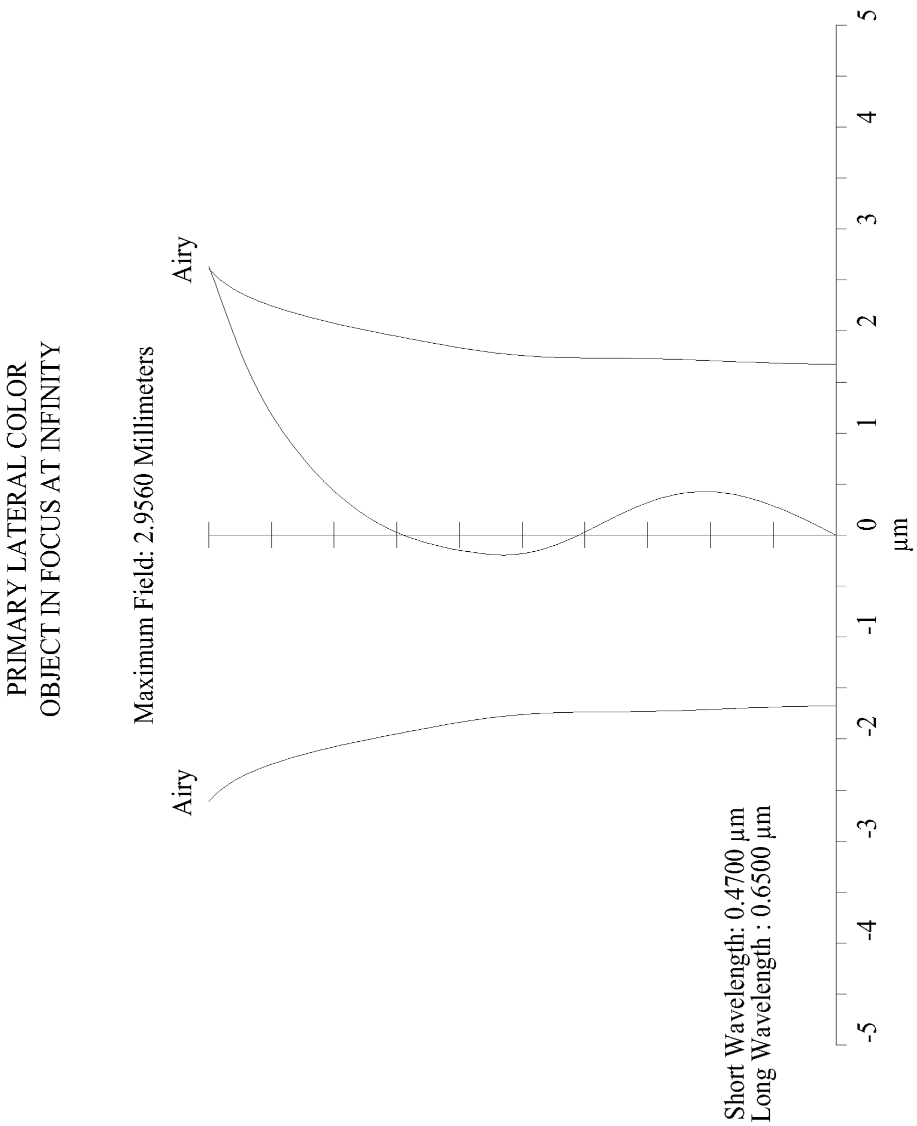
PRIMARY LATERAL COLOR
OBJECT IN FOCUS AT INFINITY
Maximum Field: 2.9560 Millimeters
Airy
Airy
-5 -4 -3 -2 -1 0 1 2 3 4 5
µm
Short Wavelength: 0.4700 µm
Long Wavelength : 0.6500 µm

FIG. 7

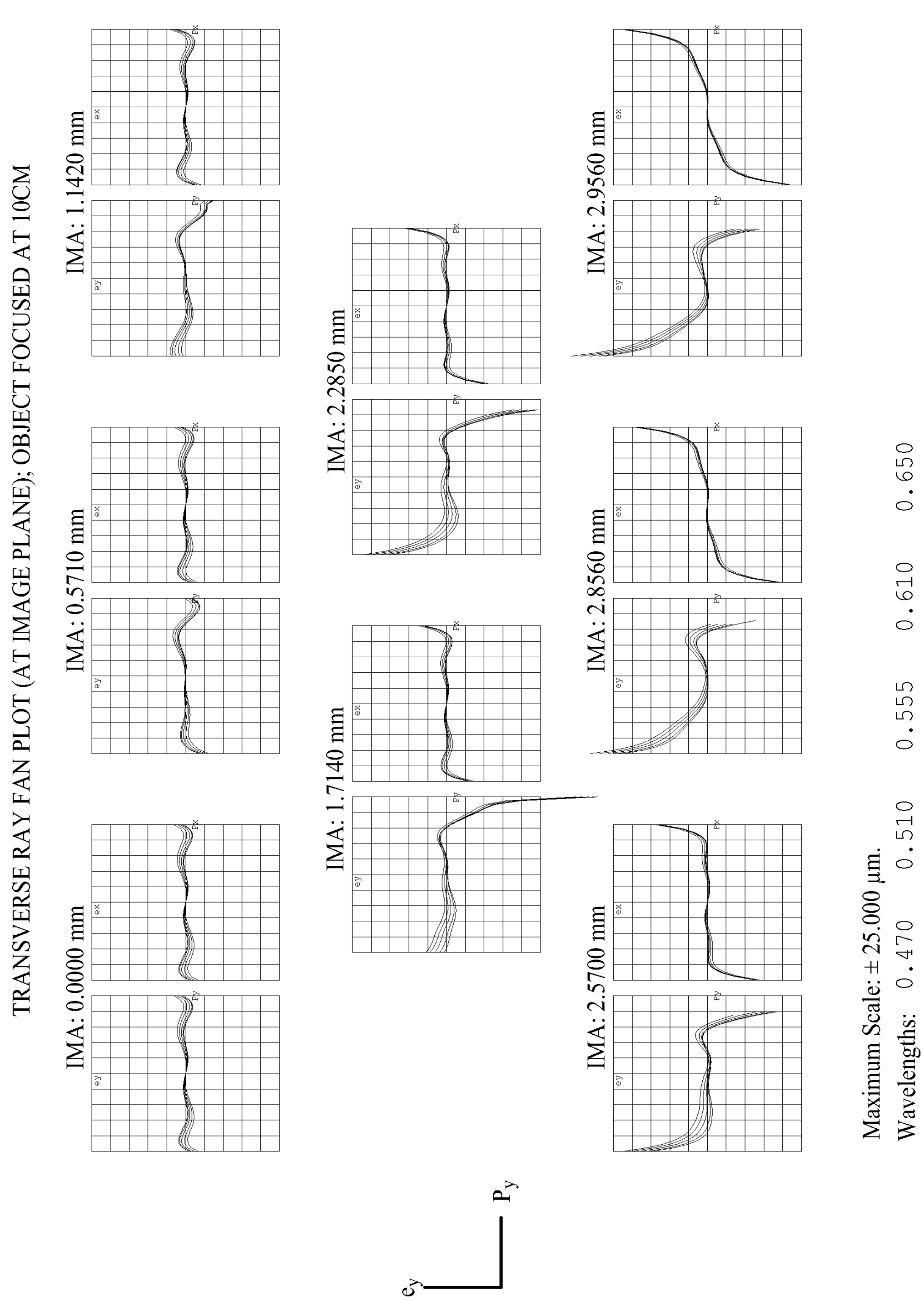
TRANSVERSE RAY FAN PLOT (AT IMAGE PLANE); OBJECT FOCUSED AT 10CM
IMA: 0.0000 mm
IMA: 0.5710 mm
IMA: 1.1420 mm
IMA: 1.7140 mm
IMA: 2.2850 mm
IMA: 2.5700 mm
IMA: 2.8560 mm
IMA: 2.9560 mm
ey
Py
ex
Px
Maximum Scale: ± 25.000 µm.
Wavelengths: 0.470 0.510 0.555 0.610 0.650

FIG. 8

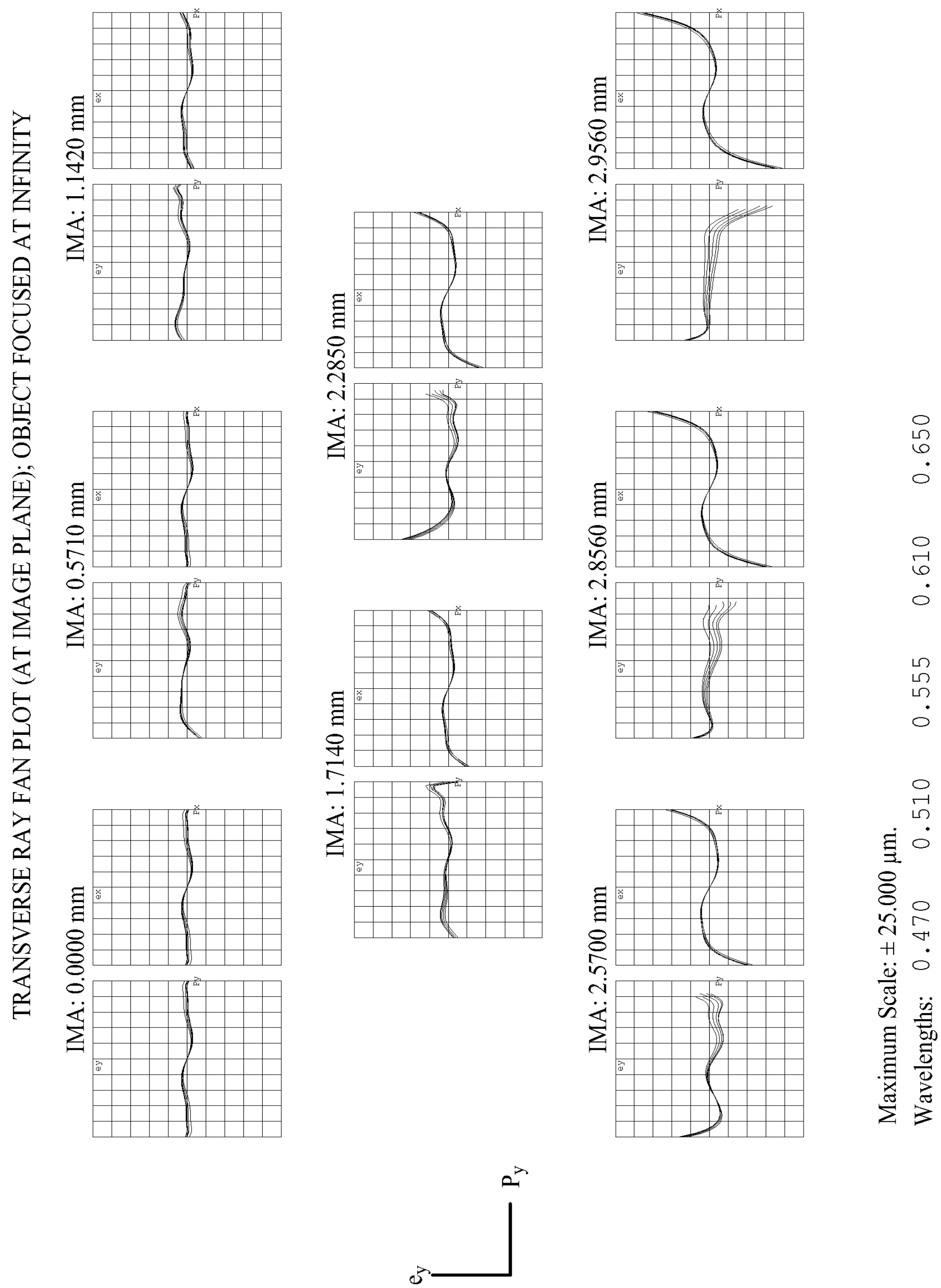
TRANSVERSE RAY FAN PLOT (AT IMAGE PLANE); OBJECT FOCUSED AT INFINITY
IMA: 0.0000 mm
IMA: 0.5710 mm
IMA: 1.1420 mm
IMA: 1.7140 mm
IMA: 2.2850 mm
IMA: 2.5700 mm
IMA: 2.8560 mm
IMA: 2.9560 mm
Maximum Scale: ± 25.000 µm.
Wavelengths: 0.470 0.510 0.555 0.610 0.650
$e_y$
$P_y$

FIG. 9

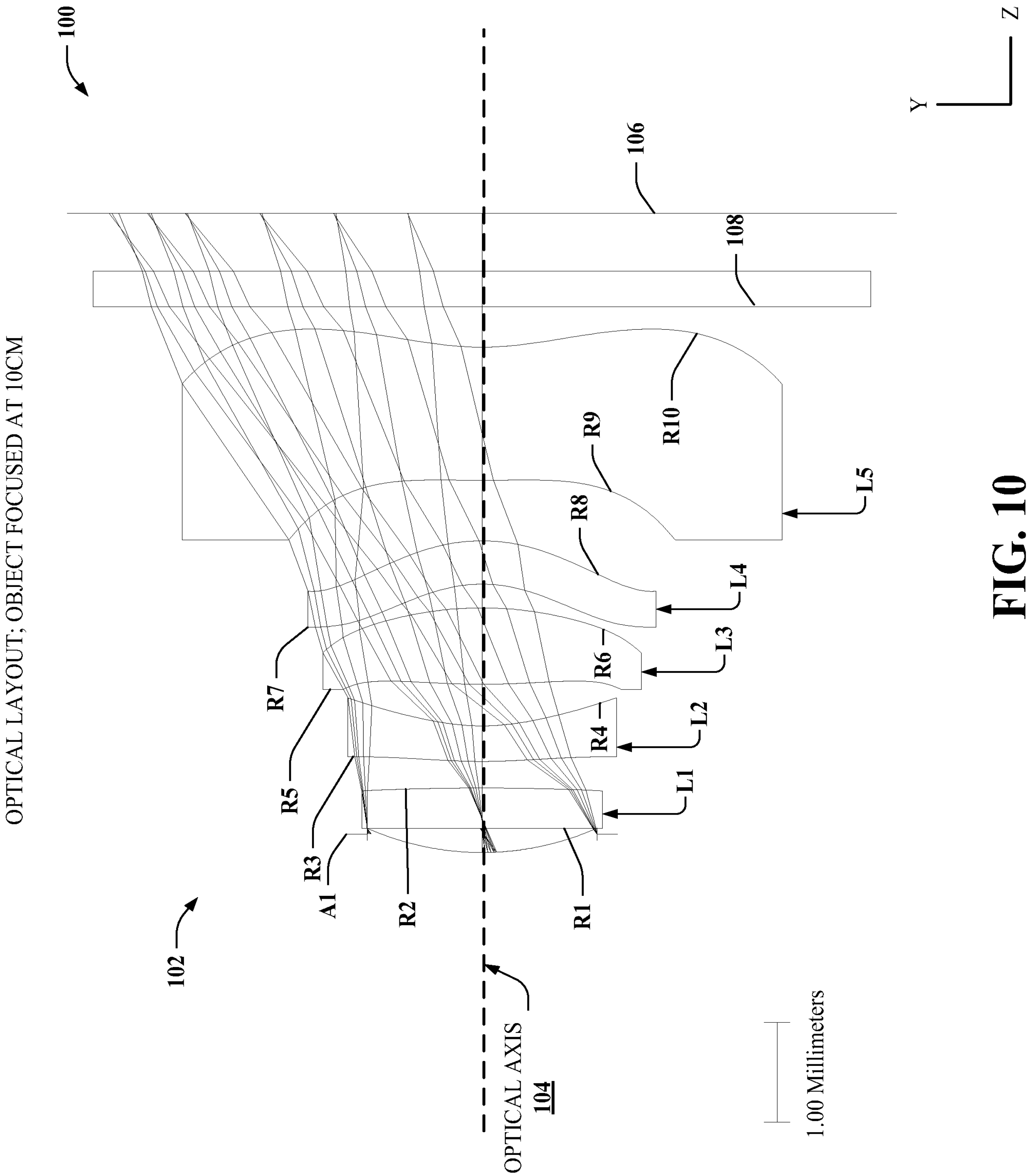
OPTICAL LAYOUT; OBJECT FOCUSED AT 10CM
100
102
106
108
R10
R9
L5
R8
L4
R7
R6
L3
R5
R4
L2
R3
L1
A1
R2
R1
OPTICAL AXIS
104
1.00 Millimeters
Y
Z

FIG. 10

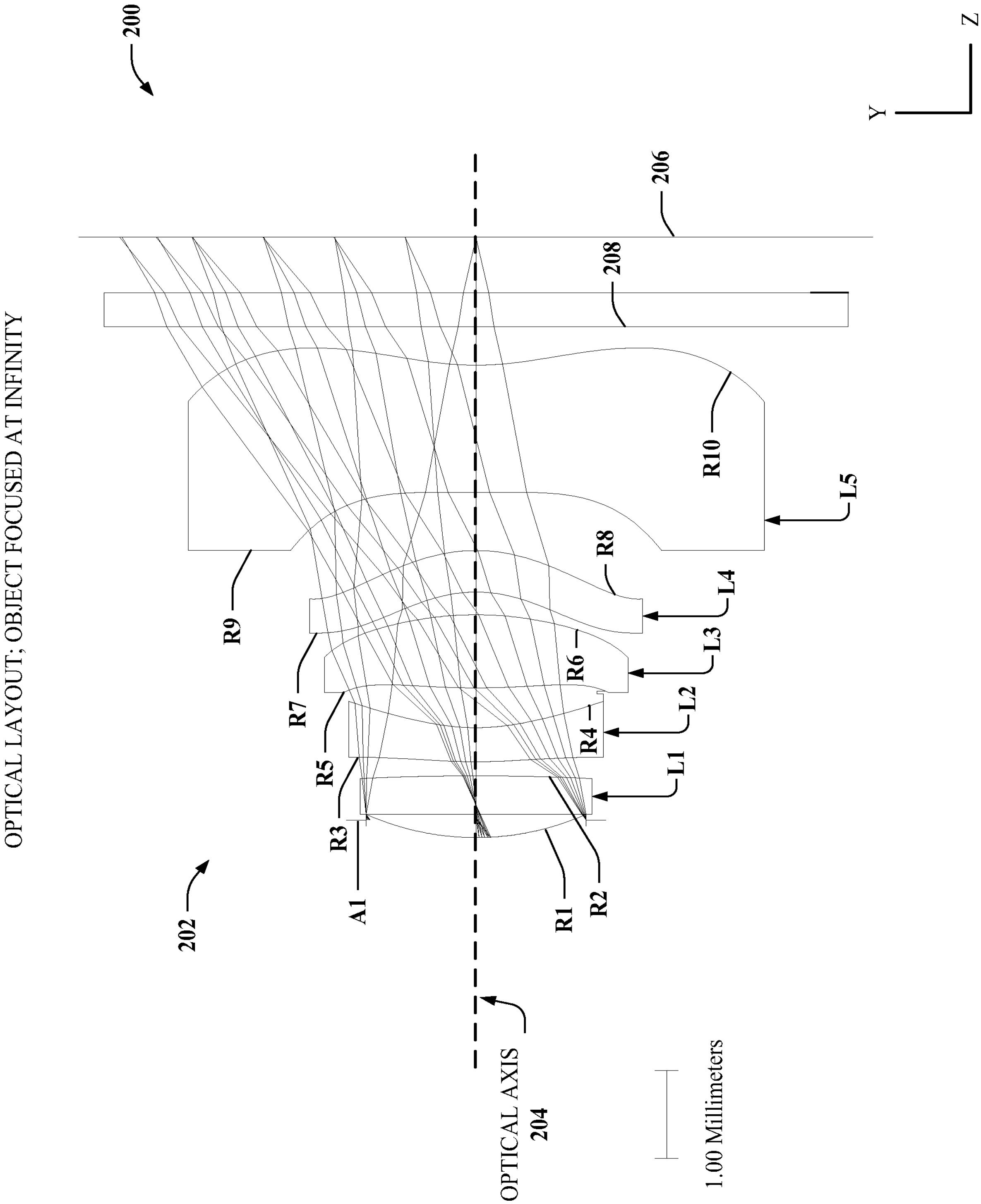
OPTICAL LAYOUT; OBJECT FOCUSED AT INFINITY
200
202
206
208
R10
L5
R9
R8
L4
R7
L3
R6
R5
L2
R4
L1
R3
A1
R1
R2
Y
Z
OPTICAL AXIS
204
1.00 Millimeters

FIG. 11

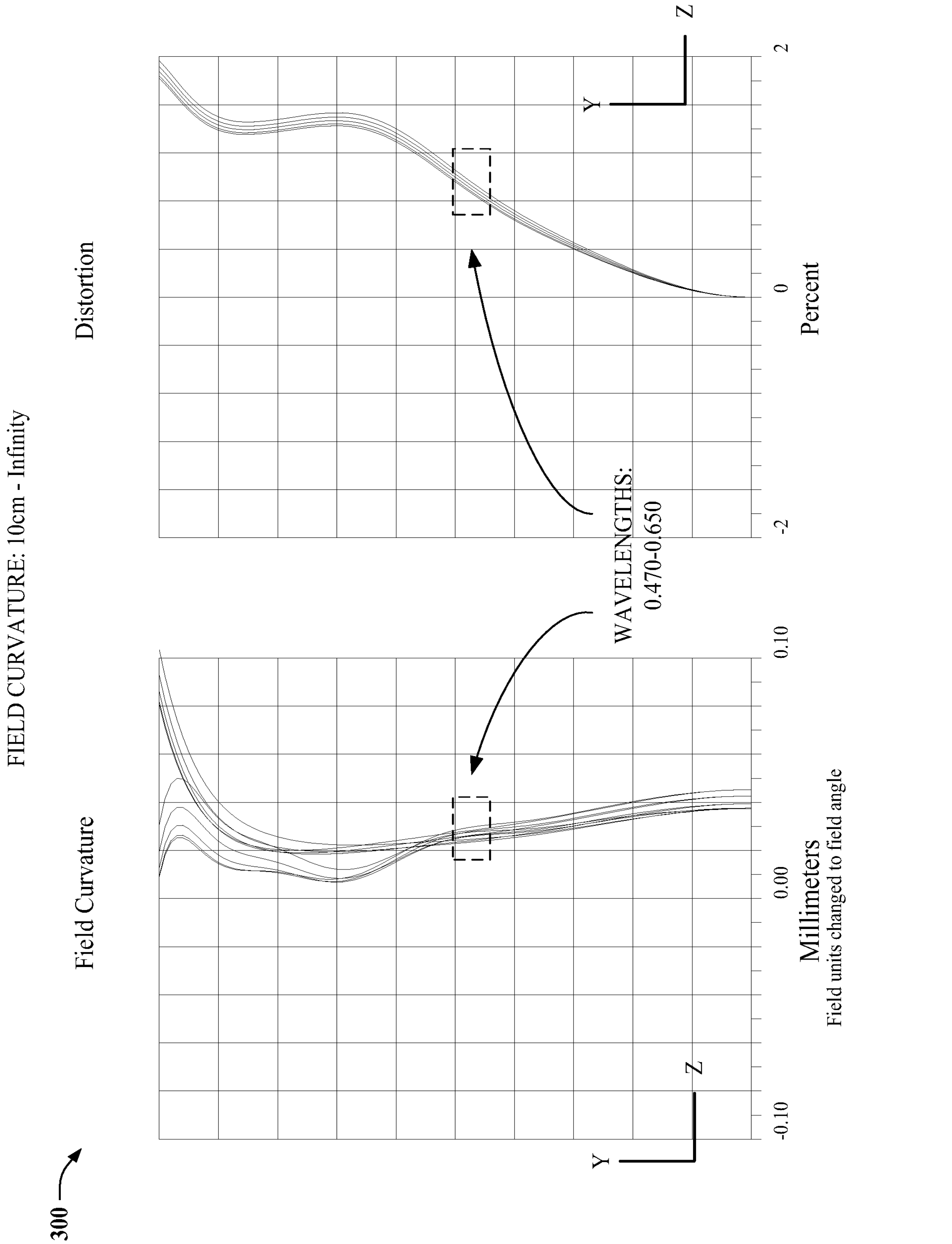
300
FIELD CURVATURE: 10cm - Infinity
Field Curvature
Distortion
WAVELENGTHS:
0.470-0.650
-0.10
0.00
0.10
Millimeters
Field units changed to field angle
-2
0
2
Percent
Y
Z
Y
Z

FIG. 12

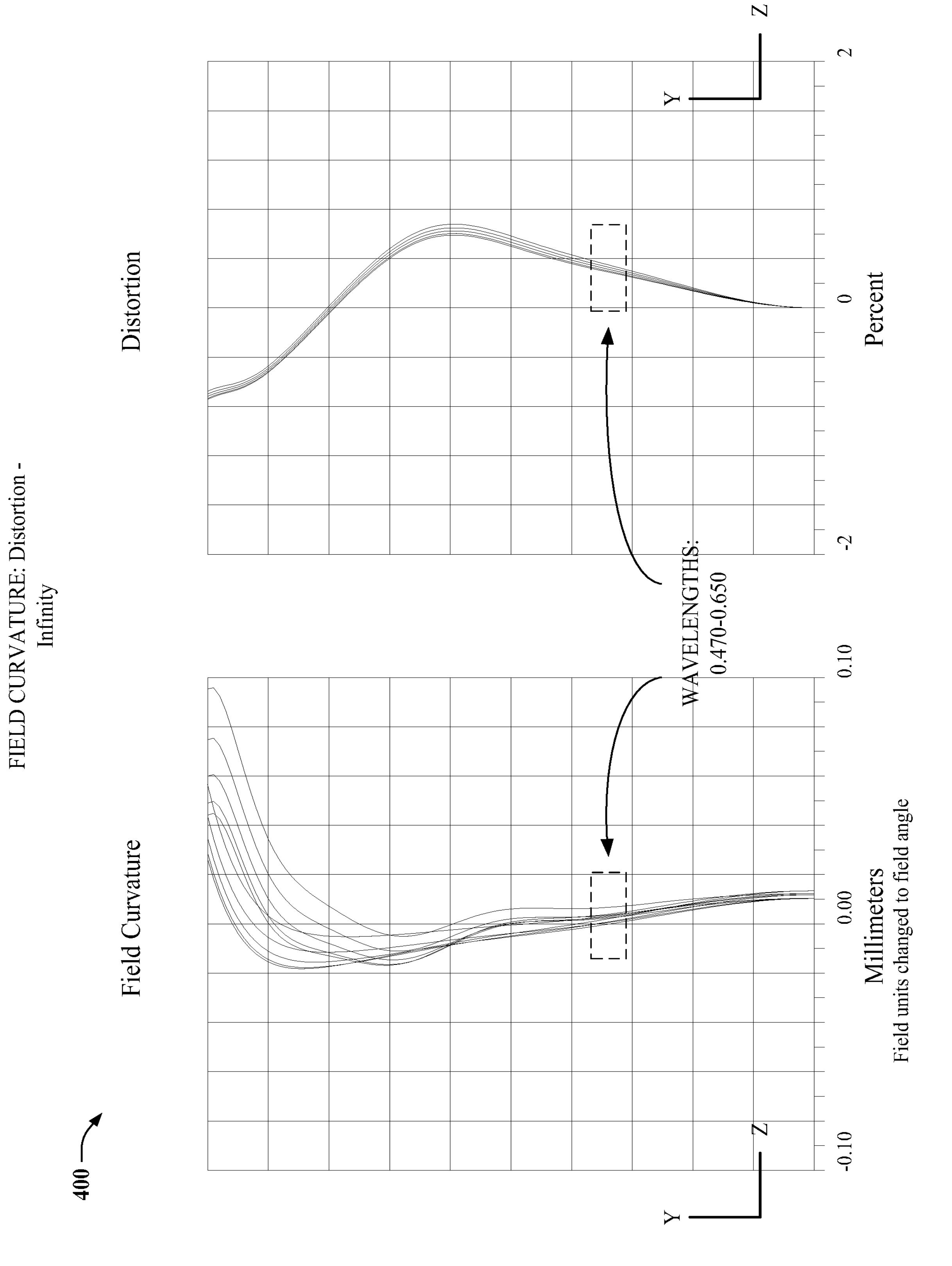
FIELD CURVATURE: Distortion - Infinity
400
Field Curvature
Distortion
Y
Z
-0.10
0.00
0.10
Millimeters
Field units changed to field angle
-2
0
2
Percent
WAVELENGTHS:
0.470-0.650

FIG. 13

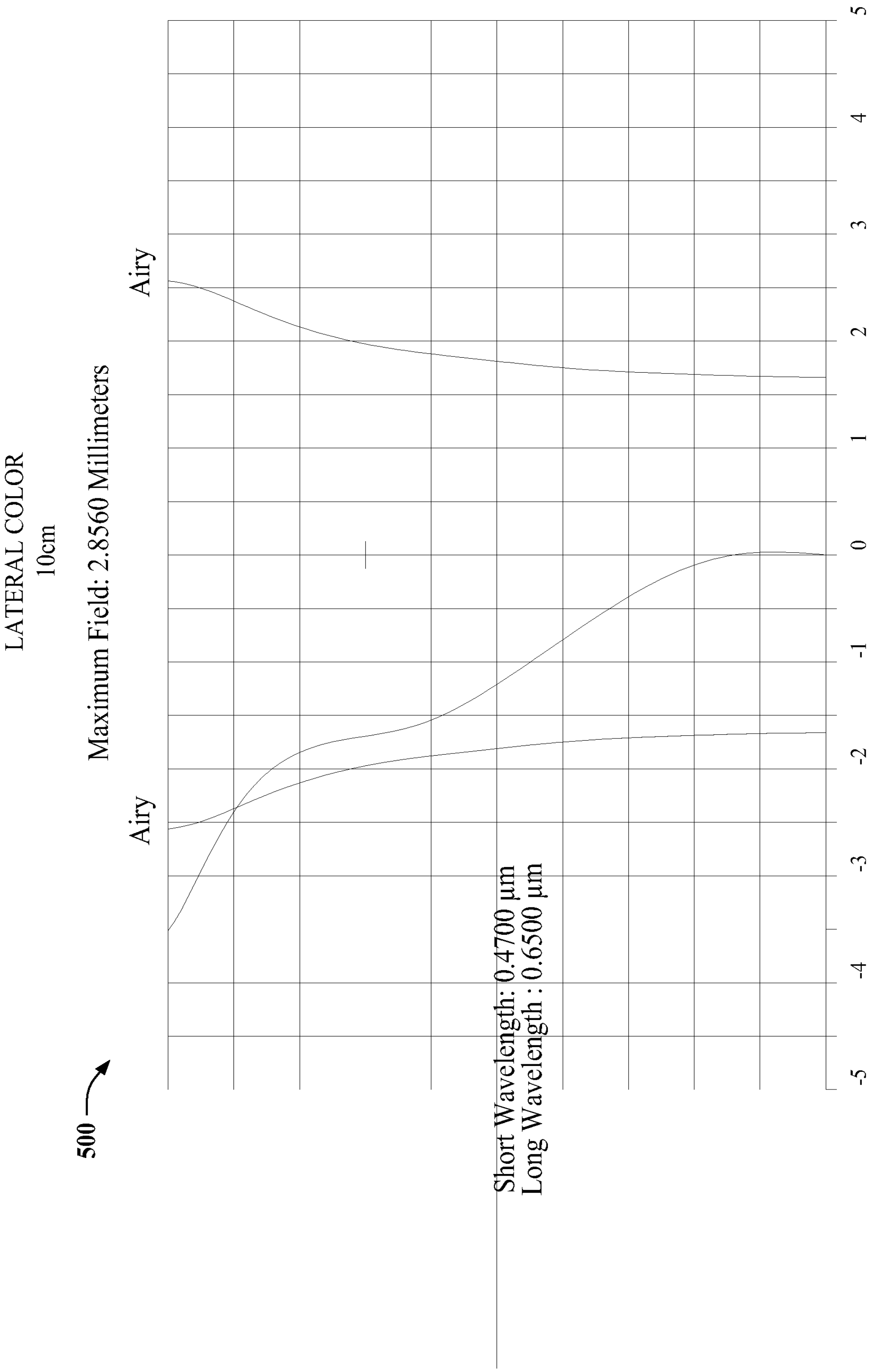
500
LATERAL COLOR
10cm
Maximum Field: 2.8560 Millimeters
Airy
Airy
Short Wavelength: 0.4700 µm
Long Wavelength : 0.6500 µm
-5
-4
-3
-2
-1
0
1
2
3
4
5
µm

