



- |   |   |
|---|---|
| <b>(51) International Patent Classification:</b><br><i>A61F 2/16</i> (2006.01)  | <b>(74) Agent: KIM, Roy;</b> Abbott Medical Optics Inc., 1700 E. St. Andrew Place, Santa Ana, CA 92705 (US).  |
| <b>(21) International Application Number:</b><br>PCT/US2013/048682  | <b>(81) Designated States</b> <i>(unless otherwise indicated, for every kind of national protection available):</i> AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW. |
| <b>(22) International Filing Date:</b><br>28 June 2013 (28.06.2013)   |   |
| <b>(25) Filing Language:</b><br>English   |   |
| <b>(26) Publication Language:</b><br>English  |   |
| <b>(30) Priority Data:</b><br>61/666,413      29 June 2012 (29.06.2012)      US   |   |
| <b>(71) Applicant: ABBOTT MEDICAL OPTICS INC.</b><br>[US/US]; 1700 E. St. Andrew Place, Santa Ana, CA 92705 (US).   | <b>(84) Designated States</b> <i>(unless otherwise indicated, for every kind of regional protection available):</i> ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).  |
| <b>(72) Inventors; and</b><br><b>(71) Applicants : ZHAO, Huawei</b> [CN/US]; 22 Easthaven, Irvine, CA 92602 (US). <b>RUDDOCKS, David, A.</b> [US/US]; 27121 Huerta, Mission Viejo, CA 92692 (US). |   |

[Continued on next page]

**(54) Title:** REDUCED GLARE INTRAOCULAR LENS

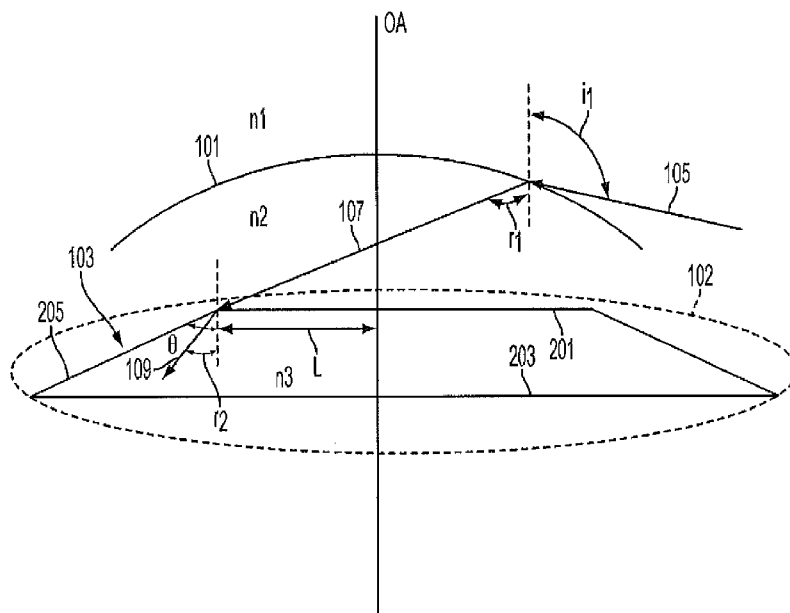


FIG. 1

**(57) Abstract:** An intraocular lens (103) for reducing aberrant optical effects includes a substantially oval, elliptical, or rectangular optic with an anterior surface (201), a posterior surface (203) and a peripheral region/zone (205) disposed

*[Continued on next page]*



---

**Published:**

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

---

about a central optical axis and a plurality of haptics coupled to the optic. The peripheral region/zone has an inflection region/transition area that is inclined with respect to the anterior surface at an angle between about 40 degrees and 120 degrees with respect to the optical axis. The thickness at the edge of the IOL is less than or about 0.03 mm.

