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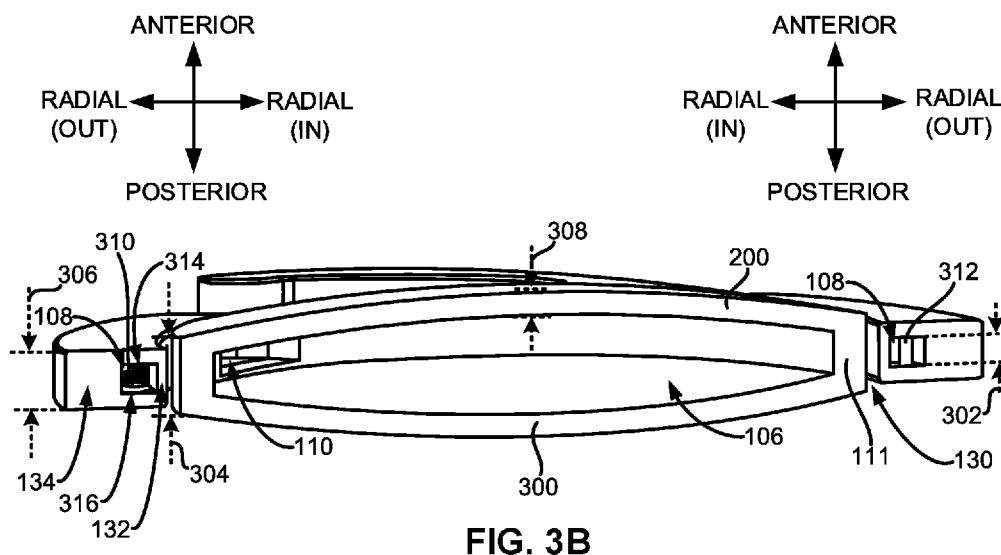


FIG. 3B

(57) Abstract: Disclosed are adjustable intraocular lenses and methods of adjusting intraocular lenses post-operatively. In one embodiment, an adjustable intraocular lens can comprise an optic portion and a peripheral portion. The peripheral portion can comprise a composite material comprising an energy absorbing constituent and a plurality of expandable components. A base power of the optic portion can be configured to change in response to an external energy directed at the composite material.



TITLE

**ADJUSTABLE INTRAOCULAR LENSES AND METHODS OF
POST-OPERATIVELY ADJUSTING INTRAOCULAR LENSES**

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application No. 62/911,039 filed on October 4, 2019, the entirety of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure relates generally to the field of intraocular lenses, and, more specifically, to adjustable intraocular lenses and methods of adjusting intraocular lenses post-operatively.

BACKGROUND

[0003] A cataract is a condition involving the clouding over of the normally clear lens of a patient's eye. Cataracts occur as a result of aging, hereditary factors, trauma, inflammation, metabolic disorders, or exposure to radiation. Age-related cataract is the most common type of cataracts. In treating a cataract, the surgeon removes the crystalline lens matrix from the patient's lens capsule and replaces it with an intraocular lens (IOL).

[0004] However, current IOL surgery may leave some patients unsatisfied with their refractive outcomes. In some cases, the pre-operative biometry measurements made on a patient's eye may be incorrect, leading to IOLs with the wrong lens power being prescribed and implanted within the patient. In other cases, once an IOL is implanted within the capsular bag, an aggressive healing response by tissue within the capsular bag can affect the optical power of the IOL. Moreover, a patient's cornea or muscles within the eye may change as a result of injury, disease, or aging. In such cases, it may also be necessary to adjust the patient's implanted IOLs to account for such changes.

[0005] Therefore, a solution is needed which allows for post-implant adjustment of IOLs to address the aforementioned problems without having to undergo additional surgery. Such a solution should not be overly complicated and still allow the IOLs to be cost-effectively manufactured.

SUMMARY

[0006] Disclosed herein are adjustable intraocular lenses and methods of adjusting intraocular lenses post-operatively. Such adjustable intraocular lenses can also be referred to as adjustable static-focus intraocular lenses or non-accommodating fluid-adjustable intraocular lenses.

[0007] In one embodiment, an intraocular lens is disclosed comprising an optic portion and a peripheral portion coupled to the optic portion. The peripheral portion can comprise a composite material comprising an energy absorbing constituent and a plurality of expandable components. A base power of the optic portion can be configured to change in response to an external energy directed at the composite material. The base power of the optic portion can be configured to be unresponsive to forces applied to the peripheral portion by a capsular bag when the intraocular lens is implanted within the capsular bag.

[0008] In some embodiments, the expandable components can be expandable microspheres. Each of the expandable microspheres can comprise a blowing agent contained within a thermoplastic shell. A thickness of the thermoplastic shell can be configured to change in response to the external energy directed at the composite material.

[0009] In certain embodiments, the blowing agent can be a branched-chain hydrocarbon. For example, the branched-chain hydrocarbon can be isopentane. Also, for example, the thermoplastic shell can be made in part of an acrylonitrile copolymer.

[0010] In some embodiments, the diameter of at least one of the expandable microspheres can be configured to increase between about 2X to about 4X in response to the external energy directed at the composite material. A volume of at least one of the expandable components can be configured to expand between about 10X to 50X in response to the external energy directed at the composite material.

[0011] In some embodiments, the expandable components can comprise between about 5% to about 15% by weight of the composite material. For example, the expandable components comprise about 10% by weight of the composite material.

[0012] In some embodiments, the energy absorbing constituent can be an energy absorbing colorant. A color of the energy absorbing colorant can be visually perceptible when the intraocular lens is implanted within the eye.

[0013] In some embodiments, the energy absorbing colorant can be a dye. For example, the dye can be an azo dye. As a more specific example, the dye can be a Disperse Red 1 dye.

1 [0014] In some embodiments, the energy absorbing colorant can be an energy absorbing
2 pigment. For example, the energy absorbing pigment can be graphitized carbon black. In
3 certain embodiments, the energy absorbing constituent can comprise between about 0.025% to
4 about 1.00% by weight of the composite material.

5 [0015] In some embodiments, the peripheral portion can be made in part of a cross-linked
6 copolymer comprising a copolymer blend. In these embodiments, the composite material can
7 also be made in part of the copolymer blend.

8 [0016] The composite material can be cured to the cross-linked copolymer at a location within
9 the peripheral portion. The composite material can remain substantially fixed at the location.

10 [0017] The base power of the optic portion can be configured to change between about ± 0.05
11 D to about ± 0.5 D in response to pulses of the external energy directed at the composite
12 material. For example, the base power of the optic portion can be configured to change by
13 about 0.1 D in response to the pulses of the external energy directed at the composite material.

14 [0018] The base power of the optic portion can be configured to change in total between about
15 ± 1.0 D and about ± 2.0 D. The change in the base power can be a persistent change.

16 [0019] In some embodiments, the external energy can be light energy. In these embodiments,
17 the light energy can be a laser light. The laser light can have a wavelength of between about
18 488 nm to about 650 nm. For example, the laser light can be a green laser light. The green
19 laser light can have a wavelength of about 532 nm.

20 [0020] In other embodiments, the laser light can have a wavelength of between about 946 nm
21 to about 1120 nm. For example, the laser light can have a wavelength of about 1030 nm. Also,
22 for example, the laser light can have a wavelength of about 1064 nm.

23 [0021] In some embodiments, the laser light can be emitted by a neodymium-doped yttrium
24 aluminum garnet (Nd:YAG) laser. In other embodiments, the laser light can be emitted by a
25 femtosecond laser.

26 [0022] The energy absorbing constituent can be configured to transfer thermal energy to the
27 plurality of expandable components in response to the external energy directed at the
28 composite material.

29 [0023] In some embodiments, the composite material can be formed as discrete peripheral
30 components such that directing the external energy at one discrete peripheral component
31 causes a change in the base power of the optic portion and directing the external energy at

another discrete peripheral component also causes a change in the base power of the optic portion. In certain embodiments, the peripheral portion can comprise between 20 and 40 peripheral components.

[0024] The optic portion of the IOL can comprise an optic fluid chamber and the peripheral portion can comprise at least one peripheral fluid chamber in fluid communication with the optic fluid chamber. In some embodiments, the peripheral fluid chamber is curved and the peripheral fluid chamber follows a curvature of the optic portion.

[0025] The peripheral fluid chamber can have a chamber height. The chamber height can be between about 0.1 mm to about 0.3 mm.

[0026] In some embodiments, the composite material can be configured as a chamber expander. The chamber expander can be configured to expand in response to the external energy directed at the chamber expander. Expansion of the chamber expander can increase a volume of the peripheral fluid chamber. The base power of the optic portion can be configured to decrease in response to the external energy directed at the chamber expander. The chamber expander can be configured as an expandable column extending from a chamber anterior wall to a chamber posterior wall.

[0027] In some embodiments, the composite material can be configured as a space-filler or piston. The space-filler or piston can be configured to expand in response to the external energy directed at the space-filler or piston. Expansion of the space-filler or piston can decrease a volume of the peripheral fluid chamber. The space-filler or piston can be configured as a pad extending from either a chamber anterior wall or a chamber posterior wall. The base power of the optic portion can be configured to increase in response to the external energy directed at the space-filler or piston.

[0028] The base power can be configured to change in response to fluid displacement between the optic fluid chamber and the peripheral fluid chamber as a result of the external energy directed at the composite material.

[0029] In certain embodiments, the peripheral portion can comprise a first composite material and a second composite material. In these embodiments, the first composite material can comprise a first energy absorbing constituent and the second composite material can comprise a second energy absorbing constituent. A color of the first energy absorbing constituent can be different from a color of the second energy absorbing constituent.

1 [0030] In some embodiments, the peripheral portion can be configured as at least one haptic
2 and the peripheral fluid chamber can be defined within the haptic. In these embodiments, the
3 peripheral fluid chamber can extend only partially into the haptic.

4 [0031] The haptic can comprise a haptic proximal portion and a haptic distal portion. The
5 haptic distal portion can comprise a haptic distal arm unattached to the optic portion except via
6 the haptic proximal portion.

7 [0032] In some embodiments, the haptic distal arm can comprise a kink or bend.

8 [0033] The peripheral fluid chamber can be defined within the haptic proximal portion and a
9 chamber segment of the haptic proximal portion can be unconnected to or separated from the
10 optic portion by a gap or space. The haptic can be connected to the optic portion at a proximal
11 end of the haptic and at a distal connecting portion located distally of the chamber segment.

12 [0034] In some embodiments, the proximal end of the haptic can be connected to and extend
13 from a lateral side of the optic portion. In these embodiments, the lateral side can have a side
14 height of about 0.65 mm.

15 [0035] The peripheral portion can be configured as a first haptic comprising a first haptic fluid
16 chamber and a second haptic comprising a second haptic fluid chamber. The optic portion can
17 comprise an optic fluid chamber.

18 [0036] The first haptic fluid chamber can be in fluid communication with the optic fluid
19 chamber via a first fluid channel. The second haptic fluid chamber can be in fluid
20 communication with the optic fluid chamber via a second fluid channel. The first fluid channel
21 can be positioned diametrically opposed to the second fluid channel.

22 [0037] In some embodiments, the optic fluid chamber, the first haptic fluid chamber, and the
23 second haptic fluid chamber can comprise a fluid having a total fluid volume of between about
24 10 μL and about 20 μL . Each of the first haptic fluid chamber and the second haptic fluid
25 chamber can comprise about 0.5 μL of the fluid. In certain embodiments, about 15 nL of the
26 fluid can be exchanged between either the first haptic fluid chamber and the second haptic
27 fluid chamber and the optic fluid chamber in response to pulses of the external energy directed
28 at the composite material. In some embodiments, the fluid can be a silicone oil.

29 [0038] In another embodiment, an intraocular lens is disclosed comprising an optic portion
30 and a peripheral portion coupled to the optic portion. The peripheral portion can comprise a
31 first peripheral component and a second peripheral component. The first peripheral component

1 can be made of a composite material comprising an energy absorbing constituent and a
2 plurality of expandable components. The second peripheral component can also be made of the
3 composite material comprising the energy absorbing constituent and the plurality of
4 expandable components. A base power of the optic portion can be configured to increase in
5 response to an external energy directed at the first peripheral component and the base power of
6 the optic portion can be configured to decrease in response to the external energy directed at
7 the second peripheral component. However, the base power of the optic portion can be
8 configured to be unresponsive to forces applied to the peripheral portion by a capsular bag
9 when the intraocular lens is implanted within the capsular bag.

10 **[0039]** In some embodiments, the optic portion can comprise an optic fluid chamber and the
11 peripheral portion can comprise at least one peripheral fluid chamber in fluid communication
12 with the optic fluid chamber. The base power can be configured to change in response to fluid
13 displacement between the optic fluid chamber and the peripheral fluid chamber as a result of
14 the external energy directed at the first peripheral component or the second peripheral
15 component.

16 **[0040]** In some embodiments, the first peripheral component can be configured as a space-
17 filler. The space-filler can be configured to expand in response to the external energy directed
18 at the space-filler. Expansion of the space-filler can decrease a volume of the peripheral fluid
19 chamber. For example, the space-filler can be configured as an expandable pad extending from
20 either a chamber anterior wall or a chamber posterior wall.

21 **[0041]** In some embodiments, the second peripheral component can be configured as a
22 chamber expander or jack. The chamber expander or jack can be configured to expand in
23 response to the external energy directed at the chamber expander or jack. Expansion of the
24 chamber expander or jack can increase a volume of the peripheral fluid chamber. For example,
25 the chamber expander or jack can be configured as an expandable column extending from a
26 chamber anterior wall to a chamber posterior wall.

27 **[0042]** In certain embodiments, the first peripheral component and the second peripheral
28 component can be located within the same peripheral fluid chamber. In these embodiments,
29 the second peripheral component can be positioned distal to the first peripheral component
30 within the same peripheral fluid chamber. Also, in these embodiments, the first peripheral
31 component can be positioned proximal to the second peripheral component within the same

1 peripheral fluid chamber. The first peripheral component can be positioned closer to a fluid
2 channel connecting the optic fluid chamber to the peripheral fluid chamber than the second
3 peripheral component.

4 **[0043]** The first peripheral component and the second peripheral component can be
5 configured as discrete peripheral components such that directing the external energy at one
6 discrete peripheral component can cause a change in the base power of the optic portion and
7 directing the external energy at another discrete peripheral component can also cause a change
8 in the base power of the optic portion.

9 **[0044]** In some embodiments, one peripheral fluid chamber can comprise at least ten first
10 peripheral components. In these and other embodiments, the same or another peripheral fluid
11 chamber can comprise at least ten second peripheral components.

12 **[0045]** A method of post-operatively adjusting an intraocular lens is also disclosed. The
13 method can comprise adjusting a base power of the intraocular lens by directing an external
14 energy at a composite material within a peripheral portion of the intraocular lens. The
15 peripheral portion can be coupled to an optic portion disposed radially inward of the peripheral
16 portion. The composite material can comprise an energy absorbing constituent and a plurality
17 of expandable components. The base power of the intraocular lens can be configured to be
18 unresponsive to forces applied to the peripheral portion by a capsular bag when the intraocular
19 lens is implanted within the capsular bag.

20 **[0046]** The optic portion can comprise an optic fluid chamber and the peripheral portion can
21 comprise at least one peripheral fluid chamber in fluid communication with the optic fluid
22 chamber. The base power of the intraocular lens can change in response to fluid displacement
23 between the optic fluid chamber and the peripheral fluid chamber as a result of the external
24 energy directed at the composite material. In some embodiments, about 15 nL of fluid can be
25 exchanged between the peripheral fluid chamber and the optic fluid chamber in response to
26 pulses of the external energy directed at the composite material.

27 **[0047]** In some embodiments, adjusting the base power of the intraocular lens can further
28 comprise increasing the base power by directing the external energy at the composite material
29 configured as a space-filler positioned within a peripheral fluid chamber defined within the
30 peripheral portion.

1 [0048] The method can also comprise decreasing the base power by directing the external
2 energy at another instance of the composite material configured as a chamber expander
3 positioned within the peripheral portion.

4 [0049] In some embodiments, adjusting the base power of the intraocular lens can further
5 comprise decreasing the base power by directing the external energy at the composite material
6 configured as a chamber expander positioned within a peripheral fluid chamber defined within
7 the peripheral portion. Decreasing the base power can further comprise directing the external
8 energy at another instance of the composite material configured as a space-filler positioned
9 within the peripheral fluid chamber.

10 [0050] In certain embodiments, adjusting the base power of the intraocular lens can further
11 comprise directing pulses of the external energy at a first peripheral component within a
12 peripheral fluid chamber defined within the peripheral portion and directing additional pulses
13 of the external energy at a second peripheral component within the same peripheral fluid
14 chamber. The first peripheral component can be made of the composite material and the
15 second peripheral component can be made of the same composite material.

16 [0051] In additional embodiments, adjusting the base power of the intraocular lens can further
17 comprise directing pulses of the external energy at a first peripheral component within a first
18 peripheral fluid chamber defined within the peripheral portion and directing additional pulses
19 of the external energy at a second peripheral component within a second peripheral fluid
20 chamber defined within the peripheral portion. The first peripheral component can be made of
21 the composite material and the second peripheral component can be made of the same
22 composite material. The first peripheral fluid chamber can be in fluid communication with the
23 second peripheral fluid chamber via an optic fluid chamber defined within the optic portion.

24 [0052] In some embodiments, adjusting the base power in a first direction can further
25 comprise directing the external energy at a first composite material and adjusting the base
26 power in a second direction by directing the external energy at a second composite material.
27 The first composite material can comprise a first energy absorbing constituent having a first
28 color. The second composite material can comprise a second energy absorbing constituent
29 having a second color different from the first color.

BRIEF DESCRIPTION OF THE DRAWINGS

[0053] Fig. 1A illustrates a top plan view of an embodiment of an adjustable intraocular lens (IOL) with part of an anterior portion of the adjustable IOL removed to better illustrate components within the IOL.

[0054] Fig. 1B illustrates the adjustable IOL implanted within a capsular bag of a subject.

[0055] Fig. 2A illustrates a perspective view of the adjustable IOL.

[0056] Fig. 2B illustrates a perspective view of the adjustable IOL with part of the anterior portion of the adjustable IOL removed to better illustrate components within the IOL.

[0057] Fig. 3A illustrates a sectional view of the adjustable IOL taken along cross-section A-A of Fig. 2A.

[0058] Fig. 3B illustrates a sectional view of the adjustable IOL taken along cross-section B-B of Fig. 2A.

[0059] Fig. 3C illustrates an external energy directed at a first peripheral component of the adjustable IOL.

[0060] Fig. 3D illustrates an external energy directed at a second peripheral component of the adjustable IOL.

[0061] Fig. 4A illustrates a composite material used to make at least part of the adjustable intraocular lens.

[0062] Fig. 4B illustrates one embodiment of an expandable component of the adjustable intraocular lens.

[0063] Fig. 5 illustrates a top plan view of another embodiment of the adjustable IOL with part of the anterior portion of the adjustable IOL removed to better illustrate components within the IOL.

[0064] Fig. 6 illustrates a top plan view of the adjustable IOL with a light splitting lens surface profile.

[0065] Fig. 7 is one embodiment of a method of adjusting an IOL post-operatively.

[0066] Fig. 8 is another embodiment of a method of adjusting an IOL post-operatively.

[0067] Fig. 9 is yet another embodiment of a method of adjusting an IOL post-operatively.

[0068] Fig. 10 is an additional embodiment of a method of adjusting an IOL post-operatively.

DETAILED DESCRIPTION

[0069] Fig. 1A illustrates a top plan view of an embodiment of an adjustable static-focus intraocular lens (IOL) 100 with part of an anterior portion of the adjustable IOL 100 removed to better illustrate components within the IOL. As depicted in Fig. 1A, the adjustable IOL 100 can comprise an optic portion 102 and a peripheral portion 103. The peripheral portion 103 can comprise one or more haptics 104 including a first haptic 104A and a second haptic 104B extending peripherally from or coupled to the optic portion 102.

[0070] For example, the adjustable IOL 100 can be a one-piece lens (see, e.g., Figs. 1A-3B) such that the peripheral portion 103 is connected to and extends from the optic portion 102. In this example embodiment, the peripheral portion 103 is formed along with the optic portion 102 and is not adhered or otherwise coupled to the optic portion 102 in a subsequent step.

[0071] In other embodiments, the peripheral portion 103 is coupled to and adhered to the optic portion 102. For example, the peripheral portion 103 can be adhered to the optic portion 102 after each is formed separately.

[0072] The optic portion 102 can comprise an optic fluid chamber 106 (see also, e.g., Figs. 2B, 3A, and 3B) and one or more peripheral fluid chambers 108 in fluid communication with the optic fluid chamber 106. The one or more peripheral fluid chambers 108 can be defined within the peripheral portion 103. For example, the at least one peripheral fluid chamber 108 can extend into the peripheral portion 103.

[0073] In some embodiments, the at least one peripheral fluid chamber 108 can extend only partially into the peripheral portion 103. For example, the at least one peripheral fluid chamber 108 can extend only partially into one-third, one-half, or three-quarters of the peripheral portion 103. Also, for example, the at least one peripheral fluid chamber 108 can extend only partially into between one-third and one-half of the peripheral portion 103 or between one-half and three-quarters of the peripheral portion 103.

[0074] In certain embodiments, the at least one peripheral fluid chamber 108 can extend only partially into one of the haptics 104 of the peripheral portion 103. For example, the at least one peripheral fluid chamber 108 can extend only partially into one-third, one-half, or three-quarters of the haptic 104. Also, for example, the at least one peripheral fluid chamber 108 can extend only partially into between one-third and one-half of the haptic 104 or between one-half and three-quarters of the haptic 104.

1 [0075] As shown in Fig. 1A, the peripheral portion 103 can comprise two haptics 104 (e.g., a
2 first haptic 104A and a second haptic 104B). In this embodiment, a peripheral fluid chamber
3 108 can extend into each of the two haptics 104. The peripheral fluid chamber 108 can extend
4 only partially into haptic 104.

5 [0076] The one or more peripheral fluid chambers 108 can also be referred to as one or more
6 haptic fluid chambers. When the peripheral portion 103 comprises a first haptic 104A and a
7 second haptic 104B, the peripheral portion 103 can comprise one peripheral fluid chamber 108
8 referred to as a first haptic fluid chamber and another peripheral fluid chamber 108 referred to
9 as a second haptic fluid chamber.

10 [0077] At least one of the haptics 104 (e.g., the first haptic 104A, the second haptic 104B, or a
11 combination thereof) can be curved. In these embodiments, the peripheral fluid chamber 108
12 (e.g., the haptic fluid chamber) can be curved. The peripheral fluid chamber 108 can follow a
13 curvature of the haptic 104. The peripheral fluid chamber 108 can also follow a curvature of
14 the optic portion 102 when at least a segment of the haptic 104 follows a curvature of at least
15 part of the optic portion 102.

16 [0078] The peripheral fluid chamber 108 can be in fluid communication with the optic fluid
17 chamber 106 or fluidly coupled to the optic fluid chamber 106 via a fluid channel 110. The
18 fluid channel 110 can be a passageway or conduit connecting the peripheral fluid chamber 108
19 to the optic fluid chamber 106. The fluid channel 110 can be defined along the posterior
20 element 300 (see, e.g., Figs. 3A and 3B) of the optic portion 102.

21 [0079] The fluid channel 110 can also refer to a gap or opening defined along a lateral side
22 111 or lateral surface (see also, e.g., Figs. 2A, 2B, 3A, and 3B) of the optic portion 102. The
23 fluid channel 110 can be curved. The fluid channel 110 can be substantially shaped as an
24 annular segment.

25 [0080] The peripheral fluid chamber 108 can be in fluid communication with the optic fluid
26 chamber 106 or fluidly coupled to the optic fluid chamber 106 via a singular fluid channel 110.
27 When the adjustable IOL 100 comprises multiple peripheral fluid chambers 108, each of the
28 peripheral fluid chambers 108 can be in fluid communication with the optic fluid chamber 106
29 or fluidly coupled to the optic fluid chamber 106 via a singular fluid channel 110.