**FIG. 14**

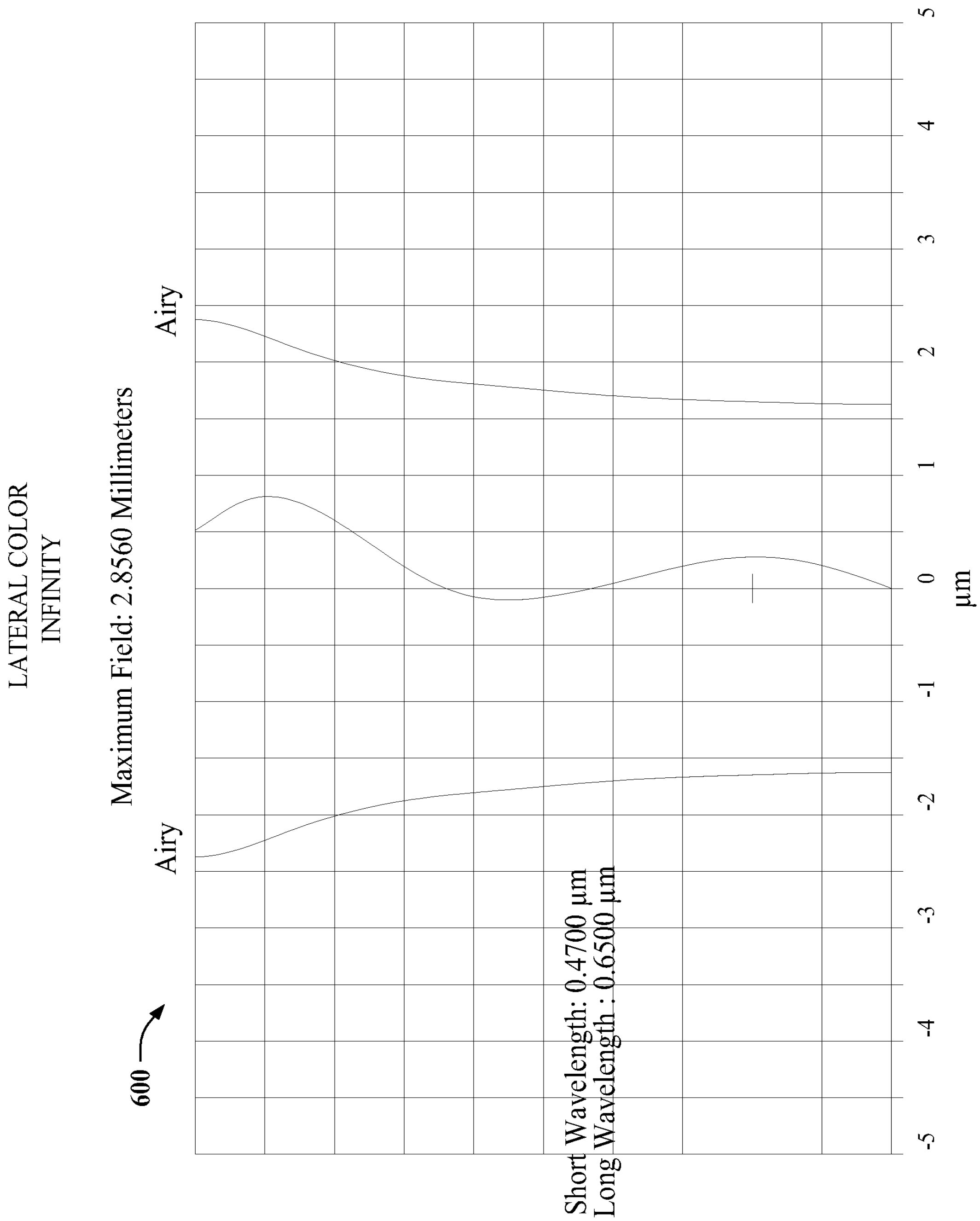
LATERAL COLOR
INFINITY
Maximum Field: 2.8560 Millimeters
Airy
Airy
600
Short Wavelength: 0.4700 µm
Long Wavelength : 0.6500 µm
-5
-4
-3
-2
-1
0
1
2
3
4
5
µm

FIG. 15

TRANSVERSE RAY FAN PLOT 10cm

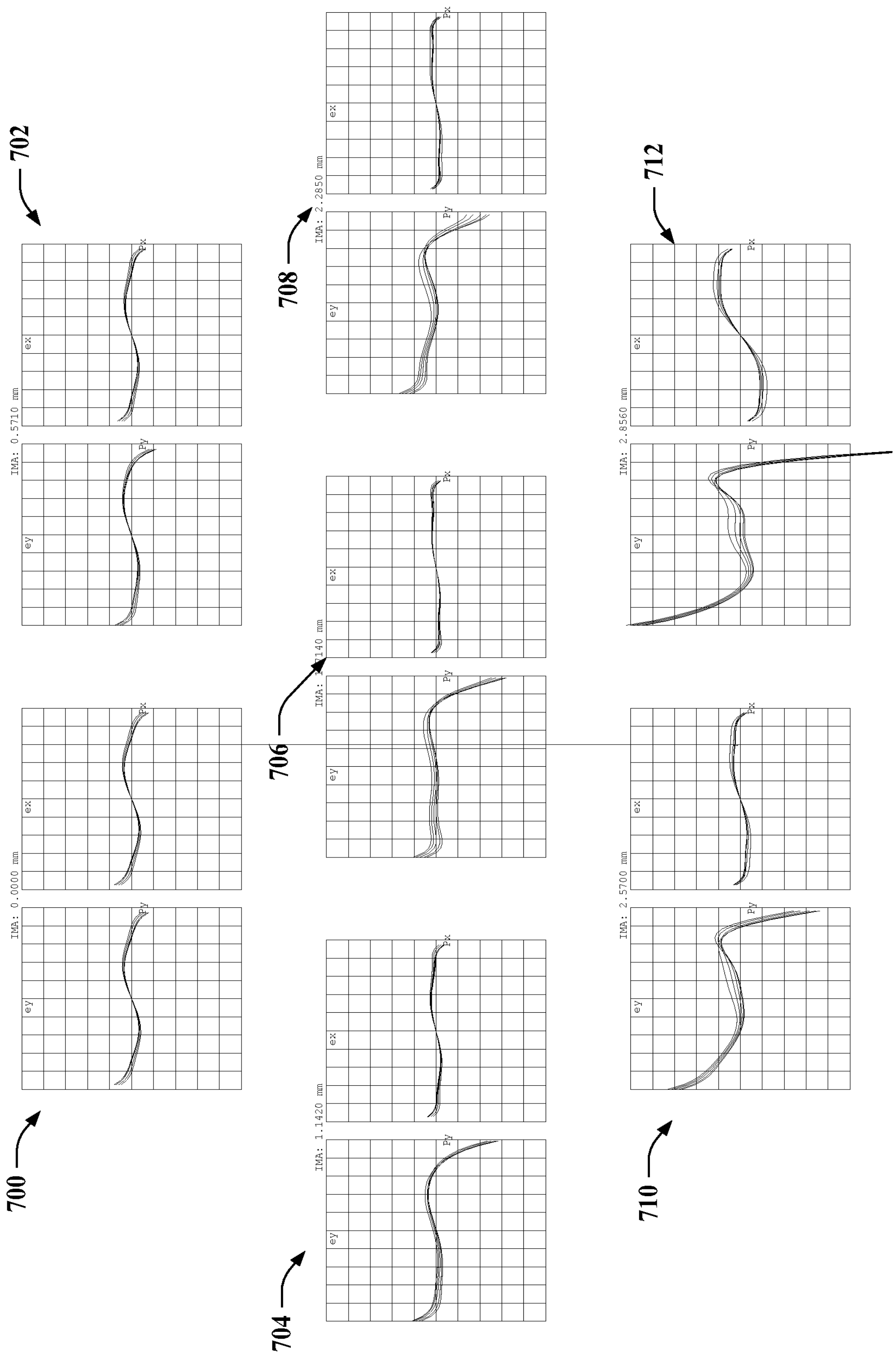


FIG. 16

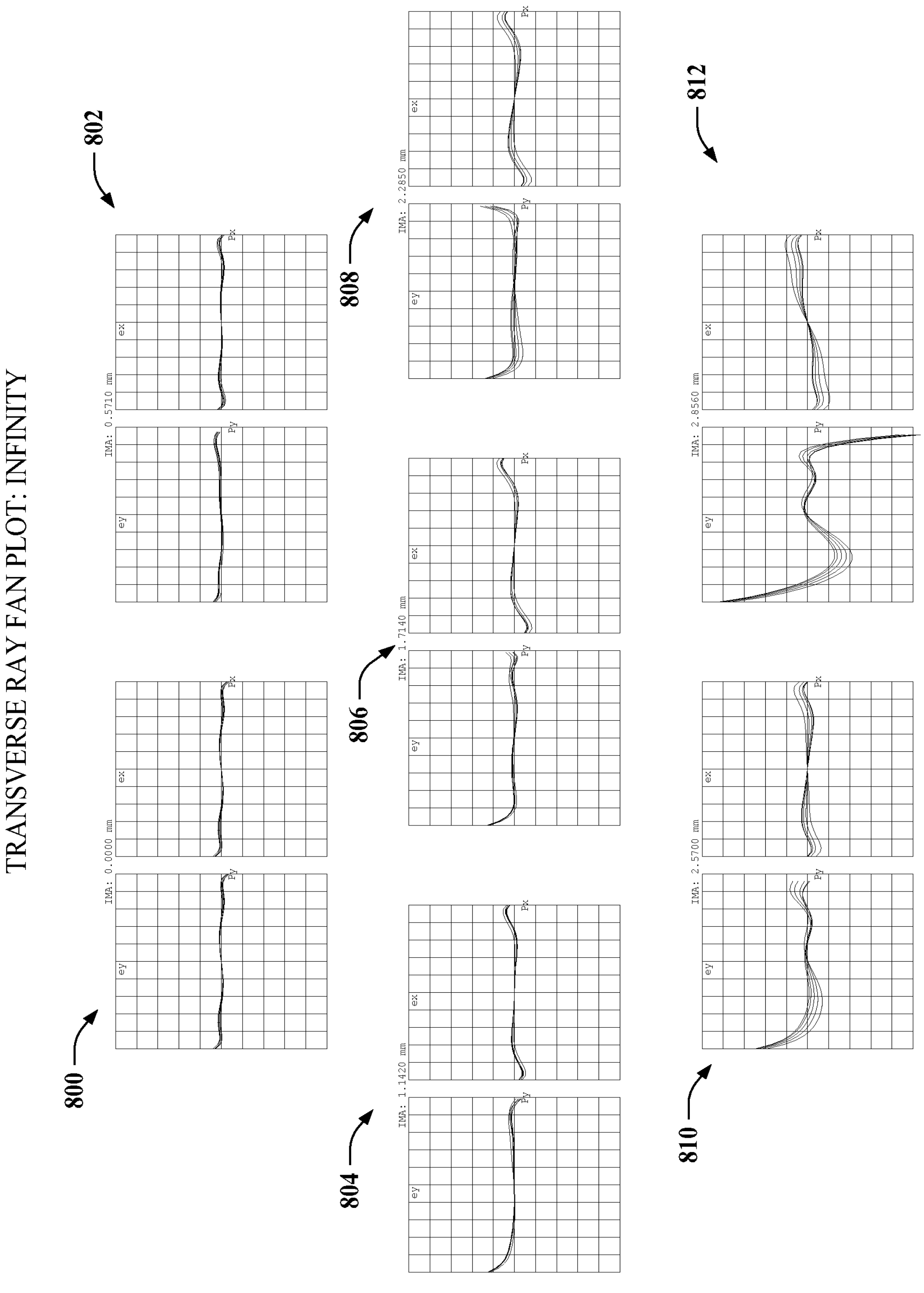
TRANSVERSE RAY FAN PLOT: INFINITY
800
802
804
806
808
810
812
IMA: 0.0000 mm
IMA: 0.5710 mm
IMA: 1.1420 mm
IMA: 1.7140 mm
IMA: 2.2850 mm
IMA: 2.5700 mm
IMA: 2.8560 mm
ey
ex
Py
Px

FIG. 17

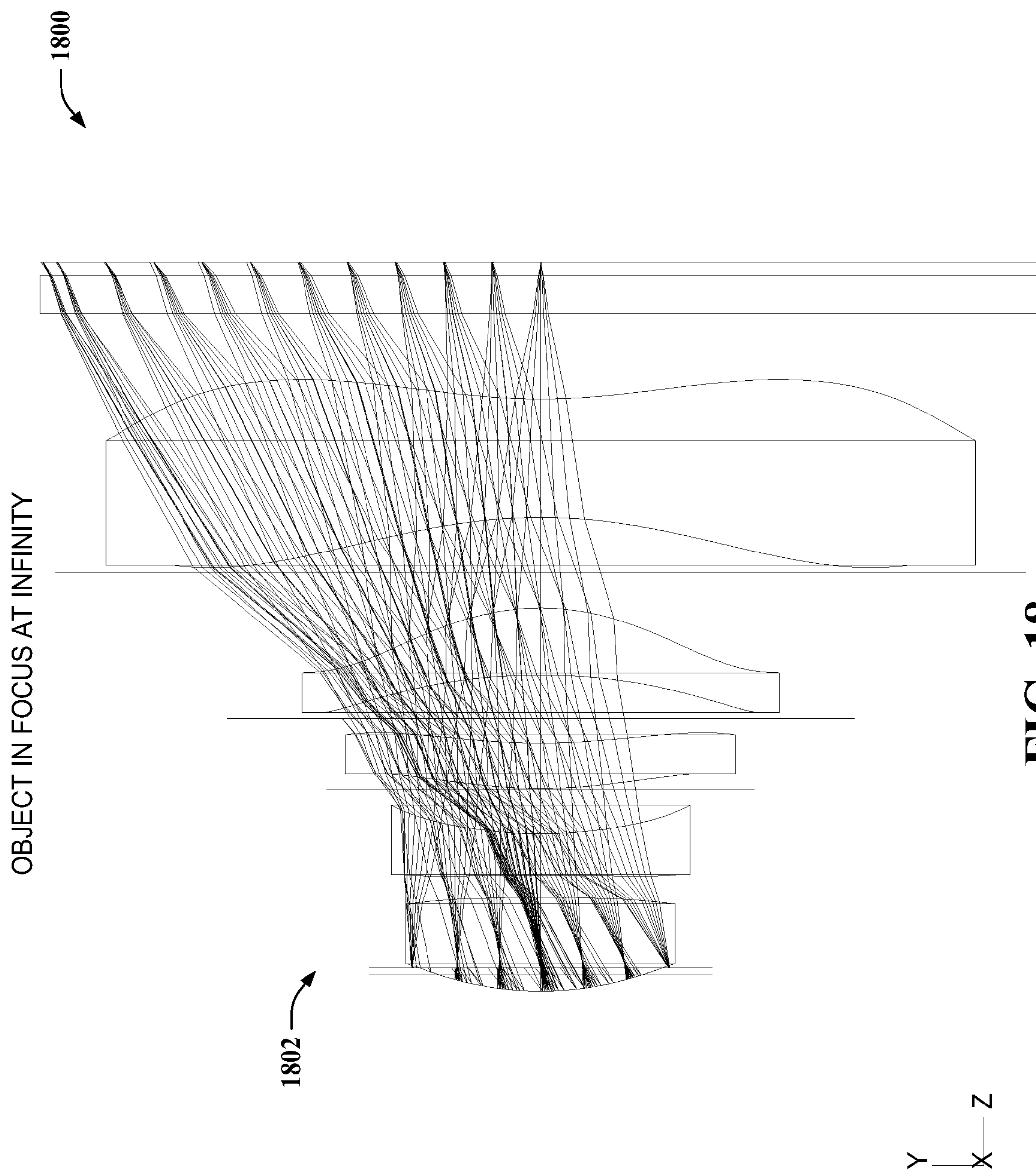


FIG. 18

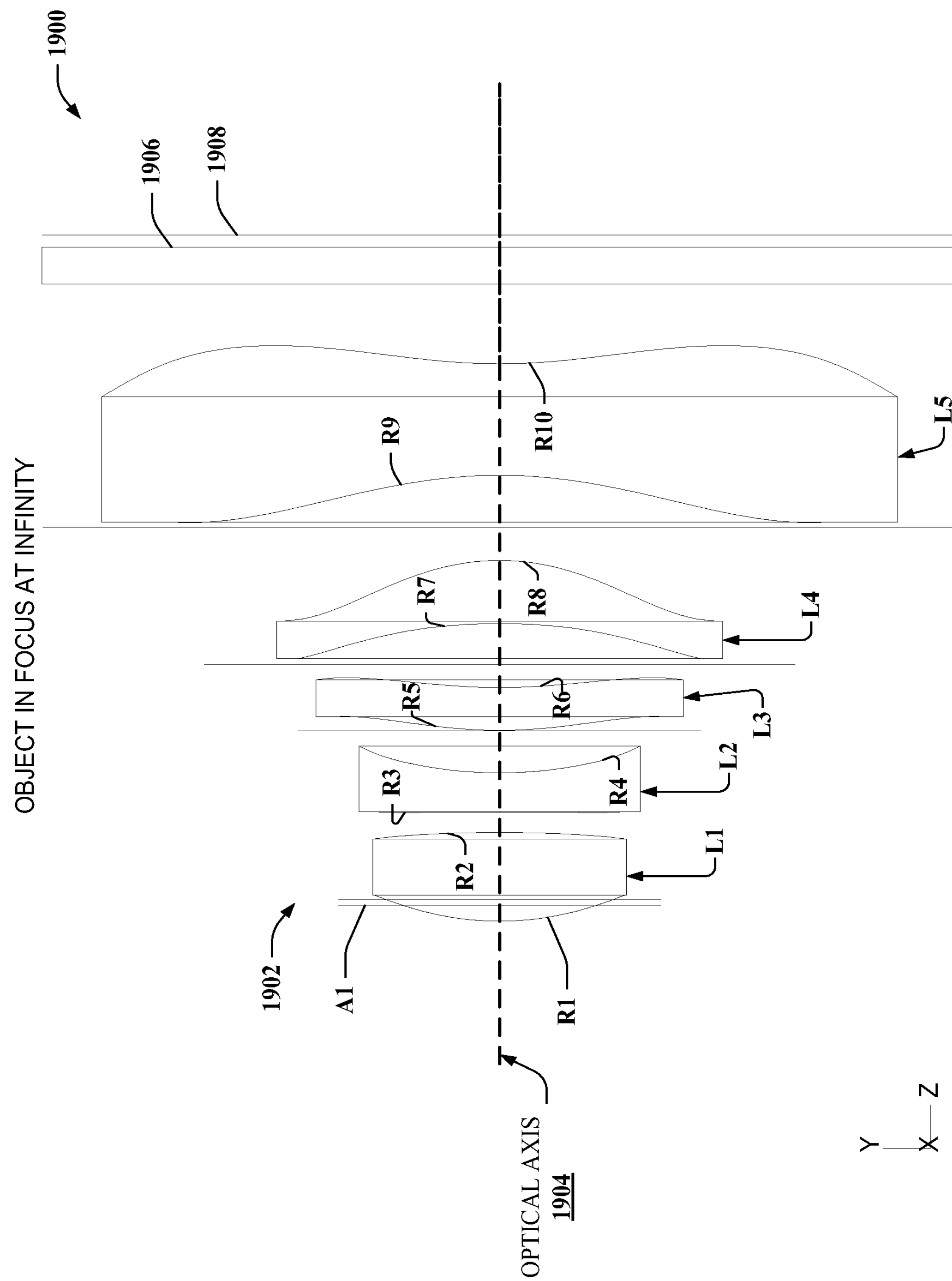
1900
1906
1908
R10
L5
R9
OBJECT IN FOCUS AT INFINITY
R7
R8
L4
R5
R6
L3
R3
R4
L2
R2
L1
1902
A1
R1
OPTICAL AXIS
1904
Y
X
Z

FIG. 19

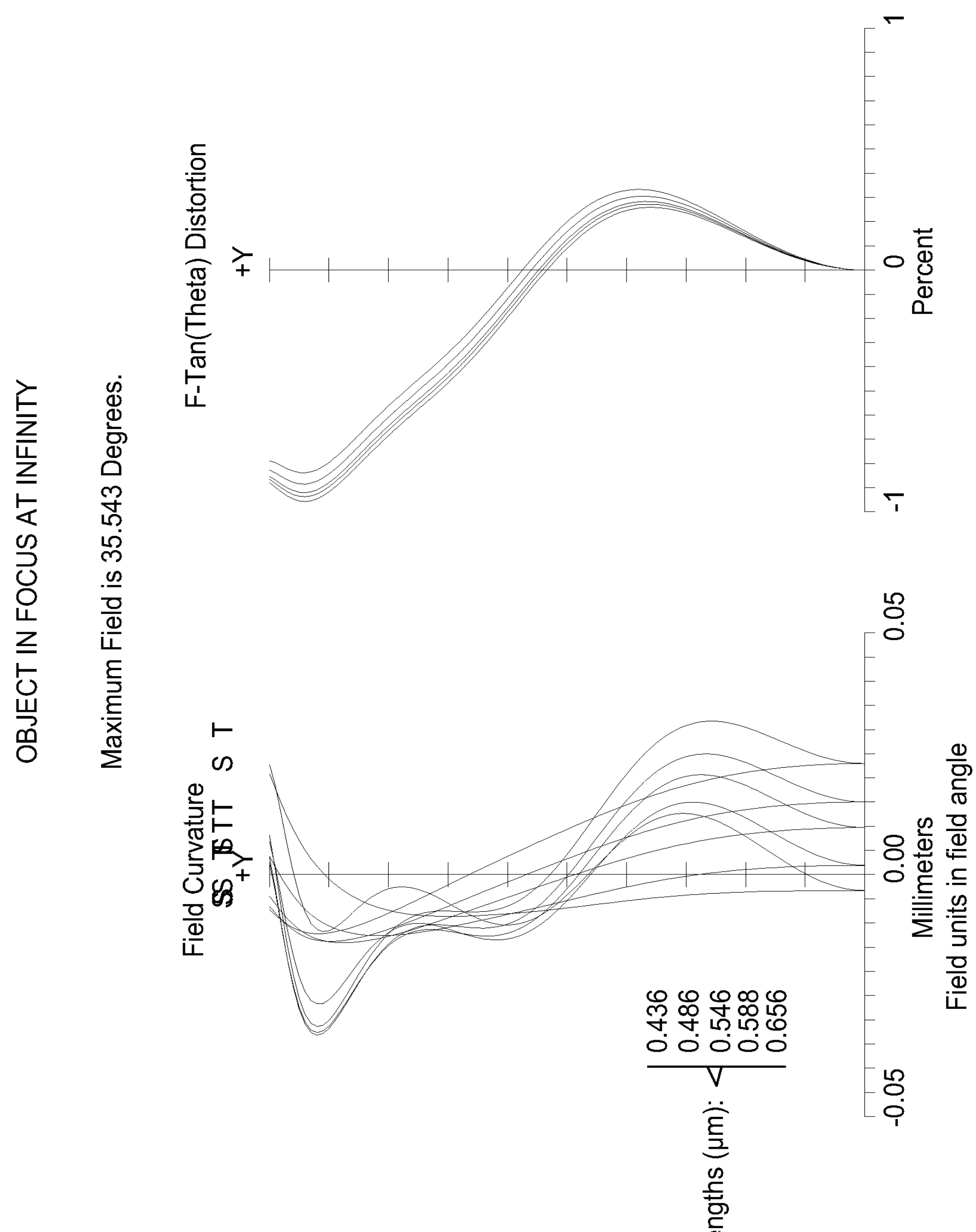
OBJECT IN FOCUS AT INFINITY
Maximum Field is 35.543 Degrees.
Field Curvature
+Y
S T
F-Tan(Theta) Distortion
+Y
Wavelengths (µm):
0.436
0.486
0.546
0.588
0.656
-0.05
0.00
0.05
Millimeters
Field units in field angle
-1
0
1
Percent

FIG. 20

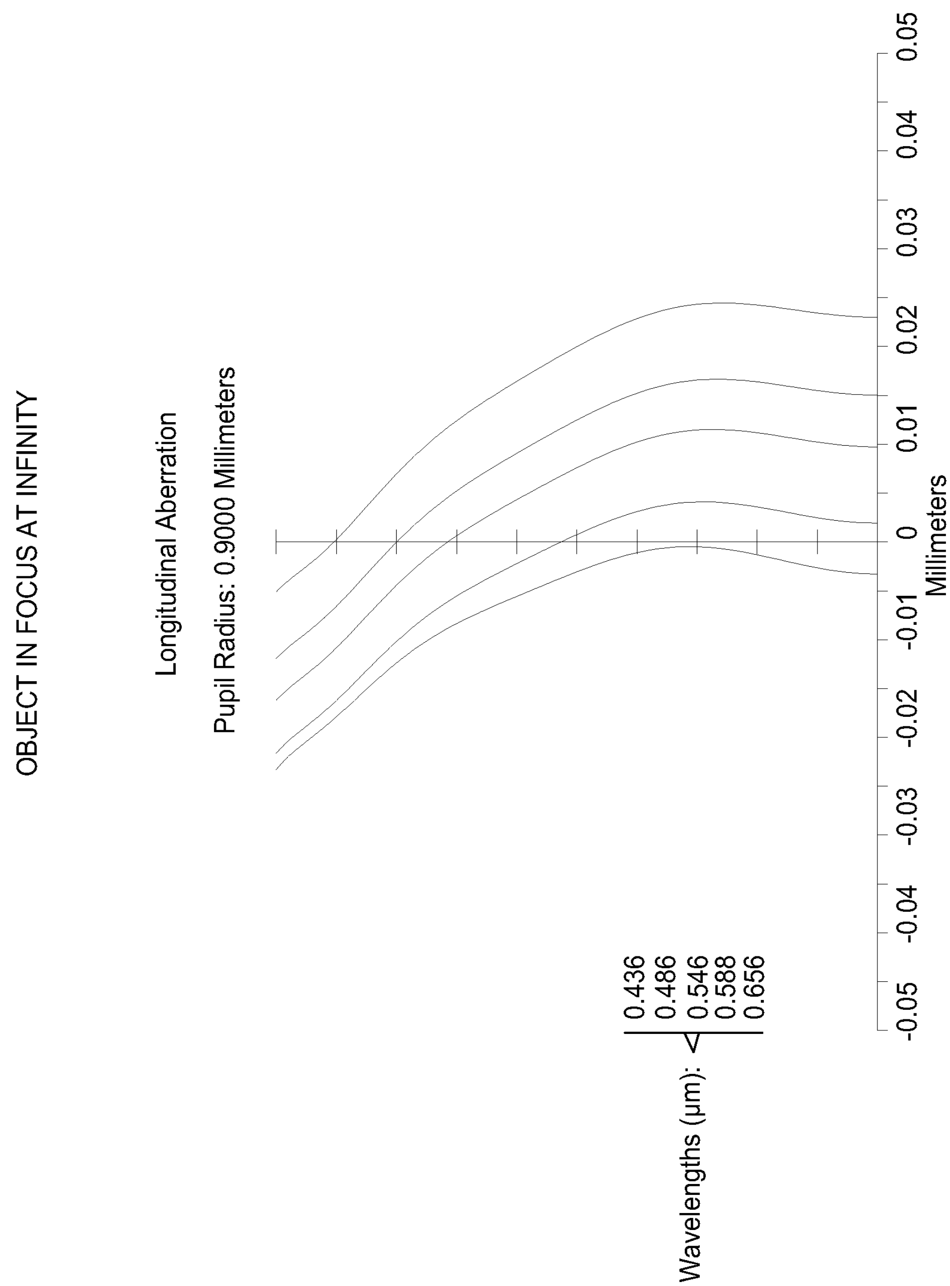
OBJECT IN FOCUS AT INFINITY
Longitudinal Aberration
Pupil Radius: 0.9000 Millimeters
Wavelengths (µm):
0.436
0.486
0.546
0.588
0.656
-0.05
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05
Millimeters

FIG. 21

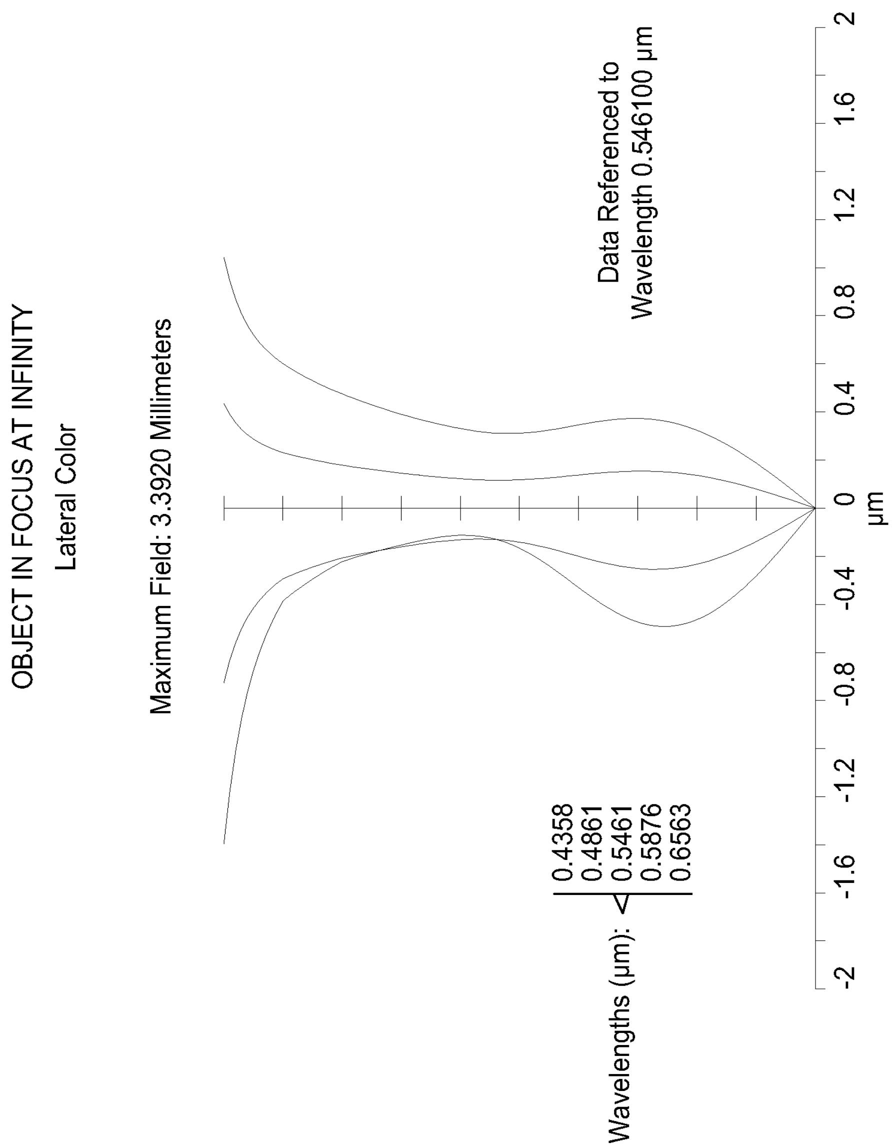
OBJECT IN FOCUS AT INFINITY
Lateral Color
Maximum Field: 3.3920 Millimeters
Data Referenced to
Wavelength 0.546100 µm
Wavelengths (µm):
0.4358
0.4861
0.5461
0.5876
0.6563
-2
-1.6
-1.2
-0.8
-0.4
0
0.4
0.8
1.2
1.6
2
µm

