



- (51) International Patent Classification:
A61B 1/00 (2006.01) A61B 1/012 (2006.01)
- (21) International Application Number:
PCT/US2016/013657
- (22) International Filing Date:
15 January 2016 (15.01.2016)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
62/106,483 22 January 2015 (22.01.2015) US
- (71) Applicant: ARIZONA BOARD OF REGENTS ON BEHALF OF THE UNIVERSITY OF ARIZONA [US/US]; 220 West Sixth Street, 4th Floor, Tucson, AZ 85701 (US).
- (72) Inventor: RONGGUANG, Liang; 4815 N Rock Canyon Road, Tucson, AZ 85750 (US).
- (74) Agents: HAUN, Niels et al.; Dann, Dorfman, Herrell and Skillman, P.C., 1601 Market Street, Suite 2400, Philadelphia, PA 19103-2307 (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, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, 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, ST, 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:

- 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: LOW-COST COMPACT DISPOSABLE IMAGING PROBE

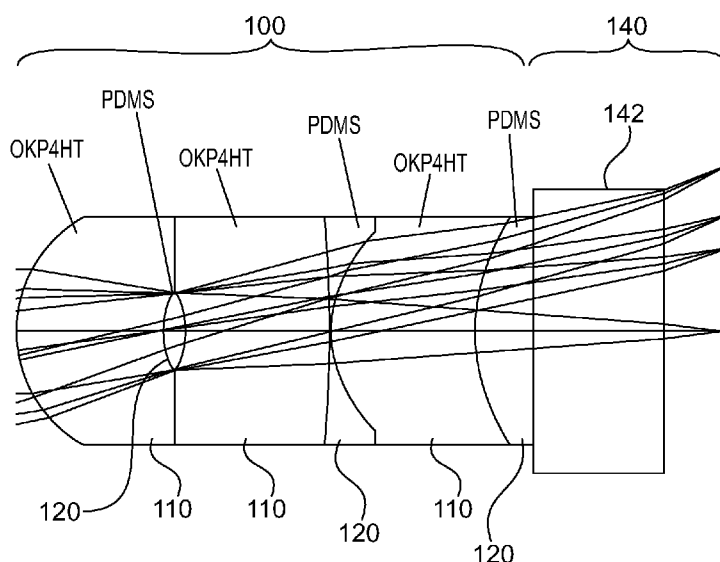


FIG. 1

(57) Abstract: Disposable imaging probes having adhesive lenses and/or other mounting features to provide a housing-free, compact design.



LOW-COST COMPACT DISPOSABLE IMAGING PROBE

Rongguang Liang

Related Applications

[0001] The present application claims the benefit of priority of U.S. Provisional Application No. 62/106,483, filed on January 22, 2015, the entire contents of which application(s) are incorporated herein by reference

Field of the Invention

[0002] The present invention relates generally to disposable endoscopes and small imaging probes, and more particularly, but not exclusively, to disposable endoscopes and imaging probes that are low-cost and have a relatively smaller diameter than existing endoscopes or probes. Although certain exemplary structures may be presented herein as an endoscope, it is to be understood that instant disclosure extends to any form of optical imaging probe.

Background of the Invention

[0003] Healthcare organizations can be expected to turn to disposables as a means to reduce potential harm to patients and staff, and federal and accreditation organizations may be expected to apply pressure to health care organizations to use disposable endoscopes for this reason. Reduced risk to patients is expected, for example, due to the elimination of cross-contamination between patients when a disposable endoscope is used. However, existing endoscopes suffer from a number of disadvantages that are inhibiting more widespread adoption, such as: an unacceptably large size (diameter), high cost, a lack of an illumination system as part of the endoscope, and insufficient resolution due to a limited number of pixels in a sensor or fiber bundle. Thus, there remains a need in the art for improved disposable endoscopes that address one or more of these disadvantages. For example, in the field of imaging probes, the solutions provided in the instant disclosure will also serve to improve upon similar size limitations.