30 [0081] In other embodiments, the peripheral fluid chamber 108 can be in fluid communication
31 with the optic fluid chamber 106 or fluidly coupled to the optic fluid chamber 106 via a

1 plurality (e.g., two or more) of fluid channels. In these embodiments, the two or more fluid
2 channels 110 can be separated by a channel divider or dividing wall.

3 **[0082]** When the peripheral portion 103 comprises a first haptic 104A having a first haptic
4 fluid chamber and a second haptic 104B having a second haptic fluid chamber, the first haptic
5 fluid chamber can be in fluid communication or fluidly coupled to the optic fluid chamber 106
6 via a first fluid channel and the second haptic fluid chamber can be in fluid communication or
7 fluidly coupled to the optic fluid chamber 106 via a second fluid channel. In these
8 embodiments, the first fluid channel can be positioned diametrically opposed to the second
9 fluid channel (see, e.g., Fig. 1A, 1B, 2B, and 3A).

10 **[0083]** Fig. 1A illustrates that when the peripheral portion 103 is implemented as one or more
11 haptics 104, each of the haptics 104 can have a haptic proximal portion 112 and a haptic distal
12 portion 114. The peripheral fluid chamber 108 or the haptic fluid chamber can be defined
13 within the haptic proximal portion 112.

14 **[0084]** At least a segment of the haptic proximal portion 112 can be curved. At least a segment
15 of the haptic proximal portion 112 can follow a curvature of at least part of the optic portion
16 102.

17 **[0085]** The haptic distal portion 114 can comprise a haptic distal arm 116. The haptic distal
18 arm 116 can be unattached to the optic portion 102 except via the haptic proximal portion 112.

19 **[0086]** The haptic distal arm 116 can comprise a kink or bend 118 defined along the haptic
20 distal arm 116. The kink or bend 118 can allow the haptic distal arm 116 to compress or flex in
21 response to capsular bag reshaping. The haptic distal arm 116 can terminate at a free or
22 unconnected haptic distal end 120.

23 **[0087]** When the peripheral portion 103 comprises two haptics 104 (e.g., a first haptic 104A
24 and a second haptic 104B), the adjustable IOL 100 can have an uncompressed haptic length
25 122 as measured from a haptic distal end 120 of the first haptic 104A to the haptic distal end
26 120 of the second haptic 104B. The uncompressed haptic length 122 can be between about
27 12.0 mm and about 14.0 mm. For example, the uncompressed haptic length 122 can be about
28 13.0 mm.

29 **[0088]** The haptic distal end 120 of each of the haptics 104 can be a closed end of the haptic
30 104 unconnected to the optic portion 102. The haptic distal end 120 can comprise a bulbous
31 feature or nodule at the terminus of the haptic distal end 120.

[0089] As shown in Fig. 1A, the optic portion 102 can have an optic portion diameter 124. The optic portion diameter 124 can be between about 5.0 mm and 8.0 mm. For example, the optic portion diameter 124 can be about 6.0 mm.

[0090] The haptic 104 can be connected to the optic portion 102 at a proximal end 126 of the haptic 104. The haptic 104 can also be connected to the optic portion 102 at a distal connecting portion 128. The distal connecting portion 128 can be portion of the haptic 104 located distally of a distal end of the peripheral fluid chamber 108 or haptic fluid chamber.

[0091] A segment of the haptic 104 in between the proximal end 126 and the distal connecting portion 128 (herein referred to as a chamber segment 129) can be physically separated from the optic portion 102. The chamber segment 129 can comprise at least a segment of the peripheral fluid chamber 108 in between a radially inner chamber wall 132 and a radially outer chamber wall 134. For example, the radially inner chamber wall 132 of the chamber segment 129 can be separated from the optic portion 102 by an elongate gap or space. The elongate gap or space can be a curved gap 130, as shown in Fig. 1A.

[0092] The curved gap 130 can allow the peripheral fluid chamber 108 or haptic fluid chamber to expand or change shape without the radially inner chamber wall 132 impinging against or applying pressure to the lateral side 111 (see also, e.g., Figs. 2A, 2B, 3A, and 3B) of the optic portion 102 adjacent to the chamber segment 129.

[0093] As shown in Fig. 1A, the radially outer chamber wall 134 can be thicker or bulkier than the radially inner chamber wall 132. In some embodiments, the radially outer chamber wall 134 can be thicker or bulkier than both the radially inner chamber wall 132 and the peripheral fluid chamber 108.

[0094] The thick or bulky radially outer chamber wall 134 can provide the chamber segment 129 with stiffness or resiliency when forces are applied to the chamber segment 129 in the radial direction by capsular bag contraction or reshaping. For example, the thick or bulky radially outer chamber wall 134 can allow the chamber segment 129 of the peripheral portion 103 to be insensitive or be less sensitive to radial forces applied to the peripheral portion 103 in the radial direction by capsular bag reshaping caused by ciliary muscle movements.

[0095] In some embodiments, the distal connecting portion 128 can be unfixed or unconnected to an adjacent section of the optic portion 102, thus allowing a greater amount of the haptic 104 to freely move for folding or splaying purposes during implantation of the IOL 100. Once

1 the IOL 100 is implanted within the capsular bag, the distal connecting portion 128 can rest
2 against or otherwise contact the adjacent section of the optic portion 102 to stabilize the haptic
3 104 and prevent the haptic 104 from twisting or otherwise moving around in response to
4 capsular bag contractions or reshaping. In other embodiments, the haptic 104 can also be
5 connected to the optic portion 102 at the distal connecting portion 128.

6 **[0096]** As shown in Fig. 1A, the peripheral fluid chamber 108 can terminate before reaching
7 the haptic distal portion 114. In some embodiments, the haptic distal arm(s) 116 can be made
8 of the same material as the haptic chamber walls.

9 **[0097]** One technical problem faced by the applicants is how to design a fluid-filled IOL that
10 can be adjusted post-operatively by a clinician or other medical professional, but that would
11 not be responsive to, or thus insensitive to, radial forces applied to the fluid-filled IOL by the
12 capsular bag. One solution discovered by the applicants is the adjustable IOL disclosed herein
13 with a peripheral fluid chamber that extends only partially into the haptic of the adjustable IOL
14 and a chamber segment of the haptic having a radially outer chamber wall thicker than a
15 radially inner chamber wall and the radially inner chamber wall separated from the optic
16 portion by an elongate gap or space. The haptic can also be connected to the optic portion at a
17 haptic proximal end and a distal connecting portion located distally of the chamber segment.

18 **[0098]** The peripheral portion 103 can comprise a composite material 400 (see, e.g., Fig. 4A)
19 or at least part of the peripheral portion 103 can be made of the composite material 400. As
20 will be discussed in more detail in the following sections, the composite material 400 can
21 comprise an energy absorbing constituent 404 and a plurality of expandable components 406
22 (see, e.g., Figs. 4A and 4B).

23 **[0099]** In some embodiments, the composite material 400 can be configured as a plurality of
24 space-fillers 310 (see, e.g., Figs. 3A and 3B) or pistons. One or more of the space-fillers 310
25 can be configured to expand in response to an external energy 318 (see, e.g., Fig. 3C) directed
26 at the one or more space-fillers 310. Expansion of the one or more space-fillers 310 can
27 decrease a volume of a peripheral fluid chamber 108 housing the one or more space-fillers
28 310. At least one of the space-fillers 310 can be configured as a pad extending from either a
29 chamber anterior wall 314 or a chamber posterior wall 316 of the peripheral fluid chamber 108
30 (see, e.g., Fig. 3B).

1 [0100] In these and other embodiments, the composite material 400 can be configured as a
2 plurality of chamber expanders 312 (see, e.g., Fig. 3B) or jacks. One or more of the chamber
3 expanders 312 can be configured to expand in response to an external energy 318 (see, e.g.,
4 Fig. 3D) directed at the one or more chamber expanders 312. Expansion of the one or more
5 chamber expanders 312 can increase a volume of the peripheral fluid chamber 108 housing the
6 one or more chamber expanders 312. At least one of the chamber expanders 312 can be
7 configured as an expandable column extending from a chamber anterior wall 314 to a chamber
8 posterior wall 316 of the peripheral fluid chamber 108 (see, e.g., Fig. 3B).

9 [0101] A base power or optical/dioptric power of the optic portion 102 can be configured to
10 change in response to an external energy 318 (see, e.g., Figs. 3C and 3D) directed at the
11 composite material 400. However, the base power of the optic portion 102 can be
12 unresponsive or insensitive to forces applied to the peripheral portion 103 by the capsular bag
13 when the adjustable IOL 100 is implanted within the capsular bag.

14 [0102] The base power of the optic portion 102 can be configured to change in response to
15 fluid being displaced between the optic fluid chamber 106 and the peripheral fluid chamber
16 108 as a result of the external energy 318 directed at the composite material 400.

17 [0103] The composite material 400 of the peripheral portion 103 can be formed, shaped, or
18 otherwise configured as a plurality of discrete peripheral components 136. For example, each
19 of the peripheral components 136 can be separated from neighboring or adjacent peripheral
20 components 136 by spaces or gaps.

21 [0104] The peripheral components 136 can be positioned or located within the peripheral fluid
22 chamber(s) 108. In some embodiments, the peripheral components 136 can occupy the entire
23 chamber length of the peripheral fluid chamber 108. In other embodiments, the peripheral
24 components 136 can occupy only part of the peripheral fluid chamber 108.

25 [0105] In some embodiments, directing external energy 318 at one of the peripheral
26 components 136 can cause that particular peripheral component 136 to change its shape or
27 expand without substantially affecting the other peripheral components 136. For example,
28 directing the external energy 318 at one of the peripheral components 136 can cause that
29 particular peripheral component 136 to change its shape or expand without causing a similar
30 shape change or expansion in the other peripheral components 136.

1 [0106] Pulses or a set amount of the external energy 318 can be directed at one peripheral
2 component 136 in order to cause a change in the base power of the optic portion 102. In these
3 embodiments, additional pulses or an additional amount of the external energy 318 can be
4 directed at another peripheral component 136 in order to cause another change in the base
5 power of the optic portion 102.

6 [0107] In some embodiments, the peripheral portion 103 can comprise between 20 and 40
7 peripheral components 136. In other embodiments, the peripheral portion 103 can comprise
8 between 10 and 20 peripheral components 136. In additional embodiments, the peripheral
9 portion 103 can comprise between 40 and 60 peripheral components 136.

10 [0108] In certain embodiments, one peripheral fluid chamber 108 can comprise 20 peripheral
11 components 136. In other embodiments, one peripheral fluid chamber 108 can comprise
12 between 10 and 20 peripheral components 136. In further embodiments, one peripheral fluid
13 chamber 108 can comprise between 20 and 30 peripheral components 136. In additional
14 embodiments, one peripheral fluid chamber 108 can comprise between 5 and 10 peripheral
15 components 136.

16 [0109] The peripheral components 136 can comprise one or more first peripheral components
17 138, one or more second peripheral components 140, or a combination thereof. The first
18 peripheral component(s) 138 and the second peripheral component(s) 140 can be positioned or
19 located within the same peripheral fluid chamber 108.

20 [0110] In some embodiments, one peripheral fluid chamber 108 can comprise at least ten first
21 peripheral components 138. In other embodiments, one peripheral fluid chamber 108 can
22 comprise between five and ten first peripheral components 138 or between ten and twenty first
23 peripheral components 138.

24 [0111] In these and other embodiments, one peripheral fluid chamber 108 can comprise at
25 least ten second peripheral components 140. In other embodiments, one peripheral fluid
26 chamber 108 can comprise between five and ten second peripheral components 140 or
27 between ten and twenty second peripheral components 140.

28 [0112] In the embodiment shown in Fig. 1A, one peripheral fluid chamber 108 can comprise
29 ten first peripheral components 138 and ten second peripheral components 140. Moreover, the
30 adjustable IOL 100 can comprise two haptics 104 with each haptic comprising a haptic fluid

1 chamber having ten first peripheral components 138 and ten second peripheral components
2 140.

3 **[0113]** The first peripheral components 138 can be positioned proximal to the second
4 peripheral components 140 within the peripheral fluid chamber 108 (that is, the second
5 peripheral components 140 can be positioned deeper within the peripheral fluid chamber 108).
6 For example, the first peripheral components 138 can be positioned closer to a fluid channel
7 110 connecting the optic fluid chamber 106 to the peripheral fluid chamber 108 than the
8 second peripheral components 140. One reason to position the second peripheral components
9 140 (e.g., the chamber expanders 312 or jacks) deeper or more distal in the peripheral fluid
10 chamber 108 is to minimize the mechanical stresses placed on the optic portion 102 (which
11 can cause unwanted aberrations) since expansion of the second peripheral components 140
12 affects the whole cross-section of the peripheral fluid chamber 108.

13 **[0114]** In other embodiments, at least some of the second peripheral components 140 can be
14 positioned more proximal or closer to the fluid channel 110 than the first peripheral
15 components 138. In further embodiments, the first peripheral components 138 can be
16 interleaved with the second peripheral components 140 such that the components form an
17 alternating pattern.

18 **[0115]** In the embodiment shown in Fig. 1A, the peripheral components 136 (including the
19 first peripheral components 138, the second peripheral components 140, or a combination
20 thereof) can be arranged in a single file (e.g., a single curved file) along a length of the
21 peripheral fluid chamber 108. In other embodiments not shown in the figures but contemplated
22 by this disclosure, the peripheral components 136 can be arranged in a zig-zag, a winding
23 pattern, or a double or triple file pattern, i.e., two or more adjacent rows of peripheral
24 components 136.

25 **[0116]** The base power of the optic portion 102 can be configured to change in response to
26 fluid displacement between the optic fluid chamber 106 and the peripheral fluid chamber 108
27 as a result of an external energy 318 directed at the peripheral component(s) 136. For example,
28 fluid can flow out of the peripheral fluid chamber 108 and into the optic fluid chamber 106 or
29 flow out of the optic fluid chamber 106 and back into the peripheral fluid chamber 108 in
30 response the external energy 318 directed at the peripheral component(s) 136.

1 [0117] The base power of the optic portion 102 can be configured to change in a first direction
2 in response to an external energy 318 directed at the first peripheral component 138. The base
3 power of the optic portion 102 can also be configured to change in a second direction opposite
4 the first direction in response to an external energy 318 directed at the second peripheral
5 component 140.

6 [0118] For example, the base power of the optic portion 102 can be configured to increase in
7 response to external energy 318 directed at the first peripheral component 138. As a more
8 specific example, fluid within the peripheral fluid chamber 108 can flow into the optic fluid
9 chamber 106 in response to the external energy directed at the first peripheral component 138.

10 [0119] Also, for example, the base power of the optic portion 102 can be configured to
11 decrease in response to external energy 318 directed at the second peripheral component 140.
12 As a more specific example, fluid within the optic fluid chamber 106 can flow into the
13 peripheral fluid chamber 108 in response to the external energy directed at the second
14 peripheral component 140.

15 [0120] As will be discussed in more detail in the following sections, the first peripheral
16 component 138 can be configured as a space-filler 310 (see, e.g., Figs. 3A and 3B) or piston.
17 The space-filler 310 can be configured to expand in response to external energy 318 directed at
18 the space-filler 310. Expansion of the space-filler 310 can decrease a volume of the peripheral
19 fluid chamber 108, which may therefore cause fluid to migrate from the peripheral fluid
20 chamber 108 to the optic fluid chamber 106.

21 [0121] The second peripheral component 140 can be configured as a chamber expander 312
22 (see, e.g., Figs. 2B, 3A, and 3B) or jack. The chamber expander 312 can be configured to
23 expand in response to external energy 318 directed at the chamber expander 312. Expansion of
24 the chamber expander 312 can increase a volume of the peripheral fluid chamber 108.

25 [0122] In some embodiments, the fluid within the optic fluid chamber 106, the peripheral fluid
26 chamber(s) 108, or a combination thereof can be an oil. More specifically, in certain
27 embodiments, the fluid within the optic fluid chamber 106, the peripheral fluid chamber(s)
28 108, or a combination thereof can be a silicone oil or fluid.

29 [0123] The fluid within the optic fluid chamber 106, the peripheral fluid chamber(s) 108, or a
30 combination thereof can be a silicone oil or fluid comprising or made in part of diphenyl
31 siloxane and dimethyl siloxane. In other embodiments, the silicone oil or fluid can comprise or

be made in part of a ratio of two dimethyl siloxane units to one diphenyl siloxane unit. In certain embodiments, the silicone oil can comprise about 20 mol% diphenyl siloxane and about 80 mol% dimethyl siloxane.

[0124] More specifically, in some embodiments, the silicone oil can comprise diphenyltetramethyl cyclotrisiloxane. In additional embodiments, the silicone oil or fluid can comprise or be made in part of a diphenyl siloxane and dimethyl siloxane copolymer.

[0125] The fluid (e.g., the silicone oil) can be index matched with the lens body material used to make the optic portion 102. When the fluid is index matched with the lens body material, the entire optic portion 102 containing the fluid acts as a single lens. For example, the fluid can be selected so that it has a refractive index of between about 1.48 and 1.53 (or between about 1.50 and 1.53). In some embodiments, the fluid (e.g., the silicone oil) can have a polydispersity index of between about 1.2 and 1.3. In other embodiments, the fluid (e.g., the silicone oil) can have a polydispersity index of between about 1.3 and 1.5. In other embodiments, the fluid (e.g., the silicone oil) can have a polydispersity index of between about 1.1 and 1.2. Other example fluids are described in U.S. Patent Publication No. 2018/0153682, which is herein incorporated by reference in its entirety.

[0126] Fig. 1B illustrates that the adjustable static-focus IOL 100 can be implanted within a native capsular bag in which a native lens has been removed. When implanted within the native capsular bag, the optic portion 102 can be adapted to refract light that enters the eye onto the retina. The one or more haptics 104 (e.g., the first haptic 104A and the second haptic 104B) can be configured to engage the capsular bag to hold the adjustable IOL 100 in place within the capsular bag.

[0127] Fig. 2A illustrates a perspective view of the adjustable IOL 100. As previously discussed, the optic fluid chamber 106 and the peripheral fluid chamber(s) 108 can be filled with a fluid (e.g., silicone oil). The base power of the optic portion 102 can be configured to change based on an internal fluid pressure within the fluid-filled optic fluid chamber 106.

[0128] The optic portion 102 can also be configured to change shape in response to fluid entering the optic fluid chamber 106. In certain embodiments, an anterior element 200 of the optic portion 102 can be configured to change shape in response to fluid entering or exiting the optic fluid chamber 106. For example, the anterior element 200 can be configured to increase its curvature in response to fluid entering the optic fluid chamber 106. Also, for example, the

anterior element 200 can be configured to decrease its curvature in response to fluid exiting the optic fluid chamber 106.

[0129] In other embodiments, a posterior element 300 (see, e.g., Figs. 3A and 3B) of the optic portion 102 can be configured to change shape (e.g., increase its curvature or decrease its curvature) in response to fluid entering or exiting the optic fluid chamber 106. In further embodiments, both the anterior element 200 and the posterior element 300 can be configured to change shape in response to the fluid entering or exiting the optic fluid chamber 106.

[0130] The base power of the optic portion 102 can be configured to increase or decrease in response to shape change(s) undertaken by the anterior element 200, the posterior element 300, or a combination thereof. Increasing the curvature of the anterior element 200, the posterior element 300, or a combination thereof can increase a base dioptric power of the optic portion 102 allowing for better near vision. Decreasing the curvature of the anterior element 200, the posterior element 300, or a combination thereof can decrease a base dioptric power of the optic portion 102 allowing for better distance vision.

[0131] For example, the base power of the optic portion 102 can be configured to increase as fluid enters the optic fluid chamber 106 from the peripheral fluid chamber(s) 108 (e.g., the haptic fluid chamber(s)). Fluid can flow from the peripheral fluid chamber(s) 108 into the optic fluid chamber 106 as the volume of the peripheral fluid chamber(s) 108 decreases in response to an expansion of one or more of the first peripheral components 138. One or more of the first peripheral components 138 can expand in response to an external energy 318 directed at the first peripheral component(s) 138.

[0132] Also, for example, the base power of the optic portion 102 can be configured to decrease as fluid exits or is drawn out of the fluid-filled optic fluid chamber 106 into the peripheral fluid chamber(s) 108. Fluid can flow from the optic fluid chamber 106 into the peripheral fluid chamber(s) 108 as the volume of the peripheral fluid chamber(s) 108 increases in response to an expansion of one or more of the second peripheral components 140. One or more of the second peripheral components 140 can expand in response to an external energy 318 directed at the second peripheral component(s) 140.

[0133] Fig. 2B illustrates a perspective view of the adjustable IOL 100 with part of the anterior portion of the adjustable IOL 100 removed to better illustrate components within the IOL. The adjustable IOL 100 can comprise a peripheral portion 103 comprising a plurality of

peripheral components 136 within the peripheral fluid chamber(s) 108. For example, parts of the peripheral portion 103 can be formed as the peripheral components 136.

[0134] As shown in Fig. 2B, the optic fluid chamber 106 can be in fluid communication with each of the peripheral fluid chambers 108 through a fluid channel 110. The fluid channel 110 can be a conduit or passageway connecting the optic fluid chamber 106 to the peripheral fluid chamber(s) 108 or haptic fluid chamber(s). Although a singular fluid channel 110 is shown connecting the optic fluid chamber 106 to each peripheral fluid chamber 108, it is contemplated by this disclosure that a plurality of fluid channels (e.g., two fluid channels) can connect the optic fluid chamber 106 to each peripheral fluid chamber 108.

[0135] The base power of the optic portion 102 can be configured to change (e.g., increase or decrease) in response to an external energy 318 directed at the peripheral components 136. As previously discussed, each of the peripheral components 136 can be made of the composite material 400.

[0136] As will be discussed in more detail in the following sections, each of the first peripheral components 138 can be configured as a space-filler 310 (see also, e.g., 3A, 3B, and 3C). The space-filler 310 can be configured to expand in response to external energy directed at the space-filler 310. Expansion of the space-filler 310 can decrease a volume of the peripheral fluid chamber 108 and causing the fluid to flow from the peripheral fluid chamber 108 into the optic fluid chamber 106.

[0137] Each of the second peripheral components 140 can be configured as a chamber expander 312 (see also, e.g., Figs. 3B and 3D). The chamber expander 312 can be configured to expand in response to external energy directed at the chamber expander 312. Expansion of the chamber expander 312 can increase a volume of the peripheral fluid chamber 108 by expanding the peripheral fluid chamber 108 and causing the fluid to flow or be drawn out from the optic fluid chamber 106 into the peripheral fluid chamber 108.

[0138] The optic fluid chamber 106 and the peripheral fluid chamber(s) 108 can comprise or hold a fluid (e.g., silicone oil) having a total fluid volume of between about 10 μL and about 20 μL . For example, the optic fluid chamber 106 and the peripheral fluid chamber(s) 108 can comprise a fluid (e.g., silicone oil) having a total fluid volume of about 15 μL .

[0139] In the embodiment shown in Fig. 2B, the peripheral portion 103 can comprise a first haptic 104A and a second haptic 104B. The first haptic 104A can have a first haptic fluid

1 chamber and the second haptic 104B can have a second haptic fluid chamber. Each of the first
2 haptic fluid chamber and the second haptic fluid chamber can be considered one of the
3 peripheral fluid chambers 108. In this embodiment, each of the haptic fluid chambers (e.g.,
4 each of the first haptic fluid chamber and the second haptic fluid chamber) can comprise or
5 hold a fluid having fluid volume of between about 0.3 μL and 0.6 μL (or about 0.5 μL).