FIG. 22

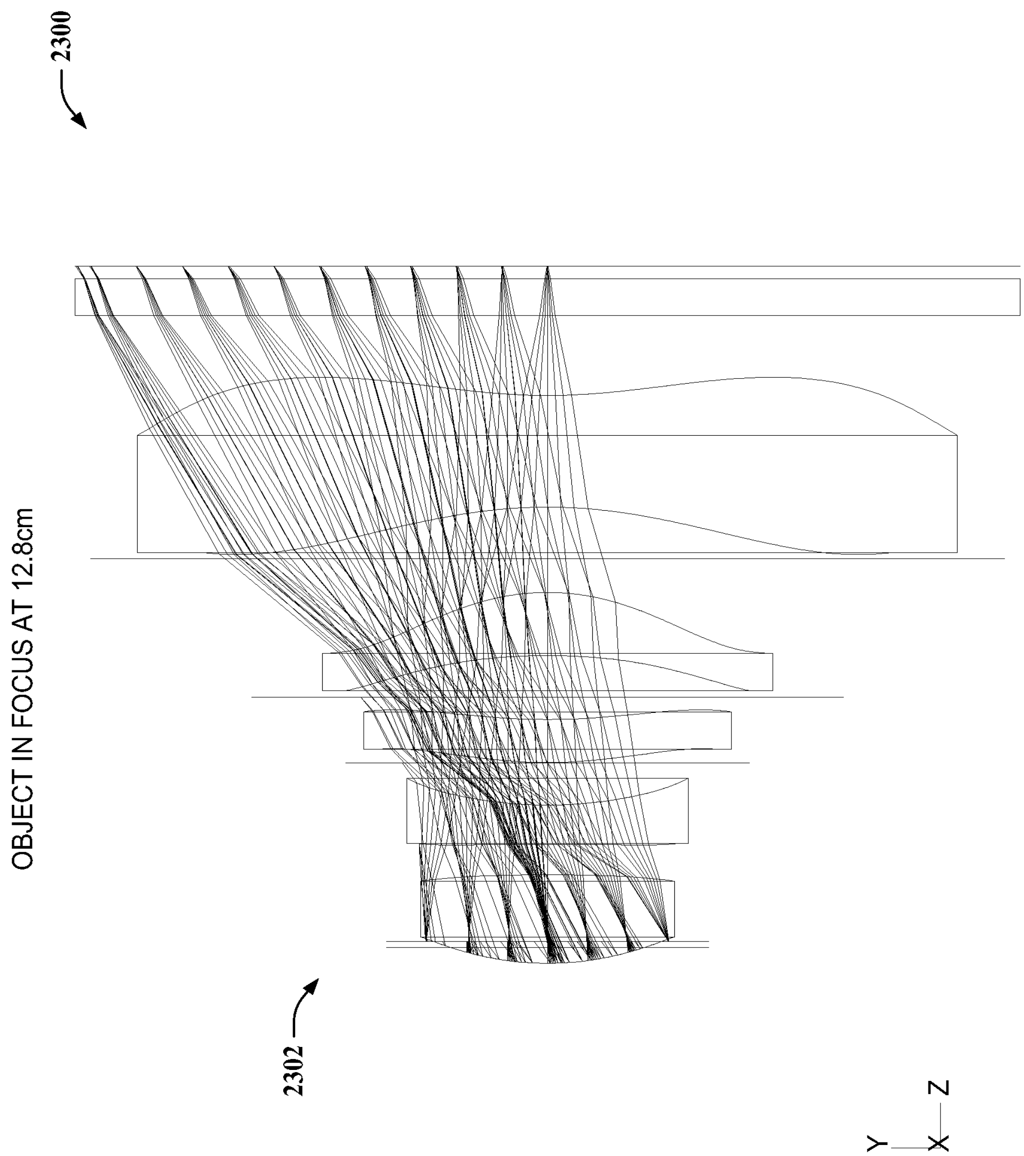


FIG. 23

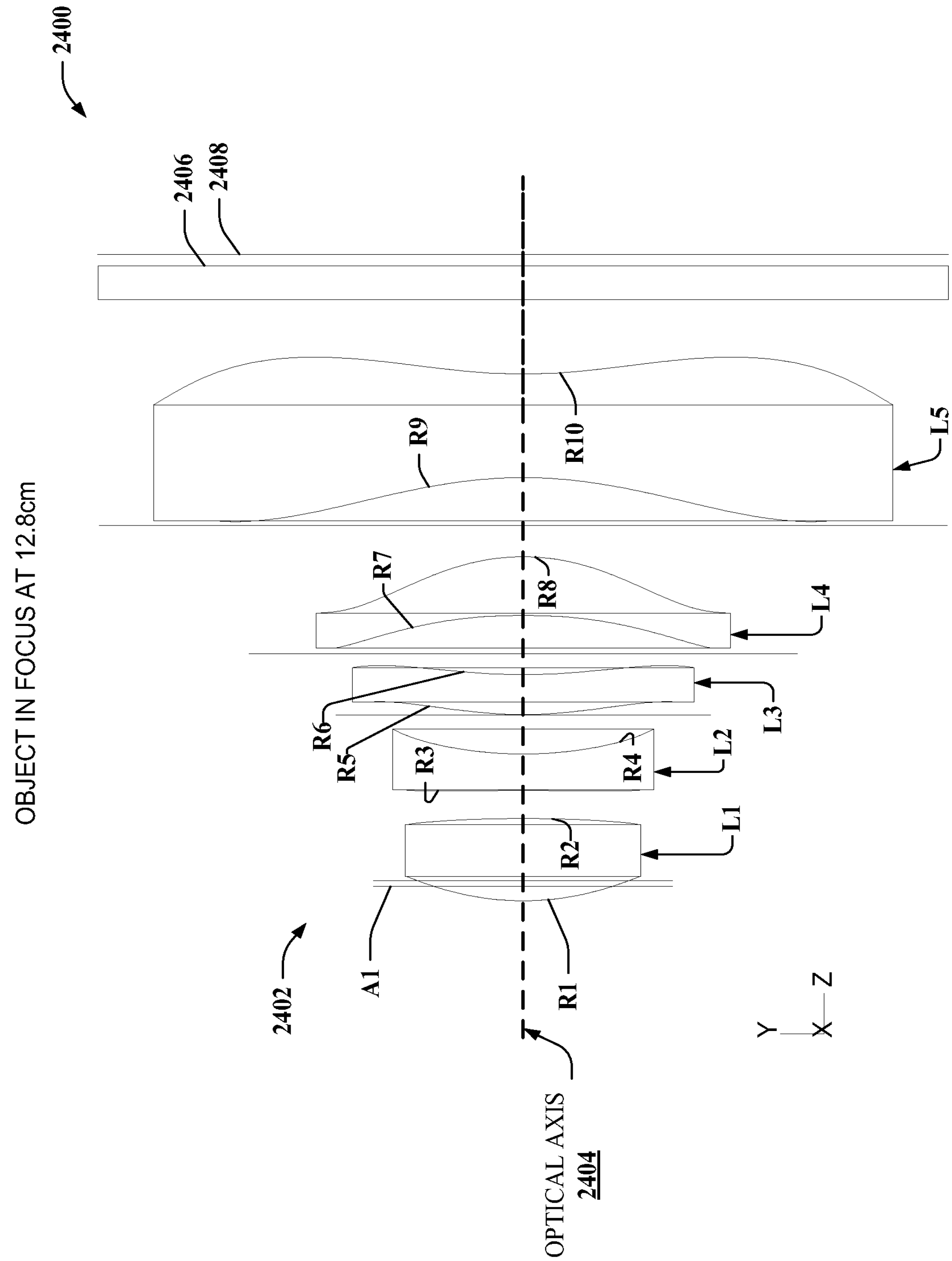
2400
2406
2408
OBJECT IN FOCUS AT 12.8cm
R9
R10
L5
R7
R8
L4
L3
R6
R5
R3
R4
L2
L1
R2
2402
A1
R1
Y
X
Z
OPTICAL AXIS
2404

FIG. 24

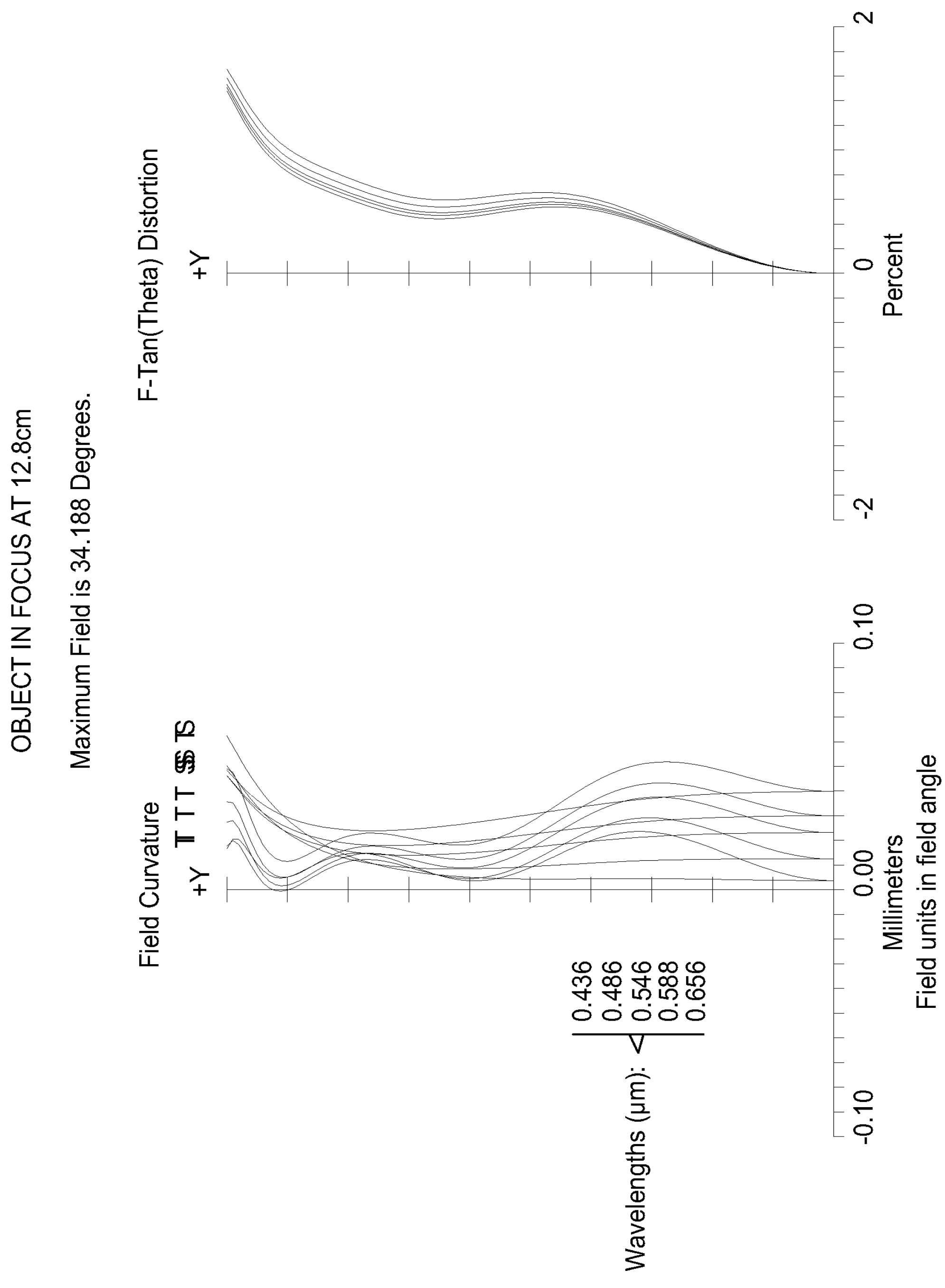
OBJECT IN FOCUS AT 12.8cm
Maximum Field is 34.188 Degrees.
Field Curvature
+Y
T T T S S S T S
Wavelengths (µm):
0.436
0.486
0.546
0.588
0.656
-0.10
0.00
0.10
Millimeters
Field units in field angle
F-Tan(Theta) Distortion
+Y
-2
0
2
Percent

FIG. 25

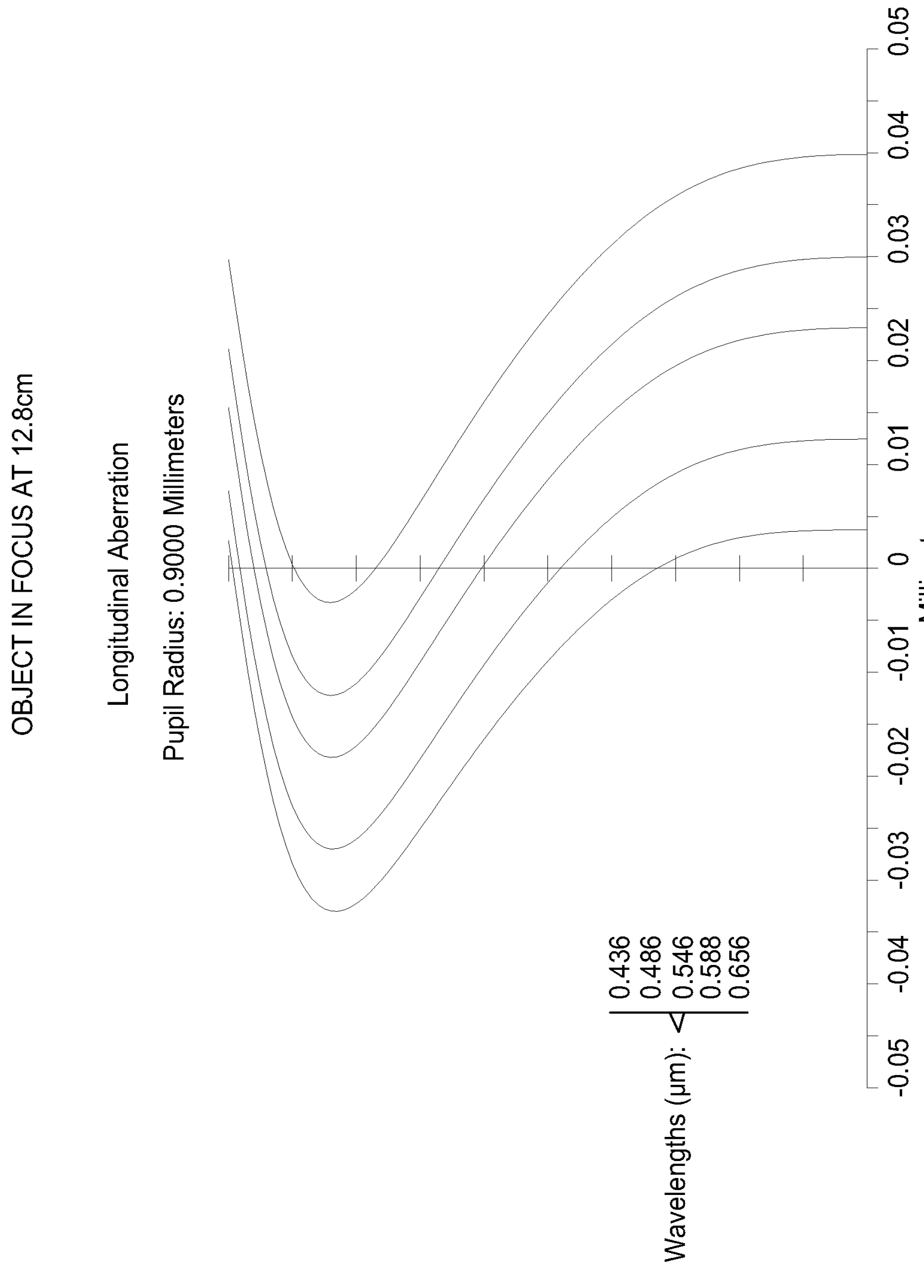
OBJECT IN FOCUS AT 12.8cm
Longitudinal Aberration
Pupil Radius: 0.9000 Millimeters
Wavelengths (µm):
0.436
0.486
0.546
0.588
0.656
-0.05
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05
Millimeters

FIG. 26

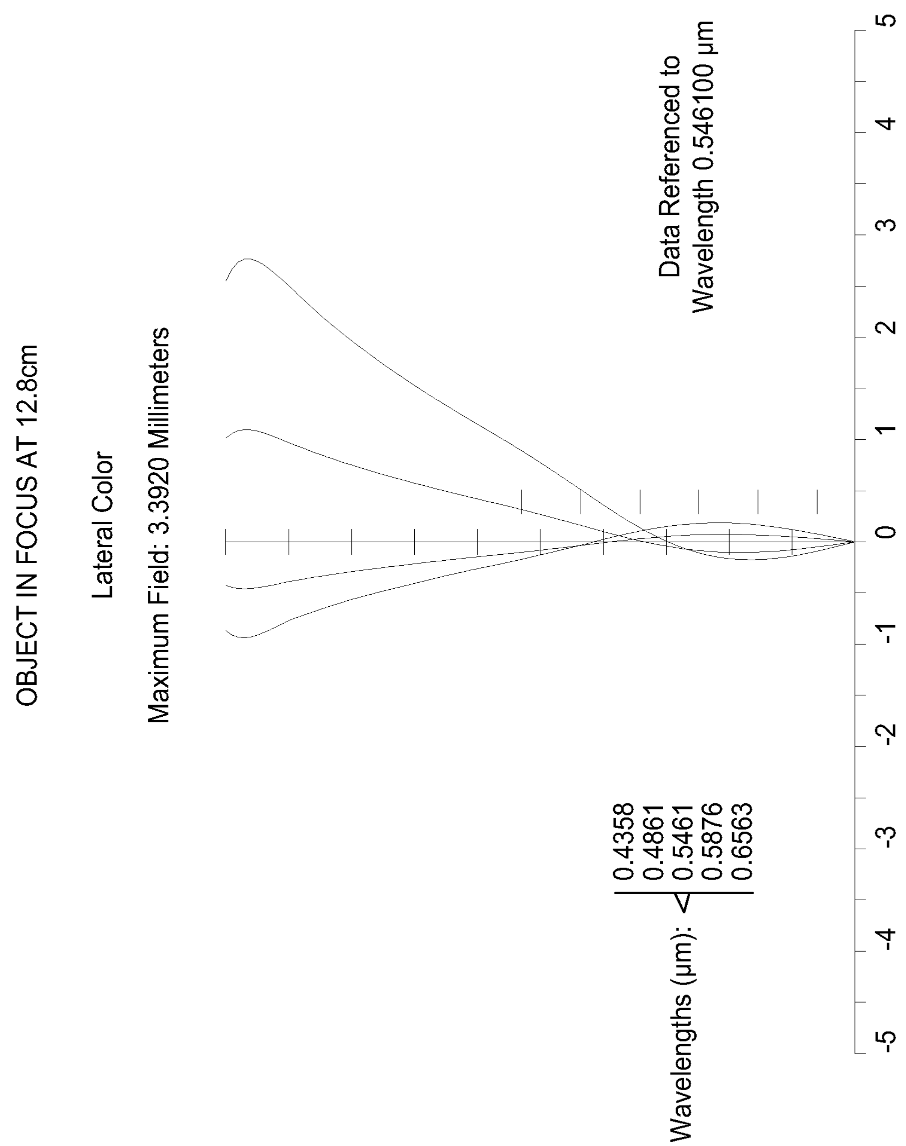
OBJECT IN FOCUS AT 12.8cm
Lateral Color
Maximum Field: 3.3920 Millimeters
Data Referenced to
Wavelength 0.546100 µm
Wavelengths (µm):
0.4358
0.4861
0.5461
0.5876
0.6563
-5
-4
-3
-2
-1
0
1
2
3
4
5
µm

FIG. 27

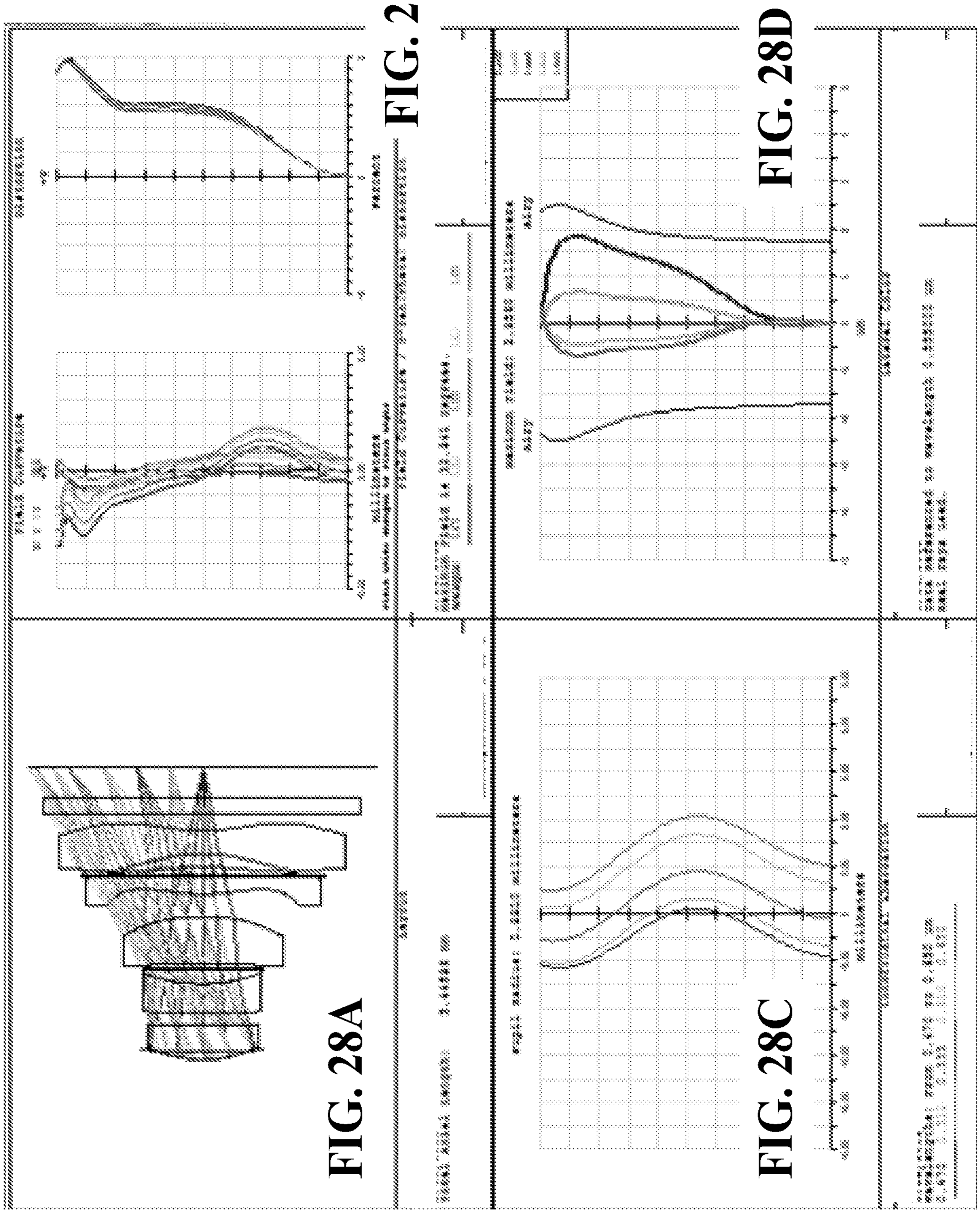

FIG. 28A

FIG. 28B

FIG. 28C

FIG. 28D

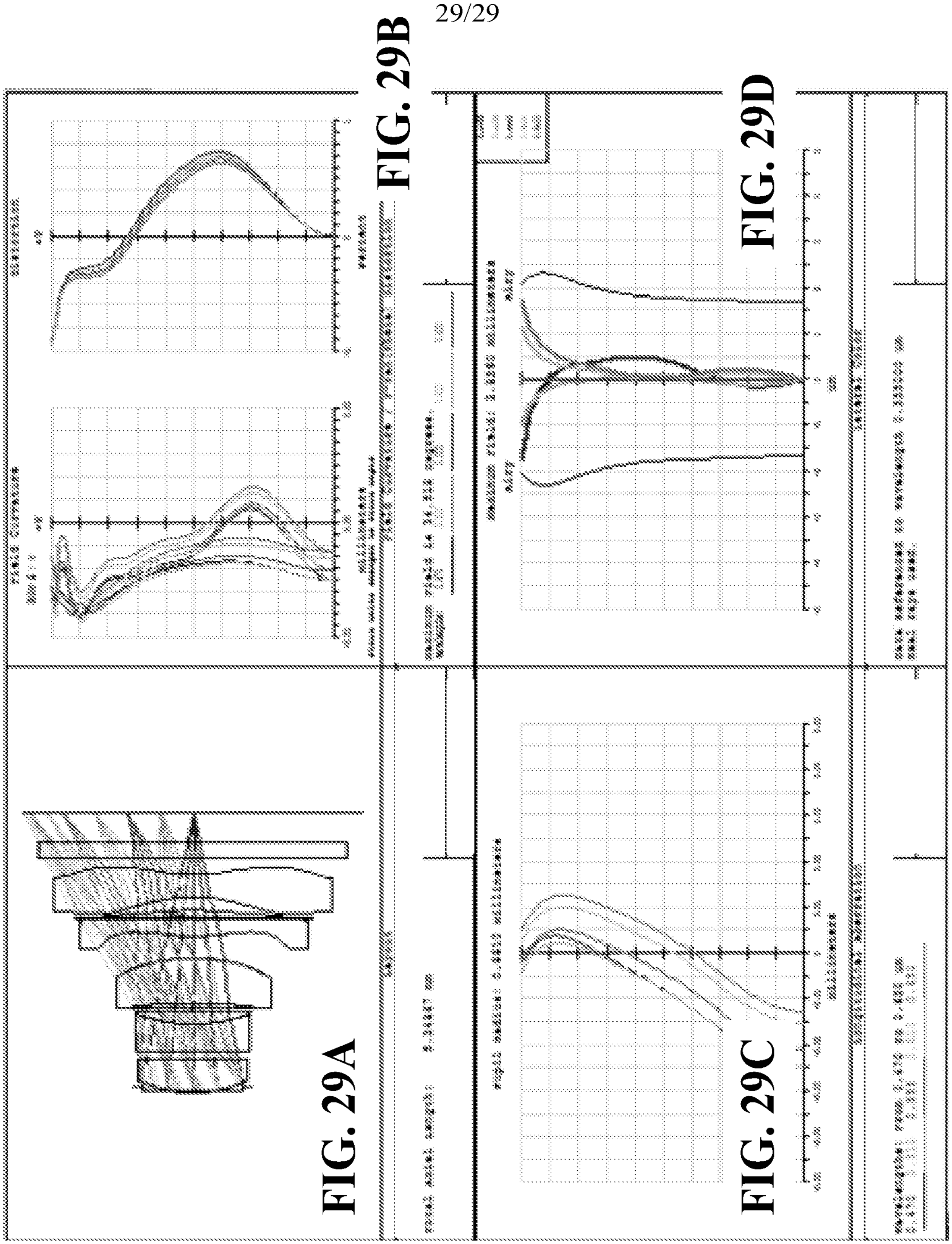

FIG. 29A

FIG. 29B

FIG. 29C

FIG. 29D

# INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/061668

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. G02B13/00 H04N5/232
ADD.

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)
G02B H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | JP 2010 224521 A (KONICA MINOLTA OPTO INC) 7 October 2010 (2010-10-07) | 1,14-18 |
| Y | abstract; figure 5 | 6-13 |
| Y | US 5 598 299 A (HAYAKAWA) 28 January 1997 (1997-01-28) figure 1 | 6-13 |
| A | JP 2011 209554 A (Y. SHINOHARA) 20 October 2011 (2011-10-20) figures 4,11; tables 7,19 | 19-30 |
| X | JP 7 181389 A (MINOLTA CO LTD) 21 July 1995 (1995-07-21) abstract; figure 1 paragraph [0023]; table 1 | 31-35, 40-42 |

☐ 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 |
|---|---|
| 14 March 2013 | 21/03/2013 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016 | Michel, Alain |

4

Form PCT/ISA/210 (second sheet) (April 2005)

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest**

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

**FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210**

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-18

Claim 1 relates to an imaging system having two lens groups, five lenses and front-focusing carried out by a MEMS actuator. Claims 2-18 depend on claim 1.
The underlying problem to be solved is how to enable a small lens displacement during focusing.
The special feature is the first lens group comprising a biconvex object-side lens, the focal length of which being greater than half of the focal length of the whole imaging system.

---

2. claims: 19-30

Independent claim 19 relates to an optical system having five lenses, focusing being carried out by moving the first lens. Claims 20-30 depend on claim 19.
The underlying problem to be solved is how to reduce field curvature and distortion.
The special feature is the lens constitution of the optical system, the first and the fourth lenses being biconvex, the second and the fifth lenses being menisci and the third lens being concave-convex.

---

3. claims: 31-45

Independent claim 31 relates to an imaging system having two lens groups, the first lens group for focusing and consisting of two lenses and the second lens group having three lenses. Claims 32-45 depend on claim 31.
The underlying problem to be solved is how to reduce primary lateral colour.
The special feature is the second lens group comprising a fore-front lens being a meniscus that has a convex surface towards the object side.

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2012/061668

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| JP 2010224521 A | 07-10-2010 | CN 101819315 A | 01-09-2010 |
| | | JP 2010224521 A | 07-10-2010 |
| | | JP 2011138175 A | 14-07-2011 |
| | | US 2010220229 A1 | 02-09-2010 |
| US 5598299 A | 28-01-1997 | JP 3141681 B2 | 05-03-2001 |
| | | JP 7294853 A | 10-11-1995 |
| | | US 5598299 A | 28-01-1997 |
| JP 2011209554 A | 20-10-2011 | NONE | |
| JP 7181389 A | 21-07-1995 | NONE | |

Form PCT/ISA/210 (patent family annex) (April 2005)

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
18 July 2013 (18.07.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/105012 A2

(51) International Patent Classification:
*G03B 3/10* (2006.01)

(21) International Application Number:
PCT/IB2013/050130

(22) International Filing Date:
7 January 2013 (07.01.2013)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/585,795 12 January 2012 (12.01.2012) US

(71) Applicant: **COREPHOTONICS LTD.** [IL/IL]; 7 Harugei Malchut St., 69714 Tel Aviv (IL).

(72) Inventors: **GOLDENBERG, Ephraim**; 32 Tel Chai St., 77510 Ashdod (IL). **SHABTAY, Gal**; 4 Shmuel Shnitzer St., 69583 Tel-Aviv (IL). **MENDLOVIC, Eliezer**; 54 Motta Gur St., 69012 Tel Aviv (IL). **KALI, Eran**; 11 Aminadav St., 93549 Jerusalem (IL).

(74) Agent: **NATHAN & ASSOCIATES PATENT AGENTS**; P.O.Box 10178, 61101 Tel Aviv (IL).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: 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) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (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).