Summary

[0004] In one of its aspects, the present invention relates to improvements in disposable endoscopes made possible by a recognition by the instant inventor that the presence of air gaps between optical elements in current endoscope objectives contributes to an overall enlarged diameter. In such prior objectives, spacers are needed to maintain the correct air gaps, and such spacers increase the diameter of the objective, as well as the cost and complexity. Moreover, a lens housing is required to hold the lens elements of the objective in the proper positions, also increasing the diameter and cost of existing objectives. Thus, in one of its aspects, the present invention provides an objective lens that contains no air gaps between lens elements, but rather the spaces between the lens elements are filled with an optically clear adhesive material. The presence of an optical adhesive may not only eliminate the need for a spacer, but can also eliminate the need for a lens housing. Moreover, unlike existing cemented doublets, the optical adhesive of the objectives of the present invention may be sufficiently thick and shaped to have optical power. As such, rather than air gaps, the present invention provides one or more optical adhesive lenses between conventional lens elements, which adhesive lenses not only adhere adjacent conventional lens elements to one another and maintain proper spacing therebetween, but also provide optical power to the objective. (As used herein, the term “conventional lens element” is defined to mean a lens made from an optical material that does not have adhesive properties, *e.g.*, glass or optical plastic; a cemented doublet is considered a conventional lens element, wherein the optical cement is sufficiently thin to effectively eliminate any optical power that could be attributed to the cement. As used herein, the term “adhesive lens” is defined to mean a lens element made from an optical material that has adhesive properties, *e.g.*, an optical adhesive or cement, such as polydimethylsiloxane (PDMS), and is shaped and sufficiently thick to exhibit optical power. Indeed, in one particularly desirable configuration, the conventional lens elements may be connected to one another by an adhesive lens, so the entire optical train forms one continuous mechanical structure. As such, the use of conventional spacers and/or an additional housing to retain and support such an objective is not required, leading to a further reduction in overall diameter. Optionally,

the objective may be adhered to an image sensor directly. The combination of the above features are expected to reduce complexity and cost of objectives of the present invention leading to a low-cost and compact endoscope.

[0005] In yet another of its aspects the present invention may provide endoscopes or, more generally, imaging probes that include an integrated illumination system, eliminating the current need for an external illumination system. Still further, in another of its aspects the present invention may provide a further approach for reducing the diameter of an objective lens through the use of rods that are provided to hold lens elements.

Brief Description of the Drawings

[0006] The foregoing summary and the following detailed description of exemplary embodiments of the present invention may be further understood when read in conjunction with the appended drawings, in which:

[0007] Figure 1 schematically illustrates an exemplary configuration of an objective lens in accordance with the present invention having both conventional and adhesive lens elements;

[0008] Figure 2 schematically illustrates an exemplary configuration of an objective lens in accordance with the present invention having an illumination system;

[0009] Figure 3 schematically illustrates the relatively reduced diameter of an objective lens of the present invention compared to a traditional objective with and without a housing;

[0010] Figures 4A and 4B schematically illustrate end and side elevational views, respectively, of an exemplary configuration for reducing the diameter of an objective lens in accordance with the present invention comprising the use of rods to hold the lens elements; and

[0011] Figures 5A and 5B schematically illustrate an objective lens in accordance with the present invention having an illumination system comprising optical fibers or an optical lightguide, respectively.