6 **[0140]** In some embodiments, between about 10 nanoliters (nL) and 20 nL of the fluid can be
7 exchanged or displaced between a peripheral fluid chamber 108 (for example, either the first
8 haptic fluid chamber or the second haptic fluid chamber) and the optic fluid chamber 106 in
9 response to pulses of the external energy 318 directed at one of the peripheral components 136.
10 More specifically, about 15 nL of the fluid can be exchanged or displaced between one or
11 more peripheral fluid chambers 108 (for example, either the first haptic fluid chamber or the
12 second haptic fluid chamber) and the optic fluid chamber 106 in response to pulses of the
13 external energy 318 directed at one of the peripheral components 136.

14 **[0141]** In some embodiments, the base power of the optic portion 102 can be configured to
15 change between about 0.05 diopter (D) to about 0.5 D in either a positive or negative direction
16 in response to pulses of the external energy 318 directed at one of the peripheral components
17 136. For example, the base power of the optic portion 102 can be configured to change by
18 about 0.1 D in response to pulses of the external energy 318 directed at one of the peripheral
19 components 136.

20 **[0142]** The change in the base power of the optic portion 102 can be a persistent or a
21 substantially permanent change. A persistent or substantially permanent change can mean that
22 the peripheral component 136 does not substantially revert back to its original shape or size
23 after the change has occurred.

24 **[0143]** In certain embodiments, the base power of the optic portion 102 can be configured to
25 change in total between about 1.0 D and about 2.0 D in either a positive or negative direction.
26 In these embodiments, the total power change can be dictated by the total number of peripheral
27 components 136, the size and/or expandable characteristics of the peripheral components 136,
28 the chamber volume of the peripheral fluid chamber 108 and/or the optic fluid chamber 106,
29 the volume of the oil within such chambers, or a combination thereof.

30 **[0144]** In other embodiments, the base power of the optic portion 102 can be configured to
31 change in total between about 2.0 D and about 3.0 D in either a positive or negative direction.

In additional embodiments, the base power of the optic portion 102 can be configured to change in total between about 3.0 D and about 5.0 D in either a positive or negative direction. In further embodiments, the base power of the optic portion 102 can be configured to change in total between about 5.0 D and about 10.0 D in either a positive or negative direction.

[0145] In some embodiments, the optic portion 102 can have an unfilled or as-manufactured optical power (i.e., an optical power of the optic portion 102 when the optic fluid chamber 106 is empty or unfilled) of between about 11 D and 13 D (a “zero power” lens). For example, the optic portion 102 can have an unfilled or as-manufactured optical power of about 12 D. The optical power of the optic portion 102 can increase as the optic fluid chamber 106 is filled with the fluid (e.g., the silicone oil).

[0146] The optic fluid chamber 106 can be filled until the base power of the filled optic portion 102 (as contributed by both the fluid and the lens surfaces of the optic portion 102) is between about 15 D (a low-powered IOL) to about 30 D (a high-powered IOL). For example, the optic fluid chamber 106 can be filled until the base power of the filled optic portion 102 is about 20 D.

[0147] The adjustable IOL 100 implanted within a capsular bag of the subject can have a base power between about 15 D to about 30 D (e.g., about 20 D). A clinician or medical professional can direct the external energy 318 (e.g., a laser light) at the peripheral components 136 to increase or decrease the base power of the optic portion 102 when the adjustable IOL 100 is implanted within the capsular bag of the subject.

[0148] For example, the adjustable IOL 100 can have a base power of about 20 D when implanted within the eye of the subject. If power correction is desired to increase the power of the lens, a clinician or medical professional can direct the external energy 318 at each of the first peripheral components 138 to increase the base power of the optic portion 102 stepwise between about +0.1 D and +0.2 D until the final base power is between about 21 D (+1.0 D change in total) and 22 D (+2.0 D change in total).

[0149] In other embodiments, the clinician or medical professional can direct the external energy 318 at each of the first peripheral components 138 to increase the base power of the optic portion 102 stepwise between about +0.1 D and +0.2 D until the final base power is between about 22 D (+2.0 D change in total) and 25 D (+5.0 D change in total).

[0150] As another example, the adjustable IOL 100 can have a base power of about 25 D when implanted within the eye of the subject. If power correction is desired to decrease the power of the lens, a clinician or medical professional can direct the external energy 318 at each of the second peripheral components 140 to decrease the base power of the optic portion 102 stepwise between about -0.1 D and -0.2 D until the final base power is between about 24 D (-1.0 D change in total) and 23 D (-2.0 D change in total).

[0151] In other embodiments, the clinician or medical professional can direct the external energy 318 at each of the second peripheral components 140 to decrease the base power of the optic portion 102 stepwise between about -0.1 D and -0.2 D until the final base power is between about 23 D (-2.0 D change in total) and 20 D (-5.0 D change in total).

[0152] In some embodiments, the adjustable IOL 100 can have an optic sensitivity of between about 100 nL to 200 nL (e.g., about 150 nL) of fluid displacement per diopter. That is, the base power of the optic portion 102 can change by about 1.0 D when between about 100 nL to 200 nL (e.g., about 150 nL) of the fluid is displaced between the peripheral fluid chamber 108 and the optic fluid chamber 106. As a more specific example, the base power of the optic portion 102 can increase by +1 D when between about 100 nL to 200 nL (e.g., about 150 nL) of the fluid enters the optic fluid chamber 106 from the peripheral fluid chamber 108 as a result of the external energy 318 directed at the first peripheral components 138. Moreover, the base power of the optic portion 102 can decrease by -1.0 D when between about 100 nL to 200 nL (e.g., about 150 nL) of the fluid exits or is drawn out of the optic fluid chamber 106 into the peripheral fluid chamber 108 as a result of the external energy 318 directed at the second peripheral components 140.

[0153] In certain embodiments, each of the peripheral fluid chambers 108 can comprise ten first peripheral components 138 and ten second peripheral components 140. In these embodiments, directing the external energy 318 at each of the first peripheral components 138 or each of the second peripheral components 140 can cause between about 10 nL and 20 nL (e.g., about 15 nL) of the fluid to be displaced or exchanged between the optic fluid chamber 106 and the peripheral fluid chamber 108. For example, directing the external energy 318 at one of the first peripheral components 138 can cause the first peripheral component 138 to expand and decrease the volume of the peripheral fluid chamber 108 housing the first peripheral component 138. This can cause between about 10 nL and about 20 nL (e.g., about

1 15 nL) of the fluid to flow from the peripheral fluid chamber 108 into the optic fluid chamber
2 106. Also, for example, directing the external energy 318 at one of the second peripheral
3 components 140 can cause the second peripheral component 140 to expand and increase the
4 volume of the peripheral fluid chamber 108 housing the second peripheral component 140.
5 This can cause between about 10 nL and about 20 nL (e.g., about 15 nL) of the fluid to be
6 drawn out of the optic fluid chamber 106 into the peripheral fluid chamber 108.

7 **[0154]** The adjustable IOL 100 can be configured such that the base power of the optic portion
8 102 changes between about 0.05 D and 0.5 D as a result of this fluid exchange or
9 displacement. As a more specific example, the base power of the optic portion 102 can change
10 by about 0.1 D in response to about 15 nL of the fluid being displaced or exchanged between
11 the optic fluid chamber 106 and the peripheral fluid chamber 108.

12 **[0155]** Fig. 3A illustrates a sectional view of the adjustable IOL 100 taken along cross-section
13 A-A of Fig. 2A. The optic portion 102 can comprise an anterior element 200 and a posterior
14 element 300. A fluid-filled optic fluid chamber 106 can be defined in between the anterior
15 element 200 and the posterior element 300.

16 **[0156]** The anterior element 200 can comprise an anterior optical surface and an anterior inner
17 surface opposite the anterior optical surface. The posterior element 300 can comprise a
18 posterior optical surface and a posterior inner surface opposite the posterior optical surface.
19 Any of the anterior optical surface, the posterior optical surface, or a combination thereof can
20 be considered and referred to as an external optical surface. The anterior inner surface and the
21 posterior inner surface can face the optic fluid chamber 106. At least part of the anterior inner
22 surface and at least part of the posterior inner surface can serve as chamber walls of the optic
23 fluid chamber 106. In some embodiments, the peripheral portion 103 (e.g., the haptics 104)
24 can be connected to or can extend from at least part of the posterior element 300 of the optic
25 portion 102.

26 **[0157]** As will be discussed in more detail in the following sections, the adjustable IOL 100
27 can have a lens surface profile or pattern (e.g., a light-splitting lens profile or pattern) defined
28 on the external optical surface. For example, the lens surface profile can comprise a diffractive
29 surface profile or pattern or a phase-shifting structure or profile. The lens surface profile or
30 pattern can allow the adjustable IOL 100 to be adapted for different use cases such as
31 providing focus for one particular distance (monofocal) or focus for multiple distances

(multifocal). For example, depending on the lens surface profile or pattern defined on the external optical surface, the adjustable IOL 100 can be configured as an adjustable monofocal IOL, an adjustable multifocal IOL (e.g., an adjustable bifocal or trifocal IOL), or an adjustable extended depth of focus (EDOF) IOL.

[0158] The optic portion 102 can be configured to deform, flex, or otherwise change shape in response to fluid entering or exiting the optic fluid chamber 106. In some embodiments, the anterior element 200 can be configured to deform, flex, or otherwise change shape (e.g., change its curvature) in response to fluid entering or exiting the optic fluid chamber 106. In other embodiments, the posterior element 300 can be configured to deform, flex, or otherwise change shape (e.g., change its curvature) in response to fluid entering or exiting the optic fluid chamber 106. In further embodiments, both the anterior element 200 and the posterior element 300 can be configured to deform, flex, or otherwise change their shape(s) in response to fluid entering or exiting the optic fluid chamber 106. The base power of the optic portion 102 can be configured to change in response to the shape change undertaken by the shape-changing components of the optic portion 102 (e.g., the anterior element 200, the posterior element 300, or a combination thereof).

[0159] The optic portion 102 can be made in part of a deformable or flexible material. In some embodiments, the optic portion 102 can be made in part of a deformable or flexible polymeric material. For example, the anterior element 200, the posterior element 300 or a combination thereof can be made in part of a deformable or flexible polymeric material. At least part of the peripheral portion 103, such as the one or more haptics 104 (e.g., the first haptic 104A, the second haptic 104B, or a combination thereof) can be made of the same deformable or flexible material as the optic portion 102. In other embodiments, the one or more haptics 104 can be made in part of different materials from the optic portion 102.

[0160] In some embodiments, the optic portion 102 and the parts of the peripheral portion 103 not made of the composite material 400 can comprise or be made in part of a polymer or a cross-linked copolymer comprising a copolymer blend.

[0161] For example, in some embodiments, the copolymer blend can comprise an alkyl acrylate or methacrylate, a fluoro-alkyl (meth)acrylate, a phenyl-alkyl acrylate, or a combination thereof. It is contemplated by this disclosure and it should be understood by one of ordinary skill in the art that these types of acrylic cross-linked copolymers can be generally

1 copolymers of a plurality of acrylates or methacrylates. The term “acrylate” as used herein can
2 be understood to mean acrylates or methacrylates unless otherwise specified.

3 **[0162]** For example, the optic portion 102 and the parts of the peripheral portion 103 not made
4 of the composite material 400 can be made of hydrophobic acrylic materials. For example, the
5 hydrophobic acrylic materials may comprise a hydrophobic acrylate/methacrylate copolymer.

6 In some embodiments, the hydrophobic acrylic materials can comprise a combination of
7 phenylethyl acrylate (PEA) and phenylethyl methacrylate (PEMA).

8 **[0163]** In one example embodiment, the cross-linked copolymer can comprise an alkyl
9 acrylate in the amount of about 3% to 20% (wt%), a fluoro-alkyl acrylate in the amount of
10 about 10% to 35% (wt%), and a phenyl-alkyl acrylate in the amount of about 50% to 80%
11 (wt%). In some embodiments, the cross-linked copolymer can comprise or be made in part of
12 an n-butyl acrylate as the alkyl acrylate, trifluoroethyl methacrylate as the fluoro-alkyl
13 acrylate, and phenylethyl acrylate as the phenyl-alkyl acrylate. More specifically, the cross-
14 linked copolymer can comprise n-butyl acrylate in the amount of about 3% to 20% (wt%)
15 (e.g., between about 12% to 16%), trifluoroethyl methacrylate in the amount of about 10% to
16 35% (wt%) (e.g., between about 17% to 21%), and phenylethyl acrylate in the amount of about
17 50% to 80% (wt%) (e.g., between about 64% to 67%).

18 **[0164]** The final composition of the cross-linked copolymer can also comprise a cross-linker
19 or cross-linking agent such as ethylene glycol dimethacrylate (EGDMA). For example, the
20 final composition of the cross-linked copolymer can also comprise a cross-linker or cross-
21 linking agent (e.g., EGDMA). The final composition of the cross-linked copolymer can also
22 comprise an initiator or initiating agent (e.g., Perkadox 16, camphorquinone, 1-phenyl-1,2-
23 propanedione, and 2-ethylhexyl-4-(dimethylamino)benzoate)) and a UV absorber.

24 **[0165]** In some embodiments, the refractive index of the material used to make the optic
25 portion 102 can be between about 1.48 and about 1.53. In certain embodiments, the refractive
26 index of the material used to make the optic portion 102 can be between about 1.50 and about
27 1.53.

28 **[0166]** In some embodiments, the optic portion 102 and the parts of the peripheral portion 103
29 not made of the composite material 400 can comprise a reactive (polymerizable) UV
30 absorber and a reactive blue-light absorber. For example, the reactive UV absorber can be or
31 comprise 2-(2'-hydroxy-3'-methallyl-5'-methylphenyl)benzotriazole, commercially available

as o-Methallyl Tinuvin P (“oMTP”) from Polysciences, Inc., Warrington, Pennsylvania, 3-(2H-benzo[d][1,2,3]triazol-2-yl)-4-hydroxyphenylethyl methacrylate, and 2-(3-(tert-butyl)-4-hydroxy-5-(5-methoxy-2H-benzo[d][1,2,3]triazol-2-yl)phenoxy)ethyl methacrylate. In certain embodiments, the reactive UV absorbers are present in an amount from about 0.1%-5% (wt%). When present, the reactive UV absorbers are typically present in an amount from about 1.5%-2.5% (wt%) or in an amount from about 1.5%-2% (wt%).

[0167] In certain embodiments, the reactive blue-light absorbing compounds can be those described in U.S. Patent Nos. 5,470,932; 8,207,244; and 8,329,775, the entire contents of which are hereby incorporated by reference. For example, the blue-light absorbing dye can be N-2-[3-(2'-methylphenylazo)-4-hydroxyphenyl]ethyl methacrylamide. When present, blue-light absorbers are typically present in an amount from about 0.005%-1 % (wt%) or in an amount from about 0.01%-0.1% (wt%).

[0168] Fig. 3B illustrates a sectional view of the adjustable IOL taken along cross-section B-B of Fig. 2A. As shown in Fig. 3B, the peripheral fluid chamber 108 can have a chamber height 302. In some embodiments, the chamber height 302 can be about 0.1 mm. In other embodiments, the chamber height 302 can be between about 0.1 mm and 0.3 mm.

[0169] In other embodiments, the chamber height 302 can be between about 0.3 mm and 1.0 mm. In further embodiments, the chamber height 302 can be between about 1.0 mm and 1.5 mm.

[0170] Fig. 3B also illustrates that the lateral side 111 of the optic portion 102 can have a side height 304 (as measured in the anterior-to-posterior direction). In some embodiments, the side height 304 can be between about 0.50 mm and 0.75 mm. For example, the side height 304 can be about 0.65 mm. In other embodiments, the side height 304 can be between about 0.40 mm and 0.50 mm or between about 0.75 mm and 1.25 mm.

[0171] The peripheral portion 103 can also have a peripheral portion height 306 (also referred to as haptic height or thickness). In some embodiments, the peripheral portion height 306 can be between about 0.50 mm and 0.60 mm. In other embodiments, the peripheral portion height 306 can be between about 0.60 mm and 0.65 mm or between about 0.45 mm and 0.50 mm.

[0172] As shown in Fig. 3B, the side height 304 of the lateral side 111 of the optic portion 102 can be greater than the peripheral portion height 306. For example, when the peripheral portion 103 comprises one or more haptics, the thickness or height of the haptics (as measured in an

anterior-to-posterior direction) can be less than the thickness or height of the optic portion 102 along all sections of the optic portion 102.

[0173] In some embodiments, the peripheral portion height 306 or thickness (in an anterior-to-posterior direction) can be substantially uniform such that no part of the peripheral portion 103 is taller or thicker than any other part of the peripheral portion 103. When the peripheral portion 103 comprises multiple haptics 104, all of the haptics 104 can have the same height or thickness.

[0174] Fig. 3B also illustrates that the anterior element 200 can have an anterior element thickness 308 (as measured in the anterior-to-posterior direction). In some embodiments, the anterior element thickness 308 can be between about 0.15 mm and about 0.25 mm. For example, the anterior element thickness 308 can be about 0.20 mm.

[0175] Figs. 3A and 3B also illustrate that the first peripheral component 138 can be configured as a space-filler 310. The space-filler 310 can be configured to expand in response to the external energy 318 directed at the space-filler 310. Expansion of the space-filler 310 can decrease a volume of the peripheral fluid chamber 108.

[0176] As a more specific example, the space-filler 310 can be implemented as an expandable pad extending from at least one of a chamber anterior wall 314 and a chamber posterior wall 316. The base power of the optic portion 102 can be configured to increase in response to the external energy 318 directed at the space-filler 310, resulting in fluid being displaced out of the peripheral fluid chamber 108 due to the increased volume of the space filler 310.

[0177] Fig. 3B also illustrates that the second peripheral component 140 can be configured as a chamber expander 312. The chamber expander 312 can be configured to expand in response to the external energy 318 directed at the chamber expander 312. Expansion of the chamber expander 312 can increase a volume of the peripheral fluid chamber 108.

[0178] As a more specific example, the chamber expander 312 can be implemented as an expandable column extending from the chamber anterior wall 314 to the chamber posterior wall 316. Expansion of the expandable column can increase the volume of the peripheral fluid chamber 108. The base power of the optic portion 102 can be configured to decrease in response to the external energy 318 directed at the expandable column, resulting in an expansion of the chamber expander 312 and an increase in the volume of the peripheral fluid chamber 108.

1 [0179] Fig. 3C illustrates that an external energy 318 can be directed at a space-filler 310 of
2 the adjustable IOL 100 to induce a shape change in the space-filler 310.

3 [0180] The first peripheral component 138 can be made of the composite material 400. The
4 first peripheral component 138 can be positioned within the peripheral fluid chamber 108.

5 [0181] In some embodiments, the composite material 400 used to make the first peripheral
6 component 138 can be cured within the peripheral fluid chamber 108 along with the rest of the
7 material used to construct the peripheral fluid chamber 108. In these embodiments, the first
8 peripheral component 138 can be cured in place within the peripheral fluid chamber 108.

9 [0182] In other embodiments, the first peripheral component 138 can be adhered to an interior
10 wall or surface of the peripheral fluid chamber 108 using an adhesive. The adhesive can be
11 cured to secure the first peripheral component 138 to the interior wall or surface of the
12 peripheral fluid chamber 108.

13 [0183] The first peripheral component 138 can be configured as a space-filler 310. In some
14 embodiments, the space-filler 310 can be implemented as an expandable disk-shaped pad (see,
15 e.g., Figs. 2B, 3A, and 3B). Although the figures illustrate the space-fillers 310 shaped as
16 substantially flat cylinders or disks, it is contemplated by this disclosure that the space-fillers
17 310 can be substantially shaped as spheres, hemispheres, ovoids, ellipsoids, cuboids or other
18 polyhedrons, or a combination thereof.

19 [0184] The space-fillers 310 can extend from, be adhered to, or otherwise be coupled to either
20 a chamber anterior wall 314 or a chamber posterior wall 316. In some embodiments, when the
21 peripheral fluid chamber 108 comprises multiple space-fillers 310, at least one of the space-
22 fillers 310 can extend from, be adhered to, or otherwise be coupled to the chamber anterior
23 wall 314 and another of the space-fillers 310 can extend from, be adhered to, or otherwise be
24 coupled to the chamber posterior wall 316.

25 [0185] In other embodiments, the space-fillers 310 can extend from, be adhered to, or
26 otherwise be coupled to a chamber interior lateral wall 320.

27 [0186] As shown in Fig. 3C, the space-filler 310 can expand in response to a burst of the
28 external energy 318 directed at the space-filler 310. Expansion of the space-filler 310 can
29 decrease an internal volume of the peripheral fluid chamber 108 and displace fluid from the
30 peripheral fluid chamber 108 into the optic fluid chamber 106. The base power of the optic

portion 102 can be configured to increase in response to the external energy 318 directed at the space-filler 310.

[0187] Fig. 3C illustrates that the space-filler 310 can be sized such that the space-filler 310 does not come into contact with the chamber interior lateral walls 320. Fig. 3C also illustrates that a separation distance 322 or gap can be maintained between the space-filler 310 and each of the chamber interior lateral walls 320 even when the space-filler 310 is enlarged in response to the external energy 318 directed at the space-filler 310. This ensures that the enlarged space-filler 310 does not expand the peripheral fluid chamber 108 or expand the peripheral fluid chamber 108 to an extent that would cancel out the effects of the enlarged space-filler 310 on reducing the volume of the peripheral fluid chamber 108. Moreover, an anterior-to-posterior height of the space-filler 310 can be significantly less than the chamber height 302 such that the enlarged space-filler 310 does not come into contact with the chamber anterior wall 314.

[0188] In some embodiments, the external energy 318 can be light energy. More specifically, the external energy 318 can be laser light. The external energy 318 can be a burst of laser light.

[0189] In certain embodiments, the laser light can have a wavelength between about 488 nm to about 650 nm. For example, the laser light can be green laser light. The green laser light can have a wavelength of between about 520 nm to about 570 nm. In one example, embodiment, the external energy 318 can be green laser light having a wavelength of about 532 nm.

[0190] For example, the laser light can be laser light emitted by an ophthalmic laser. For example, the laser light can be laser light emitted by a retinal coagulation laser.

[0191] In certain embodiments, the laser light can be emitted by a neodymium-doped yttrium aluminum garnet (Nd:YAG) laser. As a more specific example, the laser light can be a pulsed Nd:YAG laser operating in a Q-switching mode and frequency doubled to generate laser light at 532 nm.

[0192] In other embodiments, the laser light can be emitted by a femtosecond laser or an infrared or near infrared laser. For example, the laser light emitted by such lasers can have a wavelength of between about 1030 nm and 1064 nm.

[0193] As will be discussed in more detail in the following sections, when the external energy 318 is light energy, energy absorbing constituents 404 (see Fig. 4A) within the composite material 400 can absorb or otherwise capture the light energy and convert the light energy into

1 thermal energy and transfer the thermal energy to expandable components 406 (see Figs. 4A
2 and 4B) within the composite material 400 to expand the expandable components 406.

3 **[0194]** As previously discussed, in some embodiments about 15 nL of the fluid can flow from
4 the peripheral fluid chamber 108 into the optic fluid chamber 106 (through the fluid channel
5 110) in response to expansion of one of the space-fillers 310. In these and other embodiments,
6 the base power of the optic portion 102 can be configured to change by about +0.1 D in
7 response to pulses of the external energy 318 directed at one of the space-fillers 310.

8 **[0195]** Fig. 3D illustrates that an external energy 318 can be directed at a second peripheral
9 component 140 of the adjustable IOL 100 to induce a shape change in the second peripheral
10 component 140.

11 **[0196]** The second peripheral component 140 can be made of the composite material 400. The
12 second peripheral component 140 can be positioned within the peripheral fluid chamber 108.

13 **[0197]** In some embodiments, the composite material 400 used to make the second peripheral
14 component 140 can be cured within the peripheral fluid chamber 108 along with the rest of the
15 material used to construct the peripheral fluid chamber 108. In these embodiments, the second
16 peripheral component 140 can be cured in place within the peripheral fluid chamber 108.

17 **[0198]** In other embodiments, the second peripheral component 140 can be adhered to the
18 interior walls or surfaces of the peripheral fluid chamber 108 using an adhesive. The adhesive
19 can be cured to secure the second peripheral component 140 to the interior walls or surfaces of
20 the peripheral fluid chamber 108.