## **REDUCED GLARE INTRAOCULAR LENS**

### **BACKGROUND OF THE INVENTION**

#### **CROSS-REFERENCES TO RELATED APPLICATIONS**

[0001] This application claims priority to U.S. Application No. 61/666,413, filed on June 29, 2012, the contents of which are incorporated herein by reference for all purposes. Full Paris Convention priority is hereby expressly reserved.

#### **Field of the Invention**

[0002] This application relates generally to intraocular lenses, and more specifically to stable intraocular lenses with reduced aberrant optical effects, such as reduced positive and/or negative dysphotopsia and increased field of view.

#### **Description of the Related Art**

[0003] A human eye can suffer diseases that impair a patient's vision. For instance, a cataract may increase the opacity of the natural crystalline lens, eventually resulting in blindness. To restore the patient's vision, the opaque lens may be surgically removed and replaced with an artificial intraocular lens, or IOL. An IOL may also be implanted to treat presbyopia or for other elective ocular surgical procedures. The IOL can be an accommodating IOL, which can adjust its axial position and/or shape to vary the optical power within a range in response to muscle action in the eye. As a result, the patient can focus on objects in a range of distances from the eye, rather than at one discrete distance. The IOL may also be a multifocal IOL utilizing a refractive and/or diffractive surfaces resulting in multiple focal points.

[0004] Healthy phakic eyes typically have a non-compromised visual field of about 60 degrees in the nasal direction, 105 degrees in the temporal direction, 65 degrees in the superior direction, and 70 degrees in the inferior direction. With current circular IOLs, pseudophakic eyes may have reduced field of view. Also, certain plate shaped IOLs have been found to have weak stability which may lead to displacement and/or rotation.

[0005] In addition, undesirable optical effects can arise after implantation of an IOL. One of the undesirable optical effects is dysphotopsia which is defined as the

appearance of unwanted visible patterns. It is believed that light refracted into the IOL can reflect from a sharp or truncated edge of the IOL thereby causing glare, positive dysphotopsia, or other aberrant optical effects. Positive dysphotopsia can refer to the appearance of bright optical artifacts such as rings, halos, arcs or streaks. Negative dysphotopsia can refer to the appearance of dark shadows or lines in the field of vision. Negative dysphotopsia may occur when some light rays that enter the eye and are either (1) not incident on the IOL and pass by the IOL or (2) incident on the IOL edge, while immediately adjacent light rays enter the IOL and are refracted by and pass through the IOL onto the retina. Thus, stable IOLs that can reduce or mitigate aberrant optical effects, such as positive and/or negative dysphotopsia, as well as increase field of view are desirable.

#### SUMMARY OF THE INVENTION

**[0006]** The systems, methods and devices of the disclosure each have several innovative aspects, no single one of which is solely responsible for the desirable attributes disclosed herein.

**[0007]** Embodiments disclosed herein are directed to devices and methods for providing corrective vision in the event the natural lens is replaced. In some embodiments, it would be desirable to have a stable IOL that can reduce or mitigate dysphotopsia, or other aberrant optical effects and regain the phakic field of view.

**[0008]** In one aspect, an IOL is provided that can reduce or mitigate dysphotopsia. In IOLs, one of the causes of dysphotopsia is the interaction of light that is refracted by the IOL with the edge of the IOL. Accordingly, a possible solution to reduce or mitigate dysphotopsia is to design an IOL such that the edge of the IOL is outside the path of light rays entering the eye and incident on the IOL. In such a design since light rays incident on the edge of the IOL is minimized or eliminated, dysphotopsia can be reduce or eliminated. In various implementations, the IOL has an anterior surface and a posterior surface that are intersected by an optical axis. The anterior and posterior surfaces are joined by a peripheral region. Peripheral light from the side and behind a patient's eye enters the cornea refracting at a maximum angle of about  $r_1$  degrees. These rays are incident on the anterior surface of the IOL and are refracted at a maximum angle of  $r_2$  degrees. For a refractive surface, the