Detailed Description of the Invention

[0012] Referring now to the figures, Figure 1 schematically illustrates an objective lens 100 in accordance with the present invention which includes both conventional lens elements 110 and adhesive lens elements 120. Specifically, the conventional lens elements 110 may include a traditional optical material such as a glass or a plastic. As illustrated, the conventional lens elements 110 are labeled as comprising an optical grade polyester, namely OKP4HT (Osaka Gas Chemicals Co., Ltd., Osaka, Japan). The adhesive lens elements 120 may include an optical adhesive or cement, such as polydimethylsiloxane (PDMS). Other adhesives may be used for the adhesive lens elements 120, such as, NuSil Lightspan™ LS-3140 or LS-3354 Silicone Optical Gel (Nusil Technology, LLC, Carpinteria, CA), Norland Optical Adhesive NOA 1315 and NOA 164 (Norland Products, Cranbury, NJ), and/or Masterbond® MasterSil MS151 (Hackensack, NJ), for example. Moreover, the adhesive lens elements 120 may comprise different adhesives, so that some adhesive lens elements 120 comprise a first adhesive and other adhesive lens elements 120 comprise a second, different adhesive. As illustrated in Fig. 1, all conventional lens elements 110 may have an adhesive lens element 120 disposed therebetween. Thus, each conventional lens element 110 may be adhesively attached to its adjacent conventional lens element 110 via an adhesive lens element 120. Moreover, the objective 100 may be adhesively attached to a sensor 140 comprising a sensor window 142 via an adhesive lens element 120. In such a configuration, all optical elements 110, 120, both conventional and adhesive, as well as the sensor 140, may be adhesively attached to one another. As such no additional structure is required to hold the conventional 110 and adhesive lens elements 120 and/or sensor 140 in place. For example, a housing is not required for exemplary designs of the present invention. In addition, the use of adhesive lenses 120 obviates the need for conventional spacers to maintain proper spacing between the conventional lens elements 110. An illustration of the potential reduction in objective lens diameter is illustrated in Fig. 3, where the inner solid circle schematically illustrates the diameter of an objective lens 100 of the present invention, and the outer dashed circles illustrate the diameter of a traditional objective D2 and the diameter of a traditional objective with the required

housing D3, respectively. (The objectives being compared have the same f-number and field of view.) The diameter of an objective lens 100 of the present invention may be 50% smaller than the diameter D3 of a traditional objective lens with housing in place. The sensor 140 may include any suitable sensor such as a CMOS sensor comprising 400 x 400 pixels and overall size of 0.97 x 0.97 mm, such as OV6946 (Omnivision Technologies Inc, CA).

[0013] The first order layout of the lens of Fig. 1 is provided in Tables 1 – 4.

[0014] Without the need for a housing, designs of the present invention are particularly well-suited to the inclusion of an optical illumination system, Figs. 2, 5A, 5B. For example, the reduced diameter D1 of the objective lens 100 of the present invention is well-suited for the inclusion of optical fibers 152, such as a ring 150 of multimode optical fibers 152 disposed around the periphery of the objective lens 100, Figs. 2, 5A. With 50 μ m multimode fibers, the diameter of the objective lens 100 will increase by only 0.13 mm. In place of optical fibers, a lightguide 160 may be provided, Fig. 5B. The lightguide 160 may be a cylindrical hollow tube with a small wall thickness. The light entering the lightguide 160 wall will propagate to the other end of the lightguide 160. This lightguide 160 may also function as a lens housing as well, in addition to its main function as a lightguide 160.

Surf	Type	Radius (mm)	Thickness (mm)	Material		Diameter	Conic Constant (K)
				Index	V-number		
OBJ	SPHERE	INFINITY	50			21.92192	0
1	SPHERE	INFINITY	1	PMMA		1.173004	0
2	SPHERE	INFINITY	0.5			0.6991657	0
3	SPHERE	INFINITY	0			0	0
4	EVEN ASPHERE	0.5160716	0.5	1.632000	23.000000	0.64	-0.6161094
STO	SPHERE	0.2624617	0.07	1.410000	56.000000	0.2776652	0
6	EVEN ASPHERE	-0.3242367	0.5	1.632000	23.000000	0.2764173	0
7	SPHERE	-5.666473	0	1.410000	56.000000	0.64	0
6	EVEN ASPHERE	0.3971016	0.5	1.632000	23.000000	0.72	0
9	SPHERE	0.6339695	0.2	1.410000	56.000000	0.64	0
10	SPHERE	INFINITY	0.445	1.516600	64.167336	0.64	0
11	SPHERE	INFINITY	0.2			0.64	0
IMA	SPHERE	INFINITY				0.64	0

TABLE 1

Surface 4	EVEN ASPHERE
Coefficient on r^2	0
Coefficient on r^4	0.46575367
Coefficient on r^6	5.0213661
Coefficient on r^6	-25.660374
Coefficient on r^{10}	211.02565
Coefficient on r^{12}	0
Coefficient on r^{14}	0
Coefficient on r^{16}	0