21 **[0199]** The second peripheral component 140 can be configured as a chamber expander 312.
22 In some embodiments, the chamber expander 312 can be implemented as an expandable
23 column extending from the chamber anterior wall 314 to the chamber posterior wall 316 (see,
24 e.g., Fig. 3B). Although the figures illustrate the chamber expanders 312 shaped as
25 substantially elongate cylinders, it is contemplated by this disclosure that the chamber
26 expanders 312 can be substantially shaped as elongate ovoids, elongate ellipsoids, elongate
27 cuboids or other polyhedrons, cones, frustocones, or a combination thereof.

28 **[0200]** As a more specific example, the chamber expander 312 can be implemented as an
29 expandable column extending from the chamber anterior wall 314 to the chamber posterior
30 wall 316. Expansion of the expandable column can increase the volume of the peripheral fluid
31 chamber 108 by pushing on one or both of the chamber interior wall 314 and chamber

posterior wall 316 to increase the chamber height 302. The base power of the optic portion 102 can be configured to decrease in response to the external energy 318 directed at the expandable column.

[0201] As shown in Fig. 3D, the chamber expander 312 can expand in response to a burst of the external energy 318 directed at the chamber expander 312. Expansion of the chamber expander 312 can increase a volume of the peripheral fluid chamber 108 and draw fluid from the optic fluid chamber 106 into the peripheral fluid chamber 108. The base power of the optic portion 102 can be configured to decrease in response to the external energy 318 directed at the chamber expander 312.

[0202] The external energy 318 can be the same external energy 318 as previously disclosed. For example, the external energy 318 can be light energy.

[0203] Fig. 3D illustrates that the chamber expander 312 can be sized such that the chamber expander 312 does not come into contact with the chamber interior lateral walls 320 (even when expanded). This ensures that the enlarged chamber expander 312 expands the peripheral fluid chamber 108 primarily in an anterior-to-posterior direction and does not put pressure on the radially inner chamber wall 132 (which could then translate into pressure applied to the lateral sides of the optic portion 102, thereby inadvertently affecting the optical power).

[0204] As previously discussed, in some embodiments about 15 nL of the fluid can flow from the optic fluid chamber 106 into the peripheral fluid chamber 108 (through the fluid channel 110) in response to pulses of the external energy 318 directed at one of the chamber expanders 312. In these and other embodiments, the base power of the optic portion 102 can be configured to change by about -0.1 D in response to an expansion of one of the chamber expanders 312 caused by the external energy 318 directed at the chamber expander 312.

[0205] Although Figs. 1A, 1B, 2B, and 5 illustrate each of the peripheral fluid chambers 108 (e.g., each of the haptic fluid chambers) comprising both the space-fillers 310 and the chamber expanders 312, it is contemplated by this disclosure and it should be understood by one of ordinary skill in the art that each of the peripheral fluid chambers 108 can also comprise only the space-fillers 310 or only the chamber expanders 312.

[0206] One technical problem faced by the applicants is how to provide a clinician or other medical professional the ability to fine tune the optical power of an implanted IOL in both directions (i.e., providing the clinician the ability to increase or decrease the optical power of

the implanted IOL post-operatively). One solution discovered by the applicants are the peripheral components disclosed herein including, for example, the space-fillers and chamber expanders made of the composite material. As a more specific example, each peripheral fluid chamber (or haptic fluid chamber) can comprise a plurality of the space-fillers, the chamber expanders, or both the space-fillers and chamber expanders. Each peripheral component can be configured to cause the optic portion of the adjustable IOL to change by about 0.1 D in response to a burst of an external energy directed at the peripheral component.

[0207] Fig. 4A is a graphic representation of a composite material 400 comprising a composite base material 402, an energy absorbing constituent 404, and a plurality of expandable components 406. As previously discussed, at least part of the peripheral portion 103 or components within the peripheral portion 103 can be made of the composite material 400.

[0208] The composite base material 402 can be comprised of hydrophobic acrylic materials. For example, the composite base material 402 can be comprised of phenylethyl acrylate (PEA), a phenylethyl methacrylate (PEMA), or a combination thereof.

[0209] In one example embodiment, the composite base material 402 can comprise a methacrylate-functional or methacrylic-functional cross-linkable polymer and reactive acrylic monomer diluents including lauryl methacrylate (n-dodecyl methacrylate or SR313) and ADMA. By controlling the amount of lauryl methacrylate (SR313) to ADMA, the overall corresponding hardness (i.e., more ADMA) or softness (i.e., more SR313) of the cured composite material 400 can be controlled. The methacrylate-functional or methacrylic-functional cross-linkable polymer can be made using the cross-linkable polymer precursor formulation.

[0210] The cross-linkable polymer precursor formulation can comprise the same copolymer blend used to make the optic portion and the haptics.

[0211] The copolymer blend can comprise an alkyl acrylate or methacrylate (e.g., n-butyl acrylate), a fluoro-alkyl (meth)acrylate (e.g., trifluoroethyl methacrylate), and a phenyl-alkyl acrylate (e.g., phenylethyl acrylate). For example, the copolymer blend can comprise n-butyl acrylate in the amount of about 41% to about 45% (wt%), trifluoroethyl methacrylate in the amount of about 20% to about 24% (wt%), and phenylethyl acrylate in the amount of about 28% to about 32% (wt%). The cross-linkable polymer precursor formulation can comprise or be made in part of the copolymer blend, a hydroxyl-functional acrylic monomer (e.g., HEA),

and a photoinitiator (e.g., Darocur 4265 or a 50/50 blend of diphenyl(2,4,6-trimethylbenzoyl)-phosphine oxide and 2-hydroxy-2-methylpropiophenone).

[0212] The composite base material 402 can comprise the methacrylate-functional or methacrylic-functional cross-linkable polymer (as discussed above) in the amount of about 50% to about 65% (e.g., about 55% to about 60%) (wt%), the reactive acrylic monomer diluent lauryl methacrylate (SR313) in the amount of about 32% to about 38% (e.g., about 32.70%) (wt%), the reactive acrylic monomer diluent adamantyl methacrylate (ADMA) in the amount of about 5% to about 9% (e.g., about 7.30%) (wt%).

[0213] Table 1 below provides an example formulation for the composite material 400:

TABLE 1: FORMULATION OF COMPOSITE MATERIAL (WT%)

Cross-linkable polymer (in two steps from precursor formulation, as described above)	1.47% 2-hydroxyethyl acrylate (HEA) 1.96% Darocur 4265 (photoinitiator) 43.49% n-butylacrylate (nBA) 30.21% 2-phenylethylacrylate (PEA) 22.87% 2,2,2-trifluoroethylmethacrylate (TFEMA)
Composite base material	60.00% cross-linkable polymer 32.70% lauryl methacrylate (SR313) 7.30% 1-adamantyl methacrylate (ADMA)
Composite base material with red energy absorbing colorant	99.50% composite base material 0.50% Disperse Red 1 dye
Composite base material with black energy absorbing colorant	99.95% composite base material 0.05% graphitized mesoporous carbon black
Final formulation of composite material	87.70% composite base material with red or black energy absorbing colorant 10.00% expandable microspheres 1.00% Luperox peroxide (thermal initiator) 1.30% Omnirad 2022

[0214] The composite material 400 can be made in several operations. The first operation can comprise preparing an uncolored composite base material 402. The second operation can comprise mixing the composite base material 402 with an energy absorbing constituent 404, expandable components 406, and initiators such as one or more photoinitiators, thermal initiators, or a combination thereof. The third operation can comprise placing the uncured

1 composite material 400 into a desired location within the peripheral portion 103 (e.g., the
2 peripheral fluid chambers 108 and/or the haptic(s) 104), and curing the composite material 400
3 in place.

4 **[0215]** For example, the uncolored composite base material 402 can be mixed with an energy
5 absorbing constituent 404 such as a dye (e.g., Disperse Red 1 dye) or pigment (graphitized
6 carbon black). The energy absorbing constituent 404 will be discussed in more detail below.

7 **[0216]** In some embodiments, the expandable components 406 can make up about 5.0% to
8 about 15.0% by weight of a final formulation of the composite material 400. More specifically,
9 the expandable components 406 can make up about 8.0% to about 12.0% (e.g., about 10.0%)
10 by weight of a final formulation (see Table 1) of the composite material 400. In these and other
11 embodiments, the energy absorbing constituent 404 can make up about 0.044% to about
12 0.44% (or about 0.55%) by weight of the final formulation of the composite material 400.

13 **[0217]** The photoinitiator can be Omnirad 2022 (bis(2,4,6-trimethylbenzoyl)phenyl-
14 phosphineoxide/2-hydroxy-2-methyl-1-phenyl-propan-1-one). The photoinitiator can make up
15 about 1.30% by weight of a final formulation of the composite material 400 (see, e.g., Table
16 1). In addition, the composite material 400 can also comprise a thermal initiator. The thermal
17 initiator can make up about 1.00% by weight of a final formulation of the composite material
18 400 (see, e.g., Table 1). In some embodiments, the thermal initiator can be a dialkyl peroxide
19 such as Luperox® peroxide. In other embodiments, the thermal initiator can be Perkadox.

20 **[0218]** In some embodiments, the energy absorbing constituent (e.g., dye or pigment) can be
21 positioned or located adjacent to the uncolored composite base material 402. In this
22 embodiment, the energy absorbing constituent 404 can absorb the external energy 318 (e.g.,
23 laser energy), convert the energy to heat, and conduct the energy to the composite base
24 material 402 to expand the composite base material 402. One added benefit of this approach is
25 that the energy absorbing constituent 404 can be made more discrete and an easier target for a
26 clinician or surgeon to hit with a laser or other external energy 318.

27 **[0219]** Fig 4B illustrates that the expandable components 406 can be expandable microspheres
28 comprising an expandable thermoplastic shell 408 and a blowing agent 410 contained within
29 the expandable thermoplastic shell 408. The microspheres can be configured to expand such
30 that a diameter 412 of at least one of the microspheres can increase about 2X the original
31 diameter. In other embodiments, the microspheres can be configured to expand such that the

diameter 412 of at least one of the microspheres can increase about 4X or four times the original diameter. In further embodiments, the microspheres can be configured to expand such that the diameter 412 of at least one of the microspheres can increase between about 2X and about 4X (or about 3.5X) the original diameter. For example, the microspheres can have a diameter 412 of about 12 μm at the outset. In response to an external energy applied or directed at the composite material 400 or in response to energy transferred or transmitted to the microspheres, the diameter 412 of the microspheres can increase to about 40 μm .

[0220] The volume of at least one of the microspheres can be configured to expand between about ten times (10X) to about 50 times (50X) in response to the external energy applied or directed at the composite material 400 or in response to energy transferred or transmitted to the microspheres.

[0221] In some embodiments, the blowing agent 410 can be an expandable fluid, such as an expandable gas. More specifically, the blowing agent 410 can be a branched-chain hydrocarbon. For example, the blowing agent 410 can be isopentane. In other embodiments, the blowing agent 410 can be or comprise cyclopentane, pentane, or a mixture of cyclopentane, pentane, and isopentane.

[0222] The expandable components 406 can comprise differing amounts of the blowing agent 410. For example, some expandable components 406 can comprise more or a greater amount of the blowing agent (e.g., more expandable gas) to allow such expandable components 406 to expand more, resulting in greater expansion of the composite material 400 comprising such expandable components 406.

[0223] Fig. 4B illustrates that each of the expandable components 406 can comprise a thermoplastic shell 408. Fig. 4B also illustrates that a thickness of the thermoplastic shell 408 can change as the expandable component 406 increases in size. More specifically, the thickness of the thermoplastic shell 408 can decrease as the expandable component 406 increases in size. For example, when the expandable components 406 are expandable microspheres, the thickness of the thermoplastic shell 408 (i.e., its thickness in a radial direction) can decrease as the diameter 412 of the expandable microsphere increases.

[0224] For example, as previously discussed, at least one of the expandable microspheres can have a diameter 412 of about 12 μm at the outset. In this embodiment, the thermoplastic shell 408 of the expandable microsphere can have a shell thickness of about 2.0 μm . In response to

an external energy applied or directed at the composite material 400 or in response to energy transferred or transmitted to the microsphere, the diameter 412 of the microsphere can increase to about 40 μm (and the volume expand between about 10X and 50X) and the shell thickness of the microsphere can decrease to about 0.1 μm .

[0225] Although Figs. 4A and 4B illustrate the expandable components 406 as spheres or microspheres, it is contemplated by this disclosure that the expandable components 406 can be substantially shaped as ovoids, ellipsoids, cuboids or other polyhedrons, or a combination thereof.

[0226] In some embodiments, the thermoplastic shell 408 can be made in part of nitriles or acrylonitrile copolymers. For example, the thermoplastic shell 408 can be made in part of acrylonitrile, styrene, butadiene, methyl acrylate, or a combination thereof.

[0227] As previously discussed, the expandable components 406 can make up between about 8.0% to about 12% by weight of a final formulation of the composite material 400. The expandable components 406 can make up about 10% by weight of a final formulation of the composite material 400.

[0228] The expandable components 406 can be dispersed or otherwise distributed within the composite base material 402 making up the bulk of the composite material 400. The composite base material 402 can serve as a matrix for holding or carrying the expandable components 406. The composite material 400 can expand in response to an expansion of the expandable components 406 (e.g., the thermoplastic microspheres). For example, a volume of the composite material 400 can increase in response to the expansion of the expandable components 406.

[0229] The composite material 400 also comprises an energy absorbing constituent 404. In some embodiments, the energy absorbing constituent 404 can be an energy absorbing colorant.

[0230] In certain embodiments, the energy absorbing colorant can be an energy absorbing dye. For example, the energy absorbing dye can be an azo dye. In some embodiments, the azo dye can be a red azo dye such as Disperse Red 1 dye. In other embodiments, the azo dye can be an orange azo dye such as Disperse Orange dye (e.g., Disperse Orange 1), a yellow azo dye such as Disperse Yellow dye (e.g., Disperse Yellow 1), a blue azo dye such as Disperse Blue dye (e.g., Disperse Blue 1), or a combination thereof.

1 [0231] In additional embodiments, the energy absorbing colorant can be or comprise a
2 pigment. For example, the energy absorbing colorant can be or comprise graphitized carbon
3 black as the pigment.

4 [0232] Similar to the expandable components 406, the energy absorbing constituent 404 can
5 be dispersed or otherwise distributed within the composite base material 402 making up the
6 bulk of the composite material 400. The composite base material 402 can serve as a matrix for
7 holding or carrying the expandable components 406 and the energy absorbing constituent 404.

8 [0233] As previously discussed, the energy absorbing constituent 404 can make up between
9 about 0.025% to about 1.0% (or, more specifically, about 0.045% to about 0.45%) by weight
10 of a final formulation of the composite material 400. For example, when the energy absorbing
11 constituent 404 is a dye (e.g., an azo dye such as Disperse Red 1), the energy absorbing
12 constituent 404 can make up about between about 0.45% to about 1.0% by weight of a final
13 formulation of the composite material 400. When the energy absorbing constituent 404 is
14 graphitized carbon black or other types of pigments, the energy absorbing constituent 404 can
15 make up about 0.025% to about 0.045% by weight of a final formulation of the composite
16 material 400.

17 [0234] The energy absorbing constituent 404 (e.g., azo dye, graphitized carbon black, or a
18 combination thereof) can absorb or capture an external energy applied or directed at the
19 composite material 400. The energy absorbing constituent 404 can absorb or capture the
20 external energy and then transform or transfer the energy into thermal energy or heat to the
21 expandable components 406.

22 [0235] The thermoplastic shell 408 can soften and begin to flow as thermal energy is
23 transferred or transmitted to the expandable components 406. The thermoplastic shell 408 of
24 the expandable components 406 can then begin to thin or reduce in thickness in response to the
25 thermal energy transferred or transmitted to the expandable components 406. As the
26 thermoplastic shell 408 begins to soften and reduce in thickness, the blowing agent 410 within
27 the expandable components 406 can expand. The blowing agent 410 can also expand in
28 response to the thermal energy or heat transferred or transmitted to the expandable components
29 406. Expansion of the blowing agents 410 can cause the expandable components 406 (e.g., the
30 thermoplastic microspheres) to expand or increase in volume. This ultimately causes the
31 composite material 400 to expand or increase in volume.

1 [0236] The composite material 400 can expand or increase in size in an isotropic manner such
2 that the composite material 400 expands in all directions. Such isotropic expansion can be
3 harnessed to produce expansion or material displacement in specific directions by placing or
4 positioning the composite material 400 at specific locations within the peripheral fluid
5 chambers 108 along the haptic(s) 104 or optic portion 102 of the adjustable IOL 100.

6 [0237] As will be discussed in more detail in the following sections, in some embodiments,
7 the external energy can be light energy and the energy absorbing constituent 404 can absorb or
8 capture the light energy directed at the composite material 400 and transform or transfer the
9 light energy into thermal energy or heat to the expandable components 406. The blowing agent
10 410 within the expandable components 406 can expand or become energized in response to the
11 thermal energy or heat. The expandable components 406 and, ultimately, the composite
12 material 400 can expand or increase in volume in response to this light energy directed at the
13 composite material 400.

14 [0238] The shape change (e.g., increase in volume) undertaken by the expandable components
15 406 can be a persistent or a substantially permanent change. A persistent or substantially
16 permanent change can mean that the expandable components 406 do not substantially revert
17 back to its original shape or size after the shape change (e.g., after an increase in volume) has
18 occurred. As a result, any change in the size or volume of the composite material 400 caused
19 by a change in the size or volume of the expandable components 406 is also persistent or
20 substantially permanent. As will be discussed in more detail in the following sections, this
21 means that any structural changes made to the adjustable IOL 100 as a result of external
22 energy or stimulus applied or otherwise directed at the composite material 400 embedded or
23 integrated within the adjustable IOL 100 can persist or remain substantially permanent.

24 [0239] The thermoplastic shells 408 of the expandable components 406 can harden, once
25 again, when the external energy is no longer directed or applied to the composite material 400.
26 For example, the thermoplastic shells 408 may again harden when the temperature within a
27 vicinity of the expandable components 406 falls below a certain threshold. For example, the
28 thermoplastic shells 408 of the expandable microspheres can harden when light energy is no
29 longer directed at the composite material 400. After the thermoplastic shells 408 harden, the
30 expandable components 406 are locked into their new size and expanded configuration.

1 [0240] When the energy absorbing constituent 404 is an energy absorbing colorant, such as a
2 dye or graphitized carbon, the color of at least part of the composite material 400 can take on
3 the color of the energy absorbing colorant. For example, when the energy absorbing
4 constituent 404 is an azo dye such as Disperse Red 1 having a red color, at least a portion of
5 the composite material 400 comprising the energy absorbing constituent 404 can be colored
6 red. Moreover, when the energy absorbing constituent 404 is graphitized carbon having a
7 black color, at least a portion of the composite material 400 comprising the energy absorbing
8 constituent 404 can be colored black. Although two colors (e.g., red and black) are mentioned
9 in this disclosure, it is contemplated by this disclosure and it should be understood by one of
10 ordinary skill in the art that energy absorbing colorant of other types of colors can also be used
11 such as energy absorbing yellow, orange, or blue dyes or materials.

12 [0241] The color of the energy absorbing colorant can be visually perceptible to a clinician or
13 another medical professional when at least part of the adjustable IOL 100 is made of the
14 composite material 400 comprising the energy absorbing colorant. The color of the energy
15 absorbing colorant can be visually perceptible to a clinician or another medical professional
16 when the adjustable IOL 100 is implanted within an eye of a patient. For example, the
17 composite material 400 can comprise Disperse Red 1 serving as the energy absorbing colorant.
18 In this example, at least part of the adjustable IOL 100 can appear red to the clinician or
19 another medical professional when the adjustable IOL 100 is implanted within the eye of a
20 patient.

21 [0242] The color of the energy absorbing colorant can allow the clinician or another medical
22 professional to detect or determine the location or position of the composite material 400
23 within the adjustable IOL 100. The color of the energy absorbing colorant can also allow the
24 clinician or another medical professional to determine where to direct the external energy or
25 stimulus to adjust the adjustable IOL 100.

26 [0243] One technical problem faced by the applicants is how to integrate the composite
27 material into the peripheral portion (e.g., the haptics) of the adjustable IOL such that the
28 composite material would adhere to the material used to make the rest of the adjustable IOL
29 and remain substantially fixed at certain locations within the peripheral portion. One solution
30 discovered by the applicants and disclosed herein is the unique composition of the composite
31 material 400 which incorporates the same copolymer blend used to make the rest of the lens.

By designing the adjustable IOL in this manner, the composite material 400 can be compatible with the rest of the material used to construct the peripheral portion and remains substantially fixed at its location without migrating or shifting.

[0244] Another technical problem faced by the applicants is how to ensure that any adjustments made to the adjustable IOL persist long after the adjustment procedure. One solution discovered by the applicants and disclosed herein is to induce an expansion of a composite material made in part of expandable microspheres comprising a blowing agent contained within thermoplastic shells. The thermoplastic shells can soften (and the thickness of the thermoplastic shells can decrease) in response to an external energy directed or applied at the composite material (which can result in heat or thermal energy being transferred or transmitted to the expandable microspheres). The blowing agent within the thermoplastic shells can expand as the thermoplastic shells soften. Expansion of the blowing agent can expand the microspheres, which can, in turn, expand the composite base material serving as the bulk of the composite material. The expandable microspheres can retain their new enlarged or expanded configuration even after the external energy is no longer applied to the composite material.

[0245] Moreover, the energy absorbing constituent of the composite material 400 can capture or absorb a relatively harmless external energy or stimulus directed at the composite material and transform or transfer the external energy into thermal energy which can then cause the thermoplastic microspheres to expand. By designing the adjustable IOL 100 in this manner, a burst of relatively harmless energy or stimulus (e.g., light energy) can be used to induce a persistent change in the shape or size of at least part of the adjustable IOL 100. This persistent change in the shape or size of the adjustable IOL 100 can have a continuing effect on an optical parameter of the lens including, for example, its base power.

[0246] Fig. 5 illustrates a top plan view of another embodiment of the adjustable static-focus IOL 100 with part of the anterior portion of the adjustable IOL 100 removed to better illustrate components within the IOL. As shown in Fig. 5, the first peripheral components 138 can be made of a first composite material comprising a first energy absorbing constituent having a first color and the second peripheral components 140 can be made of a second composite material comprising a second energy absorbing constituent having a second color different from the first color. This difference in color can be visually perceptible to a clinician or

another medical professional and can allow the clinician or other medical professional to visually differentiate between the two types of peripheral components 136.

[0247] For example, the first energy absorbing constituent can be an energy absorbing dye. As a more specific example, the energy absorbing dye can be an azo dye such as a red azo dye (e.g., Disperse Red 1 dye). In this example, the second energy absorbing constituent can be another energy absorbing dye such as a yellow azo dye or another lighter-colored dye.

[0248] In other examples, the first energy absorbing constituent can be or comprise a pigment such as graphitized carbon black (which exhibits a black color). In these examples, the second energy absorbing constituent can be an energy absorbing dye (e.g., a red azo dye).

[0249] In additional examples, the second energy absorbing constituent can be or comprise a pigment such as graphitized carbon black (which exhibits a black color). In these examples, the first energy absorbing constituent can be an energy absorbing dye (e.g., a red azo dye).

[0250] In other embodiments, the first composite material and the second composite material can be made in part of the same energy absorbing constituents or colorants but comprise different amounts or weight percentages of such constituents or colorants.

[0251] In certain embodiments, the first peripheral component 138 made of the first composite material (and having a first color) can expand or change shape in response to a first type of external energy (e.g., light energy between 520 nm to 540 nm) directed at the first composite material and the second peripheral component 140 made of the second composite material (and having a second color different from the first color) can expand in response to a second type of external energy (e.g., light energy between 600 nm and 650 nm) directed at the second composite material.