**Published**:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) **Title**: ELECTROMAGNETIC ACTUATORS FOR DIGITAL CAMERAS

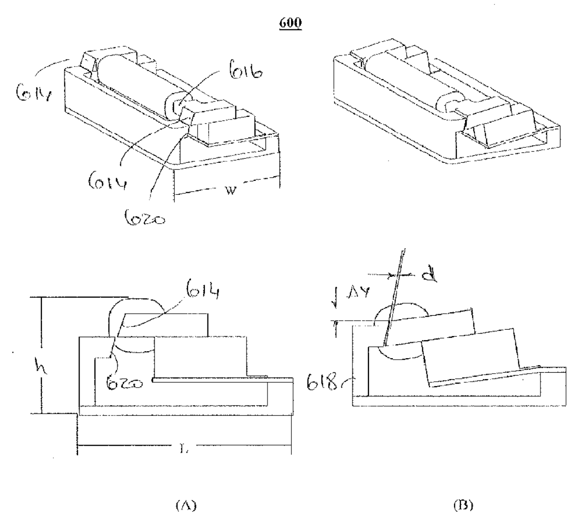


FIG. 6

**(57) Abstract**: Electromagnetic actuators for digital cameras, in particular miniature cell- phone and tablet cameras, include an electromagnet with a first elongated ferromagnetic member surrounded coaxially in part by a conductive coil along a first longitudinal axis, and a elongated second ferromagnetic member with a second longitudinal axis. The first and second ferromagnetic members have respective first and second operative surfaces and are aligned such that their longitudinal axes are parallel and such that respective operative surfaces overlap each other across a gap. The two members are mechanically coupled to respective frames. A frame hinge connects the frames and enables a relative tilt motion between the ferromagnetic members when current passes through the coil. The tilt motion is convertible into a linear displacement along an optical axis of an optical element coupled to the actuator. Two actuators can be combined into an assembly capable of providing double-axis tilt.

WO 2013/105012 A2

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
18 December 2014 (18.12.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/199338 A2

(51) International Patent Classification: Not classified

(21) International Application Number: PCT/IB2014/062180

(22) International Filing Date: 12 June 2014 (12.06.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/834,486 13 June 2013 (13.06.2013) US

(71) Applicant: **COREPHOTONICS LTD.** [IL/IL]; 3rd Floor, 25 Habarzel St., Ramat Hachayal, 6971035 Tel-Aviv (IL).

(72) Inventors: **SHABTAY, Gal**; 4 Shmuel Shnitzer Str., 6958313 Tel-Aviv (IL). **GOLDENBERG, Ephraim**; 32 Tel Chai Str., 7751025 Ashdod (IL). **GIGUSHINSKI, Oded**; 14/6, Ben Gurion Avenue, 6345414 Tel-Aviv (IL). **COHEN, Noy**; Apt. 20, 30 Shlomo Ben Yossef Str., 6912529 Tel-Aviv (IL).

(74) Agent: **NATHAN & ASSOCIATES PATENT AGENTS LTD.**; P.O.Box 10178, 6110101 Tel Aviv (IL).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: 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, IR, IS, JP, KE, KG, 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, SA, 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) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (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, KM, ML, MR, NE, SN, TD, TG).

**Published**:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

**(54) Title**: DUAL APERTURE ZOOM DIGITAL CAMERA

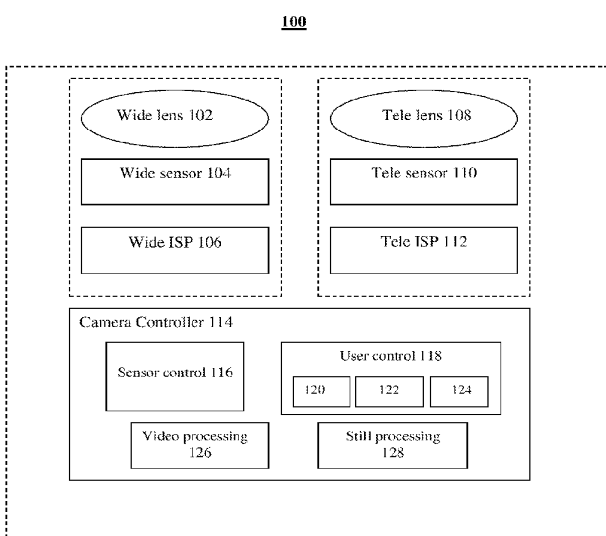


FIG. 1A

**(57) Abstract**: A dual-aperture zoom digital camera operable in both still and video modes. The camera includes Wide and Tele imaging sections with respective lens/sensor combinations and image signal processors and a camera controller operatively coupled to the Wide and Tele imaging sections. The Wide and Tele imaging sections provide respective image data. The controller is configured to combine in still mode at least some of the Wide and Tele image data to provide a fused output image from a particular point of view, and to provide without fusion continuous zoom video mode output images, each output image having a given output resolution, wherein the video mode output images are provided with a smooth transition when switching between a lower zoom factor (ZF) value and a higher ZF value or vice versa, and wherein at the lower ZF the output resolution is determined by the Wide sensor while at the higher ZF value the output resolution is determined by the Tele sensor.

WO 2014/199338 A2

# DUAL APERTURE ZOOM DIGITAL CAMERA

## CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to and claims priority from US Provisional Patent Application No. 61/834,486 having the same title and filed June 13, 2013, which is incorporated herein by reference in its entirety.

## FIELD

Embodiments disclosed herein relate in general to digital cameras and in particular to thin zoom digital cameras with both still image and video capabilities

## BACKGROUND

Digital camera modules are currently being incorporated into a variety of host devices. Such host devices include cellular telephones, personal data assistants (PDAs), computers, and so forth. Consumer demand for digital camera modules in host devices continues to grow.

Host device manufacturers prefer digital camera modules to be small, so that they can be incorporated into the host device without increasing its overall size. Further, there is an increasing demand for such cameras to have higher-performance characteristics. One such characteristic possessed by many higher-performance cameras (e.g., standalone digital still cameras) is the ability to vary the focal length of the camera to increase and decrease the magnification of the image. This ability, typically accomplished with a zoom lens, is known as optical zooming. "Zoom" is commonly understood as a capability to provide different magnifications of the same scene and/or object by changing the focal length of an optical system, with a higher level of zoom associated with greater magnification and a lower level of zoom associated with lower magnification. Optical zooming is typically accomplished by mechanically moving lens elements relative to each other. Such zoom lenses are typically more expensive, larger and less reliable than fixed focal length lenses. An alternative approach for approximating the zoom effect is achieved with what is known as digital zooming. With digital zooming, instead of varying the focal length of the lens, a processor in the camera crops the image and interpolates between the pixels of the captured image to create a magnified but lower-resolution image.

Attempts to use multi-aperture imaging systems to approximate the effect of a zoom lens are known. A multi-aperture imaging system (implemented for example in a digital camera) includes a plurality of optical sub-systems (also referred to as "sub-cameras"). Each sub-camera includes one or more lenses and/or other optical elements which define an aperture such that received electro-magnetic radiation is imaged by the optical sub-system and a resulting image is directed towards a two-dimensional (2D) pixelated image sensor region. The image sensor (or simply "sensor") region is configured to receive the image and to generate a set of image data based on the image. The digital camera may be aligned to receive electromagnetic radiation associated with scenery having a given set of one or more objects. The set of image data may be represented as digital image data, as well known in the art. Hereinafter in this description, "image" "image data" and "digital image data" may be used interchangeably. Also, "object" and "scene" may be used interchangeably.

Multi-aperture imaging systems and associated methods are described for example in US Patent Publications No. 2008/0030592, 2010/0277619 and 2011/0064327. In US 2008/0030592, two sensors are operated simultaneously to capture an image imaged through an associated lens. A sensor and its associated lens form a lens/sensor combination. The two lenses have different focal lengths. Thus, even though each lens/sensor combination is aligned to look in the same direction, each captures an image of the same subject but with two different fields of view (FOVs). One sensor is commonly called "Wide" and the other "Tele". Each sensor provides a separate image, referred to respectively as "Wide" (or "W") and "Tele" (or "T") images. A W-image reflects a wider FOV and has lower resolution than the T-image. The images are then stitched (fused) together to form a composite ("fused") image. In the composite image, the central portion is formed by the relatively higher-resolution image taken by the lens/sensor combination with the longer focal length, and the peripheral portion is formed by a peripheral portion of the relatively lower-resolution image taken by the lens/sensor combination with the shorter focal length. The user selects a desired amount of zoom and the composite image is used to interpolate values from the chosen amount of zoom to provide a respective zoom image. The solution offered by US 2008/0030592 requires, in video mode, very large processing resources in addition to high frame rate requirements and high power consumption (since both cameras are fully operational).

US 2010/0277619 teaches a camera with two lens/sensor combinations, the two lenses having different focal lengths, so that the image from one of the combinations has a FOV approximately 2-3 times greater than the image from the other combination. As a user of the camera requests a given amount of zoom, the zoomed image is provided from the lens/sensor combination having a FOV that is next larger than the requested FOV. Thus, if the requested FOV is less than the smaller FOV combination, the zoomed image is created from the image captured by that combination, using cropping and interpolation if necessary. Similarly, if the requested FOV is greater than the smaller FOV combination, the zoomed image is created from the image captured by the other combination, using cropping and interpolation if necessary. The solution offered by US 2010/0277619 leads to parallax artifacts when moving to the Tele camera in video mode.

In both US 2008/0030592 and US 2010/0277619, different focal length systems cause Tele and Wide matching FOVs to be exposed at different times using CMOS sensors. This degrades the overall image quality. Different optical F numbers ("F#") cause image intensity differences. Working with such a dual sensor system requires double bandwidth support, i.e. additional wires from the sensors to the following HW component. Neither US 2008/0030592 nor US 2010/0277619 deal with registration errors. Neither US 2008/000592 nor US 2010/0277619 refer to partial fusion, i.e. fusion of less than all the pixels of both Wide and Tele images in still mode.

US 2011/0064327 discloses multi-aperture imaging systems and methods for image data fusion that include providing first and second sets of image data corresponding to an imaged first and second scene respectively. The scenes overlap at least partially in an overlap region, defining a first collection of overlap image data as part of the first set of image data, and a second collection of overlap image data as part of the second set of image data. The second collection of overlap image data is represented as a plurality of image data sub-cameras such that each of the sub-cameras is based on at least one characteristic of the second collection, and each sub-camera spans the overlap region. A fused set of image data is produced by an image processor, by modifying the first collection of overlap image data based on at least a selected one of, but less than all of, the image data sub-cameras. The systems and methods disclosed in this application deal solely with fused still images.

None of the known art references provide a thin (e.g. fitting in a cell-phone) dual-aperture zoom digital camera with fixed focal length lenses, the camera configured to operate in both still mode and video mode to provide still and video images, wherein the camera configuration uses partial or full fusion to provide a fused image in still mode and does not use any fusion to provide a continuous, smooth zoom in video mode.

Therefore there is a need for, and it would be advantageous to have thin digital cameras with optical zoom operating in both video and still mode that do not suffer from commonly encountered problems and disadvantages, some of which are listed above.



APPL-1002 / Page 401 of 504
APPLE INC. v. COREPHOTONICS LTD.

SUMMARY

Embodiments disclosed herein teach the use of dual-aperture (also referred to as dual-lens or two-sensor) optical zoom digital cameras. The cameras include two sub-cameras, a Wide sub-camera and a Tele sub-camera, each sub-camera including a fixed focal length lens, an image sensor and an image signal processor (ISP). The Tele sub-camera is the higher zoom sub-camera and the Wide sub-camera is the lower zoom sub-camera. In some embodiments, the lenses are thin lenses with short optical paths of less than about 9mm. In some embodiments, the thickness/effective focal length (EFL) ratio of the Tele lens is smaller than about 1. The image sensor may include two separate 2D pixelated sensors or a single pixelated sensor divided into at least two areas. The digital camera can be operated in both still and video modes. In still mode, zoom is achieved "with fusion" (full or partial), by fusing W and T images, with the resulting fused image including always information from both W and T images. Partial fusion may be achieved by not using fusion in image areas where the Tele image is not focused. This advantageously reduces computational requirements (e.g. time).

In video mode, optical zoom is achieved "without fusion", by switching between the W and T images to shorten computational time requirements, thus enabling high video rate. To avoid discontinuities in video mode, the switching includes applying additional processing blocks, which include image scaling and shifting.

In order to reach optical zoom capabilities, a different magnification image of the same scene is captured (grabbed) by each camera sub-camera, resulting in FOV overlap between the two sub-cameras. Processing is applied on the two images to fuse and output one fused image in still mode. The fused image is processed according to a user zoom factor request. As part of the fusion procedure, up-sampling may be applied on one or both of the grabbed images to scale it to the image grabbed by the Tele sub-camera or to a scale defined by the user. The fusion or up-sampling may be applied to only some of the pixels of a sensor. Down-sampling can be performed as well if the output resolution is smaller than the sensor resolution. .

The cameras and associated methods disclosed herein address and correct many of the problems and disadvantages of known dual-aperture optical zoom digital cameras. They provide an overall zoom solution that refers to all aspects: optics, algorithmic processing and system hardware (HW). The proposed solution distinguishes between video and still mode in the processing flow and specifies the optical requirements and HW requirements. In addition, it provides an innovative optical design that enables a low TTL/EFL ratio using a specific lens curvature order.

Due to the large focal length, objects that are in front or behind the plane of focus appear very blurry, and a nice foreground-to-background contrast is achieved. However, it is difficult to create such a blur using a compact camera with a relatively short focal length and small aperture size, such as a cell-phone camera. In some embodiments, a dual-aperture zoom system disclosed herein can be used to capture a shallow DOF photo (shallow compared with a DOF of a Wide camera alone), by taking advantage of the longer focal length of the Tele lens. The reduced DOF effect provided by the longer Tele focal length can be further enhanced in the final image by fusing data from an image captured simultaneously with the Wide lens. Depending on the distance to the object, with the Tele lens focused on a subject of the photo, the Wide lens can be focused to a closer distance than the subject so that objects behind the subject appear very blurry. Once the two images are captured, information from the out-of-focus blurred background in the Wide image is fused with the original Tele image background information, providing a blurrier background and even shallower DOF.

In an embodiment there is provided a zoom digital camera comprising a Wide imaging section that includes a fixed focal length Wide lens with a Wide FOV, a Wide sensor and a Wide image signal processor (ISP), the Wide imaging section operative to provide Wide image data of an object or scene; a Tele imaging section that includes a fixed focal length Tele lens with a Tele FOV that is narrower than the Wide FOV, a Tele sensor and a Tele ISP, the Tele imaging section operative to provide Tele image data of the object or scene; and a camera controller operatively coupled to the Wide and Tele imaging sections, the camera controller configured to combine in still mode at least some of the Wide and Tele image data to provide a fused output image of the object or scene from a particular point of view (POV), and to provide without fusion continuous zoom video mode output images of the object or scene, a camera controller operatively coupled to the Wide and Tele imaging sections, the camera controller configured to combine in still mode at least some of the Wide and Tele image data to provide a fused output image of the object or scene from a particular point of view and to provide without fusion continuous zoom video mode output images of the object or scene, each output image having a respective output resolution, wherein the video output images are provided with a smooth transition when switching between a lower zoom factor (ZF) value and a higher ZF value or vice versa, wherein at the lower ZF value the output resolution is determined by the Wide sensor, and wherein at the higher ZF value the output resolution is determined by the Tele sensor.

In an embodiment, the camera controller configuration to provide video output images with a smooth transition when switching between a lower ZF value and a higher ZF value or vice versa includes a configuration that uses at high ZF secondary information from the Wide camera and uses at low ZF secondary information from the Tele camera. As used herein, "secondary information" refers to white balance gain, exposure time, analog gain and color correction matrix.

In a dual-aperture camera image plane, as seen by each sub-camera (and respective image sensor), a given object will be shifted and have different perspective (shape). This is referred to as point-of-view (POV). The system output image can have the shape and position of either sub-camera image or the shape or position of a combination thereof. If the output image retains the Wide image shape then it has the Wide perspective POV. If it retains the Wide camera position then it has the Wide position POV. The same applies for Tele images position and perspective. As used in this description, the perspective POV may be of the Wide or Tele sub-cameras, while the position POV may shift continuously between the Wide and Tele sub-cameras. In fused images, it is possible to register Tele image pixels to a matching pixel set within the Wide image pixels, in which case the output image will retain the Wide POV ("Wide fusion"). Alternatively, it is possible to register Wide image pixels to a matching pixel set within the Tele image pixels, in which case the output image will retain the Tele POV ("Tele fusion"). It is also possible to perform the registration after either sub-camera image is shifted, in which case the output image will retain the respective Wide or Tele perspective POV.

In an embodiment there is provided a method for obtaining zoom images of an object or scene in both still and video modes using a digital camera, the method comprising the steps of providing in the digital camera a Wide imaging section having a Wide lens with a Wide FOV, a Wide sensor and a Wide image signal processor (ISP), a Tele imaging section having a Tele lens with a Tele FOV that is narrower than the Wide FOV, a Tele sensor and a Tele ISP, and a camera controller operatively coupled to the Wide and Tele imaging sections; and configuring the camera controller to combine in still mode at least some of the Wide and Tele image data to provide a fused output image of the object or scene from a particular point of view, and to provide without fusion continuous zoom video mode output images of the object or scene, each output image having a respective output resolution, wherein the video mode output images are provided with a smooth transition when switching between a lower ZF value and a higher ZF value or vice versa, and wherein at the lower ZF value the output resolution is determined by the Wide sensor while at the higher ZF value the output resolution is determined by the Tele sensor.

BRIEF DESCRIPTION OF THE DRAWINGS

Non-limiting examples of embodiments disclosed herein are described below with reference to figures attached hereto that are listed following this paragraph. The drawings and descriptions are meant to illuminate and clarify embodiments disclosed herein, and should not be considered limiting in any way.

FIG. 1A shows schematically a block diagram illustrating a dual-aperture zoom imaging system disclosed herein;

FIG. 1B is a schematic mechanical diagram of the dual-aperture zoom imaging system of FIG. 1A:

FIG. 2 shows an example of Wide sensor, Tele sensor and their respective FOVs;

FIG. 3 shows a schematically embodiment of CMOS sensor image grabbing vs. time;

FIG. 4 shows schematically a sensor time configuration which enables sharing one sensor interface using dual sensor zoom system;

FIG. 5 shows an embodiment of a method disclosed herein for acquiring a zoom image in capture mode;

FIG. 6 shows an embodiment of a method disclosed herein for acquiring a zoom image in video/preview mode;

FIG. 7 shows a graph illustrating an effective resolution zoom factor;

FIG. 8 shows one embodiment of a lens block in a thin camera disclosed herein;

FIG. 9 shows another embodiment of a lens block in a thin camera disclosed herein.

DETAILED DESCRIPTION

FIG. 1A shows schematically a block diagram illustrating an embodiment of a dual-aperture zoom imaging system (also referred to simply as "digital camera" or "camera") disclosed herein and numbered **100**. Camera **100** comprises a Wide imaging section ("sub-camera") that includes a Wide lens block **102,** a Wide image sensor **104** and a Wide image processor **106.** Camera **100** further comprises a Tele imaging section ("sub-camera") that includes a Tele lens block **108,** a Tele image sensor **110** and a Tele image processor **112**. The image sensors may be physically separate or may be part of a single larger image sensor. The

Wide sensor pixel size can be equal to or different from the Tele sensor pixel size. Camera **100** further comprises a camera fusion processing core (also referred to as "controller") **114** that includes a sensor control module **116**, a user control module **118,** a video processing module **126** and a capture processing module **128,** all operationally coupled to sensor control block **110**. User control module **118** comprises an operational mode function **120**, a region of interest (ROI) function **122** and a zoom factor (ZF) function **124**.

Sensor control module **116** is connected to the two sub-cameras and to the user control module **118** and used to choose, according to the zoom factor, which of the sensors is operational and to control the exposure mechanism and the sensor readout. Mode choice function **120** is used for choosing capture/video modes. ROI function **122** is used to choose a region of interest. As used herein, "ROI" is a user defined as a sub-region of the image that may be exemplarily 4% or less of the image area. The ROI is the region on which both sub-cameras are focused on. . Zoom factor function **124** is used to choose a zoom factor. Video processing module **126** is connected to mode choice function **120** and used for video processing. Still processing module **128** is connected to the mode choice function **120** and used for high image quality still mode images. The video processing module is applied when the user desires to shoot in video mode. The capture processing module is applied when the user wishes to shoot still pictures.

FIG. 1B is a schematic mechanical diagram of the dual-aperture zoom imaging system of FIG. 1A. Exemplary dimensions: Wide lens TTL = 4.2mm and EFL = 3.5mm; Tele lens TTL = 6mm and EFL = 7 mm; both Wide and Tele sensors 1/3 inch. External dimensions of Wide and Tele cameras: width (w) and length (l) = 8.5 mm and height (h) = 6.8 mm. Distance "d" between camera centers = 10mm.

Following is a detailed description and examples of different methods of use of camera **100.**

**Design for continuous and smooth zoom in video mode**

In an embodiment, in order to reach high quality continuous and smooth optical zooming in video camera mode while reaching real optical zoom using fixed focal length sub-cameras, the system is designed according to the following rules (Equations 1-3):

$$\mathrm{Tan}\,(FOV_{Wide})/\mathrm{Tan}\,(FOV_{Tele}) = PL_{Wide}/\,PL_{video} \qquad (1)$$

where Tan refers to "tangent", while $FOV_{Wide}$ and $FOV_{Tele}$ refer respectively to the Wide and

Tele lens fields of view (in degrees). As used herein, the FOV is measured from the center axis to the corner of the sensor (i.e. half the angle of the normal definition). $PL_{Wide}$ and $PL_{video}$ refer respectively to the "in-line" (i.e. in a line) number of Wide sensor pixels and in-line number of output video format pixels. The ratio $PL_{Wide}/PL_{video}$ is called an "oversampling ratio". For example, in order to get full and continuous optical zoom experience with a 12Mp sensor (sensor dimensions 4000x3000) and a required 1080p (dimension 1920x1080) video format, the FOV ratio should be 4000/1920=2.083. Moreover, if the Wide lens FOV is given as $FOV_{Wide} = 37.5^0$, the required Tele lens FOV is $20.2^0$ The zoom switching point is set according to the ratio between sensor pixels in-line and the number of pixels in-line in the video format and defined as:

$$Z_{switch}=PL_{Wide}/ PL_{video} \qquad (2)$$

Maximum optical zoom is reached according to the following formula:

$$Z_{max}= \mathrm{Tan}\ (FOV_{Wide})/\mathrm{Tan}\ (FOV_{Tele}) * PL_{Tele}/ PL_{video} \qquad (3)$$

For example: for the configuration defined above and assuming $PL_{Tele}$=4000 and $PL_{video}$= 1920, $Z_{max}$=4.35.

In an embodiment, the sensor control module has a setting that depends on the Wide and Tele FOVs and on a sensor oversampling ratio, the setting used in the configuration of each sensor. For example, when using a 4000x3000 sensor and when outputting a 1920x1080 image, the oversampling ratio is 4000/1920=2.0833.

In an embodiment, the Wide and Tele FOVs and the oversampling ratio satisfy the condition

$$0.8*PL_{Wide}/ PL_{video} < \mathrm{Tan}\ (FOV_{Wide})/\mathrm{Tan}\ (FOV_{Tele}) <1.2*PL_{Wide}/ PL_{video}. \qquad (4)$$

**Still mode operation/function**

In still camera mode, the obtained image is fused from information obtained by both sub-cameras at all zoom levels, see FIG. 2, which shows a Wide sensor **202** and a Tele sensor **204** and their respective FOVs. Exemplarily, as shown, the Tele sensor FOV is half the Wide sensor FOV. The still camera mode processing includes two stages: (1) setting HW settings and configuration, where a first objective is to control the sensors in such a way that matching FOVs in both images (Tele and Wide) are scanned at the same time. A second objective is to control the relative exposures according to the lens properties. A third objective is to



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minimize the required bandwidth from both sensors for the ISPs; and (2) image processing that fuses the Wide and the Tele images to achieve optical zoom, improves SNR and provides wide dynamic range.

FIG. 3 shows image line numbers vs. time for an image section captured by CMOS sensors. A fused image is obtained by line (row) scans of each image. To prevent matching FOVs in both sensors to be scanned at different times, a particular configuration is applied by the camera controller on both image sensors while keeping the same frame rate. The difference in FOV between the sensors determines the relationship between the rolling shutter time and the vertical blanking time for each sensor. In the particular configuration, the scanning is synchronized such that the same points of the object in each view are obtained simultaneously.

Specifically with reference to FIG. 3 and according to an embodiment of a method disclosed herein, the configuration to synchronize the scanning includes: setting the Tele sensor vertical blanking time $VB_{Tele}$ to equal the Wide sensor vertical blanking time $VB_{Wide}$ plus half the Wide sensor rolling shutter time $RST_{Wide}$; setting the Tele and Wide sensor exposure times $ET_{Tele}$ and $ET_{Wide}$ to be equal or different; setting the Tele sensor rolling shutter time $RST_{Tele}$ to be $0.5^*RST_{Wide}$; and setting the frame rates of the two sensors to be equal. This procedure results in identical image pixels in the Tele and Wide sensor images being exposed at the same time

In another embodiment, the camera controller synchronizes the Wide and Tele sensors so that for both sensors the rolling shutter starts at the same time.

The exposure times applied to the two sensors could be different, for example in order to reach same image intensity using different F# and different pixel size for the Tele and Wide systems. In this case, the relative exposure time may be configured according to the formula below:

$$ET_{Tele} = ET_{Wide} \cdot (F\#_{Tele}/F\#_{Wide})^2 \cdot (\text{Pixel size}_{Wide}/\text{Pixel size}_{Tele})^2 \qquad (5)$$

Other exposure time ratios may be applied to achieve wide dynamic range and improved SNR. Fusing two images with different intensities will result in wide dynamic range image.

In more detail with reference to FIG. 3, in the first stage, after the user chooses a required zoom factor ZF, the sensor control module configures each sensor as follows:

1) Cropping index Wide sensor:

$Y_{Wide\ start} = 1/2 \cdot PC_{Wide}(1-1/ZF)$

$Y_{Wide\ end} = 1/2 \cdot PC_{Wide}(1+1/ZF)$

where PC is the number of pixels in a column, and Y is the row number

2) Cropping index Tele sensor:

If $ZF > \text{Tan}(FOV_{Wide})/\text{Tan}(FOV_{Tele})$, then

$Y_{Tele\ start} = 1/2 \cdot PC_{Tele}(1-(1/ZF) \cdot \text{Tan}(FOV_{Tele})/\text{Tan}(FOV_{Wide}))$

$Y_{Tele\ end} = 1/2 \cdot PC_{Tele}(1+(1/ZF) \cdot \text{Tan}(FOV_{Tele})/\text{Tan}(FOV_{Wide}))$

If $ZF < \text{Tan}(FOV_{Wide})/\text{Tan}(FOV_{Tele})$, then

$Y_{Tele\ start} = 0$

$Y_{Tele\ end} = PC_{Tele}$

This will result in an exposure start time of the Tele sensor with a delay of (in numbers of lines, relative to the Wide sensor start time):

$$(1-ZF/((\text{Tan}(FOV_{Wide})/\text{Tan}(FOV_{Tele}))) \cdot 1/(2 \cdot FPS) \qquad (6)$$

where FPS is the sensor's frame per second configuration. In cases where $ZF > \text{Tan}(FOV_{Wide})/\text{Tan}(FOV_{Tele})$, no delay will be introduced between Tele and Wide exposure starting point. For example, for a case where $\text{Tan}(FOV_{Wide})/\text{Tan}(FOV_{Tele})=2$ and $ZF=1$, the Tele image first pixel is exposed $1/4 \cdot (1/FPS)$ second after the Wide image first pixel was exposed.

After applying the cropping according to the required zoom factor, the sensor rolling shutter time and the vertical blank should be configured in order to satisfy the equation to keep the same frame rate:

$$VB_{Wide}+RST_{Wide}= VB_{Tele}+RST_{Tele} \qquad (7)$$

FIG. 3 exemplifies Eq. (7). One way to satisfy Eq. (7) is to increase the $RST_{Wide}$. Controlling the $RST_{Wide}$ may be done by changing the horizontal blanking (HB) of the Wide sensor. This will cause a delay between the data coming out from each row of the Wide sensor.

Generally, working with a dual-sensor system requires multiplying the bandwidth to the following block, for example the ISP. For example, using 12Mp working at 30fps, 10bit per pixel requires working at 3.6Gbit/sec. In this example, supporting this bandwidth requires 4 lanes from each sensor to the respective following ISP in the processing chain. Therefore,



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working with two sensors requires double bandwidth (7.2Gbit/sec) and 8 lanes connected to the respective following blocks. The bandwidth can be reduced by configuring and synchronizing the two sensors. Consequently, the number of lanes can be half that of a conventional configuration (3.6Gbit/sec).

FIG. 4 shows schematically a sensor time configuration that enables sharing one sensor interface using a dual-sensor zoom system, while fulfilling the conditions in the description of FIG. 3 above. For simplicity, assuming the Tele sensor image is magnified by a factor of 2 compared with the Wide sensor image, the Wide sensor horizontal blanking time $HB_{Wide}$ is set to twice the Wide sensor line readout time. This causes a delay between output Wide lines. This delay time matches exactly the time needed to output two lines from the Tele sensor. After outputting two lines from the Tele sensor, the Tele sensor horizontal blanking time $HB_{Tele}$ is set to be one Wide line readout time, so, while the Wide sensor outputs a row from the sensor, no data is being output from the Tele sensor. For this example, every 3rd line in the Tele sensor is delayed by an additional $HB_{Tele}$. In this delay time, one line from the Wide sensor is output from the dual-sensor system. After the sensor configuration stage, the data is sent in parallel or by using multiplexing into the processing section.

FIG. 5 shows an embodiment of a method disclosed herein for acquiring a zoom image in still mode. In ISP step **502**, the data of each sensor is transferred to the respective ISP component, which performs on the data various processes such as denoising, demosaicing, sharpening, scaling, etc, as known in the art. After the processing in step **502,** all following actions are performed in capture processing core **128**: in rectification step **504,** both Wide and Tele images are aligned to be on the epipolar line; in registration step **506**, mapping between the Wide and the Tele aligned images is performed to produce a registration map; in resampling step **508,** the Tele image is resampled according to the registration map, resulting in a re-sampled Tele image; in decision step **510**, the re-sampled Tele image and the Wide image are processed to detect errors in the registration and to provide a decision output. In more detail, in step **510,** the re-sampled Tele image data is compared with the Wide image data and if the comparison detects significant dissimilarities, an error is indicated. In this case, the Wide pixel values are chosen to be used in the output image. Then, in fusion step **512,** the decision output, re-sampled Tele image and the Wide image are fused into a single zoom image.

To reduce processing time and power, steps **506, 508, 510, 512** could be bypassed by not fusing the images in non-focused areas. In this case, all steps specified above should be applied on focused areas only. Since the Tele optical system will introduce shallower depth of



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field than the Wide optical system, defocused areas will suffer from lower contrast in the Tele system.

Zoom-in and Zoom-out in still camera mode

We define the following: TFOV = tan (camera FOV/2). "Low ZF" refers to all ZF that comply with ZF < Wide TFOV/Tele TFOV. "High ZF" refers to all ZF that comply with ZF > Wide TFOV/Tele TFOV. "ZFT" refers to a ZF that complies with ZF = Wide TFOV/Tele TFOV. In one embodiment, zoom-in and zoom-out in still mode is performed as follows:

Zoom-in: at low ZF up to slightly above ZFT, the output image is a digitally zoomed, Wide fusion output. For the up-transfer ZF, the Tele image is shifted and corrected by global registration (GR) to achieve smooth transition. Then, the output is transformed to a Tele fusion output. For higher (than the up-transfer) ZF, the output is the Tele fusion output digitally zoomed.

Zoom-out: at high ZF down to slightly below ZFT, the output image is a digitally zoomed, Tele fusion output. For the down-transfer ZF, the Wide image is shifted and corrected by GR to achieve smooth transition. Then, the output is transformed to a Wide fusion output. For lower (than the down-transfer) ZF, the output is basically the down-transfer ZF output digitally zoomed but with gradually smaller Wide shift correction, until for ZF=1 the output is the unchanged Wide camera output.