TABLE 2

Surface 6	EVEN ASPHERE
Coefficient on r^2	0
Coefficient on r^4	-2.6610242
Coefficient on r^6	362.30347
Coefficient on r^6	-15643.493
Coefficient on r^{10}	217604.37
Coefficient on r^{12}	0
Coefficient on r^{14}	0
Coefficient on r^{16}	0

TABLE 3

Surface 6	EVEN ASPHERE
Coefficient on r^2	0
Coefficient on r^4	-3.4576706
Coefficient on r^6	-0.4645116
Coefficient on r^6	26.623636
Coefficient on r^{10}	-662.50042
Coefficient on r^{12}	0
Coefficient on r^{14}	0
Coefficient on r^{16}	0

TABLE 4

[0015] In another of its aspects, the present invention may provide a configuration in which conventional lens elements 110 are retained in proper spacing relative to one another which may not include the use of adhesive lens elements 120. For example, in accordance with the present invention one or more rods 210, such as steel rods, may be disposed about the periphery of the lens elements 200, Figs. 4A, 4B. The rods 210 may extend along the length of the objective lens elements 200, Fig. 4B. To accommodate the rods 210, notches 212 may be provided in the periphery of the lens elements 200 in which the rods 210 may be seated, Fig. 4A. In such a case the rods 210 are disposed

interior to the diameter of the lens elements 200. The distances between lens elements may be maintained by contacting optical elements, so that traditional spacers and a lens housing may be eliminated.

[0016] These and other advantages of the present invention will be apparent to those skilled in the art from the foregoing specification. Accordingly, it will be recognized by those skilled in the art that changes or modifications may be made to the above-described embodiments without departing from the broad inventive concepts of the invention. It should therefore be understood that this invention is not limited to the particular embodiments described herein, but is intended to include all changes and modifications that are within the scope and spirit of the invention as set forth in the claims.

Claims

What is claimed is:

1. An imaging probe objective lens, comprising a conventional lens element and an adhesive lens element disposed in contact with the conventional lens element.
2. The probe objective lens of claim 1, comprising a pair of conventional lens elements, wherein the adhesive element is disposed in contact with each lens of the pair of conventional lens elements to adhere the pair of conventional lens elements to one another.
3. The probe objective lens of any one of the preceding claims, comprising a sensor, wherein the adhesive lens element is disposed in contact with the conventional lens element and the sensor to adhere the conventional lens to the sensor.
4. A probe objective lens, comprising a plurality of conventional lens elements and a plurality of rods disposed along the periphery of the lens elements and extending along the length of the objective lens to retain the lens elements in place.
5. The probe objective lens of claim 4, wherein the rods are disposed within the diameter of the lens.
6. The probe objective lens of any one of claims 4–5, comprising an adhesive element disposed in contact with each lens of an adjacent pair of conventional lens elements to adhere the pair of conventional lens elements to one another.
7. The probe objective lens of any one of claims 4–6, comprising a sensor and an adhesive lens element, wherein the adhesive lens element is disposed in contact with the conventional lens element and the sensor to adhere the conventional lens to the sensor.
8. The probe objective lens of any one of the preceding claims, comprising optical fibers disposed about the periphery of the lens and extending along the length of the lens.
9. The probe objective lens of any one of the preceding claims, comprising a lightguide disposed about the periphery of the lens and extending along the length of the lens.
10. The probe objective lens of any one of claims 1–3 and 6–9, wherein the adhesive lens has negative optical power.

11. The probe objective lens of any one of claims 1–3 and 6–10, wherein the adhesive lens element comprises an optical adhesive or cement.
12. The probe objective lens of any one of the preceding claims, wherein the conventional lens element comprises an optical glass or plastic.