[0252] By designing the adjustable IOL 100 in this manner, a clinician or another medical professional can direct external energy or stimulus at different target sites along the peripheral portion 103 using the different colors of the composite materials as guides or markers. Moreover, the different colored composite materials can also serve as indicators or visual cues as to where to direct the external energy or stimulus to cause certain changes in the base power of the optic portion 102.

[0253] For example, the adjustable IOL 100 can be configured such that a base power of the adjustable IOL 100 can be adjusted in a first manner (e.g., the base power can be increased) by directing or otherwise applying an external energy at a first peripheral component 138 made of

the first composite material (having a first color). The base power of the adjustable IOL 100 can also be adjusted in a second manner (e.g., the base power can be decreased) by directing or otherwise applying additional bursts or pulses of the external energy at a second peripheral component 140 made of a second composite material (having a second color different from the first color).

[0254] Fig. 6 illustrates a top plan view of another embodiment of the adjustable IOL 100 with an optic portion 102 comprising a light splitting lens surface profile 600. The peripheral portion 103 of the adjustable IOL 100 is shown in broken lines to emphasize the optic portion 102.

[0255] One technical problem faced by the applicants is how to design a fluid-filled IOL that can be used by patients seeking different types of vision support (e.g., near vision, intermediate vision, distance vision, etc.). One solution discovered by the applicants is the adjustable IOL disclosed herein where different lens surface profiles, both rotationally symmetric as well as in toric profiles so as to correct for astigmatism, can be defined on an external optical surface (e.g., an anterior optical surface) of the optic portion allowing for the same adjustable IOL structure to be adapted as an adjustable monofocal IOL, an adjustable bifocal IOL, an adjustable trifocal IOL, or an adjustable EDOF IOL, in both toric and non-toric shapes.

[0256] As shown in Fig. 6, the optic portion 102 of the adjustable IOL 100 can comprise a light splitting lens surface profile 600 defined on a lens surface of the optic portion 102. In some embodiments, the light splitting lens surface profile 600 can comprise a central diffractive area or structure comprising a plurality of diffractive zones or steps. In these and other embodiments, the widths of the diffractive zones can decrease in a radially outward manner such that zone widths at a periphery of the lens are smaller than zone widths near a central portion of the lens.

[0257] The light splitting lens surface profile 600 can split light into multiple foci or focal points. In these embodiments, the adjustable IOL 100 can be considered an adjustable multifocal IOL or a non-accommodating fluid-adjustable multifocal IOL. Even though the light splitting lens surface profile 600 can split light into multiple foci or focal points, each such focal point is static and the fluid-adjustable multifocal IOL is considered non-accommodating.

1 [0258] In some embodiments, the light splitting lens surface profile 600 can be configured to
2 split light into two focal points (e.g., allowing for near and distant vision). In these
3 embodiments, the adjustable IOL 100 can be considered an adjustable bifocal IOL or a non-
4 accommodating fluid-adjustable bifocal IOL. In these embodiments, even though the light
5 splitting lens surface profile 600 can split light into two focal points, each such focal point is
6 static and the fluid-adjustable bifocal IOL is considered non-accommodating.

7 [0259] The light splitting lens surface profile 600 can also be configured to split light into
8 three focal points (e.g., allowing for near, intermediate, and distant vision). In these
9 embodiments, the adjustable IOL 100 can be considered an adjustable trifocal IOL or a non-
10 accommodating fluid-adjustable trifocal IOL.

11 [0260] In other embodiments not shown in Fig. 6, the optic portion 102 of the adjustable IOL
12 100 can have a uniformly curved (e.g., a spherical) lens surface or an aspherical lens surface
13 providing focusing power for a single distance. In these embodiments, the adjustable IOL 100
14 can be considered an adjustable monofocal IOL or a non-accommodating fluid-adjustable
15 monofocal IOL.

16 [0261] In additional embodiments not shown in Fig. 6, the optic portion 102 of the adjustable
17 IOL 100 can have a lens surface profile or pattern configured to provide an extended depth of
18 focus or a single elongated focal point. In these embodiments, the adjustable IOL 100 can be
19 considered an adjustable extended depth of focus (EDOF) IOL or a non-accommodating fluid-
20 adjustable EDOF IOL.

21 [0262] It is contemplated by this disclosure that the unique peripheral portion 103 disclosed
22 herein can be compatible with optic portions 102 comprising a variety of lens surface profiles.
23 Thus, directing external energy (e.g., laser light) at peripheral component(s) 136 made of the
24 composite material 400 in the peripheral portion 103 can adjust the focusing power(s) or
25 focusing length(s) provided by such lens surface profiles.

26 [0263] Any of the adjustable monofocal IOL, the adjustable multifocal IOL, and the adjustable
27 EDOF IOL can comprise a toric lens profile.

28 [0264] Fig. 7 is one embodiment of a method 700 of adjusting an IOL 100 post operatively.
29 The method 700 can comprise increasing a base power of an IOL 100 post-operatively by
30 directing an external energy 318 at a composite material 400 configured as a space-filler 310
31 positioned within a peripheral fluid chamber 108 defined within a peripheral portion 103 of the

IOL 100 in operation 702. The method 700 can also comprise decreasing the base power by directing the external energy 318 at another instance of the composite material 400 configured as a chamber expander 312 positioned within the peripheral fluid chamber 108 in operation 704.

[0265] Fig. 8 is another embodiment of a method 800 of adjusting an IOL 100 post-operatively. The method 800 can comprise adjusting a base power of the IOL 100 by directing pulses of an external energy 318 at a first peripheral component 138 within a peripheral fluid chamber 108 defined within a peripheral portion 103 of the IOL 100 in operation 802. The method 800 can also comprise further adjusting the base power by directing additional pulses of the external energy 318 at a second peripheral component 140 within the same peripheral fluid chamber 108 in operation 804.

[0266] For example, the first peripheral component 138 can be a space-filler 310 and directing the external energy 318 at the space-filler 310 can expand the space-filler 310 and decrease a volume of the peripheral fluid chamber 108 and displace fluid from the peripheral fluid chamber 108 into the optic fluid chamber 106 (thereby increasing the base power of the optic portion 102). The second peripheral component 140 can be a chamber expander 312 and directing the external energy 318 at the chamber expander 312 can expand the chamber expander 312 and increase the volume of the peripheral fluid chamber 108 and draw fluid from the optic fluid chamber 106 into the peripheral fluid chamber 108 (thereby decreasing the base power of the optic portion 102).

[0267] Alternatively, the external energy 318 can be directed first at the chamber expander 312 to decrease the base power of the optic portion 102 and then the external energy 318 can be directed subsequently at the space-filler 310 to increase the base power of the optic portion 102.

[0268] Fig. 9 is yet another embodiment of a method 900 of adjusting an IOL 100 post-operatively. The method 900 can comprise adjusting a base power of the IOL 100 by directing pulses of an external energy at a first peripheral component 138 within a first of the peripheral fluid chambers 108 (e.g., a first haptic fluid chamber) defined within a peripheral portion 103 of the IOL 100 in operation 902. The method 900 can further comprise adjusting the base power of the IOL 100 by directing additional pulses of the external energy at a second peripheral component 140 or another instance of the first peripheral component 138 within a

second of the peripheral chambers 108 (e.g., a second haptic fluid chamber) of the peripheral portion 103 of the IOL 100 in operation 904.

[0269] The first peripheral component 138 can be a space-filler 310 and directing the external energy 318 at the space-filler 310 can expand the space-filler 310 and decrease a volume of the first peripheral fluid chamber and displace fluid from the first peripheral fluid chamber into the optic fluid chamber 106 (thereby increasing the base power of the optic portion 102). The second peripheral component 140 can be a chamber expander 312 and directing the external energy 318 at the chamber expander 312 can expand the chamber expander 312 and increase the volume of the second peripheral fluid chamber and draw fluid from the optic fluid chamber 106 into the second peripheral fluid chamber (thereby decreasing the base power of the optic portion 102).

[0270] In some embodiments, pulses of the external energy 318 can be directed at a chamber expander 312 within the first peripheral fluid chamber to decrease the base power of the optic portion 102 and additional pulses of the external energy 318 can be directed at a space-filler 310 within the second peripheral fluid chamber to increase the base power of the optic portion 102.

[0271] Fig. 10 is an additional embodiment of a method 1000 of adjusting an IOL 100 post-operatively. The method 1000 can comprise adjusting a base power of the IOL 100 in a first direction by directing an external energy 318 at a first composite material in operation 1002. The first composite material can comprise a first energy absorbing constituent having a first color. The method 1000 can further comprise adjusting the base power of the IOL 100 in a second direction by directing the external energy at a second composite material in operation 1004. The second composite material can comprise a second energy absorbing constituent having a second color different from the first color.

[0272] For example, the first composite material can be formed as a space-filler 310. In this example, the first energy absorbing constituent of the first composite material can be an azo dye having a first color (e.g., a red color). Also, in this example, the second composite material can be formed as a chamber expander 312 and the second energy absorbing constituent of the second composite material can be an energy absorbing pigment such as graphitized carbon black or an azo dye having a second color different from the first color (e.g., a blue color or yellow color).

[0273] In other embodiments, the first composite material can be formed as a chamber expander 312 and the first energy absorbing constituent of the first composite material can be an azo dye having a first color (e.g., a red color). In these embodiments, the second composite material can be formed as a space-filler 310 and the second energy absorbing constituent of the second composite material can be an energy absorbing pigment such as graphitized carbon black or an azo dye having a second color different from the first color (e.g., a blue color or yellow color).

[0274] In one or more of the methods disclosed herein, adjusting the base power of the IOL 100 can comprise adjusting the base power of the optic portion 102 by between about ± 0.05 D to about ± 0.50 D by directing pulses of the external energy 318 at the composite material 400 to expand the composite material 400. For example, adjusting the base power of the IOL 100 can comprise adjusting the base power of the optic portion 102 by about ± 0.10 D by directing pulses of the external energy 318 at the composite material 400 to expand the composite material 400.

[0275] For example, the base power of the optic portion 102 can be adjusted by between about ± 0.05 D to about ± 0.50 D in response to fluid displacement or exchange between the optic fluid chamber 106 and one of the peripheral fluid chambers 108 due to a change in the volume of the peripheral fluid chamber 108 as a result of an expansion of a peripheral component 136 caused by pulses of the external energy 318 directed at the peripheral component 136. As a more specific example, the base power of the optic portion 102 can increase by between about $+0.05$ D to about $+0.50$ D in response to fluid entering the optic fluid chamber 106 from one of the peripheral fluid chambers 108 due to a reduction in the volume of the peripheral fluid chamber 108 as a result of an expansion of a first peripheral component 138 caused by pulses of the external energy 318 directed at the first peripheral component 138. As another more specific example, the base power of the optic portion 102 can decrease by between about -0.05 D to about -0.50 D in response to fluid exiting the optic fluid chamber 106 into one of the peripheral fluid chambers 108 due to an increase in the volume of the peripheral fluid chamber 108 as a result of an expansion of a second peripheral component 140 caused by pulses of the external energy 318 directed at the second peripheral component 140.

[0276] In one or more of the methods disclosed herein, adjusting the base power of the IOL 100 can comprise adjusting the base power of the IOL 100 in total between about ± 1.0 D and

1 about ± 2.0 D by directing pulses of the external energy 318 at multiple peripheral components
2 136.

3 **[0277]** In one or more of the methods disclosed herein, directing the external energy 318 at the
4 composite material can further comprise directing light energy at the composite material 400.
5 For example, directing the external energy 318 at the composite material 400 can further
6 comprise directing laser light at the composite material 400. As a more specific example,
7 directing the external energy 318 at the composite material 400 can further comprise directing
8 green laser light at the composite material 400.

9 **[0278]** In one or more of the methods disclosed herein, directing the external energy 318 at the
10 composite material 400 can comprise directing laser light having a wavelength between about
11 488 nm to about 650 nm at the composite material 400. In other embodiments, directing the
12 external energy 318 at the composite material 400 can further comprise directing laser light
13 having a wavelength between about 946 nm to about 1120 nm at the composite material 400.

14 **[0279]** One drawback of currently available tunable IOLs (such as light adjustable lens) is that
15 the tuning procedure requires time to take effect, may require multiple visits to a clinician's
16 office, and the clinician must often purchase expensive new equipment to undertake such
17 tuning procedures. One advantage of the static-focus adjustable IOLs 100 disclosed herein is
18 that such static-focus adjustable IOLs 100 allow for post-operative refractive error correction
19 in a matter of seconds rather than hours. This allows patients to provide feedback concerning
20 their refractive error correction almost instantaneously. Moreover, the IOLs 100 disclosed
21 herein can be tuned using commercially available lasers (e.g., 532 nm photocoagulator lasers)
22 that are commonly found in most clinician's offices. Moreover, patients do not need to wear
23 U.V blocking glasses during the healing period and refractive error correction can be
24 undertaken months or even years after the initial implantation procedure.

25 **[0280]** Disclosed herein is an intraocular lens, comprising: an optic portion; a peripheral
26 portion coupled to the optic portion; wherein the peripheral portion comprises a composite
27 material comprising an energy absorbing constituent and a plurality of expandable
28 components, wherein a base power of the optic portion is configured to change in response to
29 an external energy directed at the composite material, and wherein the base power of the optic
30 portion is configured to be unresponsive to forces applied to the peripheral portion by a
31 capsular bag when the intraocular lens is implanted within the capsular bag.

1 [0281] The intraocular lens as disclosed herein, wherein the expandable components are
2 expandable microspheres, and wherein each of the expandable microspheres comprises a
3 blowing agent contained within a thermoplastic shell.

4 [0282] The intraocular lens as disclosed herein, wherein a thickness of the thermoplastic shell
5 is configured to change in response to the external energy directed at the composite material.

6 [0283] The intraocular lens as disclosed herein 2, wherein the blowing agent is a branched-
7 chain hydrocarbon.

8 [0284] The intraocular lens as disclosed herein, wherein the branched-chain hydrocarbon is
9 isopentane.

10 [0285] The intraocular lens as disclosed herein, wherein the thermoplastic shell is made in part
11 of an acrylonitrile copolymer.

12 [0286] The intraocular lens as disclosed herein, wherein a diameter of at least one of the
13 expandable microspheres is configured to increase between about 2X to about 4X in response
14 to the external energy directed at the composite material.

15 [0287] The intraocular lens as disclosed herein, wherein a volume of at least one of the
16 expandable components is configured to expand between about 10X to 50X in response to the
17 external energy directed at the composite material.

18 [0288] The intraocular lens as disclosed herein, wherein the expandable components comprise
19 between about 5% to about 15% by weight of the composite material.

20 [0289] The intraocular lens as disclosed herein, wherein the expandable components comprise
21 about 10% by weight of the composite material.

22 [0290] The intraocular lens as disclosed herein, wherein the energy absorbing constituent is an
23 energy absorbing colorant.

24 [0291] The intraocular lens as disclosed herein, wherein a color of the energy absorbing
25 colorant is visually perceptible when the intraocular lens is implanted within the eye.

26 [0292] The intraocular lens as disclosed herein, wherein the energy absorbing colorant is a
27 dye.

28 [0293] The intraocular lens as disclosed herein, wherein the dye is an azo dye.

29 [0294] The intraocular lens as disclosed herein, wherein the dye is a Disperse Red 1 dye.

30 [0295] The intraocular lens as disclosed herein, wherein the energy absorbing colorant is an
31 energy absorbing pigment.

1 [0296] The intraocular lens as disclosed herein, wherein the energy absorbing pigment is
2 graphitized carbon black.

3 [0297] The intraocular lens as disclosed herein, wherein the energy absorbing constituent
4 comprises between about 0.025% to about 1.00% by weight of the composite material.

5 [0298] The intraocular lens as disclosed herein, wherein the peripheral portion is made in part
6 of a cross-linked copolymer comprising a copolymer blend, and wherein the composite
7 material is made in part of the copolymer blend.

8 [0299] The intraocular lens as disclosed herein, wherein the composite material is cured to the
9 cross-linked copolymer at a location within the peripheral portion, and wherein the composite
10 material remains substantially fixed at the location.

11 [0300] The intraocular lens as disclosed herein, wherein the base power of the optic portion is
12 configured to change between about ± 0.05 D to about ± 0.5 D in response to pulses of the
13 external energy directed at the composite material.

14 [0301] The intraocular lens as disclosed herein, wherein the base power of the optic portion is
15 configured to change by about 0.1 D in response to pulses of the external energy directed at the
16 composite material.

17 [0302] The intraocular lens as disclosed herein, wherein the base power of the optic portion is
18 configured to change in total between about ± 1.0 D and about ± 2.0 D.

19 [0303] The intraocular lens as disclosed herein, wherein the change in the base power is a
20 persistent change.

21 [0304] The intraocular lens as disclosed herein, wherein the external energy is light energy.

22 [0305] The intraocular lens as disclosed herein, wherein the light energy is a laser light.

23 [0306] The intraocular lens as disclosed herein, wherein the laser light has a wavelength of
24 between about 488 nm to about 650 nm.

25 [0307] The intraocular lens as disclosed herein, wherein the laser light is a green laser light.

26 [0308] The intraocular lens as disclosed herein, wherein the green laser light has a wavelength
27 of about 532 nm.

28 [0309] The intraocular lens as disclosed herein, wherein the laser light has a wavelength of
29 between about 946 nm to about 1120 nm.

30 [0310] The intraocular lens as disclosed herein, wherein the laser light has a wavelength of
31 about 1030 nm.

1 [0311] The intraocular lens as disclosed herein, wherein the laser light has a wavelength of
2 between about 1030 nm and 1064 nm.

3 [0312] The intraocular lens as disclosed herein, wherein the laser light is emitted by a
4 femtosecond laser.

5 [0313] The intraocular lens as disclosed herein, wherein the laser light is emitted by a
6 neodymium-doped yttrium aluminum garnet (Nd:YAG) laser.

7 [0314] The intraocular lens as disclosed herein, wherein the energy absorbing constituent is
8 configured to transfer thermal energy to the plurality of expandable components in response to
9 the external energy directed at the composite material.

10 [0315] The intraocular lens as disclosed herein, wherein the composite material is formed as
11 discrete peripheral components such that directing the external energy at one discrete
12 peripheral component causes a change in the base power of the optic portion and directing the
13 external energy at another discrete peripheral component also causes a change in the base
14 power of the optic portion.

15 [0316] The intraocular lens as disclosed herein, wherein the peripheral portion comprises
16 between 20 and 40 peripheral components.

17 [0317] The intraocular lens as disclosed herein, wherein the optic portion comprises an optic
18 fluid chamber and the peripheral portion comprises at least one peripheral fluid chamber in
19 fluid communication with the optic fluid chamber.

20 [0318] The intraocular lens as disclosed herein, wherein the peripheral fluid chamber is curved
21 and the peripheral fluid chamber follows a curvature of the optic portion.

22 [0319] The intraocular lens as disclosed herein, wherein the peripheral fluid chamber has a
23 chamber height, and wherein the chamber height is between about 0.1 mm to about 0.3 mm.

24 [0320] The intraocular lens as disclosed herein, wherein the composite material is configured
25 as a chamber expander, wherein the chamber expander is configured to expand in response to
26 the external energy directed at the chamber expander, and wherein expansion of the chamber
27 expander increases a volume of the peripheral fluid chamber.

28 [0321] The intraocular lens as disclosed herein, wherein the base power of the optic portion is
29 configured to decrease in response to the external energy directed at the chamber expander.

30 [0322] The intraocular lens as disclosed herein, wherein the chamber expander is configured
31 as an expandable column extending from a chamber anterior wall to a chamber posterior wall.

1 [0323] The intraocular lens as disclosed herein, wherein the composite material is configured
2 as a space-filler, wherein the space-filler is configured to expand in response to the external
3 energy directed at the space-filler, and wherein expansion of the space-filler decreases a
4 volume of the peripheral fluid chamber.

5 [0324] The intraocular lens as disclosed herein, wherein the space-filler is configured as a pad
6 extending from either a chamber anterior wall or a chamber posterior wall.

7 [0325] The intraocular lens as disclosed herein, wherein the base power of the optic portion is
8 configured to increase in response to the external energy directed at the space-filler.

9 [0326] The intraocular lens as disclosed herein, wherein the base power is configured to
10 change in response to fluid displacement between the optic fluid chamber and the peripheral
11 fluid chamber as a result of the external energy directed at the composite material.

12 [0327] The intraocular lens as disclosed herein, wherein the peripheral portion is configured as
13 at least one haptic, wherein the peripheral fluid chamber is defined within the haptic, wherein
14 the peripheral fluid chamber extends only partially into the haptic.

15 [0328] The intraocular lens as disclosed herein, wherein the at least one haptic comprises a
16 haptic proximal portion and a haptic distal portion, wherein the haptic distal portion comprises
17 a haptic distal arm unattached to the optic portion except via the haptic proximal portion.

18 [0329] The intraocular lens as disclosed herein, wherein the haptic distal arm comprises a kink
19 or bend.

20 [0330] The intraocular lens as disclosed herein, wherein the peripheral fluid chamber is
21 defined within the haptic proximal portion, wherein a chamber segment of the haptic proximal
22 portion is unconnected to the optic portion.

23 [0331] The intraocular lens as disclosed herein, wherein the at least one haptic is connected to
24 the optic portion at a proximal end of the haptic and at a distal connecting portion located
25 distally of the chamber segment.

26 [0332] The intraocular lens as disclosed herein, wherein the proximal end of the haptic is
27 connected to and extends from a lateral side of the optic portion, wherein the lateral side has a
28 side height, and wherein the side height is about 0.65 mm.

29 [0333] The intraocular lens as disclosed herein, wherein the peripheral portion is configured as
30 a first haptic comprising a first haptic fluid chamber and a second haptic comprising a second
31 haptic fluid chamber, and wherein the optic portion comprises an optic fluid chamber.

1 [0334] The intraocular lens as disclosed herein, wherein the first haptic fluid chamber is in
2 fluid communication with the optic fluid chamber via a first fluid channel, wherein the second
3 haptic fluid chamber is in fluid communication with the optic fluid chamber via a second fluid
4 channel, and wherein the first fluid channel is positioned diametrically opposed to the second
5 fluid channel.

6 [0335] The intraocular lens as disclosed herein, wherein the optic fluid chamber, the first
7 haptic fluid chamber, and the second haptic fluid chamber comprise a fluid having a total fluid
8 volume of between about 10 μ L and about 20 μ L.

9 [0336] The intraocular lens as disclosed herein, wherein each of the first haptic fluid chamber
10 and the second haptic fluid chamber comprises about 0.5 μ L of the fluid.

11 [0337] The intraocular lens as disclosed herein, wherein about 15 nL of the fluid is exchanged
12 between either the first haptic fluid chamber and the second haptic fluid chamber and the optic
13 fluid chamber in response to an expansion of the composite material.

14 [0338] The intraocular lens as disclosed herein, wherein the fluid is a silicone oil.

15 [0339] The intraocular lens as disclosed herein, wherein the peripheral portion comprises a
16 first composite material and a second composite material, wherein the first composite material
17 comprises a first energy absorbing constituent and the second composite material comprises a
18 second energy absorbing constituent, wherein a color of the first energy absorbing constituent
19 is different from a color of the second energy absorbing constituent.

20 [0340] Also disclosed herein is an intraocular lens, comprising: an optic portion; and a
21 peripheral portion coupled to the optic portion, wherein the peripheral portion comprises a first
22 peripheral component and a second peripheral component, wherein the first peripheral
23 component is made of a composite material comprising an energy absorbing constituent and a
24 plurality of expandable components, wherein the second peripheral component is made of the
25 composite material comprising the energy absorbing constituent and the plurality of
26 expandable components, wherein a base power of the optic portion is configured to increase in
27 response to an external energy directed at the first peripheral component, wherein the base
28 power of the optic portion is configured to decrease in response to the external energy directed
29 at the second peripheral component, and wherein the base power of the optic portion is
30 configured to be unresponsive to forces applied to the peripheral portion by a capsular bag
31 when the intraocular lens is implanted within the capsular bag.