In another embodiment, zoom-in and zoom-out in still mode is performed as follows:

Zoom-in: at low ZF up to slightly above ZFT, the output image is a digitally zoomed, Wide fusion output. For the up-transfer ZF and above, the output image is the Tele fusion output.

Zoom-out: at high ZF down to slightly below ZFT, the output image is a digitally zoomed, Tele fusion output. For the down-transfer ZF and below, the output image is the Wide fusion output.

**Video mode operation/function**

Smooth transition

When a dual-aperture camera switches the camera output between sub-cameras or points of view, a user will normally see a "jump" (discontinuous) image change. However, a



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change in the zoom factor for the same camera and POV is viewed as a continuous change. A "smooth transition" is a transition between cameras or POVs that minimizes the jump effect. This may include matching the position, scale, brightness and color of the output image before and after the transition. However, an entire image position matching between the sub-camera outputs is in many cases impossible, because parallax causes the position shift to be dependent on the object distance. Therefore, in a smooth transition as disclosed herein, the position matching is achieved only in the ROI region while scale brightness and color are matched for the entire output image area.

Zoom-in and Zoom-out in video mode

In video mode, sensor oversampling is used to enable continuous and smooth zoom experience. Processing is applied to eliminate the changes in the image during crossover from one sub-camera to the other. Zoom from 1 to $Z_{switch}$ is performed using the Wide sensor only. From $Z_{switch}$ and on, it is performed mainly by the Tele sensor. To prevent "jumps" (roughness in the image), switching to the Tele image is done using a zoom factor which is a bit higher ($Z_{switch}$ +$\Delta$Zoom) than $Z_{switch}$. $\Delta$Zoom is determined according to the system's properties and is different for cases where zoom-in is applied and cases where zoom-out is applied ($\Delta Zoom_{in} \neq \Delta Zoom_{out}$). This is done to prevent residual jumps artifacts to be visible at a certain zoom factor. The switching between sensors, for an increasing zoom and for decreasing zoom, is done on a different zoom factor.

The zoom video mode operation includes two stages: (1) sensor control and configuration, and (2) image processing. In the range from 1 to $Z_{switch}$, only the Wide sensor is operational, hence, power can be supplied only to this sensor. Similar conditions hold for a Wide AF mechanism. From $Z_{switch}$+$\Delta$Zoom to $Z_{max}$ only the Tele sensor is operational, hence, power is supplied only to this sensor. Similarly, only the Tele sensor is operational and power is supplied only to it for a Tele AF mechanism. Another option is that the Tele sensor is operational and the Wide sensor is working in low frame rate. From $Z_{switch}$ to $Z_{switch}$+$\Delta$Zoom, both sensors are operational.

Zoom-in: at low ZF up to slightly above ZFT, the output image is the digitally zoomed, unchanged Wide camera output. For the up-transfer ZF, the output is a transformed Tele sub-camera output, where the transformation is performed by a global registration (GR) algorithm to achieve smooth transition. For higher (than the up-transfer), the output is the transfer ZF output digitally zoomed.



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Zoom-out: at high ZF down to slightly below ZFT, the output image is the digitally zoomed transformed Tele camera output. For the down-transfer ZF, the output is a shifted Wide camera output, where the Wide shift correction is performed by the GR algorithm to achieve smooth transition, i.e. with no jump in the ROI region. For lower (than the down-transfer) ZF, the output is basically the down-transfer ZF output digitally zoomed but with gradually smaller Wide shift correction, until for ZF=1 the output is the unchanged Wide camera output.

FIG. 6 shows an embodiment of a method disclosed herein for acquiring a zoom image in video/preview mode for 3 different zoom factor (ZF) ranges: (a) ZF range = 1 : $Z_{switch}$; (b) ZF range = $Z_{switch}$ : $Z_{switch}$ + $\Delta Zoom_{in}$; and (c) Zoom factor range = $Z_{switch}$ + $\Delta Zoom_{in}$ : $Z_{max}$. The description is with reference to a graph of effective resolution vs. zoom value (FIG. 7). In step **602**, sensor control module **116** chooses (directs) the sensor (Wide, Tele or both) to be operational. Specifically, if the ZF range = 1:$Z_{switch}$, module **116** directs the Wide sensor to be operational and the Tele sensor to be non-operational. If the ZF range is $Z_{switch}$ : $Z_{switch}$ + $\Delta Zoom_{in}$, module **116** directs both sensors to be operational and the zoom image is generated from the Wide sensor. If the ZF range is $Z_{switch}$ + $\Delta Zoom_{in}$ : $Z_{max}$, module **116** directs the Wide sensor to be non-operational and the Tele sensor to be operational. After the sensor choice in step **602,** all following actions are performed in video processing core **126**. Optionally, in step **604**, color balance is calculated if two images are provided by the two sensors. Optionally yet, in step **606**, the calculated color balance is applied in one of the images (depending on the zoom factor). Further optionally, in step **608**, registration is performed between the Wide and Tele images to output a transformation coefficient. The transformation coefficient can be used to set an AF position in step **610**. In step **612**, an output of any of steps **602-608** is applied on one of the images (depending on the zoom factor) for image signal processing that may include denoising, demosaicing, sharpening, scaling, etc. In step **614**, the processed image is resampled according to the transformation coefficient, the requested ZF (obtained from zoom function **124**) and the output video resolution (for example 1080p). To avoid a transition point to be executed at the same ZF, $\Delta$Zoom can change while zooming in and while zooming out. This will result in hysteresis in the sensor switching point.

In more detail, for ZF range 1 : $Z_{switch}$, for ZF < $Z_{switch}$, the Wide image data is transferred to the ISP in step **612** and resampled in step **614**. For ZF range = $Z_{switch}$ : $Z_{switch}$ + $\Delta Zoom_{in}$, both sensors are operational and the zoom image is generated from the Wide sensor. The color balance is calculated for both images according to a given ROI. In addition, for a given ROI, registration is performed between the Wide and Tele images to output a



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transformation coefficient. The transformation coefficient is used to set an AF position. The transformation coefficient includes the translation between matching points in the two images. This translation can be measured in a number of pixels. Different translations will result in a different number of pixel movements between matching points in the images. This movement can be translated into depth and the depth can be translated into an AF position. This enables to set the AF position by only analyzing two images (Wide & Tele). The result is fast focusing.

Both color balance ratios and transformation coefficient are used in the ISP step. In parallel, the Wide image is processed to provide a processed image, followed by resampling. For ZF range = $Z_{switch} + \Delta Zoom_{in} : Z_{max}$ and for Zoom factor > $Z_{switch,} + \Delta Zoom_{in}$, the color balance calculated previously is now applied on the Tele image. The Tele image data is transferred to the ISP in step **612** and resampled in step **614**. To eliminate crossover artifacts and to enable smooth transition to the Tele image, the processed Tele image is resampled according to the transformation coefficient, the requested ZF (obtained from zoom function **124**) and the output video resolution (for example 1080p).

FIG. 7 shows the effective resolution as a function of the zoom factor for a zoom-in case and for a a zoom-out case $\Delta Zoom_{up}$ is set when we zoom in, and $\Delta Zoom_{down}$ is set when we zoom out. Setting $\Delta Zoom_{up}$ to be different from $\Delta Zoom_{down}$ will result in transition between the sensors to be performed at different zoom factor ("hysteresis") when zoom-in is used and when zoom-out is used. This hysteresis phenomenon in the video mode results in smooth continuous zoom experience.

**Optical Design**

Additional optical design considerations were taken into account to enable reaching optical zoom resolution using small total track length (TTL). These considerations refer to the Tele lens. In an embodiment, the camera is "thin" (see also FIG. 1B) in the sense that is has an optical path of less than 9mm and a thickness/focal length (FP) ratio smaller than about 0.85. Exemplarily, as shown in FIG. 8, such a thin camera has a lens block that includes (along an optical axis starting from an object) five lenses: a first lens element **802** with positive power and two lenses **804** and **806** and with negative power, a fourth lens **808** with positive power and a fifth lens **810** with negative power. In the embodiment of FIG. 8, the EFL is 7 mm, the TTL is 4.7 mm, f = 6.12 and FOV = $20^0$. Thus the Tele lens TTL/EFL ratio is smaller than 0.9. In other embodiments, the Tele lens TTL/EFL ratio may be smaller than 1.



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In another embodiment of a lens block in a thin camera, shown in FIG. 9, the camera has a lens block that includes (along an optical axis starting from an object) a first lens element **902** with positive power a second lens element **904** with negative power, a third lens element with positive power **906** and a fourth lens element with negative power **908**, and a fifth filed lens element **910** with positive or negative power. In this embodiment, f =7.14, F# = 3.5, TTL = 5.8mm and FOV = $22.7^0$.

In conclusion, dual aperture optical zoom digital cameras and associate methods disclosed herein reduce the amount of processing resources, lower frame rate requirements, reduce power consumption, remove parallax artifacts and provide continuous focus (or provide loss of focus) when changing from Wide to Tele in video mode. They provide a dramatic reduction of the disparity range and avoid false registration in capture mode. They reduce image intensity differences and enable work with a single sensor bandwidth instead of two, as in known cameras.

All patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present disclosure.

While this disclosure has been described in terms of certain embodiments and generally associated methods, alterations and permutations of the embodiments and methods will be apparent to those skilled in the art. The disclosure is to be understood as not limited by the specific embodiments described herein, but only by the scope of the appended claims.



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WHAT IS CLAIMED IS:

1. A zoom digital camera comprising:

a) a Wide imaging section that includes a fixed focal length Wide lens with a Wide field of view (FOV), a Wide sensor and a Wide image signal processor (ISP), the Wide imaging section operative to provide Wide image data of an object or scene;

b) a Tele imaging section that includes a fixed focal length Tele lens with a Tele FOV that is narrower than the Wide FOV, a Tele sensor and a Tele ISP, the Tele imaging section operative to provide Tele image data of the object or scene; and

c) a camera controller operatively coupled to the Wide and Tele imaging sections, the camera controller configured to combine in still mode at least some of the Wide and Tele image data to provide a fused output image of the object or scene from a particular point of view and to provide without fusion continuous zoom video mode output images of the object or scene, each output image having a respective output resolution;

wherein the video output images are provided with a smooth transition when switching between a lower zoom factor (ZF) value and a higher ZF value or vice versa, wherein at the lower ZF value the output resolution is determined by the Wide sensor, and wherein at the higher ZF value the output resolution is determined by the Tele sensor.

2. The camera of claim 1, wherein the controller includes a user control module for receiving user inputs and a sensor control module for configuring each sensor to acquire the Wide and Tele image data based on the user inputs.

3. The camera of claim 2, wherein the user inputs include a zoom factor, a camera mode and a region of interest (ROI).

4. The camera of claim 2, wherein the sensor control module has a setting that depends on the Wide and Tele fields of view and on a sensor oversampling ratio, the setting used in the configuration of each sensor.

5. The camera of claim 4, wherein the Wide and Tele FOVs and the sensor oversampling ratio satisfy the condition $0.8*PL_{Wide}/ PL_{video} < \mathrm{Tan}(FOV_{Wide})/\mathrm{Tan}(FOV_{Tele}) < 1.2*PL_{Wide}/ PL_{video}$, wherein $PL_{Wide}$ is an in-line number of Wide sensor pixels and wherein $PL_{video}$ is an in-line number of output video format pixels.

6. The camera of claim 1, wherein the Tele lens includes a ratio of total length (TTL)/effective focal length (EFL) smaller than 1.

7. The camera of claim 5 wherein each lens includes five lens elements.

8. The camera of claim 6, wherein the five elements have, in order from the object side, positive-negative-negative-positive-negative powers.

9. The camera of claim 6, wherein the five elements have, in order from the object side, positive-negative-positive-negative and positive or negative powers.

10. The camera of claim 1, wherein the camera controller configuration to provide video output images with a smooth transition when switching between a lower ZF value and a higher ZF value or vice versa includes a configuration that uses information either from the Wide sensor or from the Tele sensor.

11. The camera of claim 1,wherein the camera controller configuration to provide video output images with a smooth transition when switching between a lower ZF value and a higher ZF value or vice versa includes a configuration that uses at high ZF secondary information from the Wide camera and uses at low ZF secondary information from the Tele camera.

12. A method for obtaining zoom images of an object or scene in both still and video modes using a digital camera, the method comprising the steps of:

a) providing in the digital camera a Wide imaging section having a Wide lens with a Wide field of view (FOV), a Wide sensor and a Wide image signal processor (ISP), a Tele imaging section having a Tele lens with a Tele FOV that is narrower than the Wide FOV, a Tele sensor and a Tele ISP, and a camera controller operatively coupled to the Wide and Tele imaging sections; and

b) configuring the camera controller to combine in still mode at least some of the Wide and Tele image data to provide a fused output image of the object or scene from a particular point of view, and to provide without fusion continuous zoom video mode output images of the object or scene, each output image having a respective output resolution, wherein the video mode output images are provided with a smooth transition when switching between a lower zoom factor (ZF) value and a higher ZF value or vice versa, and wherein at the lower ZF value the output resolution is determined by the Wide sensor while at the higher ZF value the output resolution is determined by the Tele sensor.

13. The method of claim 12, wherein the step of configuring the camera controller to provide without fusion continuous zoom video mode output images of the object or scene includes configuring each sensor with a setting that depends on the Wide and Tele FOVs and on a sensor oversampling ratio.

14. The method of claim 13, wherein the Wide and Tele FOVs and the oversampling ratio satisfy the condition $0.8*PL_{WIDE}/ PL_{video} < \mathrm{Tan}(FOV_{Wide})/\mathrm{Tan}(FOV_{Tele}) <1.2*PL_{Wide}/ PL_{video}$, wherein $PL_{Wide}$ is an inline number of Wide sensor pixels and $PL_{video}$ is an in-line number of output video format pixels.

15. The method of claim 12, wherein the step of configuring the camera controller to provide without fusion continuous zoom video mode output images of the object or scene includes performing a registration between the Wide and Tele images to output a transformation coefficient and using the transformation coefficient to set an autofocus position.

16. The method of claim 12, wherein the smooth transition is obtained when zooming-in by switching between a lower ZF factor and a higher ZF factor at a first ZF value, and is obtained when zooming-out by switching between a higher ZF factor and a lower ZF factor at a second ZF value different from the first ZF value.

17. The method of claim 12, wherein the step of configuring the camera controller to combine in still mode at least some of the Wide and Tele image data to provide a fused output image includes configuring the camera controller to combine Wide and Tele image data only in focused areas.

18. The method of claim 12, wherein each lens has a different F number and wherein the step of configuring the camera controller to combine in still mode at least some of the Wide

and Tele image data to provide a fused output image includes configuring the camera controller to set an exposure time based on a ratio of the different F numbers.

19. The method of claim 12, wherein the step of wherein the step of configuring the camera controller to combine in still mode at least some of the Wide and Tele image data to provide a fused output image includes configuring the camera controller to set two images with different intensities to provide a wide dynamic range image.

20. The method of claim 12, wherein the step of configuring the camera controller to combine in still mode at least some of the Wide and Tele image data to provide a fused output image includes configuring the two sensors to obtain the fused image using a single sensor bandwidth.

21. The method of claim 12, wherein the step of configuring the camera controller to combine in still mode at least some of the Wide and Tele image data to provide a fused output image includes configuring the camera controller to synchronize the Wide and Tele sensors to force an overlap area in the object image to be exposed at the same time, wherein the synchronizing includes:

i. setting a Tele sensor vertical blanking time $VB_{Tele}$ to equal a Wide sensor vertical blanking time $VB_{Wide}$ plus half a Wide sensor rolling shutter time $RST_{Wide}$,

ii. setting respective Tele and Wide sensor exposure times $ET_{Tele}$ and $ET_{Wide}$ to be equal,

iii. setting a Tele sensor rolling shutter time $RST_{tele}$ to be $RST_{Wide}/2$, and

iv. setting frame rates of the two sensors to be equal.

22. The method of claim 12, wherein the step of configuring the camera controller to combine in still mode at least some of the Wide and Tele image data to provide a fused output image includes configuring the camera controller to synchronize the Wide and Tele sensors to force the two sensors to start exposure at the same time.



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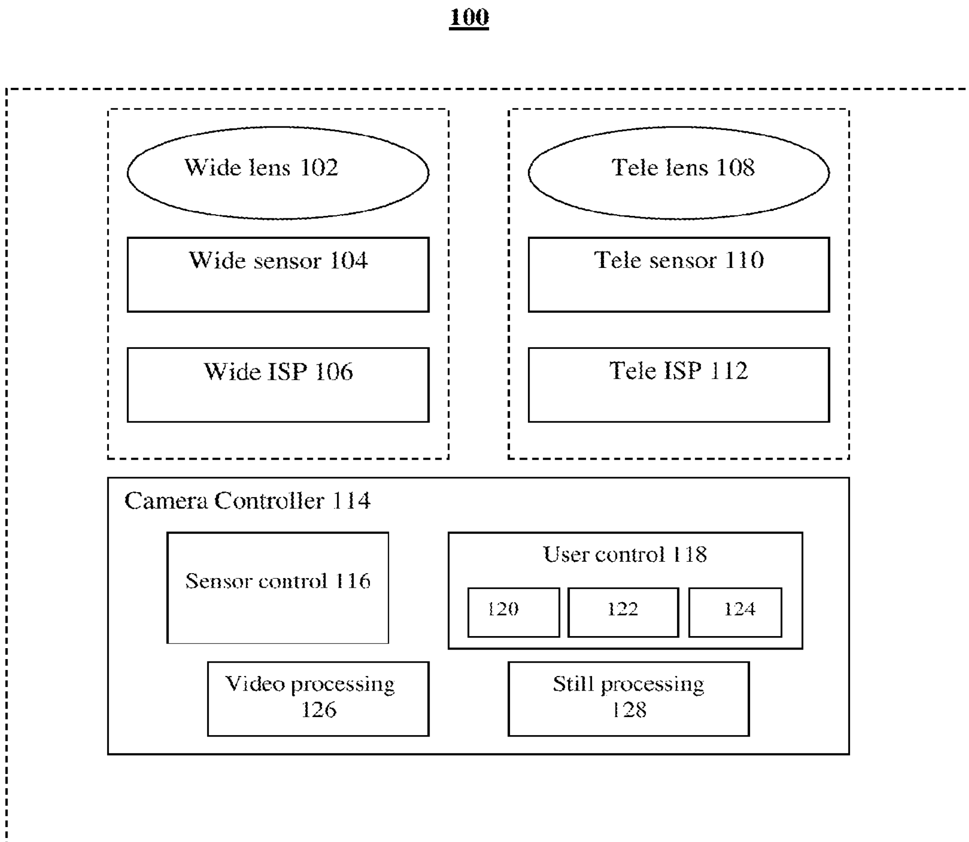
100
Wide lens 102
Wide sensor 104
Wide ISP 106
Tele lens 108
Tele sensor 110
Tele ISP 112
Camera Controller 114
Sensor control 116
User control 118
120
122
124
Video processing 126
Still processing 128

FIG. 1A

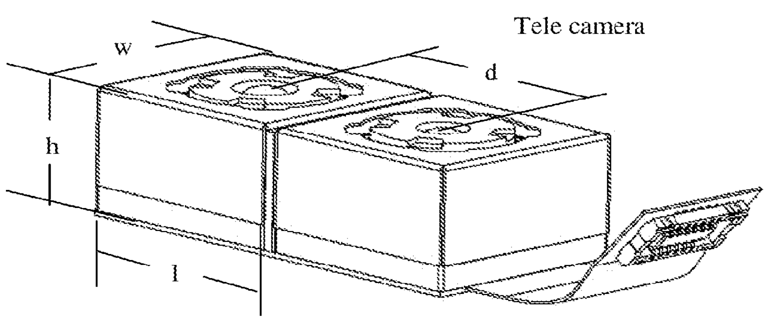
Tele camera
w
d
h
l

FIG. 1B

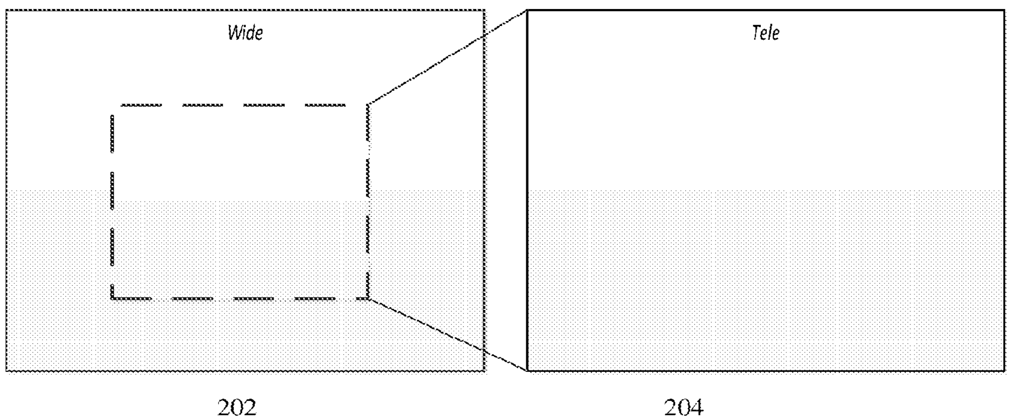


FIG. 2



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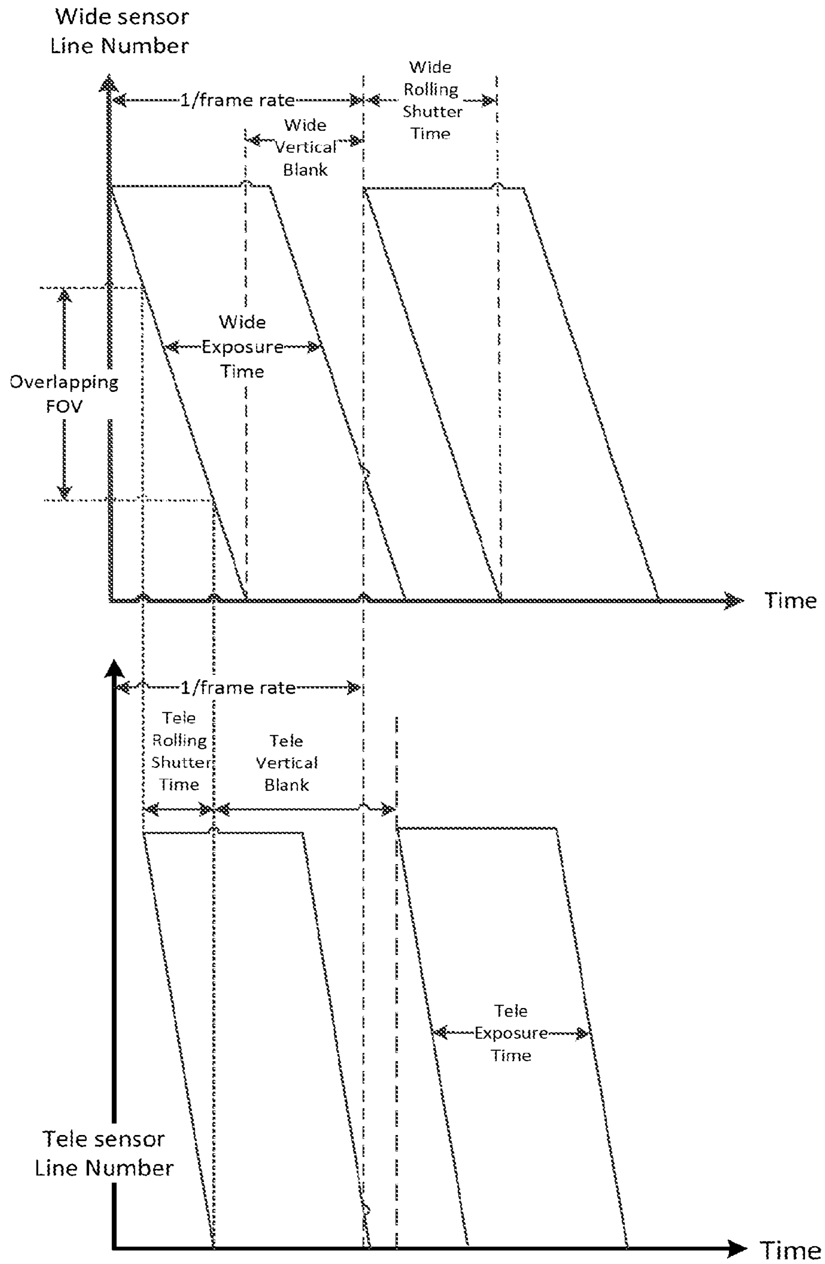


FIG. 3



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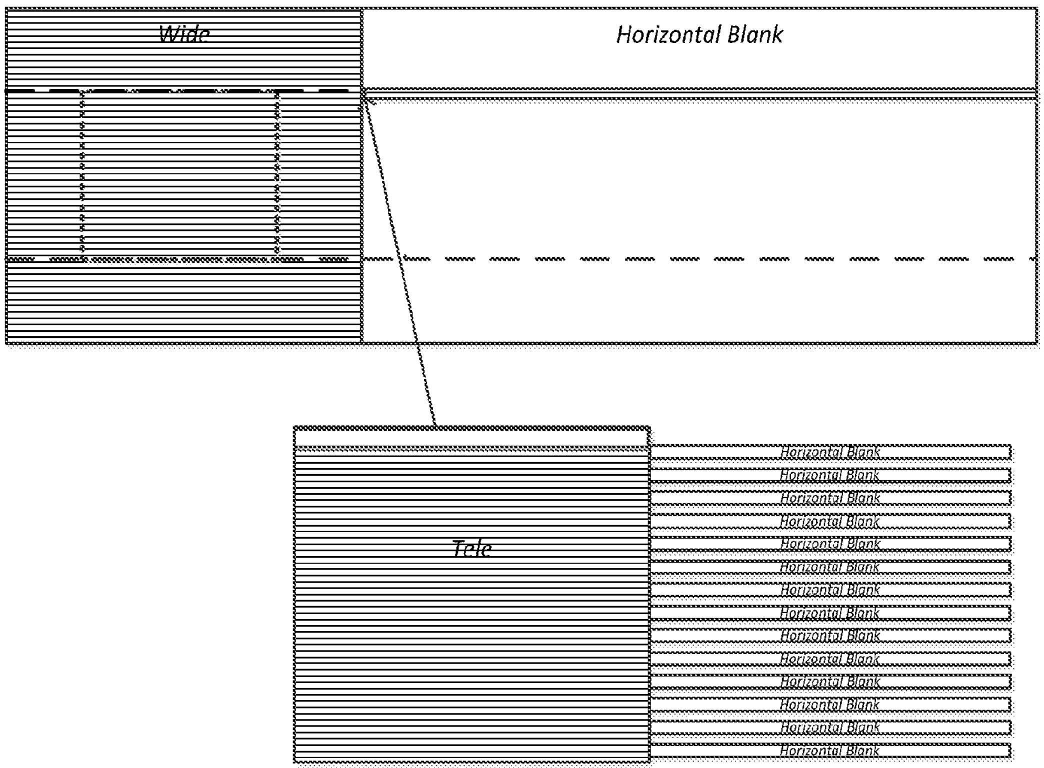
APPLE INC. v. COREPHOTONICS LTD.