1/4

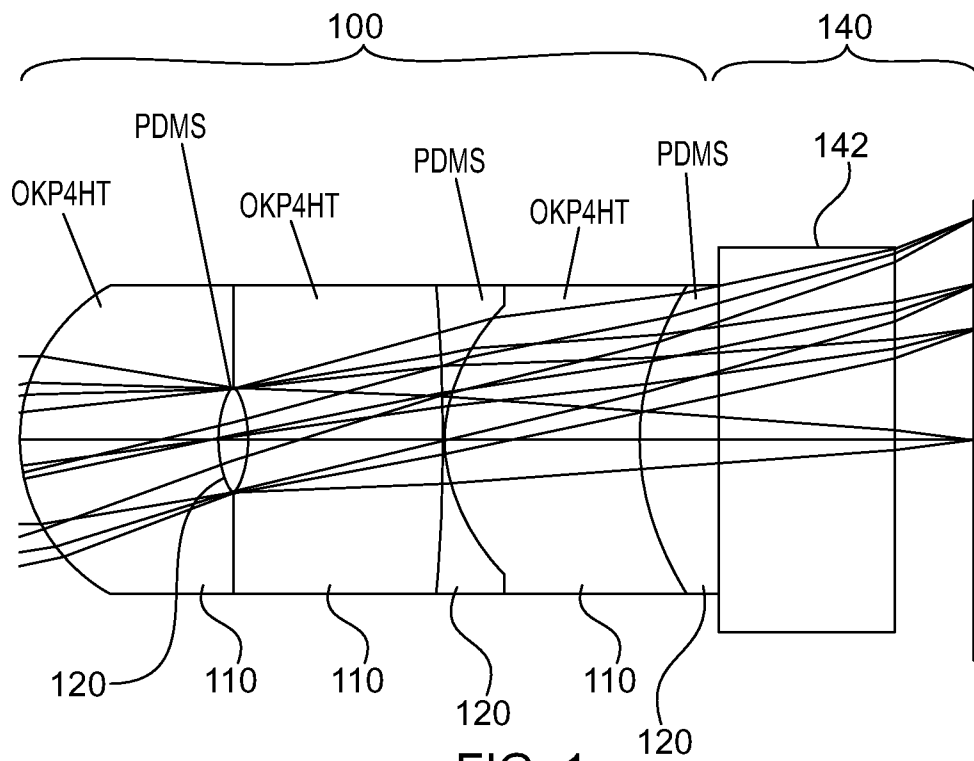


FIG. 1

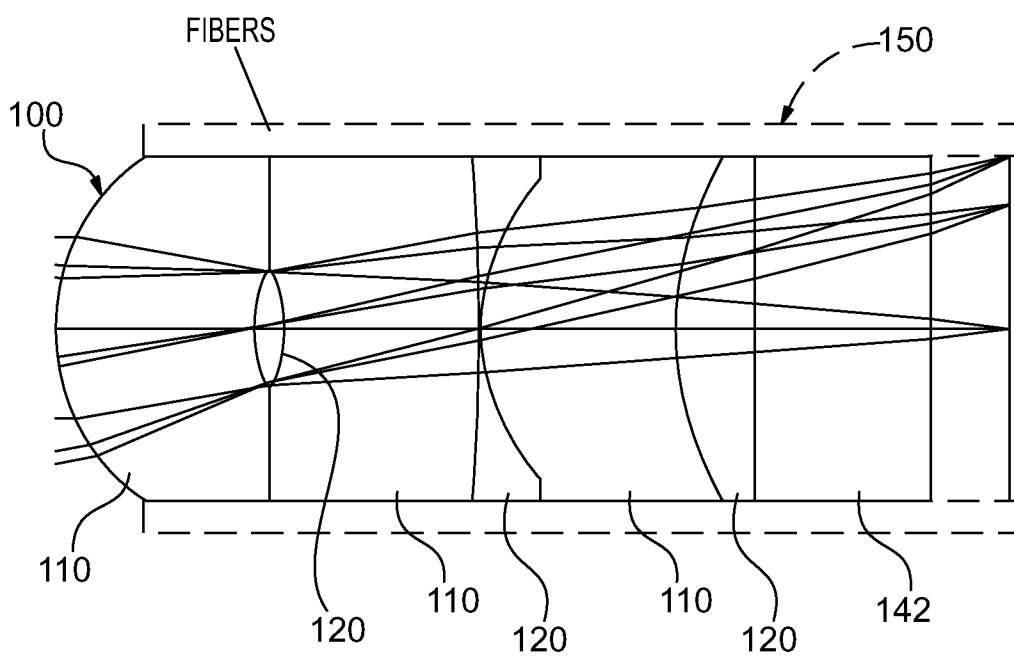