1 [0341] The intraocular lens as disclosed herein, wherein the optic portion comprises an optic
2 fluid chamber and the peripheral portion comprises at least one peripheral fluid chamber in
3 fluid communication with the optic fluid chamber.

4 [0342] The intraocular lens as disclosed herein, wherein the base power is configured to
5 change in response to fluid displacement between the optic fluid chamber and the peripheral
6 fluid chamber as a result of the external energy directed at the first peripheral component or
7 the second peripheral component.

8 [0343] The intraocular lens as disclosed herein, wherein the first peripheral component is
9 configured as a space-filler, wherein the space-filler is configured to expand in response to the
10 external energy directed at the space-filler, and wherein expansion of the space-filler decreases
11 a volume of the peripheral fluid chamber.

12 [0344] The intraocular lens as disclosed herein, wherein the space-filler is configured as an
13 expandable pad extending from either a chamber anterior wall or a chamber posterior wall.

14 [0345] The intraocular lens as disclosed herein, wherein the second peripheral component is
15 configured as a chamber expander, wherein the chamber expander is configured to expand in
16 response to the external energy directed at the chamber expander, and wherein expansion of
17 the chamber expander increases a volume of the peripheral fluid chamber.

18 [0346] The intraocular lens as disclosed herein, wherein the chamber expander is configured
19 as an expandable column extending from a chamber anterior wall to a chamber posterior wall.

20 [0347] The intraocular lens as disclosed herein, wherein the first peripheral component and the
21 second peripheral component are located within the same peripheral fluid chamber.

22 [0348] The intraocular lens as disclosed herein, wherein the second peripheral component is
23 positioned distal to the first peripheral component within the same peripheral fluid chamber.

24 [0349] The intraocular lens as disclosed herein, wherein the first peripheral component is
25 positioned proximal to the second peripheral component within the same peripheral fluid
26 chamber and wherein the first peripheral component is positioned closer to a fluid channel
27 connecting the optic fluid chamber to the peripheral fluid chamber than the second peripheral
28 component.

29 [0350] The intraocular lens as disclosed herein, wherein the first peripheral component and the
30 second peripheral component are configured as discrete peripheral components such that
31 directing the external energy at one discrete peripheral component causes a change in the base

power of the optic portion and directing the external energy at another discrete peripheral component also causes a change in the base power of the optic portion.

[0351] The intraocular lens as disclosed herein, wherein one peripheral fluid chamber comprises at least ten first peripheral components.

[0352] The intraocular lens as disclosed herein, wherein one peripheral fluid chamber comprises at least ten second peripheral components.

[0353] The intraocular lens as disclosed herein, wherein the expandable components are expandable microspheres, and wherein each of the expandable microspheres comprises a blowing agent contained within a thermoplastic shell.

[0354] The intraocular lens as disclosed herein, wherein the energy absorbing constituent is an energy absorbing colorant.

[0355] The intraocular lens as disclosed herein, wherein the base power of the optic portion is configured to change between about ± 0.05 D to about ± 0.5 D in response to pulses of the external energy directed at either the first peripheral component or the second peripheral component.

[0356] The intraocular lens as disclosed herein, wherein the base power of the optic portion is configured to change by about 0.1 D in response to the pulses of the external energy directed at either the first peripheral component or the second peripheral component.

[0357] The intraocular lens as disclosed herein, wherein the base power of the optic portion is configured to change in total between about ± 1.0 D and about ± 2.0 D.

[0358] The intraocular lens as disclosed herein, wherein the external energy is light energy.

[0359] The intraocular lens as disclosed herein, wherein the light energy is a laser light.

[0360] Also disclosed herein is a method of post-operatively adjusting an intraocular lens, comprising: adjusting a base power of the intraocular lens by directing an external energy at a composite material within a peripheral portion of the intraocular lens, wherein the peripheral portion is coupled to an optic portion disposed radially inward of the peripheral portion, wherein the composite material comprises an energy absorbing constituent and a plurality of expandable components, and wherein the base power of the intraocular lens is configured to be unresponsive to forces applied to the peripheral portion by a capsular bag when the intraocular lens is implanted within the capsular bag.

1 [0361] The method as disclosed herein, wherein the optic portion comprises an optic fluid
2 chamber and the peripheral portion comprises at least one peripheral fluid chamber in fluid
3 communication with the optic fluid chamber, and wherein the base power of the intraocular
4 lens changes in response to fluid displacement between the optic fluid chamber and the
5 peripheral fluid chamber as a result of the external energy directed at the composite material.

6 [0362] The method as disclosed herein, wherein about 15 nL of fluid is exchanged between
7 the peripheral fluid chamber and the optic fluid chamber in response to an expansion of the
8 composite material.

9 [0363] The method as disclosed herein, wherein adjusting the base power of the intraocular
10 lens further comprises increasing the base power by directing the external energy at the
11 composite material configured as a space-filler positioned within a peripheral fluid chamber
12 defined within the peripheral portion.

13 [0364] The method as disclosed herein, further comprising decreasing the base power by
14 directing the external energy at another instance of the composite material configured as a
15 chamber expander positioned within the peripheral portion.

16 [0365] The method as disclosed herein, wherein adjusting the base power of the intraocular
17 lens further comprises decreasing the base power by directing the external energy at the
18 composite material configured as a chamber expander positioned within a peripheral fluid
19 chamber defined within the peripheral portion.

20 [0366] The method as disclosed herein, further comprising decreasing the base power by
21 directing the external energy at another instance of the composite material configured as a
22 space-filler positioned within the peripheral fluid chamber.

23 [0367] The method as disclosed herein, wherein adjusting the base power of the intraocular
24 lens further comprises: directing pulses of the external energy at a first peripheral component
25 within a peripheral fluid chamber defined within the peripheral portion, wherein the first
26 peripheral component is made of the composite material; and directing additional pulses of the
27 external energy at a second peripheral component within the same peripheral fluid chamber,
28 wherein the second peripheral component is made of the composite material.

29 [0368] The method as disclosed herein, wherein adjusting the base power of the intraocular
30 lens further comprises: directing pulses of the external energy at a first peripheral component
31 within a first peripheral fluid chamber defined within the peripheral portion, wherein the first

1 peripheral component is made of the composite material; and directing additional pulses of the
2 external energy at a second peripheral component within a second peripheral fluid chamber
3 defined within the peripheral portion, wherein the second peripheral component is made of the
4 composite material.

5 **[0369]** The method as disclosed herein, wherein the first peripheral fluid chamber is in fluid
6 communication with the second peripheral fluid chamber via an optic fluid chamber defined
7 within the optic portion.

8 **[0370]** The method as disclosed herein, wherein the composite material comprises a first
9 composite material and a second composite material, wherein the method further comprises:
10 adjusting the base power in a first direction by directing the external energy at the first
11 composite material, wherein the first composite material comprises a first energy absorbing
12 constituent having a first color; and adjusting the base power in a second direction by directing
13 the external energy at the second composite material, wherein the second composite material
14 comprises a second energy absorbing constituent having a second color different from the first
15 color.

16 **[0371]** The method as disclosed herein, wherein the expandable components are expandable
17 microspheres, and wherein each of the expandable microspheres comprises a blowing agent
18 contained within a thermoplastic shell.

19 **[0372]** The method as disclosed herein, further comprising adjusting the base power of the
20 intraocular lens by between about ± 0.05 D to about ± 0.50 D by directing pulses of the external
21 energy at the composite material.

22 **[0373]** The method as disclosed herein, further comprising adjusting the base power of the
23 intraocular lens by about ± 0.10 D by directing the pulses of the external energy at the
24 composite material.

25 **[0374]** The method as disclosed herein, further comprising adjusting the base power of the
26 intraocular lens in total between about ± 1.0 D and about ± 2.0 D by directing multiple pulses of
27 the external energy at the composite material.

28 **[0375]** The method as disclosed herein, wherein directing the external energy at the composite
29 material further comprises directing light energy at the composite material.

30 **[0376]** The method as disclosed herein, wherein directing the external energy at the composite
31 material further comprises directing laser light at the composite material.

1 [0377] The method as disclosed herein, wherein directing the external energy at the composite
2 material further comprises directing green laser light at the composite material.

3 [0378] The method as disclosed herein, wherein directing the external energy at the composite
4 material further comprises directing laser light having a wavelength between about 488 nm to
5 about 650 nm at the composite material.

6 [0379] The method as disclosed herein, wherein directing the external energy at the composite
7 material further comprises directing laser light having a wavelength between about 946 nm to
8 about 1120 nm at the composite material.

9 [0380] A number of embodiments have been described. Nevertheless, it will be understood by
10 one of ordinary skill in the art that various changes and modifications can be made to this
11 disclosure without departing from the spirit and scope of the embodiments. Elements of
12 systems, devices, apparatus, and methods shown with any embodiment are exemplary for the
13 specific embodiment and can be used in combination or otherwise on other embodiments
14 within this disclosure. For example, the steps of any methods depicted in the figures or
15 described in this disclosure do not require the particular order or sequential order shown or
16 described to achieve the desired results. In addition, other steps operations may be provided, or
17 steps or operations may be eliminated or omitted from the described methods or processes to
18 achieve the desired results. Moreover, any components or parts of any apparatus or systems
19 described in this disclosure or depicted in the figures may be removed, eliminated, or omitted
20 to achieve the desired results. In addition, certain components or parts of the systems, devices,
21 or apparatus shown or described herein have been omitted for the sake of succinctness and
22 clarity.

23 [0381] Accordingly, other embodiments are within the scope of the following claims and the
24 specification and/or drawings may be regarded in an illustrative rather than a restrictive sense.

25 [0382] Each of the individual variations or embodiments described and illustrated herein has
26 discrete components and features which may be readily separated from or combined with the
27 features of any of the other variations or embodiments. Modifications may be made to adapt a
28 particular situation, material, composition of matter, process, process act(s) or step(s) to the
29 objective(s), spirit or scope of the present invention.

30 [0383] Methods recited herein may be carried out in any order of the recited events that is
31 logically possible, as well as the recited order of events. Moreover, additional steps or

1 operations may be provided or steps or operations may be eliminated to achieve the desired
2 result.

3 **[0384]** Furthermore, where a range of values is provided, every intervening value between the
4 upper and lower limit of that range and any other stated or intervening value in that stated
5 range is encompassed within the invention. Also, any optional feature of the inventive
6 variations described may be set forth and claimed independently, or in combination with any
7 one or more of the features described herein. For example, a description of a range from 1 to 5
8 should be considered to have disclosed subranges such as from 1 to 3, from 1 to 4, from 2 to 4,
9 from 2 to 5, from 3 to 5, etc. as well as individual numbers within that range, for example 1.5,
10 2.5, etc. and any whole or partial increments therebetween.

11 **[0385]** All existing subject matter mentioned herein (e.g., publications, patents, patent
12 applications) is incorporated by reference herein in its entirety except insofar as the subject
13 matter may conflict with that of the present invention (in which case what is present herein
14 shall prevail). The referenced items are provided solely for their disclosure prior to the filing
15 date of the present application. Nothing herein is to be construed as an admission that the
16 present invention is not entitled to antedate such material by virtue of prior invention.

17 **[0386]** Reference to a singular item, includes the possibility that there are plural of the same
18 items present. More specifically, as used herein and in the appended claims, the singular forms
19 “a,” “an,” “said” and “the” include plural referents unless the context clearly dictates
20 otherwise. It is further noted that the claims may be drafted to exclude any optional element.
21 As such, this statement is intended to serve as antecedent basis for use of such exclusive
22 terminology as “solely,” “only” and the like in connection with the recitation of claim
23 elements, or use of a “negative” limitation. Unless defined otherwise, all technical and
24 scientific terms used herein have the same meaning as commonly understood by one of
25 ordinary skill in the art to which this invention belongs.

26 **[0387]** Reference to the phrase “at least one of”, when such phrase modifies a plurality of
27 items or components (or an enumerated list of items or components) means any combination
28 of one or more of those items or components. For example, the phrase “at least one of A, B,
29 and C” means: (i) A; (ii) B; (iii) C; (iv) A, B, and C; (v) A and B; (vi) B and C; or (vii) A and
30 C.

1 [0388] In understanding the scope of the present disclosure, the term “comprising” and its
2 derivatives, as used herein, are intended to be open-ended terms that specify the presence of
3 the stated features, elements, components, groups, integers, and/or steps, but do not exclude
4 the presence of other unstated features, elements, components, groups, integers and/or steps.
5 The foregoing also applies to words having similar meanings such as the terms, “including”,
6 “having” and their derivatives. Also, the terms “part,” “section,” “portion,” “member”
7 “element,” or “component” when used in the singular can have the dual meaning of a single
8 part or a plurality of parts. As used herein, the following directional terms “forward, rearward,
9 above, downward, vertical, horizontal, below, transverse, laterally, and vertically” as well as
10 any other similar directional terms refer to those positions of a device or piece of equipment or
11 those directions of the device or piece of equipment being translated or moved.

12 [0389] Finally, terms of degree such as “substantially”, “about” and “approximately” as used
13 herein mean the specified value or the specified value and a reasonable amount of deviation
14 from the specified value (e.g., a deviation of up to $\pm 0.1\%$, $\pm 1\%$, $\pm 5\%$, or $\pm 10\%$, as such
15 variations are appropriate) such that the end result is not significantly or materially changed.
16 For example, “about 1.0 cm” can be interpreted to mean “1.0 cm” or between “0.9 cm and 1.1
17 cm.” When terms of degree such as “about” or “approximately” are used to refer to numbers or
18 values that are part of a range, the term can be used to modify both the minimum and
19 maximum numbers or values.

20 [0390] This disclosure is not intended to be limited to the scope of the particular forms set
21 forth, but is intended to cover alternatives, modifications, and equivalents of the variations or
22 embodiments described herein. Further, the scope of the disclosure fully encompasses other
23 variations or embodiments that may become obvious to those skilled in the art in view of this
24 disclosure.

CLAIMS

We claim:

1. An intraocular lens, comprising:
 - an optic portion;
 - a peripheral portion coupled to the optic portion;
 - wherein the peripheral portion comprises a composite material comprising an energy absorbing constituent and a plurality of expandable components,
 - wherein a base power of the optic portion is configured to change in response to an external energy directed at the composite material, and
 - wherein the base power of the optic portion is configured to be unresponsive to forces applied to the peripheral portion by a capsular bag when the intraocular lens is implanted within the capsular bag.
2. The intraocular lens of claim 1, wherein the expandable components are expandable microspheres, and wherein each of the expandable microspheres comprises a blowing agent contained within a thermoplastic shell.
3. The intraocular lens of claim 1, wherein the energy absorbing constituent is an azo dye.
4. The intraocular lens of claim 1, wherein the energy absorbing constituent is graphitized carbon black.
5. The intraocular lens of claim 1, wherein the peripheral portion is made in part of a cross-linked copolymer comprising a copolymer blend, and wherein the composite material is made in part of the copolymer blend.
6. The intraocular lens of claim 1, wherein the base power of the optic portion is configured to change between about 0.05 D to about 0.5 D in either a positive or negative direction in response to pulses of the external energy directed at the composite material.
7. The intraocular lens of claim 1, wherein the external energy is laser light having a wavelength of between about 488 nm to about 650 nm.
8. The intraocular lens of claim 1, wherein the external energy is laser light having a wavelength of between about 946 nm to about 1120 nm.

- 1 9. The intraocular lens of claim 1, wherein the external energy is laser light emitted by a
2 femtosecond laser.
- 3 10. The intraocular lens of claim 1, wherein the composite material is formed as discrete
4 peripheral components such that directing the external energy at one discrete peripheral
5 component causes a change in the base power of the optic portion and directing the
6 external energy at another discrete peripheral component also causes a change in the
7 base power of the optic portion.
- 8 11. The intraocular lens of claim 1, wherein the optic portion comprises an optic fluid
9 chamber and the peripheral portion comprises at least one peripheral fluid chamber in
10 fluid communication with the optic fluid chamber.
- 11 12. The intraocular lens of claim 11, wherein the composite material is configured as a
12 chamber expander, wherein the chamber expander is configured to expand in response
13 to the external energy directed at the chamber expander, and wherein expansion of the
14 chamber expander increases a volume of the peripheral fluid chamber.
- 15 13. The intraocular lens of claim 12, wherein the base power of the optic portion is
16 configured to decrease in response to the external energy directed at the chamber
17 expander.
- 18 14. The intraocular lens of claim 12, wherein the chamber expander is configured as an
19 expandable column extending from a chamber anterior wall to a chamber posterior
20 wall.
- 21 15. The intraocular lens of claim 11, wherein the composite material is configured as a
22 space-filler, wherein the space-filler is configured to expand in response to the external
23 energy directed at the space-filler, and wherein expansion of the space-filler decreases
24 a volume of the peripheral fluid chamber.
- 25 16. The intraocular lens of claim 15, wherein the base power of the optic portion is
26 configured to increase in response to the external energy directed at the space-filler.
- 27 17. The intraocular lens of claim 11, wherein the peripheral portion is configured as at least
28 one haptic, wherein the peripheral fluid chamber is defined within the haptic, wherein
29 the peripheral fluid chamber extends only partially into the haptic.

- 1 18. The intraocular lens of claim 1, wherein the peripheral portion is configured as a first
2 haptic comprising a first haptic fluid chamber and a second haptic comprising a second
3 haptic fluid chamber, and wherein the optic portion comprises an optic fluid chamber.
- 4 19. The intraocular lens of claim 18, wherein the first haptic fluid chamber is in fluid
5 communication with the optic fluid chamber via a first fluid channel, wherein the
6 second haptic fluid chamber is in fluid communication with the optic fluid chamber via
7 a second fluid channel, and wherein the first fluid channel is positioned diametrically
8 opposed to the second fluid channel.
- 9 20. The intraocular lens of claim 18, wherein the optic fluid chamber, the first haptic fluid
10 chamber, and the second haptic fluid chamber comprise a fluid having a total fluid
11 volume of between about 10 μL and about 20 μL .
- 12 21. The intraocular lens of claim 20, wherein each of the first haptic fluid chamber and the
13 second haptic fluid chamber comprises about 0.5 μL of the fluid.
- 14 22. The intraocular lens of claim 20, wherein about 15 nL of the fluid is exchanged
15 between either the first haptic fluid chamber and the second haptic fluid chamber and
16 the optic fluid chamber in response to an expansion of the composite material.
- 17 23. The intraocular lens of claim 1, wherein the peripheral portion comprises a first
18 composite material and a second composite material, wherein the first composite
19 material comprises a first energy absorbing constituent and the second composite
20 material comprises a second energy absorbing constituent, wherein a color of the first
21 energy absorbing constituent is different from a color of the second energy absorbing
22 constituent.
- 23 24. An intraocular lens, comprising:
24 an optic portion; and
25 a peripheral portion coupled to the optic portion, wherein the peripheral portion
26 comprises a first peripheral component and a second peripheral component,
27 wherein the first peripheral component is made of a composite material
28 comprising an energy absorbing constituent and a plurality of expandable
29 components,

1 wherein the second peripheral component is made of the composite material
2 comprising the energy absorbing constituent and the plurality of expandable
3 components,
4 wherein a base power of the optic portion is configured to increase in response
5 to an external energy directed at the first peripheral component, and
6 wherein the base power of the optic portion is configured to decrease in
7 response to the external energy directed at the second peripheral
8 component.

9 25. The intraocular lens of claim 24, wherein the optic portion comprises an optic fluid
10 chamber and the peripheral portion comprises at least one peripheral fluid chamber in
11 fluid communication with the optic fluid chamber.

12 26. The intraocular lens of claim 25, wherein the first peripheral component is configured
13 as a space-filler, wherein the space-filler is configured to expand in response to the
14 external energy directed at the space-filler, and wherein expansion of the space-filler
15 decreases a volume of the peripheral fluid chamber.

16 27. The intraocular lens of claim 25, wherein the second peripheral component is
17 configured as a chamber expander, wherein the chamber expander is configured to
18 expand in response to the external energy directed at the chamber expander, and
19 wherein expansion of the chamber expander increases a volume of the peripheral fluid
20 chamber.

21 28. The intraocular lens of claim 25, wherein the first peripheral component and the second
22 peripheral component are located within the same peripheral fluid chamber.

23 29. The intraocular lens of claim 28, wherein the second peripheral component is
24 positioned distal to the first peripheral component within the same peripheral fluid
25 chamber.

26 30. The intraocular lens of claim 28, wherein the first peripheral component is positioned
27 proximal to the second peripheral component within the same peripheral fluid chamber
28 and wherein the first peripheral component is positioned closer to a fluid channel
29 connecting the optic fluid chamber to the peripheral fluid chamber than the second
30 peripheral component.

31 31. A method of post-operatively adjusting a static focus intraocular lens, comprising:

1 changing a base power of the static focus intraocular lens by directing an external
2 energy at a composite material within a peripheral portion of the intraocular lens,
3 wherein the peripheral portion is coupled to an optic portion disposed radially
4 inward of the peripheral portion, and

5 wherein the composite material comprises an energy absorbing constituent and
6 a plurality of expandable components.

7 32. The method of claim 31, wherein the optic portion comprises an optic fluid chamber
8 and the peripheral portion comprises at least one peripheral fluid chamber in fluid
9 communication with the optic fluid chamber, and wherein the base power of the
10 intraocular lens changes in response to fluid displacement between the optic fluid
11 chamber and the peripheral fluid chamber as a result of the external energy directed at
12 the composite material.

13 33. The method of claim 32, wherein about 15 nL of fluid is exchanged between the
14 peripheral fluid chamber and the optic fluid chamber in response to an expansion of the
15 composite material.

16 34. The method of claim 31, wherein adjusting the base power of the intraocular lens
17 further comprises increasing the base power by directing the external energy at the
18 composite material configured as a space-filler positioned within a peripheral fluid
19 chamber defined within the peripheral portion.

20 35. The method of claim 31, wherein adjusting the base power of the intraocular lens
21 further comprises decreasing the base power by directing the external energy at the
22 composite material configured as a chamber expander positioned within a peripheral
23 fluid chamber defined within the peripheral portion.

24 36. The method of claim 31, wherein the composite material comprises a first composite
25 material and a second composite material, wherein the method further comprises:
26 adjusting the base power in a first direction by directing the external energy at the first
27 composite material, wherein the first composite material comprises a first energy
28 absorbing constituent having a first color; and
29 adjusting the base power in a second direction by directing the external energy at the
30 second composite material, wherein the second composite material comprises a

1 second energy absorbing constituent having a second color different from the first
2 color.

3 37. The method of claim 31, further comprising adjusting the base power of the intraocular
4 lens by between about 0.05 D to about 0.50 D in either a positive or a negative
5 direction by directing pulses of the external energy at the composite material.

6 38. The method of claim 31, further comprising adjusting the base power of the intraocular
7 lens in total between about 1.0 D and about 2.0 D in either a positive or a negative
8 direction by directing multiple pulses of the external energy at the composite material.

9 39. The method of claim 31, wherein directing the external energy at the composite
10 material further comprises directing laser light having a wavelength between about 488
11 nm to about 650 nm at the composite material.

12 40. The method of claim 31, wherein directing the external energy at the composite
13 material further comprises directing laser light having a wavelength between about 946
14 nm to about 1120 nm at the composite material.