Wide
Horizontal Blank
Tele
Horizontal Blank
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Horizontal Blank

FIG. 4

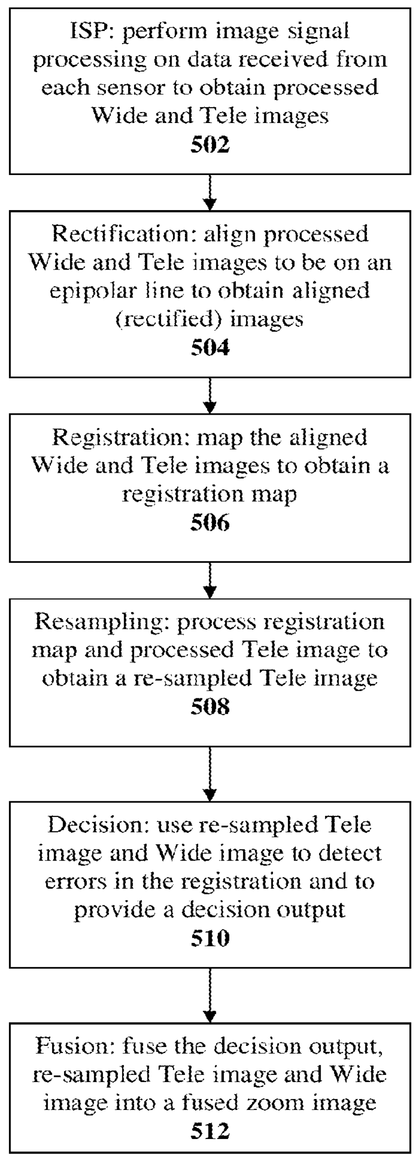
ISP: perform image signal processing on data received from each sensor to obtain processed Wide and Tele images
502
Rectification: align processed Wide and Tele images to be on an epipolar line to obtain aligned (rectified) images
504
Registration: map the aligned Wide and Tele images to obtain a registration map
506
Resampling: process registration map and processed Tele image to obtain a re-sampled Tele image
508
Decision: use re-sampled Tele image and Wide image to detect errors in the registration and to provide a decision output
510
Fusion: fuse the decision output, re-sampled Tele image and Wide image into a fused zoom image
512

FIG. 5

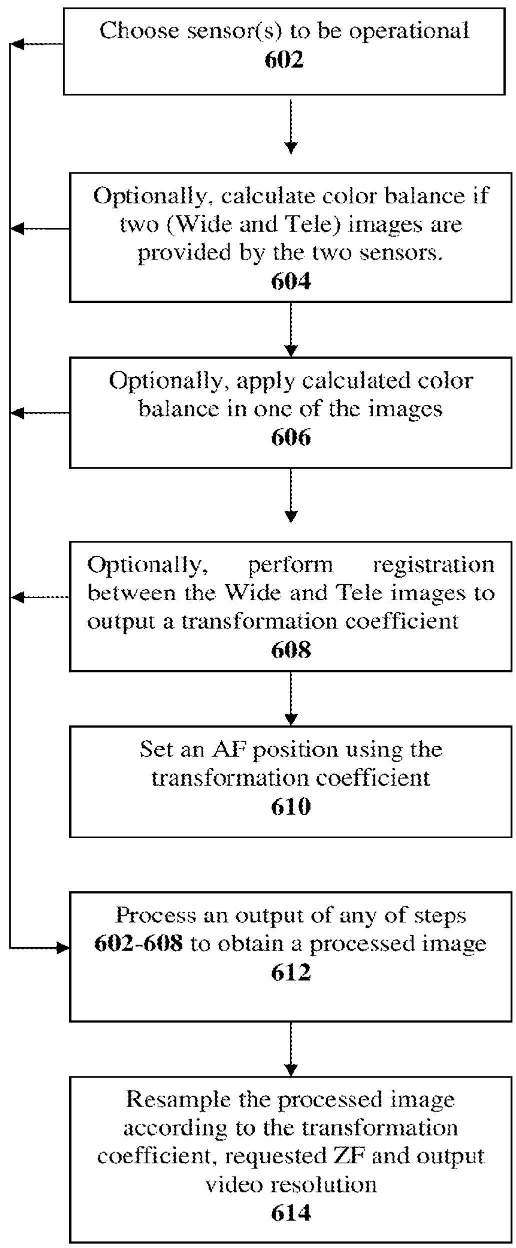
Choose sensor(s) to be operational
602
Optionally, calculate color balance if two (Wide and Tele) images are provided by the two sensors.
604
Optionally, apply calculated color balance in one of the images
606
Optionally, perform registration between the Wide and Tele images to output a transformation coefficient
608
Set an AF position using the transformation coefficient
610
Process an output of any of steps 602-608 to obtain a processed image
612
Resample the processed image according to the transformation coefficient, requested ZF and output video resolution
614

FIG. 6

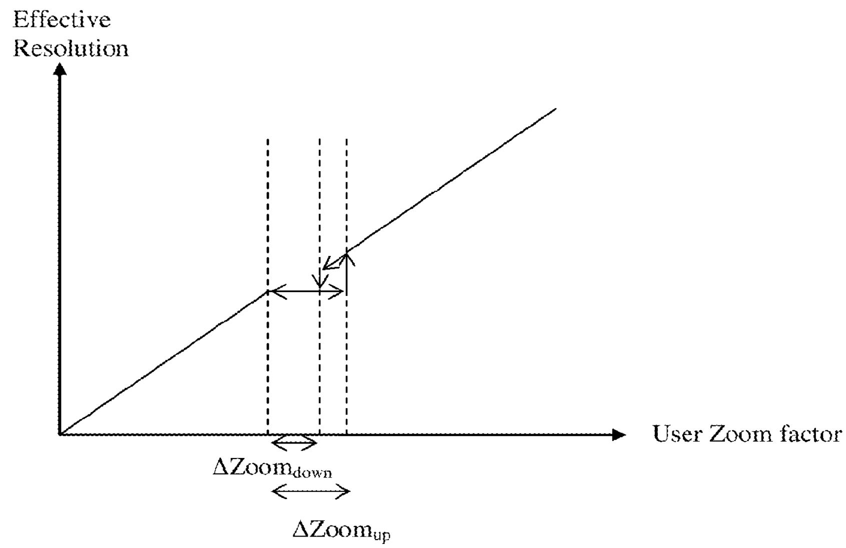


FIG. 7



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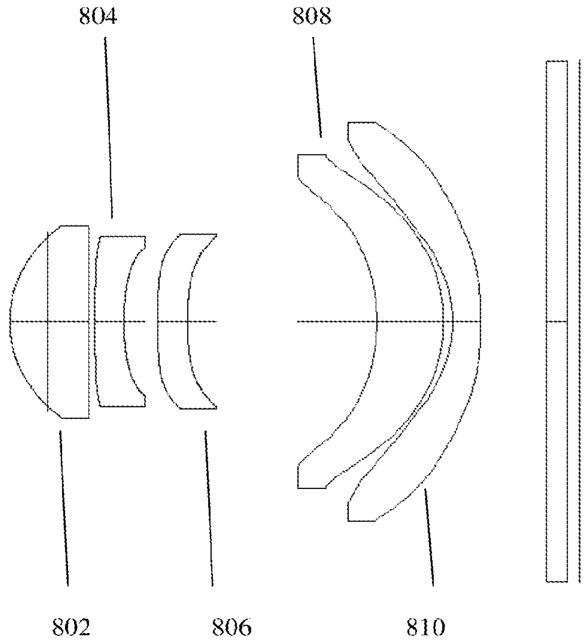


FIG. 8

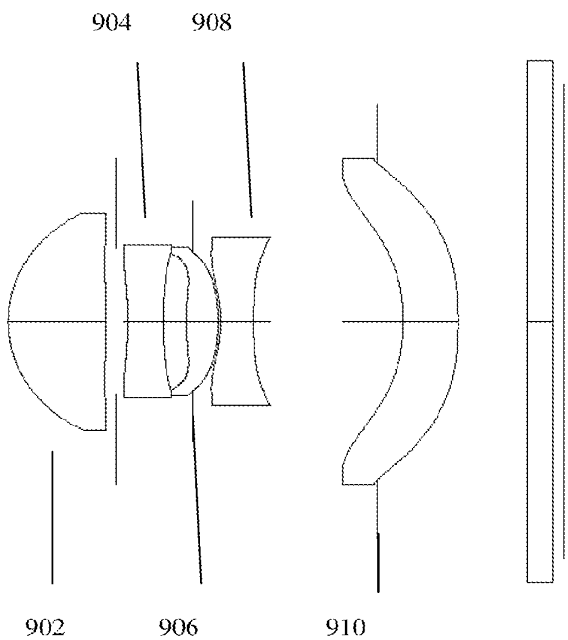


FIG. 9

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
5 February 2015 (05.02.2015)

WIPO | PCT

(10) International Publication Number
**WO 2015/015383 A2**

(51) International Patent Classification: *H04N 5/225* (2006.01)

(21) International Application Number: PCT/IB2014/063393

(22) International Filing Date: 24 July 2014 (24.07.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/861,185 1 August 2013 (01.08.2013) US

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(74) Agent: NATHAN & ASSOCIATES PATENT AGENTS LTD.; P.O.Box 10178, 6110101 Tel Aviv (IL).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: 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, IR, IS, JP, KE, KG, 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, SA, 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.

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**(54) Title**: THIN MULTI-APERTURE IMAGING SYSTEM WITH AUTO-FOCUS AND METHODS FOR USING SAME

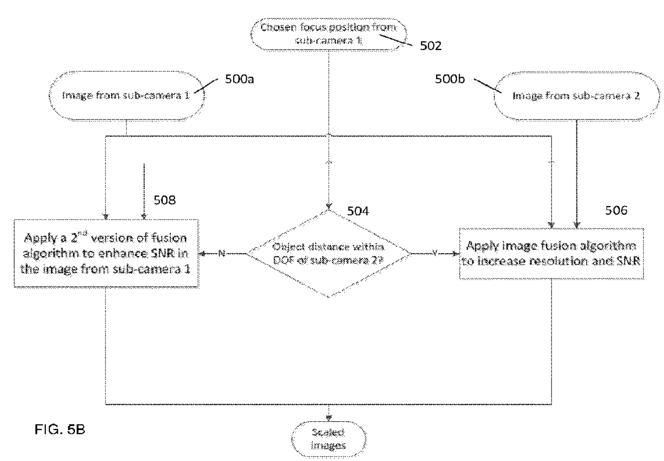


FIG. 5B

**(57) Abstract**: Dual-aperture digital cameras with auto-focus (AF) and related methods for obtaining a focused and, optionally optically stabilized color image of an object or scene. A dual- aperture camera includes a first sub-camera having a first optics bloc and a color image sensor for providing a color image, a second sub-camera having a second optics bloc and a clear image sensor for providing a luminance image, the first and second sub-cameras having substantially the same field of view, an AF mechanism coupled mechanically at least to the first optics bloc, and a camera controller coupled to the AF mechanism and to the two image sensors and configured to control the AF mechanism, to calculate a scaling difference and a sharpness difference between the color and luminance images, the scaling and sharpness differences being due to the AF mechanism, and to process the color and luminance images into a fused color image using the calculated differences.

WO 2015/015383 A2

# Electronic Acknowledgement Receipt

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| **EFS ID:** | 33079574 |
| **Application Number:** | 15976391 |
| **International Application Number:** | |
| **Confirmation Number:** | 1858 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Customer Number:** | 92342 |
| **Filer:** | Menachem Nathan |
| **Filer Authorized By:** | |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |
| **Receipt Date:** | 03-JUL-2018 |
| **Filing Date:** | 10-MAY-2018 |
| **Time Stamp:** | 13:09:16 |
| **Application Type:** | Utility under 35 USC 111(a) |

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| PATENT APPLICATION FEE DETERMINATION RECORD<br>Substitute for Form PTO-875 | Application or Docket Number<br>15/976,391 |
|---|---|

APPLICATION AS FILED - PART I

| | (Column 1) | (Column 2) | SMALL ENTITY | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|
| FOR | NUMBER FILED | NUMBER EXTRA | RATE($) | FEE($) | | RATE($) | FEE($) |
| BASIC FEE (37 CFR 1.16(a), (b), or (c)) | N/A | N/A | N/A | 75 | | N/A | |
| SEARCH FEE (37 CFR 1.16(k), (i), or (m)) | N/A | N/A | N/A | 330 | | N/A | |
| EXAMINATION FEE (37 CFR 1.16(o), (p), or (q)) | N/A | N/A | N/A | 380 | | N/A | |
| TOTAL CLAIMS (37 CFR 1.16(i)) | 30 minus 20 = | * 10 | x 50 = | 500 | OR | | |
| INDEPENDENT CLAIMS (37 CFR 1.16(h)) | 2 minus 3 = | * | x 230 = | 0.00 | | | |
| APPLICATION SIZE FEE (37 CFR 1.16(s)) | If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). | | | 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 | 1285 | | TOTAL | |

APPLICATION AS AMENDED - PART II

| AMENDMENT A | | (Column 1) | | (Column 2) | (Column 3) | SMALL ENTITY | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE($) | ADDITIONAL FEE($) | | RATE($) | ADDITIONAL FEE($) |
| | 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 | |

| AMENDMENT B | | (Column 1) | | (Column 2) | (Column 3) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE($) | ADDITIONAL FEE($) | | RATE($) | ADDITIONAL FEE($) |
| | 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
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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 |
|---|---|---|---|---|---|---|
| 15/976,391 | 05/10/2018 | 2872 | 1365 | COREPH-0080 US CON4 | 30 | 2 |

**CONFIRMATION NO. 1858**

**UPDATED FILING RECEIPT**

OC000000100385503

92342
Nathan & Associates Patent Agents Ltd
P.O.Box 10178
Tel Aviv, 6110101
ISRAEL

Date Mailed: 06/20/2018

Receipt is acknowledged of this non-provisional 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 APPLICANT, 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 Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections 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**

**Inventor(s)**

Michael Dror, Nes Ziona, ISRAEL;
Ephraim Goldenberg, Ashdod, ISRAEL;
Gal Shabtay, Tel Aviv, ISRAEL;

**Applicant(s)**

Corephotonics Ltd., Tel-Aviv, ISRAEL;

**Power of Attorney:** The patent practitioners associated with Customer Number 92342

**Domestic Priority data as claimed by applicant**

This application is a CON of 15/817,235 11/19/2017
which is a CON of 15/418,925 01/30/2017 PAT 9857568
which is a CON of 15/170,472 06/01/2016 PAT 9568712
which is a CON of 14/932,319 11/04/2015 PAT 9402032
which is a CON of 14/367,924 09/19/2014 ABN *
which is a 371 of PCT/IB2014/062465 06/20/2014
which claims benefit of 61/842,987 07/04/2013
(*)Data provided by applicant is not consistent with PTO records.

**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:** 06/06/2018
The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 15/976,391**
**Projected Publication Date:** 09/27/2018
**Non-Publication Request:** No
**Early Publication Request:** No
**** SMALL ENTITY ****
**Title**

MINIATURE TELEPHOTO LENS ASSEMBLY

**Preliminary Class**

359

**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).

---

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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/AIA/08 (11-15)
Approved for use through 11/30/2020. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

| **DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)** | Attorney Docket Number | COREPH-0080 US CON4 |
|---|---|---|
| | First Named Inventor | Michael Dror |
| | *COMPLETE IF KNOWN* | |
| ☐ Declaration Submitted With Initial Filing OR ☒ Declaration Submitted After Initial Filing (surcharge (37 CFR 1.16(f)) required) | Application Number | 15/976,391 |
| | Filing Date | 05/10/2018 |
| | Art Unit | |
| | Examiner Name | |

MINIATURE TELEPHOTO LENS ASSEMBLY

*(Title of the Invention)*

As a below named inventor, I hereby declare that:

This declaration is directed to:

☒ The attached application,

OR

☐ United States Application Number or PCT International application number ____________________

filed on ____________________.

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

I believe 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.

| Direct all correspondence to: | ☒ The address associated with Customer Number: | 92342 | OR | ☐ Correspondence address below |
|---|---|---|---|---|

| Name | | |
|---|---|---|
| Address | | |
| City | State | Zip |
| Country | Telephone | Email |



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 21 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.

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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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# DECLARATION — Utility or Design Patent Application

## 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. Petitioner/applicant is advised that documents which form the record of a patent application (such as the PTO/SB/01) are placed into the Privacy Act system of records DEPARTMENT OF COMMERCE, COMMERCE-PAT-7, System name: *Patent Application Files* . Documents not retained in an application file (such as the PTO-2038) are placed into the Privacy Act system of COMMERCE/PAT-TM-10, System name: *Deposit Accounts and Electronic Funds Transfer Profiles*.

**LEGAL NAME OF SOLE OR FIRST INVENTOR:**

(*E.g.,* Given Name (first and middle if any) and Family Name or Surname)

Michael Dror

| Inventor's Signature | Date (Optional) |
|---|---|
| /Michael Dror/ | 06/16/2018 |

| Residence: City | State | Country |
|---|---|---|
| Nes Ziona | | IL |

Mailing Address

5 Eliyahu Meron St.

| City | State | Zip | Country |
|---|---|---|---|
| Nes Ziona | 7401905 | Nes Ziona | IL |

☒ Additional inventors are being named on the 1 Supplemental sheet(s) PTO/AIA/10 attached hereto

## 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.

# Electronic Patent Application Fee Transmittal

| | |
|---|---|
| **Application Number:** | 15976391 |
| **Filing Date:** | 10-May-2018 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Filer:** | Menachem Nathan |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |

Filed as Small Entity

**Filing Fees for Utility under 35 USC 111(a)**

| Description | Fee Code | Quantity | Amount | Sub-Total in USD($) |
|---|---|---|---|---|
| **Basic Filing:** | | | | |
| **Pages:** | | | | |
| **Claims:** | | | | |
| **Miscellaneous-Filing:** | | | | |
| LATE FILING FEE FOR OATH OR DECLARATION | 2051 | 1 | 80 | 80 |
| **Petition:** | | | | |
| **Patent-Appeals-and-Interference:** | | | | |
| **Post-Allowance-and-Post-Issuance:** | | | | |

| Description | Fee Code | Quantity | Amount | Sub-Total in USD($) |
|---|---|---|---|---|
| **Extension-of-Time:** | | | | |
| **Miscellaneous:** | | | | |
| | **Total in USD ($)** | | | **80** |

| Electronic Acknowledgement Receipt | |
|---|---|
| **EFS ID:** | 32917868 |
| **Application Number:** | 15976391 |
| **International Application Number:** | |
| **Confirmation Number:** | 1858 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Customer Number:** | 92342 |
| **Filer:** | Menachem Nathan |
| **Filer Authorized By:** | |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |
| **Receipt Date:** | 16-JUN-2018 |
| **Filing Date:** | 10-MAY-2018 |
| **Time Stamp:** | 16:46:33 |
| **Application Type:** | Utility under 35 USC 111(a) |

## Payment information:

| | |
|---|---|
| Submitted with Payment | yes |
| Payment Type | CARD |
| Payment was successfully received in RAM | $80 |
| RAM confirmation Number | 061818INTEFSW16472300 |
| Deposit Account | |
| Authorized User | |
| The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: | |

## File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 1 | Oath or Declaration filed | Corrected_Declaration.pdf | 106044<br>8a427b11c13220cb0e7ae092824e9e0c187341c7 | no | 3 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 2 | Fee Worksheet (SB06) | fee-info.pdf | 30237<br>5e12a0bb1c113f3c497d6b8ca0bb7252a419c450 | no | 2 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| | | | **Total Files Size (in bytes):** | 136281 | |

**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.**

| Electronic Acknowledgement Receipt | |
|---|---|
| **EFS ID:** | 32917868 |
| **Application Number:** | 15976391 |
| **International Application Number:** | |
| **Confirmation Number:** | 1858 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Customer Number:** | 92342 |
| **Filer:** | Menachem Nathan |
| **Filer Authorized By:** | |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |
| **Receipt Date:** | 16-JUN-2018 |
| **Filing Date:** | 10-MAY-2018 |
| **Time Stamp:** | 16:46:33 |
| **Application Type:** | Utility under 35 USC 111(a) |

## Payment information:

| | |
|---|---|
| Submitted with Payment | yes |
| Payment Type | CARD |
| Payment was successfully received in RAM | $80 |
| RAM confirmation Number | 061818INTEFSW16472300 |
| Deposit Account | |
| Authorized User | |

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

## File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 1 | Oath or Declaration filed | Corrected_Declaration.pdf | 106044<br>8a427b11c13220cb0e7ae092824e9e0c187341c7 | no | 3 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 2 | Fee Worksheet (SB06) | fee-info.pdf | 30237<br>5e12a0bb1c113f3c497d6b8ca0bb7252a419c450 | no | 2 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| | | | **Total Files Size (in bytes):** 136281 | | |

**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.**

**<u>New Applications Under 35 U.S.C. 111</u>**
**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.**

**<u>National Stage of an International Application under 35 U.S.C. 371</u>**
**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.**

**<u>New International Application Filed with the USPTO as a Receiving Office</u>**
**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

| APPLICATION NUMBER | FILING OR 371(C) DATE | FIRST NAMED APPLICANT | ATTY. DOCKET NO./TITLE |
|---|---|---|---|
| 15/976,391 | 05/10/2018 | Michael Dror | COREPH-0080 US CON4 |

**CONFIRMATION NO. 1858**

**FORMALITIES LETTER**

*OC000000100081973*

92342
Nathan & Associates Patent Agents Ltd
P.O.Box 10178
Tel Aviv, 6110101
ISRAEL

Date Mailed: 06/08/2018

# NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

**FILED UNDER 37 CFR 1.53(b)**

***Filing Date Granted***

**Items Required To Avoid Abandonment:**

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing.

Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- Surcharge as set forth in 37 CFR 1.16(f) must be submitted.
  The surcharge is due for any one of:
  - late submission of the basic filing fee, search fee, or examination fee,
  - late submission of inventor's oath or declaration,
  - filing an application that does not contain at least one claim on filing, or
  - submission of an application filed by reference to a previously filed application.

**SUMMARY OF FEES DUE:**

The fee(s) required within **TWO MONTHS** from the date of this Notice to avoid abandonment is/are itemized below. Small entity discount is in effect. If applicant is qualified for micro entity status, an acceptable Certification of Micro Entity Status must be submitted to establish micro entity status. (See 37 CFR 1.29 and forms PTO/SB/15A and 15B.)

- $ **80** surcharge.
- $( **0**) previous unapplied payment amount.
- $ **80** TOTAL FEE BALANCE DUE.

**Items Required To Avoid Processing Delays:**

Applicant is notified that the above-identified application contains the deficiencies noted below. No period for reply is set forth in this notice for correction of these deficiencies. However, if a deficiency relates to the inventor's oath or declaration, the applicant must file an oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each actual inventor no later than the expiration of the time period set in the "Notice of Allowability" to avoid abandonment. See 37 CFR 1.53(f).

- A properly executed inventor's oath or declaration has not been received for the following inventor(s):

Michael Dror

Replies must be received in the USPTO within the set time period or must include a proper Certificate of Mailing or Transmission under 37 CFR 1.8 with a mailing or transmission date within the set time period. For more information and a suggested format, see Form PTO/SB/92 and MPEP 512.

Replies should be mailed to:

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web, including a copy of this Notice and selecting the document description "Applicant response to Pre-Exam Formalities Notice". https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html

For more information about EFS-Web please call the USPTO Electronic Business Center at 1-866-217-9197 or visit our website at http://www.uspto.gov/ebc.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/hachristian/

| PATENT APPLICATION FEE DETERMINATION RECORD<br>Substitute for Form PTO-875 | Application or Docket Number<br>15/976,391 |
|---|---|

## APPLICATION AS FILED - PART I

| FOR | NUMBER FILED (Column 1) | | NUMBER EXTRA (Column 2) | 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 | 75 | | N/A | |
| SEARCH FEE (37 CFR 1.16(k), (i), or (m)) | N/A | | N/A | N/A | 330 | | N/A | |
| EXAMINATION FEE (37 CFR 1.16(o), (p), or (q)) | N/A | | N/A | N/A | 380 | | N/A | |
| TOTAL CLAIMS (37 CFR 1.16(i)) | 30 | minus 20 = | * 10 | x 50 = | 500 | OR | | |
| INDEPENDENT CLAIMS (37 CFR 1.16(h)) | 2 | minus 3 = | * | x 230 = | 0.00 | | | |
| APPLICATION SIZE FEE (37 CFR 1.16(s)) | If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). | | | | 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 | 1285 | | TOTAL | |

## APPLICATION AS AMENDED - PART II

| AMENDMENT A | CLAIMS REMAINING AFTER AMENDMENT (Column 1) | | HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2) | PRESENT EXTRA (Column 3) | SMALL ENTITY RATE($) | ADDITIONAL FEE($) | OR | OTHER THAN SMALL ENTITY RATE($) | ADDITIONAL FEE($) |
|---|---|---|---|---|---|---|---|---|---|
| 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 | |

| AMENDMENT B | CLAIMS REMAINING AFTER AMENDMENT (Column 1) | | HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2) | PRESENT EXTRA (Column 3) | SMALL ENTITY RATE($) | ADDITIONAL FEE($) | OR | OTHER THAN SMALL ENTITY RATE($) | ADDITIONAL FEE($) |
|---|---|---|---|---|---|---|---|---|---|
| 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.

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|---|---|---|---|---|---|---|
| 15/976,391 | 05/10/2018 | 2872 | 1285 | COREPH-0080 US CON4 | 30 | 2 |

**CONFIRMATION NO. 1858**

**FILING RECEIPT**

OC000000100081972

92342
Nathan & Associates Patent Agents Ltd
P.O.Box 10178
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ISRAEL

Date Mailed: 06/08/2018

Receipt is acknowledged of this non-provisional 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 APPLICANT, 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 Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections 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**

**Inventor(s)**

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**Power of Attorney:** The patent practitioners associated with Customer Number 92342

**Domestic Priority data as claimed by applicant**

This application is a CON of 15/817,235 11/19/2017
which is a CON of 15/418,925 01/30/2017 PAT 9857568
which is a CON of 15/170,472 06/01/2016 PAT 9568712
which is a CON of 14/932,319 11/04/2015 PAT 9402032
which is a CON of 14/367,924 09/19/2014 ABN *
which is a 371 of PCT/IB2014/062465 06/20/2014
which claims benefit of 61/842,987 07/04/2013
(*)Data provided by applicant is not consistent with PTO records.

**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:** 06/06/2018
The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 15/976,391**
**Projected Publication Date:** 09/13/2018
**Non-Publication Request:** No
**Early Publication Request:** No
**** SMALL ENTITY ****
**Title**

MINIATURE TELEPHOTO LENS ASSEMBLY

**Preliminary Class**

359

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

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## Title 37, Code of Federal Regulations, 5.11 & 5.15

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**MINIATURE TELEPHOTO LENS ASSEMBLY**

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a Continuation application of US patent application No. 15/817,235 November 19, 2017, which was a Continuation application of US patent application No. 15/418,925 filed January 30, 2017, which was a Continuation in Part application of US patent application No. 15/170,472 filed June 1, 2016, which was a Continuation application of US patent application No. 14/932319 filed November 4, 2015, which was a Continuation application of US patent application No. 14/367924 filed June 22, 2014, which was a 371 of international application PCT/IB2014/062465 filed June 20, 2014, and is related to and claims priority from US Provisional Patent Application No. 61/842,987 filed July 4, 2013, which is incorporated herein by reference in its entirety.

FIELD

Embodiments disclosed herein relate to an optical lens system and lens assembly, and more particularly, to a miniature telephoto lens assembly included in such a system and used in a portable electronic product such as a cellphone.

BACKGROUND

Digital camera modules are currently being incorporated into a variety of host devices. Such host devices include cellular telephones, personal data assistants (PDAs), computers, and so forth. Consumer demand for digital camera modules in host devices continues to grow**.** Cameras in cellphone devices in particular require a compact imaging lens system for good quality imaging and with a small total track length (TTL). Conventional lens assemblies comprising four lens elements are no longer sufficient for good quality imaging in such devices. The latest lens assembly designs, e.g. as in US 8,395,851, use five lens elements. However, the design in US 8,395,851 suffers from at least the fact that the TTL/EFL (effective focal length) ratio is too large.

Therefore, a need exists in the art for a five lens element optical lens assembly that can provide a small TTL/EFL ratio and better image quality than existing lens assemblies.

SUMMARY

Embodiments disclosed herein refer to an optical lens assembly comprising, in order from an object side to an image side: a first lens element with positive refractive power having a convex object-side surface, a second lens element with negative refractive power having a thickness $d_2$ on an optical axis and separated from the first lens element by a first air gap, a third lens element with negative refractive power and separated from the second lens element by a second air gap, a fourth lens element having a positive refractive power and separated from the third lens element by a third air gap, and a fifth lens element having a negative refractive power, separated from the fourth lens element by a fourth air gap, the fifth lens element having a thickness $d_5$ on the optical axis.

An optical lens system incorporating the lens assembly may further include a stop positioned before the first lens element, a glass window disposed between the image-side surface of the fifth lens element and an image sensor with an image plane on which an image of the object is formed.

The effective focal length of the lens assembly is marked "EFL" and the total track length on an optical axis between the object-side surface of the first lens element and the electronic sensor is marked "TTL". In all embodiments, TTL is smaller than the EFL, i.e. the TTL/EFL ratio is smaller than 1.0. In some embodiments, the TTL/EFL ratio is smaller than 0.9. In an embodiment, the TTL/EFL ratio is about 0.85. In all embodiments, the lens assembly has an F number F# < 3.2. In an embodiment, the focal length of the first lens element f1 is smaller than TTL/2, the first, third and fifth lens elements have each an Abbe number ("Vd") greater than 50, the second and fourth lens elements have each an Abbe number smaller than 30, the first air gap is smaller than $d_2/2$, the third air gap is greater than TTL/5 and the fourth air gap is smaller than $1.5d_5$. In some embodiments, the surfaces of the lens elements may be aspheric.

In an optical lens assembly disclosed herein, the first lens element with positive refractive power allows the TTL of the lens system to be favorably reduced. The combined design of the first, second and third lens elements plus the relative short distances between them enable a long EFL and a short TTL. The same combination,

together with the high dispersion (low Vd) for the second lens element and low dispersion (high Vd) for the first and third lens elements, also helps to reduce chromatic aberration. In particular, the ratio TTL/EFL < 1.0 and minimal chromatic aberration are obtained by fulfilling the relationship 1.2x|f3| > |f2| > 1.5xf1, where "f" indicates the lens element effective focal length and the numerals 1, 2, 3, 4, 5 indicate the lens element number.

The conditions TTL/EFL < 1.0 and F# < 3.2 can lead to a large ratio L11/L1e (e.g. larger than 4) between the largest width (thickness) L11 and the smallest width (thickness) of the first lens element (facing the object) L1e. The largest width is along the optical axis and the smallest width is of a flat circumferential edge of the lens element. L11 and L1e are shown in each of elements **102**, **202** and **302**. A large L11/L1e ratio (e.g. > 4) impacts negatively the manufacturability of the lens and its quality. Advantageously, the present inventors have succeeded in designing the first lens element to have a L11/L1e ratio smaller than 4, smaller than 3.5, smaller than 3.2, smaller than 3.1 (respectively 3.01 for element **102** and 3.08 for element **302**) and even smaller than 3.0 (2.916 for element **202**). The significant reduction in the L11/L1e ratio improves the manufacturability and increases the quality of lens assemblies disclosed herein.

The relatively large distance between the third and the fourth lens elements plus the combined design of the fourth and fifth lens elements assist in bringing all fields' focal points to the image plane. Also, because the fourth and fifth lens elements have different dispersions and have respectively positive and negative power, they help in minimizing chromatic aberration.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A shows a first embodiment of an optical lens system disclosed herein;

FIG. 1B shows the modulus of the optical transfer function (MTF) vs. focus shift of the entire optical lens assembly for various fields in the first embodiment;

FIG. 1C shows the distortion vs. field angle (+Y direction) in percent in the first embodiment;

FIG. 2A shows a second embodiment of an optical lens system disclosed herein;

FIG. 2B shows the MTF vs. focus shift of the entire optical lens assembly for various fields in the second embodiment;

FIG. 2C shows the distortion +Y in percent in the second embodiment;

FIG. 3A shows a third embodiment of an optical lens system disclosed herein;

FIG. 3B shows the MTF vs. focus shift of the entire optical lens system for various fields in the third embodiment;

FIG. 3C shows the distortion +Y in percent in the third embodiment.

DETAILED DESCRIPTION

In the following description, the shape (convex or concave) of a lens element surface is defined as viewed from the respective side (i.e. from an object side or from an image side). FIG. 1A shows a first embodiment of an optical lens system disclosed herein and marked **100**. FIG. 1B shows the MTF vs. focus shift of the entire optical lens system for various fields in embodiment **100**. FIG. 1C shows the distortion +Y in percent vs. field. Embodiment **100** comprises in order from an object side to an image side: an optional stop **101**; a first plastic lens element **102** with positive refractive power having a convex object-side surface **102a** and a convex or concave image-side surface **102b**; a second plastic lens element **104** with negative refractive power and having a meniscus convex object-side surface **104a**, with an image side surface marked **104b**; a third plastic lens element **106** with negative refractive power having a concave object-side surface **106a** with an inflection point and a concave image-side surface **106b**; a fourth plastic lens element **108** with positive refractive power having a positive meniscus, with a concave object-side surface marked **108a** and an image-side surface marked **108b**; and a fifth plastic lens element **110** with negative refractive power having a negative meniscus, with a concave object-side surface marked **110a** and an image-side surface marked **110b**. The optical lens system further comprises an optional glass window **112** disposed between the image-side surface **110b** of fifth lens element **110** and an image plane **114** for image formation of an object. Moreover, an image sensor (not shown) is disposed at image plane **114** for the image formation.