FIG. 2

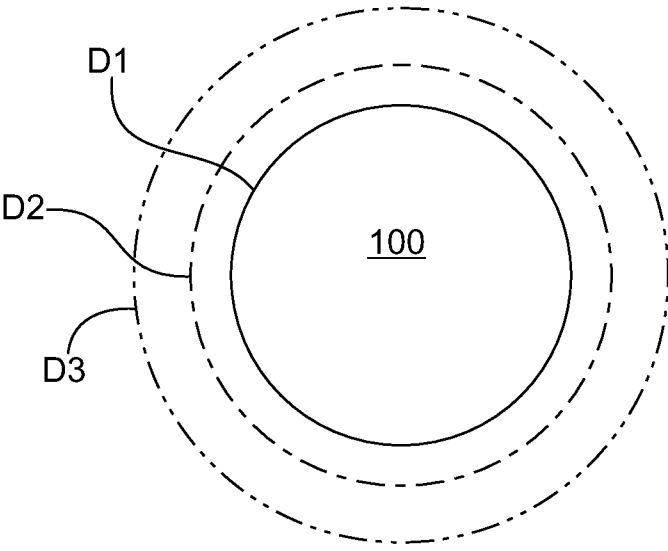
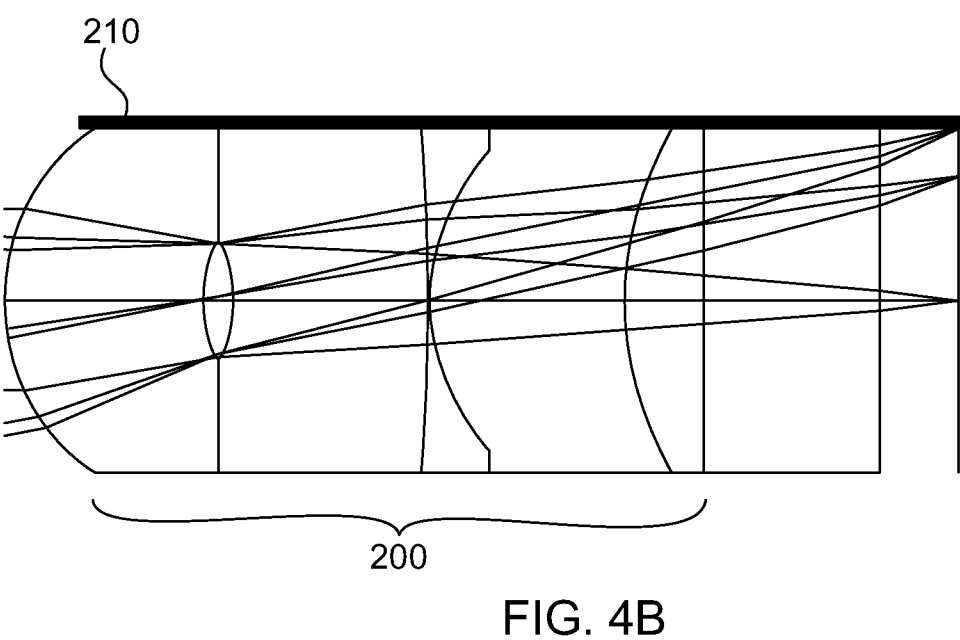
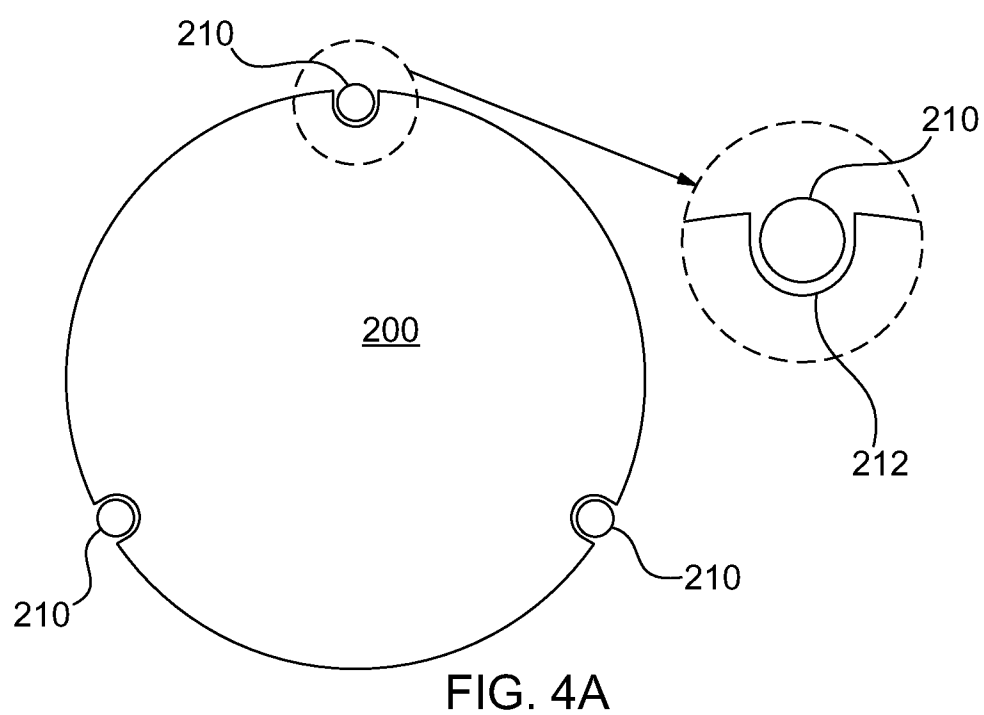