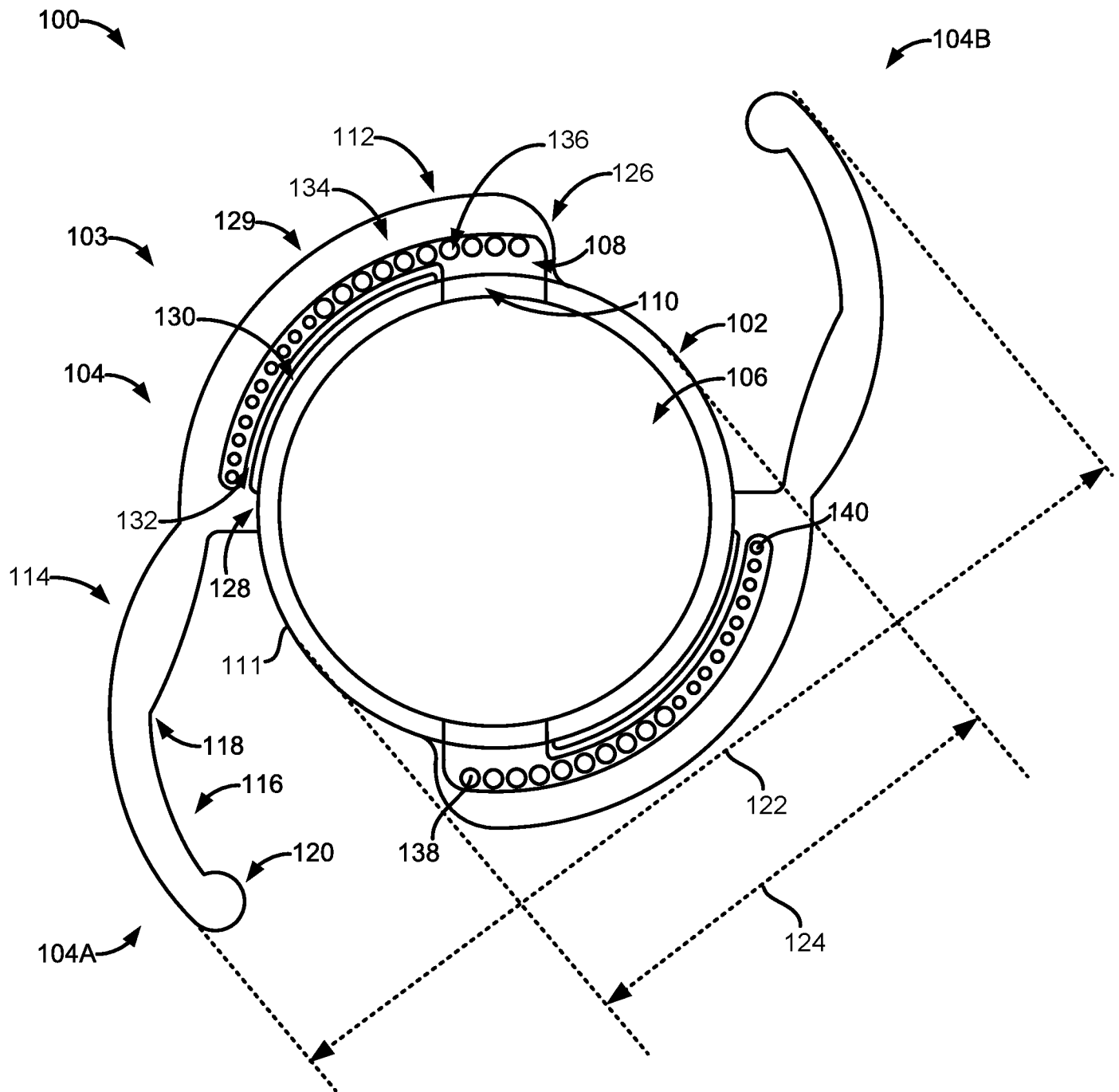


FIG. 1A

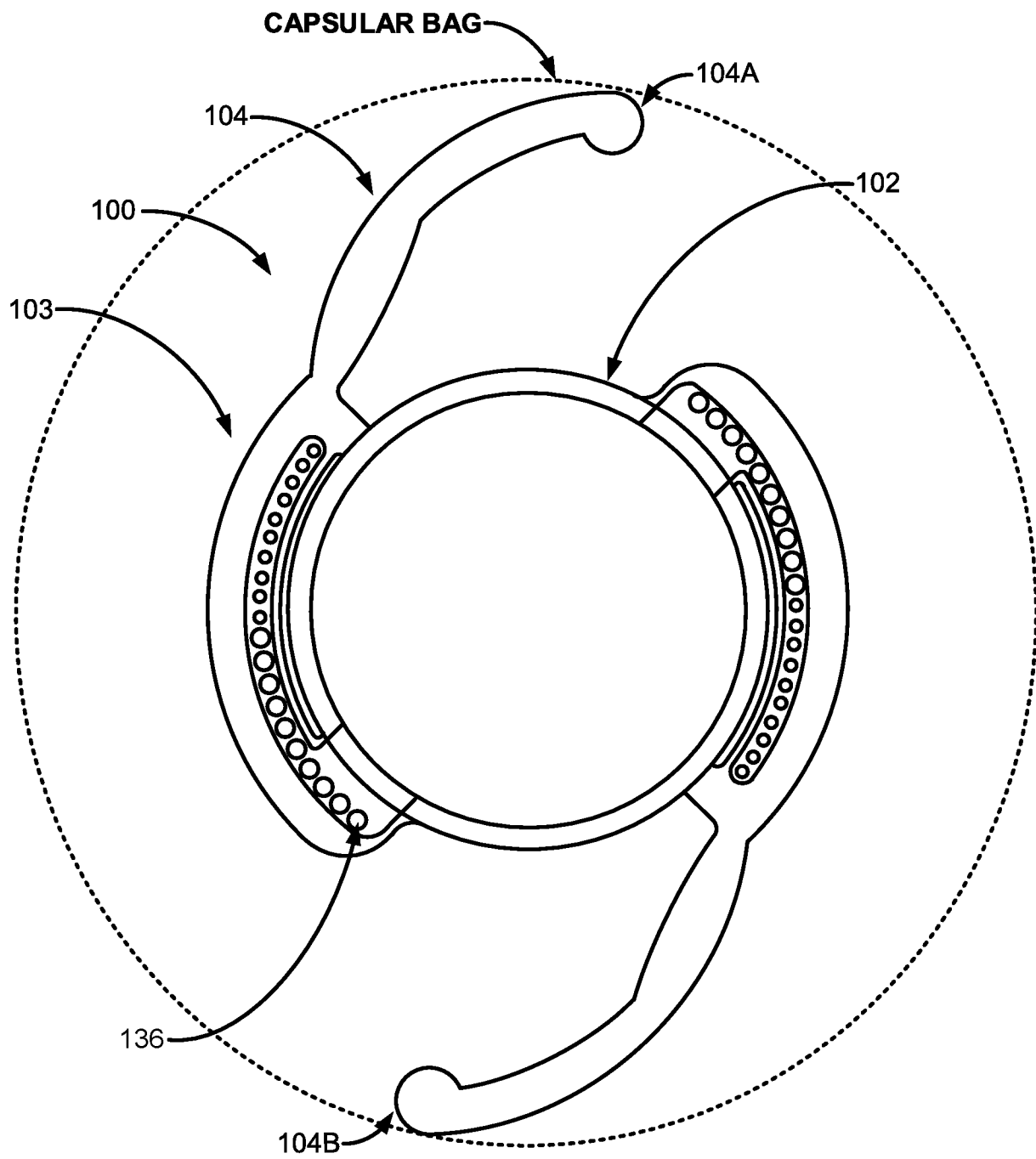


FIG. 1B

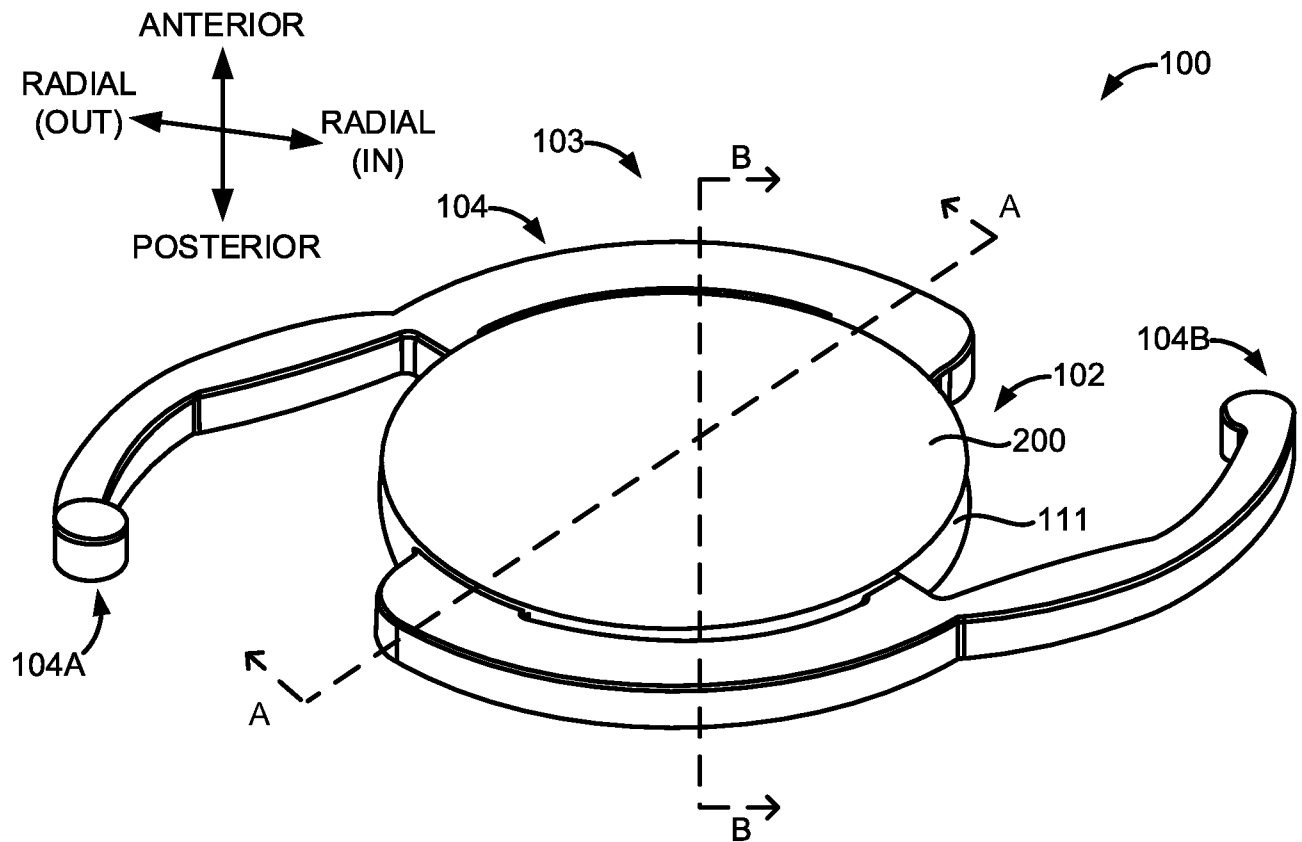


FIG. 2A

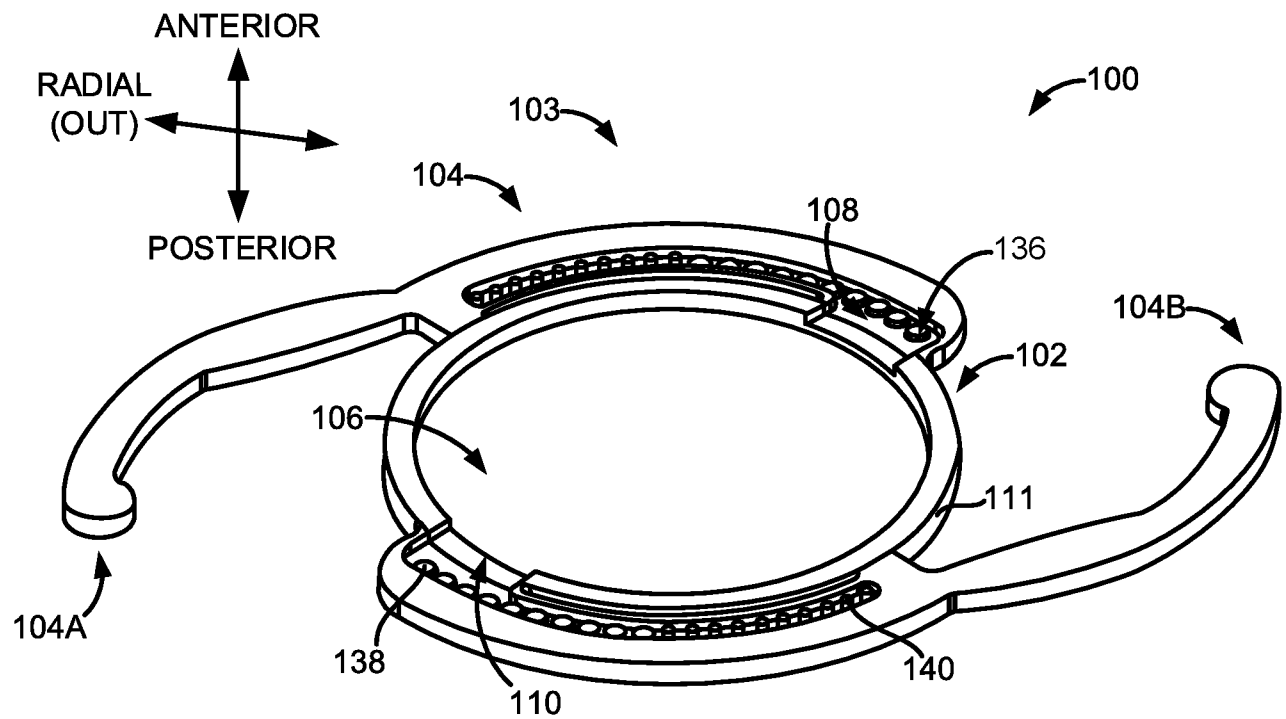


FIG. 2B

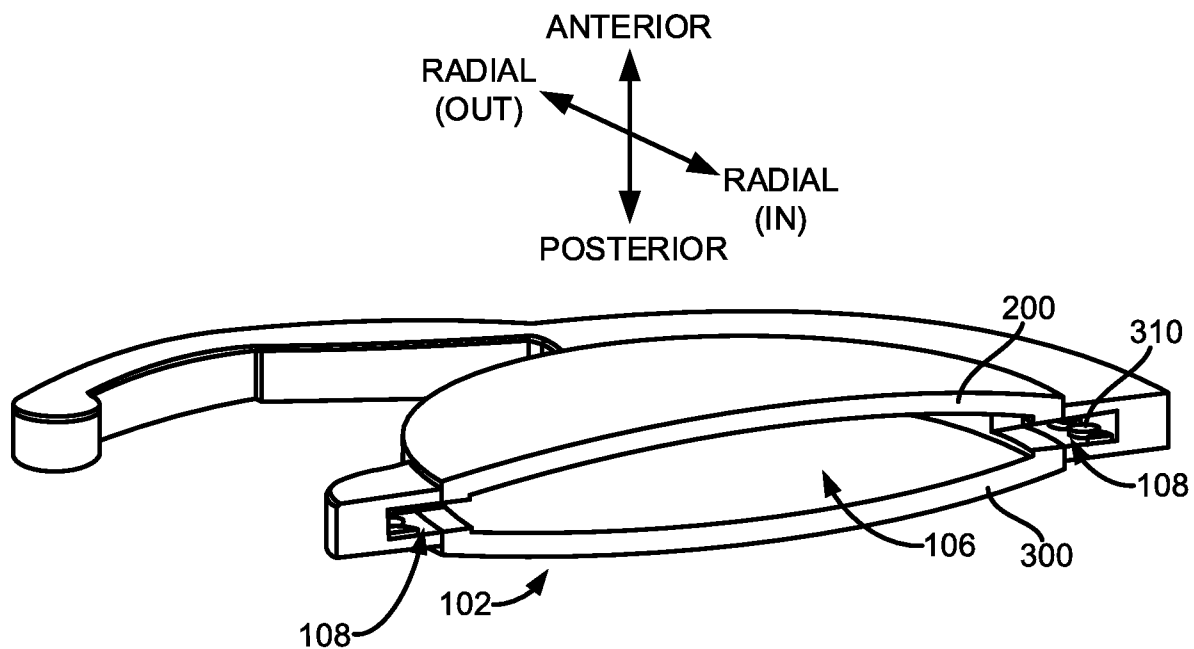


FIG. 3A

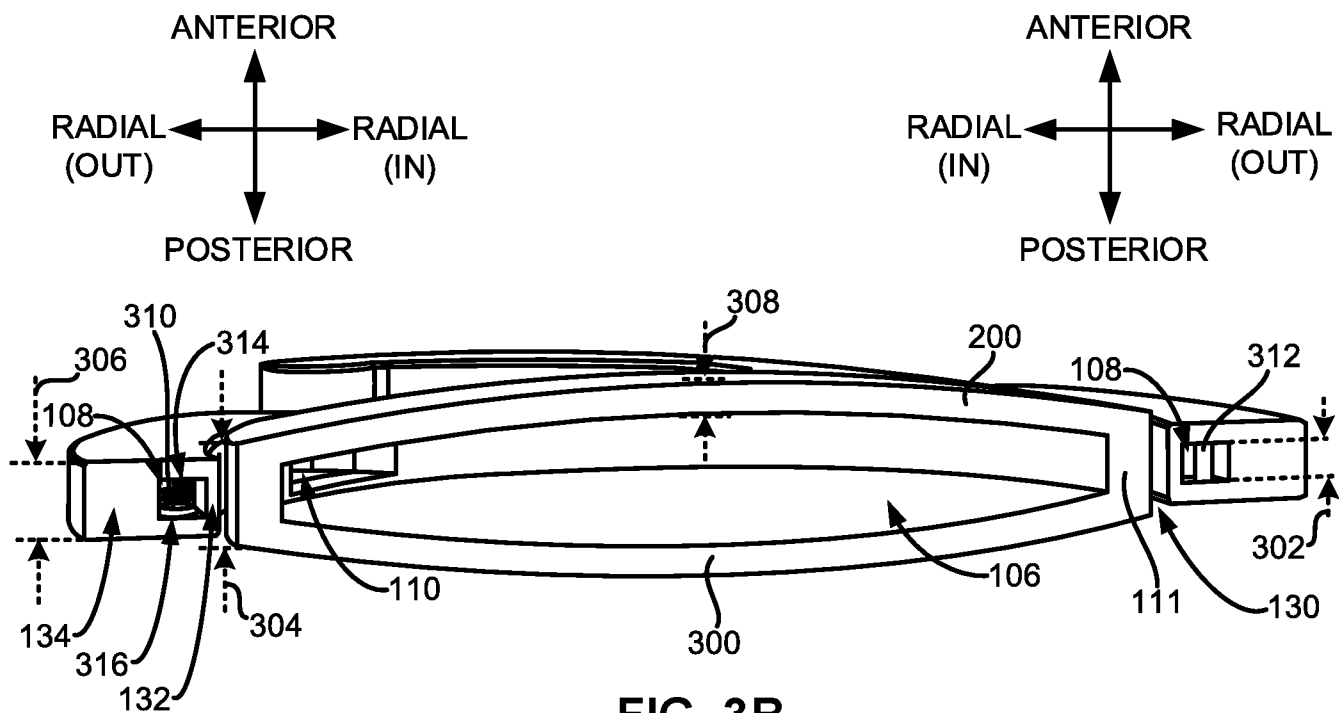


FIG. 3B

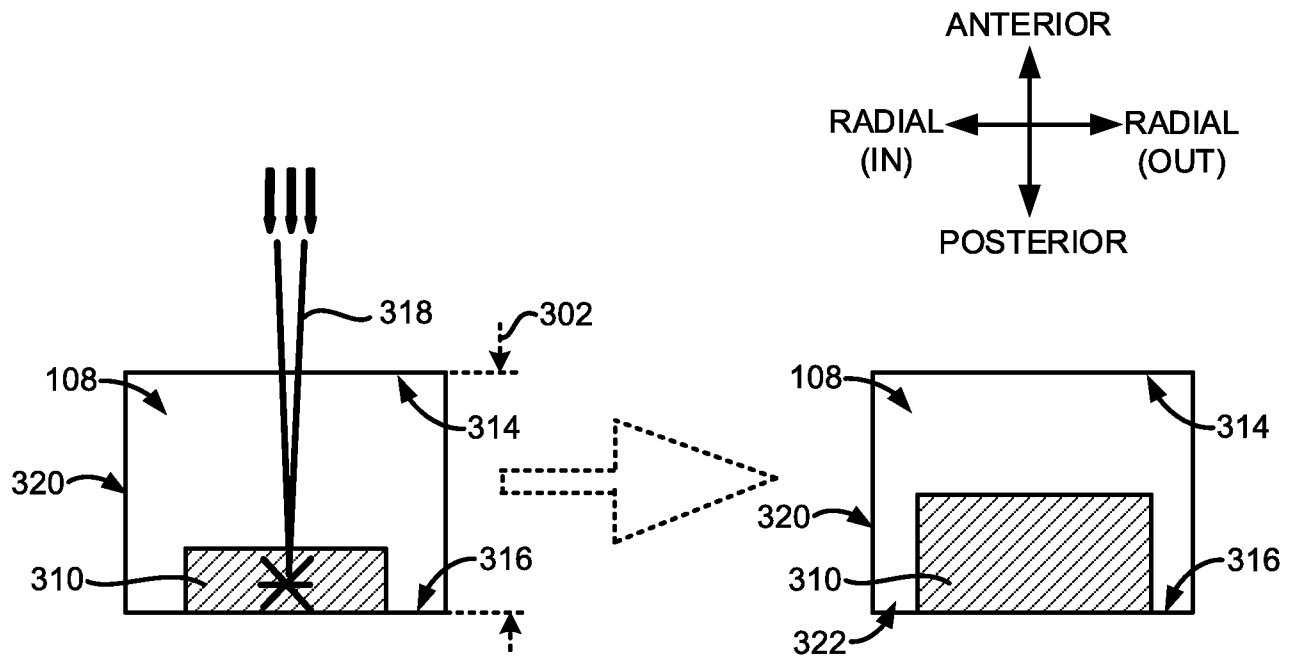


FIG. 3C

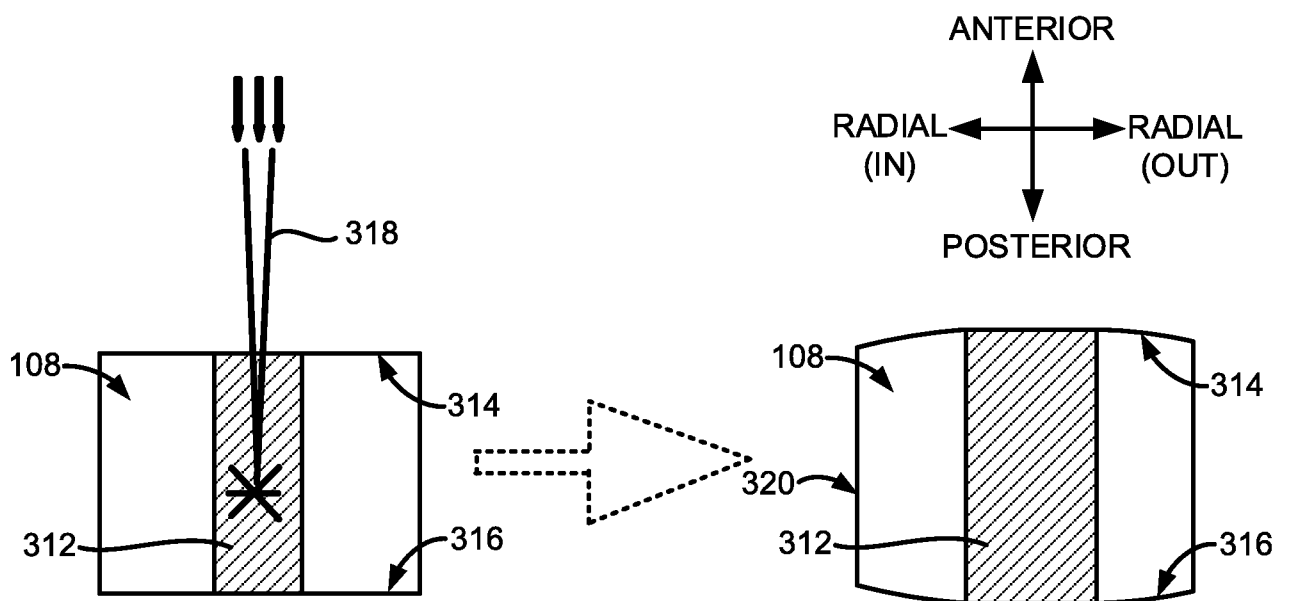


FIG. 3D

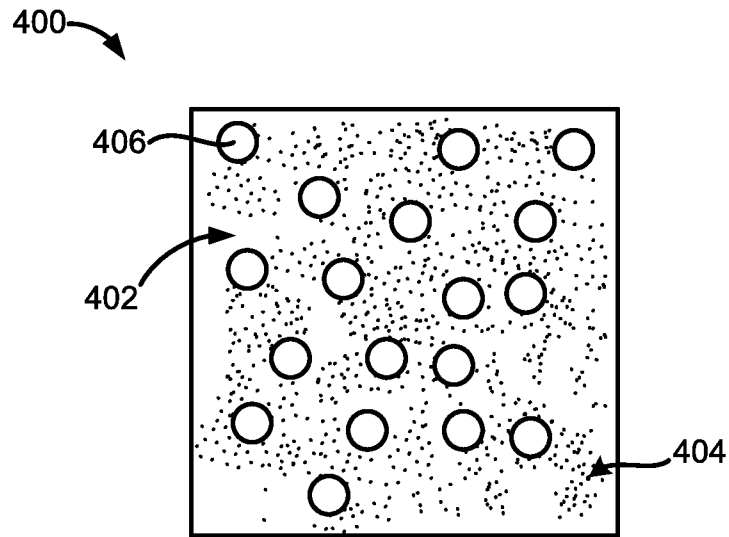


FIG. 4A

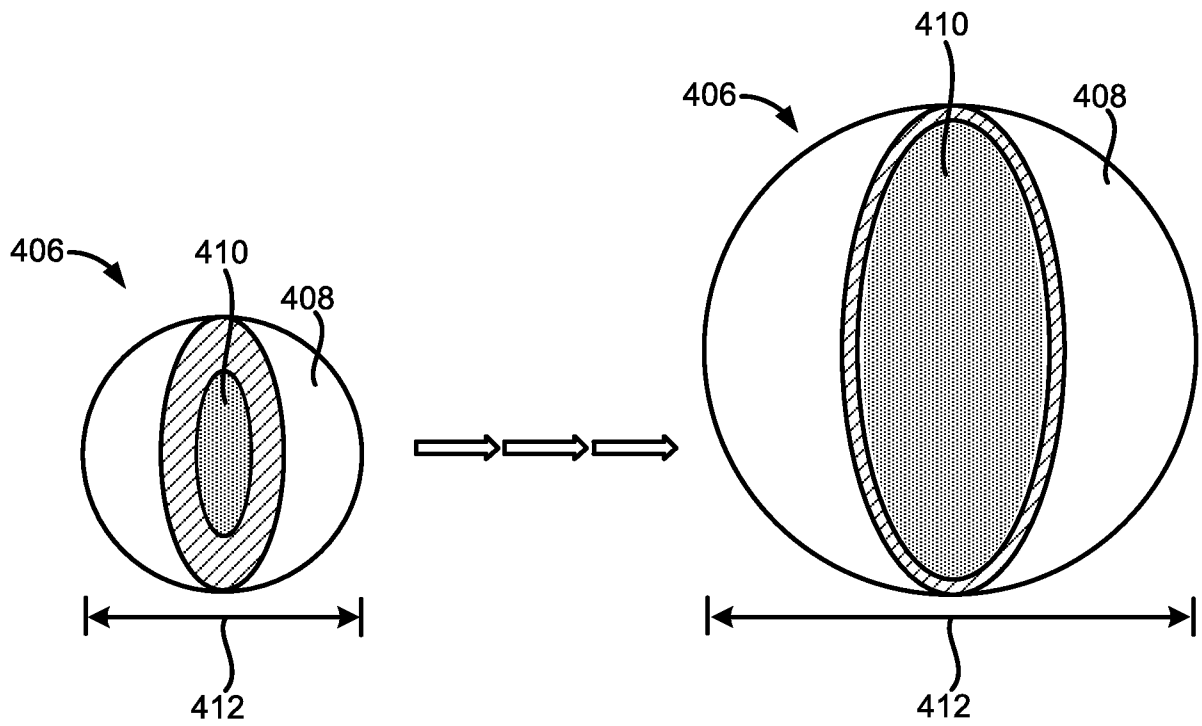


FIG. 4B

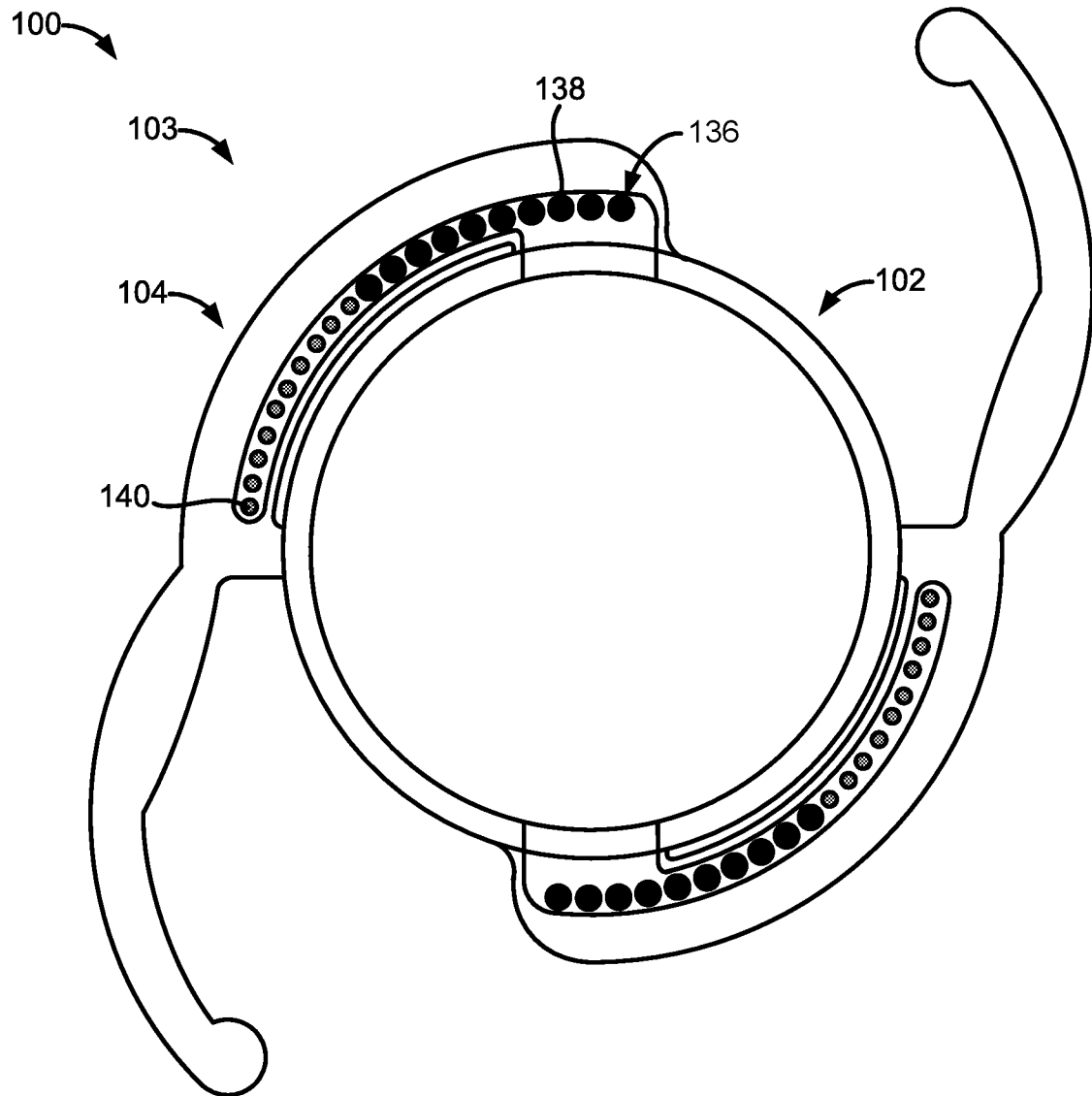


FIG. 5

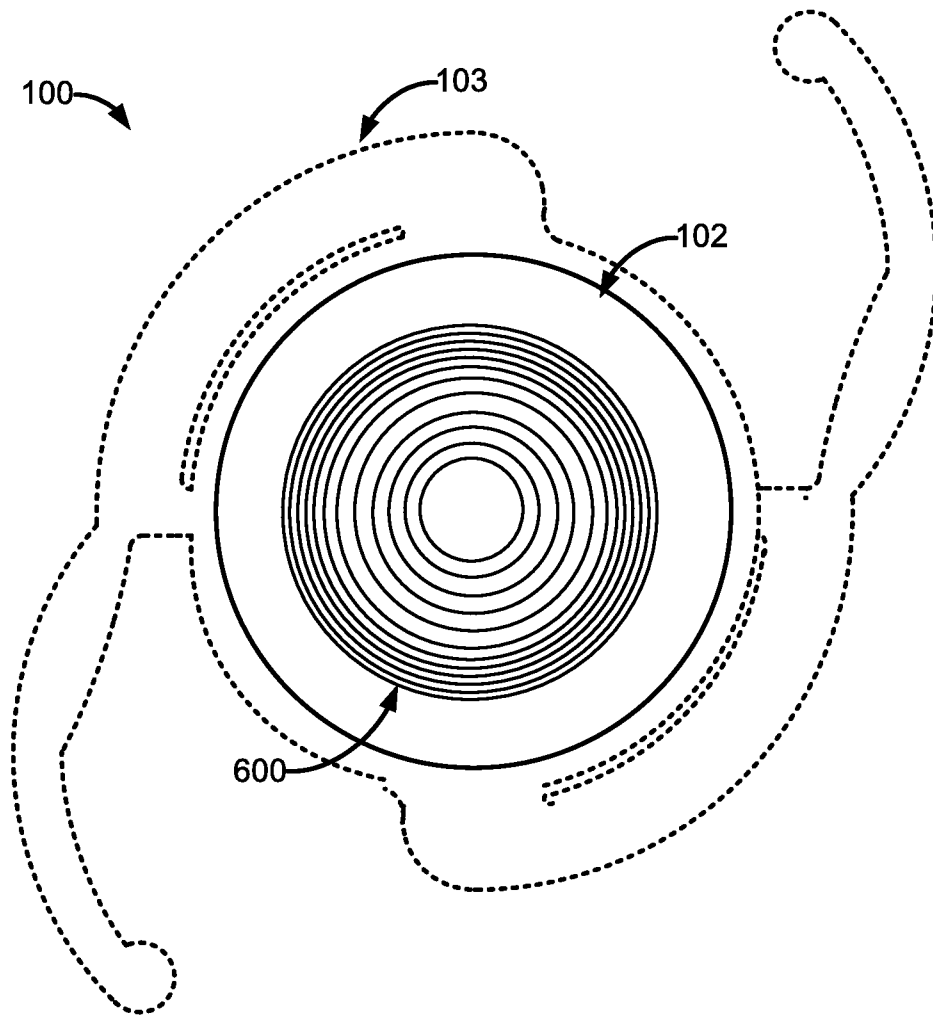


FIG. 6

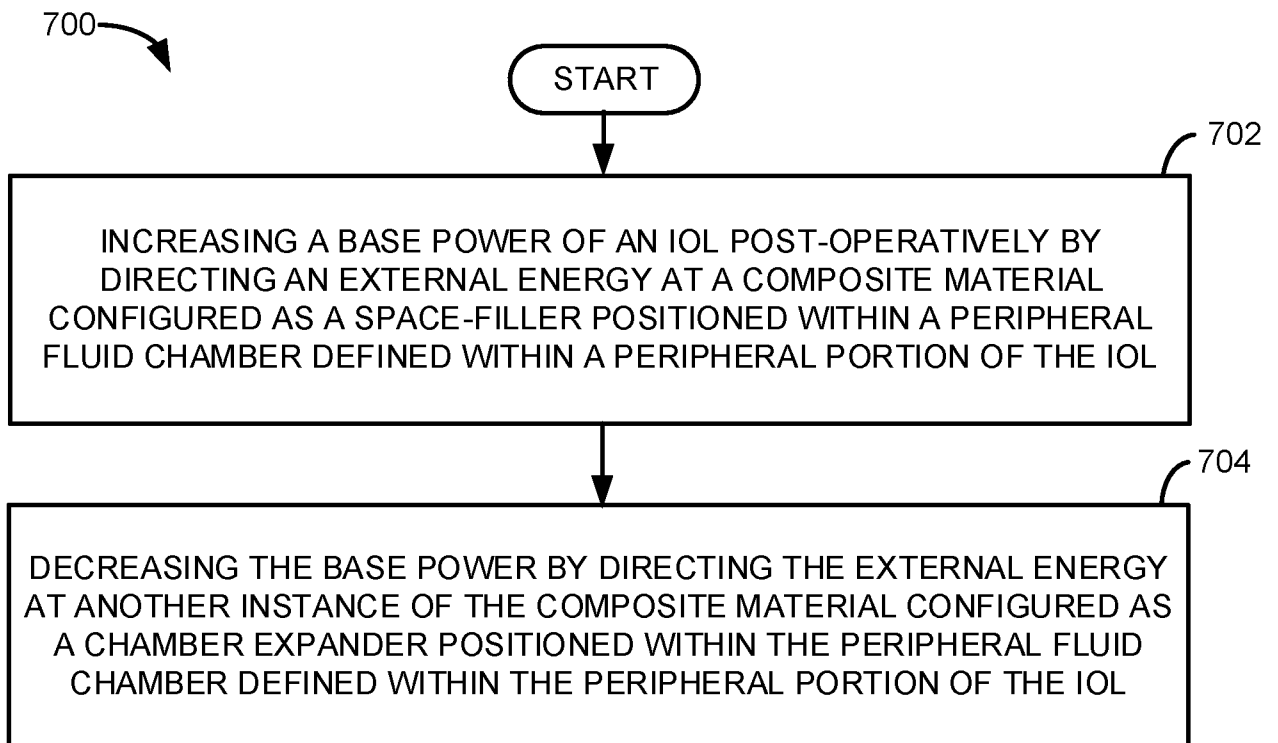


FIG. 7

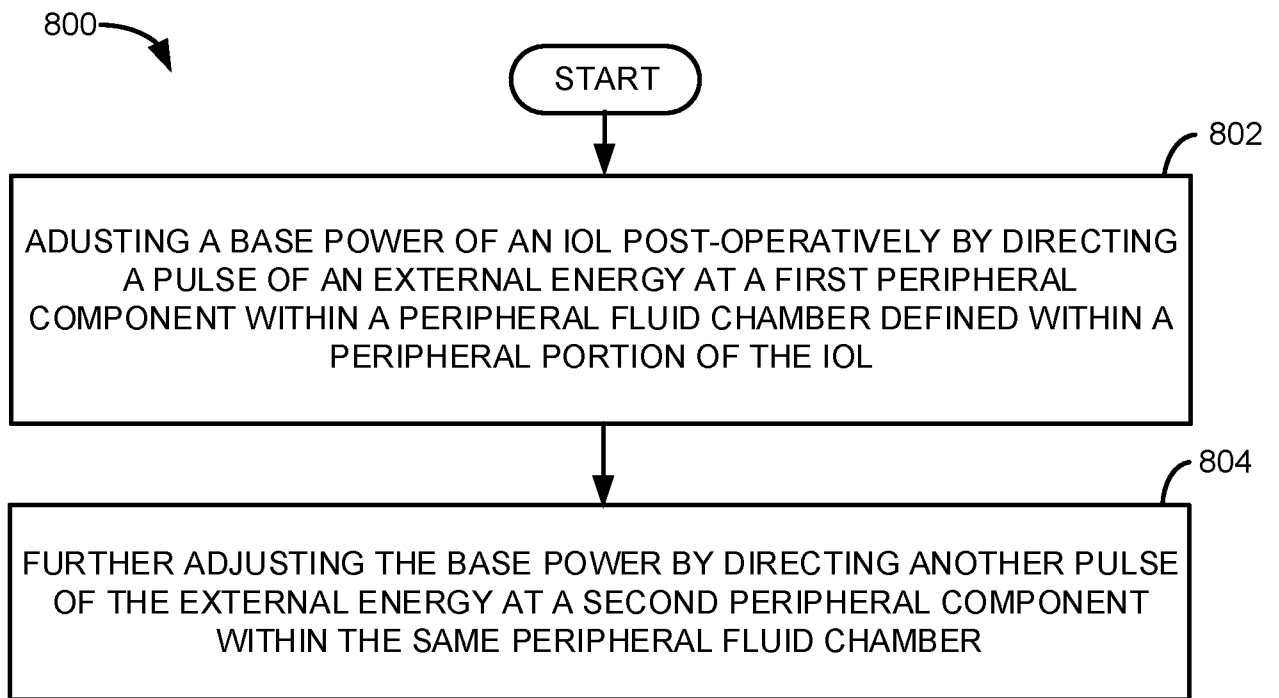
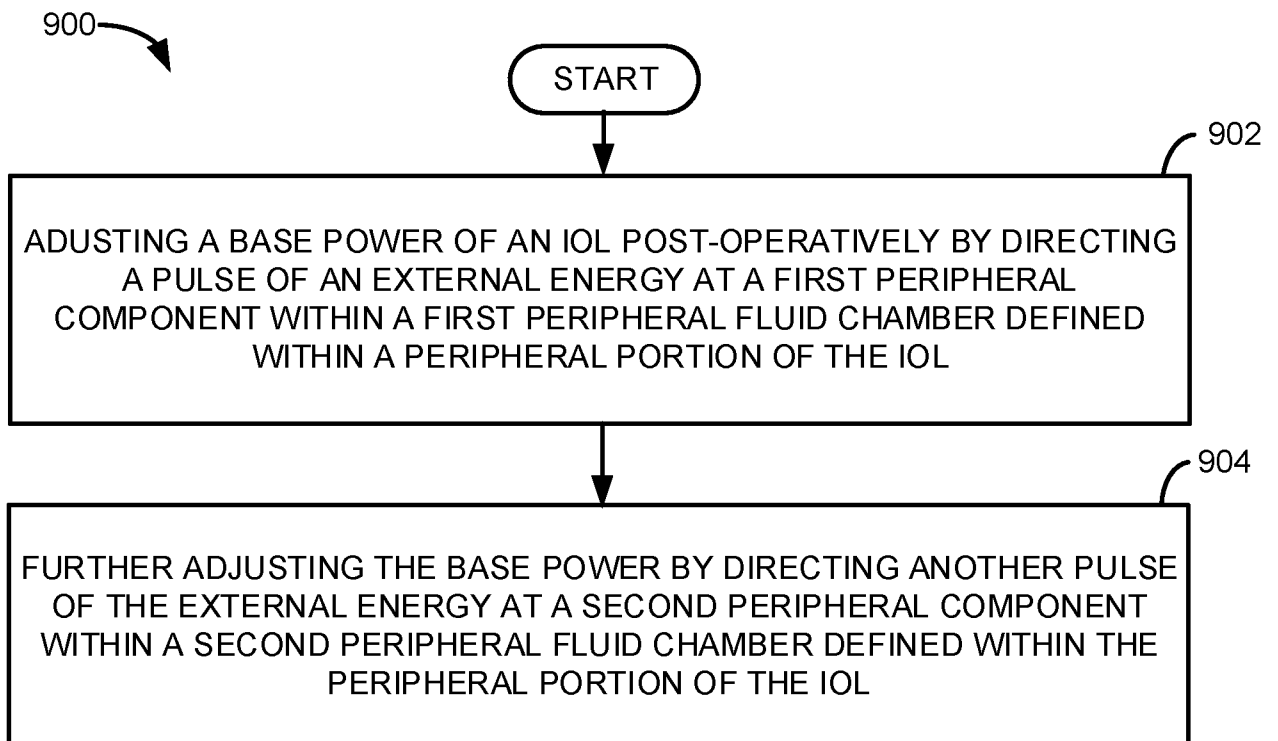


FIG. 8

**FIG. 9**

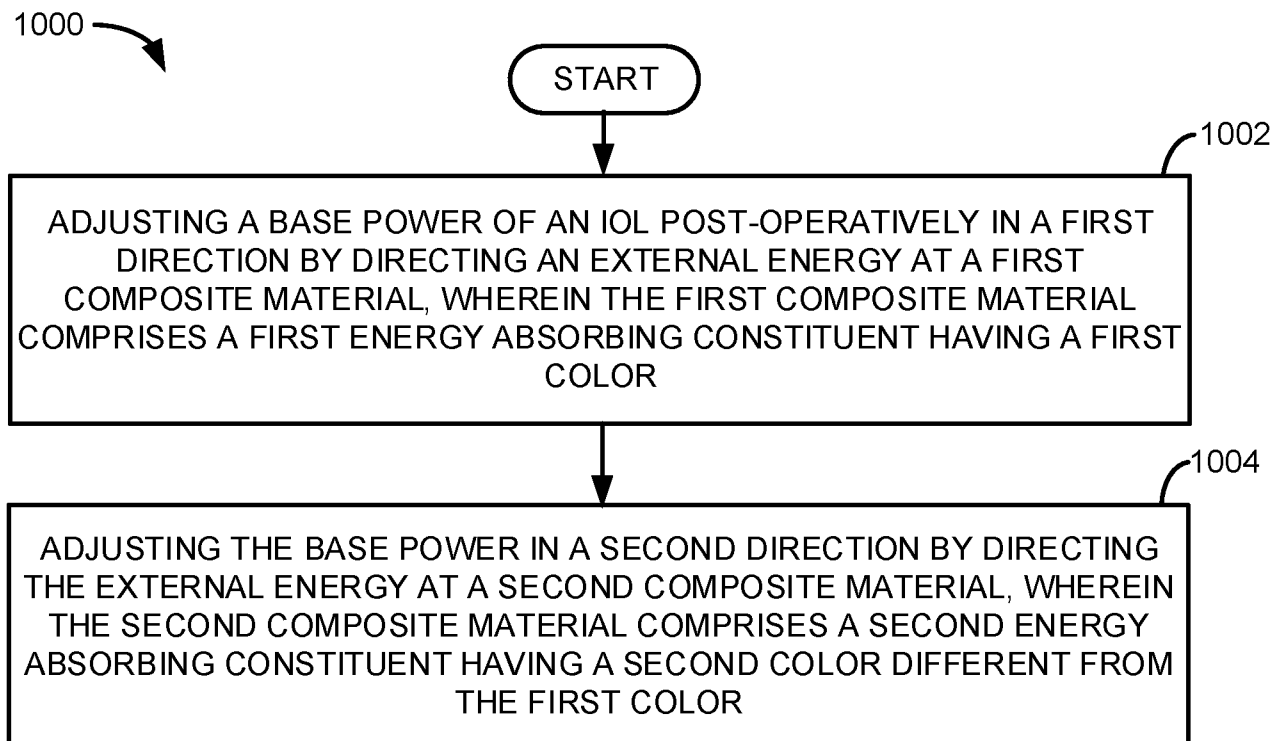


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2020/053767

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61F 2/16; A61F 2/14; G02C 7/02; G02C 7/04 (2020.01)

CPC - A61F 2/1613; A61F 2/145; A61F 2/16; A61F 2/1635; A61F 2/1648 (2020.08)

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)

see Search History document

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

see Search History document

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

see Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2009/015234 A2 (POWERSVISION INC) 29 January 2009 (29.01.2009) entire document	24-28, 31-35, 37-40
A	US 2019/0053892 A1 (VISUSNANO LIMITED) 21 February 2019 (21.02.2019) entire document	1-40
A	US 7,278,739 B2 (SHADDUCK) 09 October 2007 (09.10.2007) entire document	1-40
A	US 5,217,491 A (VANDERBILT) 08 June 1993 (08.06.1993) entire document	1-40

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:	"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
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"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	

Date of the actual completion of the international search
20 November 2020Date of mailing of the international search report
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