In embodiment **100**, all lens element surfaces are aspheric. Detailed optical data is given in Table 1, and the aspheric surface data is given in Table 2, wherein the units of the radius of curvature (R), lens element thickness and/or distances between elements along the optical axis and diameter are expressed in mm. "Nd" is the refraction index. The equation of the aspheric surface profiles is expressed by:

$$z = \frac{cr^2}{1+\sqrt{1-(1+k)c^2r^2}} + \alpha_1 r^2 + \alpha_2 r^4 + \alpha_3 r^6 + \alpha_4 r^8 + \alpha_5 r^{10} + \alpha_6 r^{12} + \alpha_7 r^{14}$$

where r is distance from (and perpendicular to) the optical axis, k is the conic coefficient, c = 1/R where R is the radius of curvature, and α are coefficients given in Table 2. In the equation above as applied to embodiments of a lens assembly disclosed herein, coefficients $\alpha_1$ and $\alpha_7$ are zero. Note that the maximum value of r "max r" = Diameter/2. Also note that Table 1 (and in Tables 3 and 5 below), the distances between various elements (and/or surfaces) are marked "Lmn" (where *m* refers to the lens element number, *n* =1 refers to the element thickness and *n* = 2 refers to the air gap to the next element) and are measured on the optical axis z, wherein the stop is at z = 0. Each number is measured from the previous surface. Thus, the first distance -0.466 mm is measured from the stop to surface **102a**, the distance L11 from surface **102a** to surface **102b** (i.e. the thickness of first lens element **102)** is 0.894 mm, the gap L12 between surfaces **102b** and **104a** is 0.020 mm, the distance L21 between surfaces **104a** and **104b** (i.e. thickness d2 of second lens element **104)** is 0.246 mm, etc. Also, L21 = $d_2$ and L51 = $d_5$. L11 for lens element **102** is indicated in FIG. 1A. Also indicated in FIG. 1A is a width L1e of a flat circumferential edge (or surface) of lens element **102.** L11 and L1e are also indicated for each of first lens elements **202** and **302** in, respectively, embodiments **200** (FIG. 2A) and **300** (FIG. 3A).

| # | Comment | Radius R [mm] | Distances [mm] | Nd/Vd | Diameter [mm] |
|---|---|---|---|---|---|
| 1 | Stop | Infinite | -0.466 | | 2.4 |
| 2 | L11 | 1.5800 | 0.894 | 1.5345/57.095 | 2.5 |
| 3 | L12 | -11.2003 | 0.020 | | 2.4 |
| 4 | L21 | 33.8670 | 0.246 | 1.63549/23.91 | 2.2 |
| 5 | L22 | 3.2281 | 0.449 | | 1.9 |
| 6 | L31 | -12.2843 | 0.290 | 1.5345/57.095 | 1.9 |
| 7 | L32 | 7.7138 | 2.020 | | 1.8 |
| 8 | L41 | -2.3755 | 0.597 | 1.63549/23.91 | 3.3 |
| 9 | L42 | -1.8801 | 0.068 | | 3.6 |
| 10 | L51 | -1.8100 | 0.293 | 1.5345/57.095 | 3.9 |
| 11 | L52 | -5.2768 | 0.617 | | 4.3 |
| 12 | Window | Infinite | 0.210 | 1.5168/64.17 | 3.0 |

| | | | | | |
|---|---|---|---|---|---|
| 13 | | Infinite | 0.200 | | 3.0 |

Table 1

| # | Conic coefficient k | $\alpha_2$ | $\alpha_3$ | $\alpha_4$ | $\alpha_5$ | $\alpha_6$ |
|---|---|---|---|---|---|---|
| 2 | -0.4668 | 7.9218E-03 | 2.3146E-02 | -3.3436E-02 | 2.3650E-02 | -9.2437E-03 |
| 3 | -9.8525 | 2.0102E-02 | 2.0647E-04 | 7.4394E-03 | -1.7529E-02 | 4.5206E-03 |
| 4 | 10.7569 | -1.9248E-03 | 8.6003E-02 | 1.1676E-02 | -4.0607E-02 | 1.3545E-02 |
| 5 | 1.4395 | 5.1029E-03 | 2.4578E-01 | -1.7734E-01 | 2.9848E-01 | -1.3320E-01 |
| 6 | 0.0000 | 2.1629E-01 | 4.0134E-02 | 1.3615E-02 | 2.5914E-03 | -1.2292E-02 |
| 7 | -9.8953 | 2.3297E-01 | 8.2917E-02 | -1.2725E-01 | 1.5691E-01 | -5.9624E-02 |
| 8 | 0.9938 | -1.3522E-02 | -7.0395E-03 | 1.4569E-02 | -1.5336E-02 | 4.3707E-03 |
| 9 | -6.8097 | -1.0654E-01 | 1.2933E-02 | 2.9548E-04 | -1.8317E-03 | 5.0111E-04 |
| 10 | -7.3161 | -1.8636E-01 | 8.3105E-02 | -1.8632E-02 | 2.4012E-03 | -1.2816E-04 |
| 11 | 0.0000 | -1.1927E-01 | 7.0245E-02 | -2.0735E-02 | 2.6418E-03 | -1.1576E-04 |

Table 2

Embodiment **100** provides a field of view (FOV) of 44 degrees, with EFL = 6.90 mm, F# = 2.80 and TTL of 5.904 mm. Thus and advantageously, the ratio TTL/EFL = 0.855. Advantageously, the Abbe number of the first, third and fifth lens element is 57.095. Advantageously, the first air gap between lens elements **102** and **104** (the gap between surfaces **102b** and **104a**) has a thickness (0.020 mm) which is less than a tenth of thickness $d_2$ (0.246 mm). Advantageously, the Abbe number of the second and fourth lens elements is 23.91. Advantageously, the third air gap between lens elements **106** and **108** has a thickness (2.020 mm) greater than TTL/5 (5.904/5 mm). Advantageously, the fourth air gap between lens elements **108** and **110** has a thickness (0.068 mm) which is smaller than $1.5d_5$ (0.4395 mm).

The focal length (in mm) of each lens element in embodiment **100** is as follows: f1 = 2.645, f2 = -5.578, f3 = -8.784, f4 = 9.550 and f5 = -5.290. The condition 1.2x|f3| > |f2| < 1.5xf1 is clearly satisfied, as 1.2x8.787 > 5.578 > 1.5x2.645. f1 also fulfills the condition f1< TTL/2, as 2.645 < 2.952.

Using the data from row #2 in Tables 1 and 2, L1e in lens element **102** equals 0.297 mm, yielding a center-to-edge thickness ratio L11/L1e of 3.01.

FIG. 2A shows a second embodiment of an optical lens system disclosed herein and marked **200**. FIG. 2B shows the MTF vs. focus shift of the entire optical lens system for various fields in embodiment **200**. FIG. 2C shows the distortion +Y in percent vs. field. Embodiment **200** comprises in order from an object side to an image side: an optional stop **201**; a first plastic lens element **202** with positive refractive power having a convex object-side surface **202a** and a convex or concave image-side surface **202b**; a second glass lens element **204** with negative refractive power, having a meniscus convex object-side surface **204a**, with an image side surface marked **204b**; a third plastic lens element **206** with negative refractive power having a concave object-side surface **206a** with an inflection point and a concave image-side surface **206b**; a fourth plastic lens element **208** with positive refractive power having a positive meniscus, with a concave object-side surface marked **208a** and an image-side surface marked **208b**; and a fifth plastic lens element **210** with negative refractive power having a negative meniscus, with a concave object-side surface marked **110a** and an image-side surface marked **210b**. The optical lens system further comprises an optional glass window **212** disposed between the image-side surface **210b** of fifth lens element **210** and an image plane **214** for image formation of an object.

In embodiment **200**, all lens element surfaces are aspheric. Detailed optical data is given in Table 3, and the aspheric surface data is given in Table 4, wherein the markings and units are the same as in, respectively, Tables 1 and 2. The equation of the aspheric surface profiles is the same as for embodiment **100**.

| # | Comment | Radius R [mm] | Distances [mm] | Nd/Vd | Diameter [mm] |
|---|---|---|---|---|---|
| 1 | Stop | Infinite | -0.592 | | 2.5 |
| 2 | L11 | 1.5457 | 0.898 | 1.53463/56.18 | 2.6 |
| 3 | L12 | -127.7249 | 0.129 | | 2.6 |
| 4 | L21 | 6.6065 | 0.251 | 1.91266/20.65 | 2.1 |
| 5 | L22 | 2.8090 | 0.443 | | 1.8 |
| 6 | L31 | 9.6183 | 0.293 | 1.53463/56.18 | 1.8 |
| 7 | L32 | 3.4694 | 1.766 | | 1.7 |
| 8 | L41 | -2.6432 | 0.696 | 1.632445/23.35 | 3.2 |
| 9 | L42 | -1.8663 | 0.106 | | 3.6 |
| 10 | L51 | -1.4933 | 0.330 | 1.53463/56.18 | 3.9 |
| 11 | L52 | -4.1588 | 0.649 | | 4.3 |

| | | | | | |
|---|---|---|---|---|---|
| 12 | Window | Infinite | 0.210 | 1.5168/64.17 | 5.4 |
| 13 | | Infinite | 0.130 | | 5.5 |

Table 3

| # | Conic coefficient k | $\alpha_2$ | $\alpha_3$ | $\alpha_4$ | $\alpha_5$ | $\alpha_6$ |
|---|---|---|---|---|---|---|
| 2 | 0.0000 | -2.7367E-03 | 2.8779E-04 | -4.3661E-03 | 3.0069E-03 | -1.2282E-03 |
| 3 | -10.0119 | 4.0790E-02 | -1.8379E-02 | 2.2562E-02 | -1.7706E-02 | 4.9640E-03 |
| 4 | 10.0220 | 4.6151E-02 | 5.8320E-02 | -2.0919E-02 | -1.2846E-02 | 8.8283E-03 |
| 5 | 7.2902 | 3.6028E-02 | 1.1436E-01 | -1.9022E-02 | 4.7992E-03 | -3.4079E-03 |
| 6 | 0.0000 | 1.6639E-01 | 5.6754E-02 | -1.2238E-02 | -1.8648E-02 | 1.9292E-02 |
| 7 | 8.1261 | 1.5353E-01 | 8.1427E-02 | -1.5773E-01 | 1.5303E-01 | -4.6064E-02 |
| 8 | 0.0000 | -3.2628E-02 | 1.9535E-02 | -1.6716E-02 | -2.0132E-03 | 2.0112E-03 |
| 9 | 0.0000 | 1.5173E-02 | -1.2252E-02 | 3.3611E-03 | -2.5303E-03 | 8.4038E-04 |
| 10 | -4.7688 | -1.4736E-01 | 7.6335E-02 | -2.5539E-02 | 5.5897E-03 | -5.0290E-04 |
| 11 | 0.00E+00 | -8.3741E-02 | 4.2660E-02 | -8.4866E-03 | 1.2183E-04 | 7.2785E-05 |

Table 4

Embodiment **200** provides a FOV of 43.48 degrees, with EFL = 7 mm, F# = 2.86 and TTL = 5.90mm. Thus and advantageously, the ratio TTL/EFL = 0.843. Advantageously, the Abbe number of the first, third and fifth lens elements is 56.18. The first air gap between lens elements **202** and **204** has a thickness (0.129 mm) which is about half the thickness $d_2$ (0.251 mm). Advantageously, the Abbe number of the second lens element is 20.65 and of the fourth lens element is 23.35. Advantageously, the third air gap between lens elements **206** and **208** has a thickness (1.766 mm) greater than TTL/5 (5.904/5 mm). Advantageously, the fourth air gap between lens elements **208** and **210** has a thickness (0.106 mm) which is less than 1.5x$d_5$ (0.495 mm).

The focal length (in mm) of each lens element in embodiment **200** is as follows: f1 = 2.851, f2 = -5.468, f3 = -10.279, f4 = 7.368 and f5 = -4.536. The condition 1.2x|f3| > |f2| < 1.5xf1 is clearly satisfied, as 1.2x10.279 > 5.468 > 1.5x 2.851. f1 also fulfills the condition f1< TTL/2, as 2.851 < 2.950.

Using the data from row #2 in Tables 3 and 4, L1e in lens element **202** equals 0.308 mm, yielding a center-to-edge thickness ratio L11/L1e of 2.916.

FIG. 3A shows a third embodiment of an optical lens system disclosed herein and marked **300**. FIG. 3B shows the MTF vs. focus shift of the entire optical lens system for various fields in embodiment **300**. FIG. 3C shows the distortion +Y in percent vs. field. Embodiment **300** comprises in order from an object side to an image side: an optional stop **301**; a first glass lens element **302** with positive refractive power having a convex object-side surface **302a** and a convex or concave image-side surface **302b**; a second plastic lens element **204** with negative refractive power, having a meniscus convex object-side surface **304a**, with an image side surface marked **304b**; a third plastic lens element **306** with negative refractive power having a concave object-side surface **306a** with an inflection point and a concave image-side surface **306b**; a fourth plastic lens element **308** with positive refractive power having a positive meniscus, with a concave object-side surface marked **308a** and an image-side surface marked **308b**; and a fifth plastic lens element **310** with negative refractive power having a negative meniscus, with a concave object-side surface marked **310a** and an image-side surface marked **310b**. The optical lens system further comprises an optional glass window **312** disposed between the image-side surface **310b** of fifth lens element **310** and an image plane **314** for image formation of an object.

In embodiment **300**, all lens element surfaces are aspheric. Detailed optical data is given in Table 5, and the aspheric surface data is given in Table 6, wherein the markings and units are the same as in, respectively, Tables 1 and 2. The equation of the aspheric surface profiles is the same as for embodiments **100** and **200**.

| # | Comment | Radius R [mm] | Distances [mm] | Nd/Vd | Diameter [mm] |
|---|---|---|---|---|---|
| 1 | Stop | Infinite | -0.38 | | 2.4 |
| 2 | L11 | 1.5127 | 0.919 | 1.5148/63.1 | 2.5 |
| 3 | L12 | -13.3831 | 0.029 | | 2.3 |
| 4 | L21 | 8.4411 | 0.254 | 1.63549/23.91 | 2.1 |
| 5 | L22 | 2.6181 | 0.426 | | 1.8 |
| 6 | L31 | -17.9618 | 0.265 | 1.5345/57.09 | 1.8 |
| 7 | L32 | 4.5841 | 1.998 | | 1.7 |
| 8 | L41 | -2.8827 | 0.514 | 1.63549/23.91 | 3.4 |
| 9 | L42 | -1.9771 | 0.121 | | 3.7 |
| 10 | L51 | -1.8665 | 0.431 | 1.5345/57.09 | 4.0 |

| | | | | | |
|---|---|---|---|---|---|
| 11 | L52 | -6.3670 | 0.538 | | 4.4 |
| 12 | Window | Infinite | 0.210 | 1.5168/64.17 | 3.0 |
| 13 | | Infinite | 0.200 | | 3.0 |

Table 5

| # | Conic coefficient k | $\alpha_2$ | $\alpha_3$ | $\alpha_4$ | $\alpha_5$ | $\alpha_6$ |
|---|---|---|---|---|---|---|
| 2 | -0.534 | 1.3253E-02 | 2.3699E-02 | -2.8501E-02 | 1.7853E-02 | -4.0314E-03 |
| 3 | -13.473 | 3.0077E-02 | 4.7972E-03 | 1.4475E-02 | -1.8490E-02 | 4.3565E-03 |
| 4 | -10.132 | 7.0372E-04 | 1.1328E-01 | 1.2346E-03 | -4.2655E-02 | 8.8625E-03 |
| 5 | 5.180 | -1.9210E-03 | 2.3799E-01 | -8.8055E-02 | 2.1447E-01 | -1.2702E-01 |
| 6 | 0.000 | 2.6780E-01 | 1.8129E-02 | -1.7323E-02 | 3.7372E-02 | -2.1356E-02 |
| 7 | 10.037 | 2.7660E-01 | -1.0291E-02 | -6.0955E-02 | 7.5235E-02 | -1.6521E-02 |
| 8 | 1.703 | 2.6462E-02 | -1.2633E-02 | -4.7724E-04 | -3.2762E-03 | 1.6551E-03 |
| 9 | -1.456 | 5.7704E-03 | -1.8826E-02 | 5.1593E-03 | -2.9999E-03 | 8.0685E-04 |
| 10 | -6.511 | -2.1699E-01 | 1.3692E-01 | -4.2629E-02 | 6.8371E-03 | -4.1415E-04 |
| 11 | 0.000 | -1.5120E-01 | 8.6614E-02 | -2.3324E-02 | 2.7361E-03 | -1.1236E-04 |

Table 6

Embodiment **300** provides a FOV of 44 degrees, EFL = 6.84 mm, F# = 2.80 and TTL = 5.904 mm. Thus and advantageously, the ratio TTL/EFL = 0.863. Advantageously, the Abbe number of the first lens element is 63.1, and of the third and fifth lens elements is 57.09. The first air gap between lens elements **302** and **304** has a thickness (0.029 mm) which is about $1/10^{th}$ the thickness $d_2$ (0.254 mm). Advantageously, the Abbe number of the second and fourth lens elements is 23.91. Advantageously, the third air gap between lens elements **306** and **308** has a thickness (1.998 mm) greater than TTL/5 (5.904/5 mm). Advantageously, the fourth air gap between lens elements **208** and **210** has a thickness (0.121 mm) which is less than $1.5d_5$ (0.6465 mm).

The focal length (in mm) of each lens element in embodiment **300** is as follows: f1 = 2.687, f2 = -6.016, f3 = -6.777, f4 = 8.026 and f5 = -5.090. The condition 1.2x|f3| > |f2| < 1.5xf1 is clearly satisfied, as 1.2x6.777> 6.016 > 1.5x 2.687. f1 also fulfills the condition f1< TTL/2, as 2.687 < 2.952.

Using the data from row #2 in Tables 5 and 6, L1e in lens element **302** equals 0.298 mm, yielding a center-to-edge thickness ratio L11/L1e of 3.08.



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While this disclosure has been described in terms of certain embodiments and generally associated methods, alterations and permutations of the embodiments and methods will be apparent to those skilled in the art. The disclosure is to be understood as not limited by the specific embodiments described herein, but only by the scope of the appended claims.

WHAT IS CLAIMED IS:

1. A lens assembly, comprising: a plurality of lens elements arranged along an optical axis and spaced apart by respective spaces, wherein the lens assembly has an effective focal length (EFL), a total track length (TTL) of 6.5 millimeters or less and a ratio TTL/EFL $< 1.0$, wherein the plurality of lens elements includes, in order from an object side to an image side, a first group comprising lens elements $L_{1\_1}$, $L_{1\_2}$ and $L_{1\_3}$ with respective focal lengths $f_{1\_1}$, $f_{1\_2}$ and $f_{1\_3}$ and a second group comprising lens elements $L_{2\_1}$ and $L_{2\_2}$, wherein the first and second groups of lens elements are separated by a gap that is larger than twice any other gap between lens elements, wherein lens element $L_{1\_1}$ has positive refractive power and lens element $L_{1\_2}$ has negative refractive power and wherein lens elements $L_{2\_1}$ and $L_{2\_2}$ have opposite refractive powers.

2. The lens assembly of claim 1, wherein the TTL is equal or smaller than 6.0mm and wherein the lens assembly has a f-number F# < 2.9

3. The lens assembly of claim 1, wherein the TTL is equal or smaller than 6.0mm and wherein lens element $L_{1\_1}$ has an image-side surface diameter between 2.3mm and 2.5mm.

4. The lens assembly of claim 1, wherein $f_{1\_1}<TTL/2$.

5. The lens assembly of claim 1, wherein the lens assembly has a f-number F# < 2.9.

6. The lens assembly of claim 5, wherein lens element $L_{1\_1}$ has a concave image-side surface.

7. The lens assembly of claim 1, wherein the lens assembly has a f-number F# = 2.8

8. The lens assembly of claim 5, wherein lens element $L_{1\_1}$ has a convex image-side surface.

9. The lens assembly of claim 1, wherein $1.2x|f_{1\_3}| > 1.5xf_{1\_1}$.

10. The lens assembly of claim 1, wherein $1.2x|f_{1\_3}| > |f_{1\_2}| > 1.5xf_{1\_1}$.

11. The lens assembly of claim 1, wherein a combined power of lens elements $L_{1\_2}$ and $L_{1\_3}$ is negative.

12. The lens assembly of claim 1, wherein $L_{1\_3}$ has negative refractive power.

13. The lens assembly of claim 1, wherein the gap between lens elements $L_{2\_1}$ and $L_{2\_2}$ is smaller than $1.5xd_{2\_2}$, where $d_{2\_2}$ is a thickness of lens element $L_{2\_2}$ along the optical axis.

14. The lens assembly of claim 1, wherein lens elements $L_{2\_1}$ and $L_{2\_2}$ are separated by a gap smaller than TTL/20.

15. The lens assembly of claim 1, wherein $L_{2\_1}$ and $L_{2\_2}$ are made of different lens materials having different Abbe numbers, such that one lens element has Abbe number that is smaller than 30 and the other lens element has an Abbe number that is larger than 50.

16. The lens assembly of claim 2, wherein the lens assembly further includes a ratio between a largest optical axis thickness L11 and a circumferential edge thickness L1e of lens element $L_{1\_1}$ of L11/L1e < 3.

17. A lens assembly, comprising a plurality of lens elements arranged along an optical axis and spaced apart by respective spaces, wherein the lens assembly has an effective focal length (EFL), a total track length (TTL) of 6.5 millimeters or less and a ratio TTL/EFL < 1.0, wherein the plurality of lens elements includes, in order from an object side to an image side, a first group comprising lens elements $L_{1\_1}$, $L_{1\_2}$ and $L_{1\_3}$ with respective focal lengths $f_{1\_1}$, $f_{1\_2}$ and $f_{1\_3}$, and a second group comprising lens elements $L_{2\_1}$ and $L_{2\_2}$, wherein lens element $L_{1\_1}$ has positive refractive power and lens element $L_{1\_2}$ has negative refractive power, wherein $1.2x|f_{1\_3}|>|f_{1\_2}|>1.5xf_{1\_1}$ and wherein lens elements $L_{2\_1}$ and $L_{2\_2}$ have opposite refractive powers.

18. The lens assembly of claim 17, wherein the TTL is equal or smaller than 6.0mm and wherein the lens assembly has a f-number F# < 2.9

19. The lens assembly of claim 17, wherein the TTL is equal or smaller than 6.0mm and wherein lens element $L_{1\_1}$ has an image-side surface diameter between 2.3mm and 2.5mm

20. The lens assembly of claim 17, wherein $f_{1\_1}$ < TTL/2.

21. The lens assembly of claim 17, wherein the lens assembly has a f-number F# < 2.9.

22. The lens assembly of claim 21, wherein lens element $L_{1\_1}$ has a concave image-side

surface.

23. The lens assembly of claim 17, wherein the lens assembly has a f-number F# = 2.8

24. The lens assembly of claim 21, wherein lens element $L_{1\_1}$ has a convex image-side surface.

25. The lens assembly of claim 17, wherein a combined power of lens elements $L_{1\_2}$ and $L_{1\_3}$ is negative.

26. The lens assembly of claim 17, wherein $L_{1\_3}$ has negative refractive power.

27. The lens assembly of claim 17, wherein a gap between lens elements $L_{2\_1}$ and $L_{2\_2}$ is smaller than $1.5xd_5$, where $d_5$ is a thickness of lens element $L_{2\_2}$ along the optical axis.

28. The lens assembly of claim 17, wherein lens elements $L_{2\_1}$ and $L_{2\_2}$ are separated by a gap smaller than TTL/20.

29. The lens assembly of claim 17, wherein $L_{2\_1}$ and $L_{2\_2}$ are made of different lens materials having different Abbe numbers, such that one lens element has an Abbe number that is smaller than 30 and the other lens element has an Abbe number that is larger than 50.

30. The lens assembly of claim 18, wherein the lens assembly further includes a ratio between a largest optical axis thickness L11 and a circumferential edge thickness L1e of lens element $L_{1\_1}$ of $L11/L1e < 3$.

ABSTRACT

An optical lens assembly includes five lens elements and provides a TTL/EFL < 1.0. In an embodiment, the focal length of the first lens element f1 < TTL/2, an air gap between first and second lens elements is smaller than half the second lens element thickness, an air gap between the third and fourth lens elements is greater than TTL/5 and an air gap between the fourth and fifth lens elements is smaller than about 1.5 times the fifth lens element thickness. All lens elements may be aspheric.



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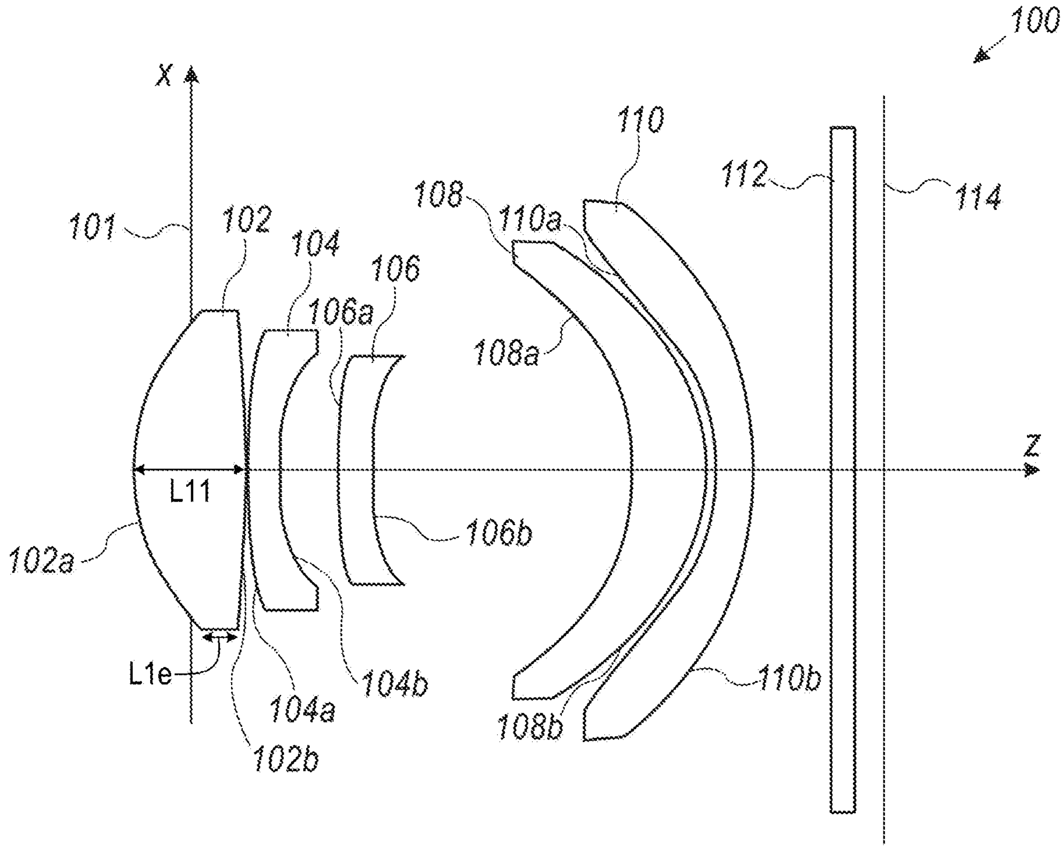
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110a
101
102
104
106
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L11
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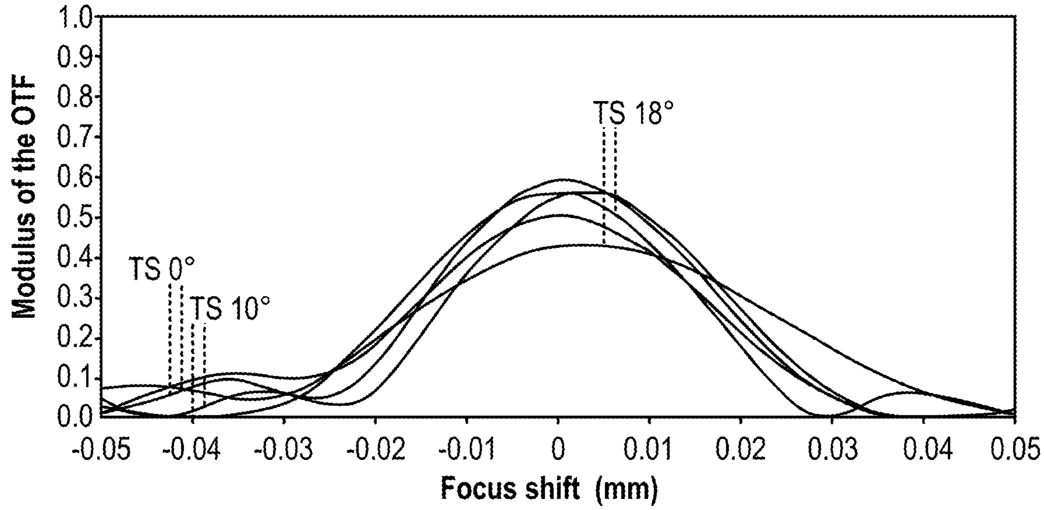
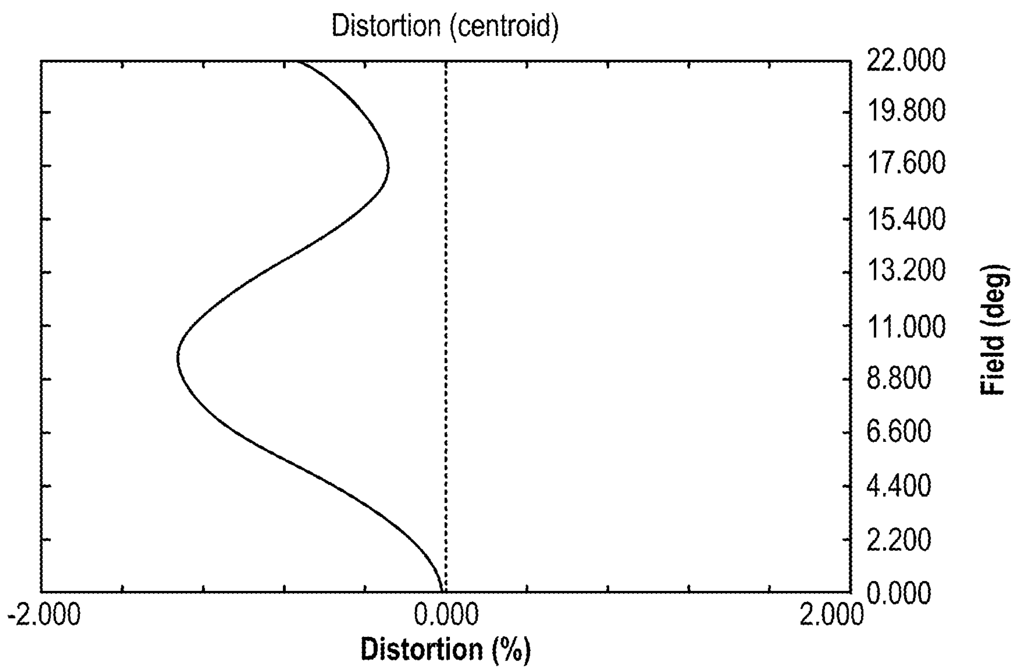
L1e
104b
110b
104a
108b
102b

FIG. 1A



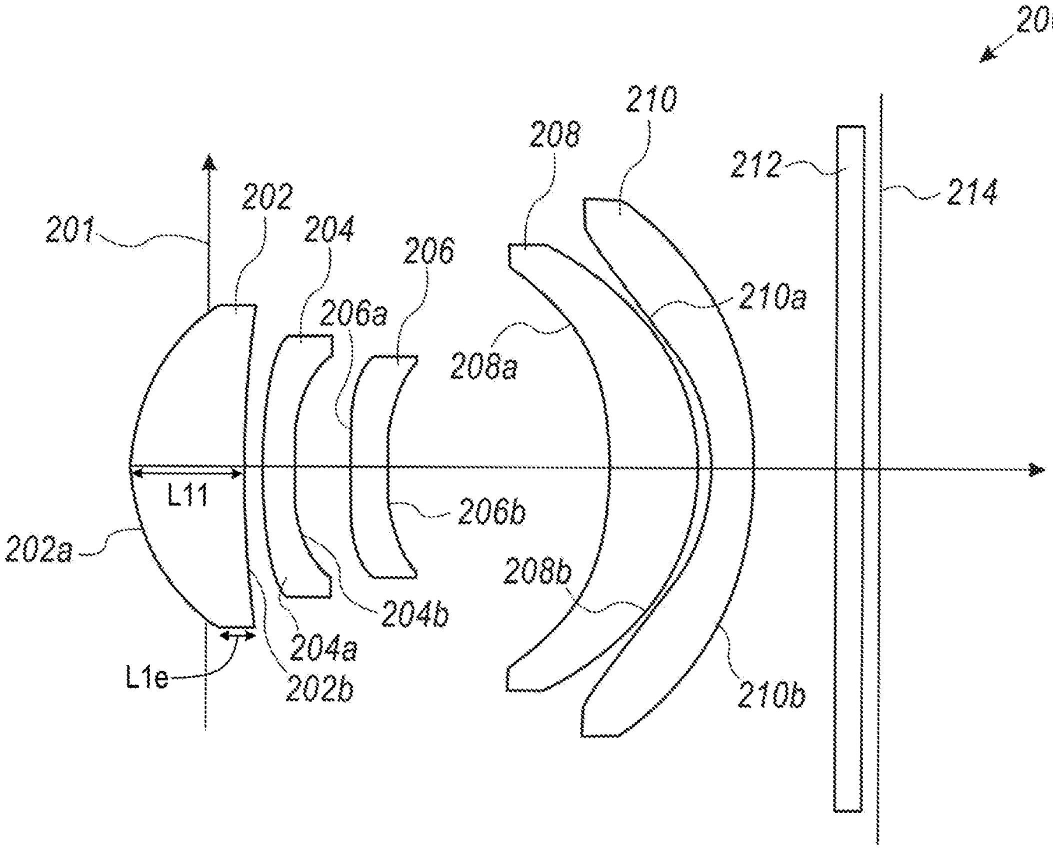

Polychromatic Diffraction Through Focus MTF
Angle 6/2/2013
Data for 0.4350 to 0.6560 µm.
Spatial Frequency: 180.0000 cycles/mm.