FIG. 3

3/4



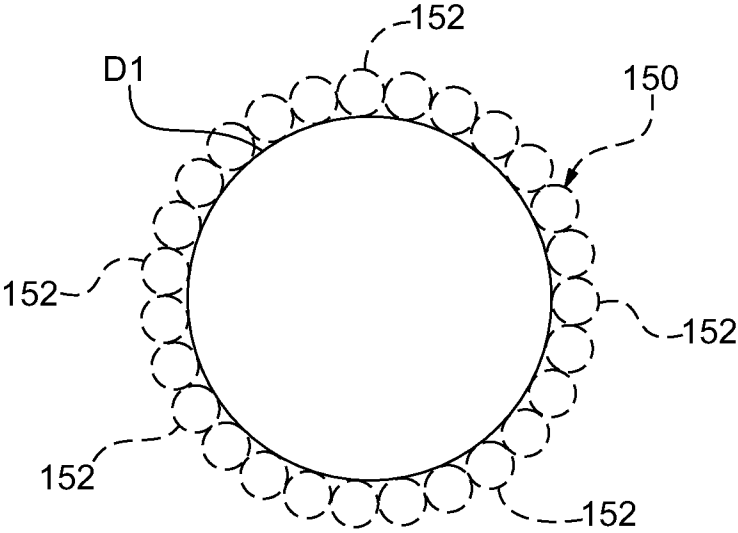


FIG. 5A

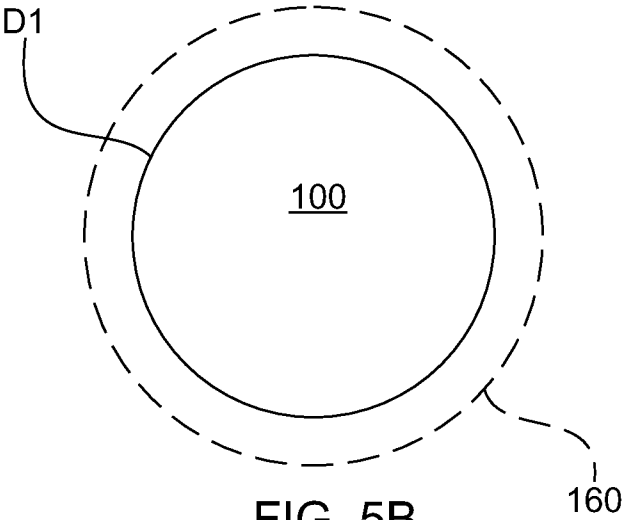


FIG. 5B

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 16/13657

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61B 1/00, A61B 1/012 (2016.01)

CPC - A61B 1/00064, A61B 1/00071, A61B 1/00137, A61B 1/00142, G02B 3/14, G02B 1/041

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)
 CPC - A61B 1/00064, A61B 1/00071, A61B 1/00137, A61B 1/00142, G02B 3/14, G02B 1/041
 IPC(8) - A61B1/00, A61B1/012 (2016.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
 CPC - A61B1/00064, A61B1/00071, A61B1/0008, A61B1/00096, A61B1/00137, A61B1/00142, G02B3/14, G02B1/041
 IPC(8) - A61B1/00, A61B1/012 (2016.01); USPC - 600/172

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

Patbase; Google Web; Freepatentsonline; Google Patent

Search terms used: objective lens compound composite stack layers adhesive properties intrinsic adhere endoscope optical imaging
 probe pdms polydimethylsiloxane norland mastersil disposable

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y --- A	US 2013/0237762 A1 (FENGLER et al.) 12 September 2013 (12.09.2013), para [0008], [0040], [0041]	1 ----- 2, 3
Y --- A	WO 2014/147060 A1 (POLIGHT AS) 25 September 2014 (25.09.2014), pg 24, ln 33-34; pg 4, ln 33-pg 5, ln 6	1 ----- 2, 3
A	US 2010/0165485 A1 (DO) 01 July 2010 (01.07.2010), entire document	1-3
A	WO 2014/048972 A1 (SOFRADIM PRODUCTION) 03 April 2014 (03.04.2014), entire document	1-3
A	US 2002/0091325 A1 (OSTROVSKY) 11 July 2002 (11.07.2002), para [0030]	1-3
A	US 6,236,513 R1 (MAILLARY) 22 May 2001 (22.05.2001), entire document	1-3
A	US 2001/0023314 A1 (DODOR et al.) 20 September 2001 (20.09.2001), entire document	1-3

☐ Further documents are listed in the continuation of Box C.


* 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

10 May 2016

Date of mailing of the international search report

03 JUN 2016

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
 P.O. Box 1450, Alexandria, Virginia 22313-1450
 Facsimile No. 571-273-8300

Authorized officer:

Lee W. Young

PCT Helpdesk: 571-272-4300
 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 16/13657

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.: 7-12
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:

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-3, drawn to an imaging probe.

Group II: Claims 4-6, drawn to a probe objective lens.

-- see extra 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 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.:
1-3

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.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 16/13657

Continuation of Box No. III -- Observations where unity of invention is lacking

The inventions listed as Groups I and II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Special Technical Features

Group I includes the special technical feature of an adhesive lens element disposed in contact with the conventional lens element, not included in the other group.

Group II includes the special technical feature of a plurality of rods disposed along the periphery of the lens elements, not included in the other group.

Common Technical Features:

The only technical feature shared by Groups I and II that would otherwise unify the groups, is an objective lens, comprising a conventional lens element. However, this shared technical feature does not represent a contribution over prior art, because the shared technical feature is disclosed by US 2007/0091288 A1 to Lin et al. (hereinafter Lin).

Lin discloses an objective lens, comprising a conventional lens element (para [0022]).

As the technical feature was known in the art at the time of the invention, this cannot be considered a special technical feature that would otherwise unify the groups.

Therefore, Groups I-II lack unity under PCT Rule 13.

Note: Claims 7-12 are determined to be unsearchable because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a) and are, therefore, not included in any claim group.