*FIG. 1B*




30/06/2013
Maximum distortion = 1.3%

*FIG. 1C*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208
212
214
201
202
204
206
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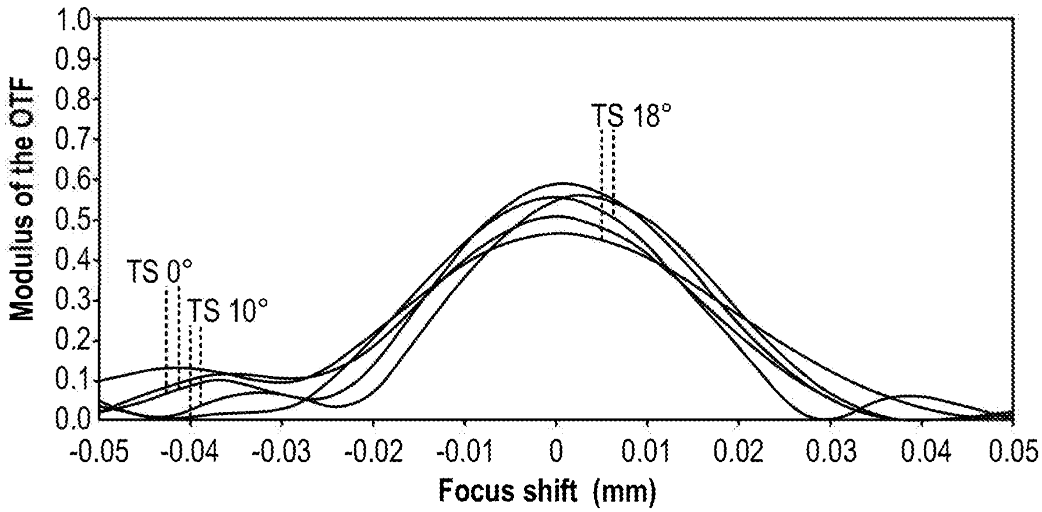
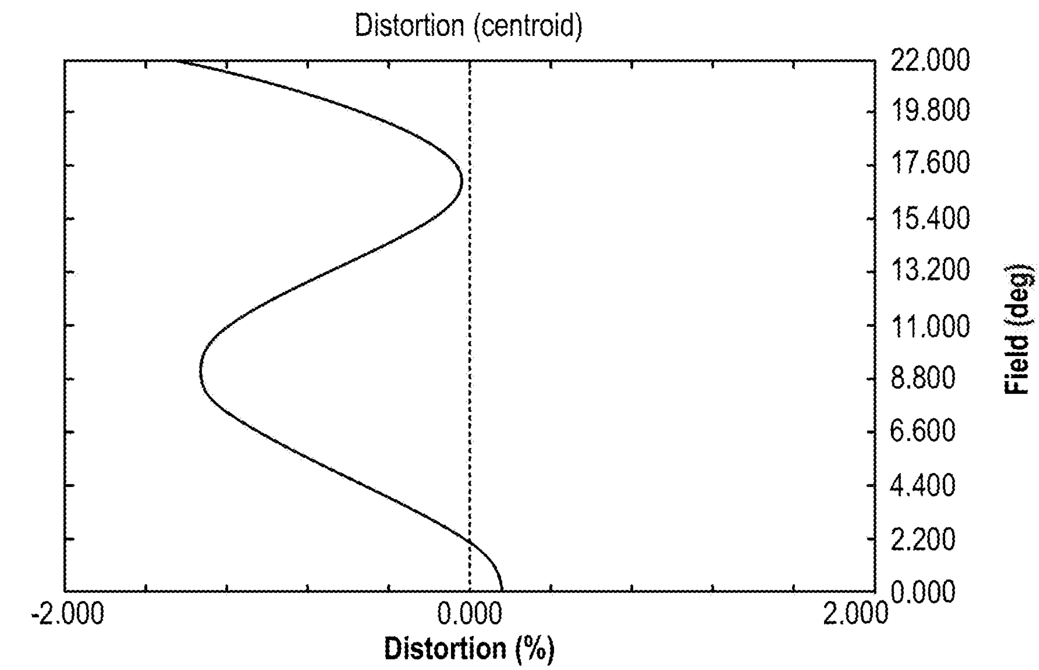
210a
208a
L11
206b
202a
208b
204b
204a
L1e
202b
210b

FIG. 2A



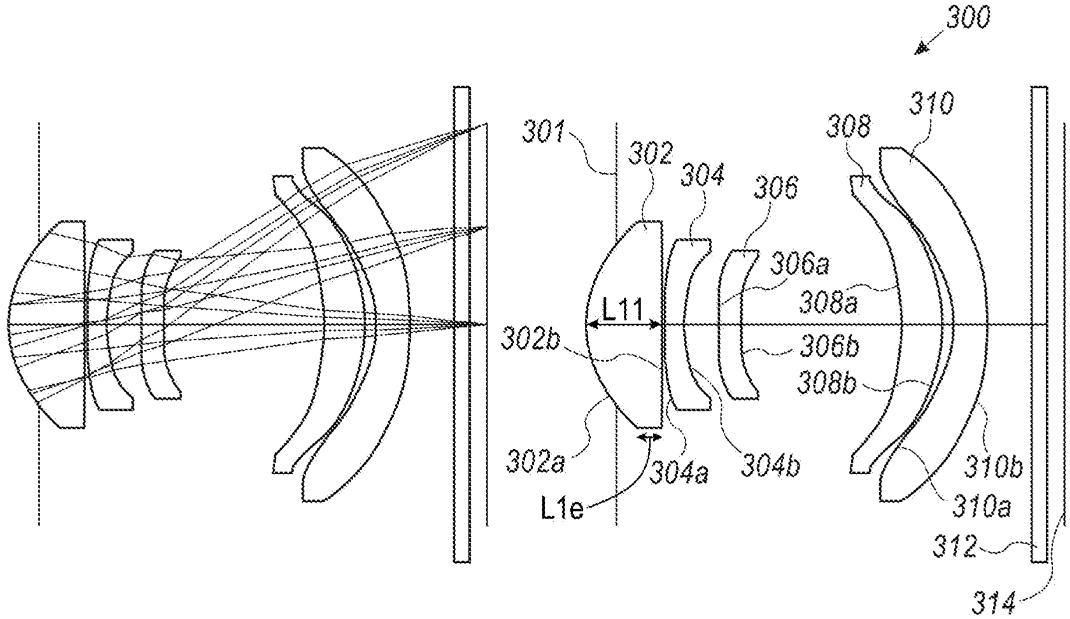

Polychromatic Diffraction Through Focus MTF
Angle 6/2/2013
Data for 0.4350 to 0.6560 μm.
Spatial Frequency: 180.0000 cycles/mm.

*FIG. 2B*




30/06/2013
Maximum distortion = 1.5%

*FIG. 2C*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302
304
306
308
310
306a
308a
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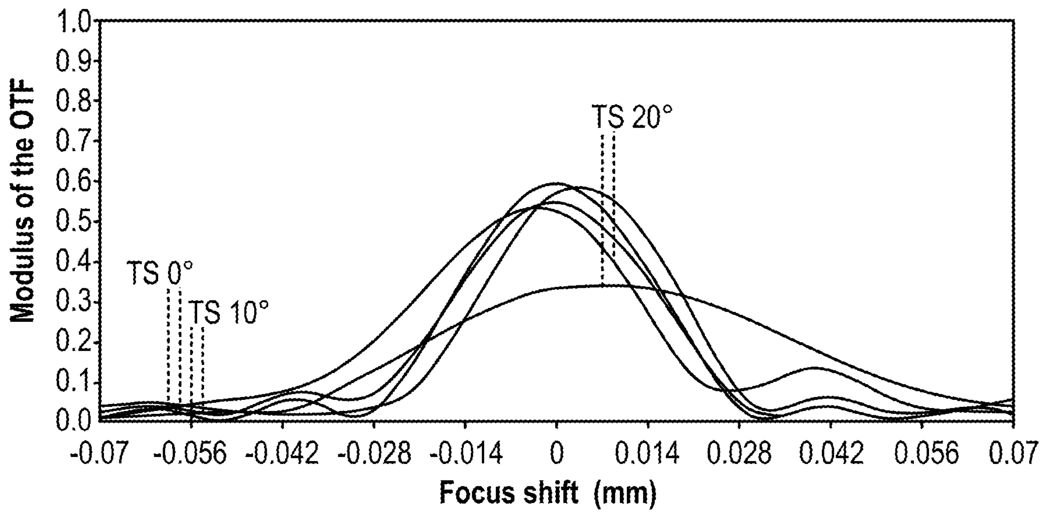
302b
306b
308b
302a
304a
304b
310b
310a
L1e
312
314

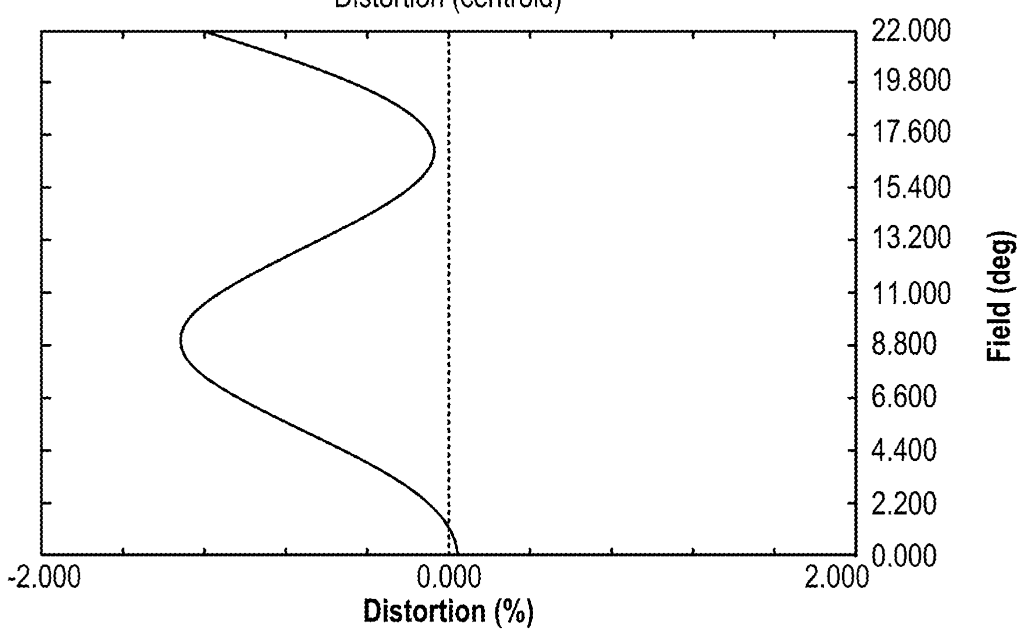
FIG. 3A




Polychromatic Diffraction Through Focus MTF
Angle 6/9/2013
Data for 0.4350 to 0.6560 μm.
Spatial Frequency: 180.0000 cycles/mm.

*FIG. 3B*

Distortion (centroid)




30/06/2013
Maximum distortion = 1.3%

*FIG. 3C*

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| Application Data Sheet 37 CFR 1.76 | Attorney Docket Number | COREPH-0080 US CON4 |
|---|---|---|
| | Application Number | |
| Title of Invention | MINIATURE TELEPHOTO LENS ASSEMBLY | |

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.
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| Postal Code | 7751025 | Country i | IL |

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| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | COREPH-0080 US CON4 |
|---|---|---|
| | Application Number | |
| Title of Invention | MINIATURE TELEPHOTO LENS ASSEMBLY | |

| **Prefix** | **Given Name** | **Middle Name** | **Family Name** | **Suffix** |
|---|---|---|---|---|
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| **Postal Code** | 6958313 | **Country** | IL |

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## Application Information:

| | | | |
|---|---|---|---|
| **Title of the Invention** | MINIATURE TELEPHOTO LENS ASSEMBLY | | |
| **Attorney Docket Number** | COREPH-0080 US CON4 | **Small Entity Status Claimed** | ☒ |
| **Application Type** | Nonprovisional | | |
| **Subject Matter** | Utility | | |
| **Total Number of Drawing Sheets (if any)** | 6 | **Suggested Figure for Publication (if any)** | A1 |

## 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 |
|---|---|---|
| | | |

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| Application Data Sheet 37 CFR 1.76 | Attorney Docket Number | COREPH-0080 US CON4 |
|---|---|---|
| | Application Number | |
| Title of Invention | MINIATURE TELEPHOTO LENS ASSEMBLY | |

## 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.

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|---|---|---|---|
| Customer Number | 92342 | | |

## 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 | 15817235 | 2017-11-19 |
| Prior Application Status | Pending | | Remove |
| Application Number | Continuity Type | Prior Application Number | Filing or 371(c) Date (YYYY-MM-DD) |
| 15817235 | Continuation of | 15418925 | 2017-01-30 |

| Prior Application Status | Patented | | | | Remove |
|---|---|---|---|---|---|
| Application Number | Continuity Type | Prior Application Number | Filing Date (YYYY-MM-DD) | Patent Number | Issue Date (YYYY-MM-DD) |
| 15418925 | Continuation of | 15170472 | 2016-06-01 | 9568712 | 2017-02-14 |
| Prior Application Status | Patented | | | | Remove |
| Application Number | Continuity Type | Prior Application Number | Filing Date (YYYY-MM-DD) | Patent Number | Issue Date (YYYY-MM-DD) |
| 15170472 | Continuation of | 14932319 | 2015-11-04 | 9402032 | 2016-07-26 |

| Application Data Sheet 37 CFR 1.76 | Attorney Docket Number | COREPH-0080 US CON4 |
|---|---|---|
| | Application Number | |
| Title of Invention | MINIATURE TELEPHOTO LENS ASSEMBLY | |

| Prior Application Status | Abandoned | | Remove |
|---|---|---|---|
| Application Number | Continuity Type | Prior Application Number | Filing or 371(c) Date (YYYY-MM-DD) |
| 14932319 | Continuation of | 14367924 | 2014-06-22 |
| Prior Application Status | Expired | | Remove |
| Application Number | Continuity Type | Prior Application Number | Filing or 371(c) Date (YYYY-MM-DD) |
| 14367924 | a 371 of international | PCT/IB2014/062465 | 2014-06-20 |
| Prior Application Status | Expired | | Remove |
| Application Number | Continuity Type | Prior Application Number | Filing or 371(c) Date (YYYY-MM-DD) |
| PCT/IB2014/062465 | Claims benefit of provisional | 61842987 | 2013-07-04 |
| 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.

| Application Data Sheet 37 CFR 1.76 | Attorney Docket Number | COREPH-0080 US CON4 |
|---|---|---|
| | Application Number | |

| Title of Invention | MINIATURE TELEPHOTO LENS ASSEMBLY |
|---|---|

## 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.

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 | COREPH-0080 US CON4 |
|---|---|---|
| | Application Number | |
| Title of Invention | MINIATURE TELEPHOTO LENS ASSEMBLY | |

## 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 | Corephotonics Ltd. | | |
| **Mailing Address Information For Applicant:** | | | |
| **Address 1** | 25 Habarzel St. | | |
| Address 2 | Ramat Hachayal | | |
| **City** | Tel-Aviv | **State/Province** | |
| **Country** | IL | Postal Code | 6971035 |
| 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.

| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | COREPH-0080 US CON4 |
|---|---|---|
| | Application Number | |
| Title of Invention | MINIATURE TELEPHOTO LENS ASSEMBLY | |

**Assignee 1**

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

Remove

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

| Prefix | **Given Name** | Middle Name | **Family Name** | Suffix |
|---|---|---|---|---|
| | | | | |

**Mailing Address Information For Assignee including Non-Applicant Assignee:**

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

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

## Signature:

Remove

**NOTE:** This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the <u>INITIAL</u> filing of the application <u>and</u> either box A or B is <u>not</u> 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 **<u>must</u>** 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, **<u>all</u>** 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 **<u>all</u>** joint inventor-applicants.

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

| **Signature** | /Menachem Nathan/ | | | Date (YYYY-MM-DD) | 2018-05-10 |
|---|---|---|---|---|---|
| First Name | MENACHEM | Last Name | NATHAN | Registration Number | 65392 |

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

| Application Data Sheet 37 CFR 1.76 | Attorney Docket Number | COREPH-0080 US CON4 |
|---|---|---|
| | Application Number | |
| Title of Invention | MINIATURE TELEPHOTO LENS ASSEMBLY | |

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.

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# DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

☒ Declaration Submitted With Initial Filing OR ☐ Declaration Submitted After Initial Filing (surcharge (37 CFR 1.16(f)) required)

| | |
|---|---|
| Attorney Docket Number | COREPH-0080 US CON4 |
| First Named Inventor | Michael Dror |
| *COMPLETE IF KNOWN* | |
| Application Number | |
| Filing Date | |
| Art Unit | |
| Examiner Name | |

MINIATURE TELEPHOTO LENS ASSEMBLY

*(Title of the Invention)*

As a below named inventor, I hereby declare that:

This declaration is directed to:

☒ The attached application,

OR

☐ United States Application Number or PCT International application number ______________________

filed on ______________________.

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

I believe 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.

Direct all correspondence to: ☒ The address associated with Customer Number: 92342 **OR** ☐ Correspondence address below

| | | |
|---|---|---|
| Name | | |
| Address | | |
| City | State | Zip |
| Country | Telephone | Email |



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 21 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.

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# DECLARATION — Utility or Design Patent Application

## 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. Petitioner/applicant is advised that documents which form the record of a patent application (such as the PTO/SB/01) are placed into the Privacy Act system of records DEPARTMENT OF COMMERCE, COMMERCE-PAT-7, System name: *Patent Application Files*. Documents not retained in an application file (such as the PTO-2038) are placed into the Privacy Act system of COMMERCE/PAT-TM-10, System name: *Deposit Accounts and Electronic Funds Transfer Profiles*.

**LEGAL NAME OF SOLE OR FIRST INVENTOR:**

(*E.g.,* Given Name (first and middle if any) and Family Name or Surname)

Michael Dror

| Inventor's Signature | Date (Optional) |
|---|---|
| /Michael Dror | |

| Residence: City | State | Country |
|---|---|---|
| Nes Ziona | | IL |

Mailing Address

5 Eliyahu Meron St.

| City | State | Zip | Country |
|---|---|---|---|
| Nes Ziona | 7401905 | Nes Ziona | IL |

☒ Additional inventors are being named on the 1 Supplemental sheet(s) PTO/AIA/10 attached hereto

# 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.

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| **SUPPLEMENTAL SHEET FOR DECLARATION** | **ADDITIONAL INVENTOR(S)** **Supplemental Sheet (for PTO/AIA/08,09)** Page 1 of 1 |
|---|---|

**Legal Name of Additional Joint Inventor, if any:**

(*E.g.*, Given Name (first and middle (if any)) and Family Name or Surname)
EPHRAIM GOLDENBERG

| | | | |
|---|---|---|---|
| Inventor's Signature /Ephraim Goldenberg/ | | | Date (Optional) |
| Residence: City Ashdod | State | Country IL | |
| Mailing Address 32 Tel Chai St. | | | |
| City Ashdod | State | Zip 7751025 | Country IL |

**Legal Name of Additional Joint Inventor, if any:**

(*E.g.*, Given Name (first and middle (if any)) and Family Name or Surname)
GAL SHABTAY

| | | | |
|---|---|---|---|
| Inventor's Signature /GAL SHABTAY/ | | | Date (Optional) |
| Residence: City Tel Aviv | State | Country IL | |
| Mailing Address 4 Shmuel Shnitzer St. | | | |
| City Tel Aviv | State | Zip 6958313 | Country IL |

**Legal Name of Additional Joint Inventor, if any:**

(*E.g.*, Given Name (first and middle (if any)) and Family Name or Surname)

| | | | |
|---|---|---|---|
| Inventor's Signature | | | Date (Optional) |
| Residence: City | State | Country | |
| Mailing Address | | | |
| City | State | Zip | Country |

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 21 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 (1-800-786-9199) and select option 2.*

## Privacy Act Statement

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

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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.

# Electronic Patent Application Fee Transmittal

| | |
|---|---|
| **Application Number:** | |
| **Filing Date:** | |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Filer:** | Menachem Nathan |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |

Filed as Small Entity

**Filing Fees for Utility under 35 USC 111(a)**

| Description | Fee Code | Quantity | Amount | Sub-Total in USD($) |
|---|---|---|---|---|
| **Basic Filing:** | | | | |
| UTILITY FILING FEE (ELECTRONIC FILING) | 4011 | 1 | 75 | 75 |
| UTILITY SEARCH FEE | 2111 | 1 | 330 | 330 |
| UTILITY EXAMINATION FEE | 2311 | 1 | 380 | 380 |
| **Pages:** | | | | |
| **Claims:** | | | | |
| CLAIMS IN EXCESS OF 20 | 2202 | 10 | 50 | 500 |
| **Miscellaneous-Filing:** | | | | |
| **Petition:** | | | | |

| Description | Fee Code | Quantity | Amount | Sub-Total in USD($) |
|---|---|---|---|---|
| **Patent-Appeals-and-Interference:** | | | | |
| **Post-Allowance-and-Post-Issuance:** | | | | |
| **Extension-of-Time:** | | | | |
| **Miscellaneous:** | | | | |
| | **Total in USD ($)** | | | **1285** |

# Electronic Acknowledgement Receipt

| | |
|---|---|
| **EFS ID:** | 32591809 |
| **Application Number:** | 15976391 |
| **International Application Number:** | |
| **Confirmation Number:** | 1858 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Customer Number:** | 92342 |
| **Filer:** | Menachem Nathan |
| **Filer Authorized By:** | |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |
| **Receipt Date:** | 10-MAY-2018 |
| **Filing Date:** | |
| **Time Stamp:** | 15:56:45 |
| **Application Type:** | Utility under 35 USC 111(a) |

## Payment information:

| | |
|---|---|
| Submitted with Payment | yes |
| Payment Type | CARD |
| Payment was successfully received in RAM | $1285 |
| RAM confirmation Number | 051118INTEFSW15584200 |
| Deposit Account | |
| Authorized User | |

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

## File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 1 | Specification | filing.pdf | 191895<br>8f6c7ffa367ec0ec2edbbec9ee0ca039aea740b7 | no | 15 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 2 | Drawings-only black and white line drawings | Figures.pdf | 2312628<br>cabd01b5ecb74d26f32ba0dcbe9c3f909b3a276c | no | 6 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 3 | Application Data Sheet | ADS.pdf | 1312765<br>4bca8d8078dc10d88d074b33214d6d2f24215782 | no | 9 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 4 | Oath or Declaration filed | Declaration.pdf | 102163<br>623db702c047a9fdd0291fd6421916c27e4f080d | no | 3 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 5 | Oath or Declaration filed | Supplemental_declaration.pdf | 207453<br>403f0fbfe7848c0b67035732f708e13bac6369bc | no | 2 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 6 | Fee Worksheet (SB06) | fee-info.pdf | 36421<br>7938164cc9395e59074abe582c86a8a4254e22a7 | no | 2 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |

| | |
|---|---|
| **Total Files Size (in bytes):** | 4163325 |

**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.**

# Electronic Acknowledgement Receipt

| | |
|---|---|
| **EFS ID:** | 32591809 |
| **Application Number:** | 15976391 |
| **International Application Number:** | |
| **Confirmation Number:** | 1858 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Customer Number:** | 92342 |
| **Filer:** | Menachem Nathan |
| **Filer Authorized By:** | |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |
| **Receipt Date:** | 10-MAY-2018 |
| **Filing Date:** | |
| **Time Stamp:** | 15:56:45 |
| **Application Type:** | Utility under 35 USC 111(a) |

## Payment information:

| | |
|---|---|
| Submitted with Payment | yes |
| Payment Type | CARD |
| Payment was successfully received in RAM | $1285 |
| RAM confirmation Number | 051118INTEFSW15584200 |
| Deposit Account | |
| Authorized User | |

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

## File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 1 | Specification | filing.pdf | 191895<br>8f6c7ffa367ec0ec2edbbec9ee0ca039aea740b7 | no | 15 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 2 | Drawings-only black and white line drawings | Figures.pdf | 2312628<br>cabd01b5ecb74d26f32ba0dcbe9c3f909b3a276c | no | 6 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 3 | Application Data Sheet | ADS.pdf | 1312765<br>4bca8d8078dc10d88d074b33214d6d2f24215782 | no | 9 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 4 | Oath or Declaration filed | Declaration.pdf | 102163<br>623db702c047a9fdd0291fd6421916c27e4f080d | no | 3 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 5 | Oath or Declaration filed | Supplemental_declaration.pdf | 207453<br>403f0fbfe7848c0b67035732f708e13bac6369bc | no | 2 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 6 | Fee Worksheet (SB06) | fee-info.pdf | 36421<br>7938164cc9395e59074abe582c86a8a4254e22a7 | no | 2 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |

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|---|---|
| **Total Files Size (in bytes):** | 4163325 |

**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.**
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**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/AIA/80 (07-17)
Approved for use through 01/31/2018. OMB 0651-0035
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

# POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(c).

I hereby appoint:

[X] Practitioners associated with Customer Number: 92342

**OR**

[ ] Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

| Name | Registration Number | Name | Registration Number |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

As attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(c).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(c) to:

[X] The address associated with Customer Number: 92342

**OR**

[ ]

| Firm or individual name | | |
|---|---|---|
| Address | | |
| City | State | Zip |
| Country | | |
| Telephone | Email | |

Assignee name and address: Corephotonics Ltd.
25 Habarzel St.
Ramat Hachayal
Tel-Aviv, 6971035
ISRAEL

**A copy of this form, together with a statement under 37 CFR 3.73(c) (Form PTO/AIA/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(c) may be completed by one of the practitioners appointed in this form, and must identify the application in which this Power of Attorney is to be filed.**

**SIGNATURE of Assignee of Record**

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee.

| Signature /Gal Shabtay/ | Date 05-10-2018 |
|---|---|
| Name GAL SHABTAY | Telephone |
| Title VP-R&D | |

This collection of information is required by 37 CFR 1.31, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public, which is to update (and by the USPTO to process) the file of a patent or reexamination proceeding. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 18 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.*

# 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.

# Electronic Acknowledgement Receipt

| | |
|---|---|
| **EFS ID:** | 32591983 |
| **Application Number:** | 15976391 |
| **International Application Number:** | |
| **Confirmation Number:** | 1858 |
| **Title of Invention:** | MINIATURE TELEPHOTO LENS ASSEMBLY |
| **First Named Inventor/Applicant Name:** | Michael Dror |
| **Customer Number:** | 92342 |
| **Filer:** | Menachem Nathan |
| **Filer Authorized By:** | |
| **Attorney Docket Number:** | COREPH-0080 US CON4 |
| **Receipt Date:** | 10-MAY-2018 |
| **Filing Date:** | |
| **Time Stamp:** | 16:04:01 |
| **Application Type:** | Utility under 35 USC 111(a) |

## Payment information:

| | |
|---|---|
| Submitted with Payment | no |

## File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 1 | Assignee showing of ownership per 37 CFR 3.73 | Assignment.pdf | 59451<br>b55fbf80ac4fc12638ea9dcdda58a0e52aa2690a | no | 1 |

**Warnings:**

| | | | | | |
|---|---|---|---|---|---|
| **Information:** | | | | | |
| 2 | Assignee showing of ownership per 37 CFR 3.73 | STATEMENT.pdf | 144436<br>7c97fb8cbaecdeab7f50b3b2876e7df978febcf7 | no | 3 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| 3 | Power of Attorney | POA.pdf | 537542<br>2412ff065f30b35fd2125e100e3f6c51c711de31 | no | 2 |
| **Warnings:** | | | | | |
| **Information:** | | | | | |
| | | **Total Files Size (in bytes):** | 741429 | | |

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**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.**

# ASSIGNMENT

For good and valuable consideration, the receipt and sufficiency of which is hereby acknowledged, the undersigned:

MICHAEL DROR EPHRAIM GOLDENBERG GAL SHABTAY

(hereinafter called the "assignor(s)"), hereby sell(s), assign(s) and transfer(s) to:

Corephotonics Ltd.
25 Habarzel St.
Ramat Hachayal, Tel-Aviv, 6971035
Israel

(hereinafter called the "assignee(s)"), its/his successors, assignees, nominees or other legal representatives, the Assignor's entire right, title and interest in and to the invention entitled:

**MINIATURE TELEPHOTO LENS ASSEMBLY**

described and claimed in the following US Continuation in part Application No. 15/976,391identified as Attorney docket No. COREPH-0080 US CON4 filed 05-10-2018;
and in and to said Patent Applications, and all original and reissued Patents granted therefor, and all divisions and continuations thereof, including the right to apply and obtain Patents in all other countries, the priority rights under International Conventions, and the Letters Patent which may be granted thereon;

Signed and sealed this10 day of May 2018

MICHAEL DROR / Michael Dror /

EPHRAIM GOLDENBERG / Ephraim Goldenberg /

GAL SHABTAY / Gal Shabtay /

PTO/AIA/96 (08-12)
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# STATEMENT UNDER 37 CFR 3.73(c)

Applicant/Patent Owner: Corephotonics Ltd.

Application No./Patent No.: 15/976,391 Filed/Issue Date: 2018-05-10

Titled: MINIATURE TELEPHOTO LENS ASSEMBLY

Corephotonics Ltd., a COMPANY

(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that, for the patent application/patent identified above, it is (choose **one** of options 1, 2, 3 or 4 below):

1. ☑ The assignee of the entire right, title, and interest.

2. ☐ An assignee of less than the entire right, title, and interest (check applicable box):

☐ The extent (by percentage) of its ownership interest is ____________%. Additional Statement(s) by the owners holding the balance of the interest must be submitted to account for 100% of the ownership interest.

☐ There are unspecified percentages of ownership. The other parties, including inventors, who together own the entire right, title and interest are:

Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

3. ☐ The assignee of an undivided interest in the entirety (a complete assignment from one of the joint inventors was made). The other parties, including inventors, who together own the entire right, title, and interest are:

Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

4. ☐ The recipient, via a court proceeding or the like (*e.g.*, bankruptcy, probate), of an undivided interest in the entirety (a complete transfer of ownership interest was made). The certified document(s) showing the transfer is attached.

The interest identified in option 1, 2 or 3 above (not option 4) is evidenced by either (choose **one** of options A or B below):

A. ☑ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel ____________, Frame ____________, or for which a copy thereof is attached.

B. ☐ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: ________________________ To: ________________________

The document was recorded in the United States Patent and Trademark Office at

Reel ____________, Frame ____________, or for which a copy thereof is attached.

2. From: ________________________ To: ________________________

The document was recorded in the United States Patent and Trademark Office at

Reel ____________, Frame ____________, or for which a copy thereof is attached.



This collection of information is required by 37 CFR 3.73(b). 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 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.*

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## STATEMENT UNDER 37 CFR 3.73(c)

3. From: ________________________ To: ________________________

The document was recorded in the United States Patent and Trademark Office at

Reel ____________, Frame ____________, or for which a copy thereof is attached.

4. From: ________________________ To: ________________________

The document was recorded in the United States Patent and Trademark Office at

Reel ____________, Frame ____________, or for which a copy thereof is attached.

5. From: ________________________ To: ________________________

The document was recorded in the United States Patent and Trademark Office at

Reel ____________, Frame ____________, or for which a copy thereof is attached.

6. From: ________________________ To: ________________________

The document was recorded in the United States Patent and Trademark Office at

Reel ____________, Frame ____________, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet(s).

☐ As required by 37 CFR 3.73(c)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

| | |
|---|---|
| /GAL SHABTAY/ | 05-03-2018 |
| Signature | Date |
| GAL SHABTAY | VP-R&D |
| Printed or Typed Name | Title or Registration 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.