peripheral region is inclined at an angle of inclination greater than  $\sin^{-1}\left(\frac{n_2}{n_3}\sin r_1\right)$ , where  $n_3$  is the refractive index of the material of the intraocular lens,  $n_2$  is the combined refractive index of the cornea and the aqueous humor. When the anterior and/or posterior surface contains a diffractive surface, formulas based on diffractive optics are applicable as known to those skilled in the art. The angle of inclination in this sense is defined with respect to an axis parallel to the central optical axis OA, intersecting the peripheral region at the inflection point and extending in the posterior direction from the inflection point. Additionally, the peripheral region may angle posteriorly from the anterior surface. By way of example, in a 20 Diopter IOL, the peripheral region may be inclined posteriorly and defined at an angle greater than about 40 degrees in order to prevent rays from striking the edge of the IOL.

**[0009]** In one preferred embodiment, an intraocular lens is comprised of an anterior optical surface extending peripherally from a central optical axis of the intraocular lens; a posterior optical surface extending peripherally from the central optical axis; and a peripheral zone disposed about and extending laterally from the anterior optical surface, the peripheral zone being inclined posteriorly from the anterior optical surface; wherein the extent of the posterior incline of the peripheral zone is sufficient to prevent aberrant optical effects from high angle optical rays directed posteriorly toward the intraocular lens and refracted by the anterior surface. The peripheral zone may comprise of a peripheral surface extending laterally and posteriorly from a point of inflection disposed between the anterior surface and the peripheral zone. The point of inflection may be disposed laterally from the central optical axis by a distance greater than the distance to the location of the optic where the rays of greatest divergence refracted into the eye by the cornea strike the anterior surface of the lens when implanted in the capsular bag of a patient's eye. The point of inflection may be disposed laterally of the optical axis by at least about 2 mm, and is preferably at least about 2.5 mm, but may be configured to match the capsular bag size which is typically up to at least about 5 mm. An angle may be provided between the peripheral surface and an axis extending posteriorly from the point of inflection disposed between the anterior surface and the peripheral zone, wherein the angle is greater than or equal to a maximum angle of refraction by the anterior surface of the rays of greatest divergence refracted into the eye by the cornea. The aforementioned angle may be greater than or equal to about 40 degrees and

is preferably greater than or equal to about 55 degrees, and more preferably greater than or equal to about 60 degrees. Depending on the configuration, the angle may be as large as about 120 degrees.

**[0010]** In another preferred embodiment, the intraocular lens may be comprised of an anterior optical surface extending peripherally from a central optical axis of the intraocular lens; a posterior optical surface extending peripherally from the central optical axis; and a peripheral surface disposed about and extending laterally from the anterior optical surface, the peripheral surface being inclined posteriorly from the anterior optical surface; wherein the intraocular lens is configured to minimize dysphotopsia by preventing peripheral light rays from passing through the peripheral surface of the lens. The intraocular lens may be configured to minimize negative and/or positive dysphotopsia with the peripheral surface located laterally outward of the trajectory of peripheral light rays refracted by the anterior surface of the lens.

**[0011]** In another preferred embodiment, a dysphotopsia reducing intraocular lens may be comprised of an optic configured for implantation in the eye of a patient, the optic having anterior surface and posterior surfaces intersected by an optical axis, the anterior and posterior surfaces being joined by a transition area disposed about the optical axis, wherein the transition area inclines posteriorly from the anterior surface and intersects the anterior surface at an angle greater than approximately 40 degrees with respect to the optical axis. The rays of greatest divergence refracted into the eye by the cornea strike the anterior surface of the lens when implanted in the capsular bag of a patient's eye at the intersection of the first edge and the anterior surface. The rays of greatest divergence refracted into the eye by the cornea may be refracted by the anterior surface such that they are not incident on the first edge.

**[0012]** In another preferred embodiment, an intraocular lens may be comprised of an optic configured for implantation in the eye of a patient, the optic having anterior surface and posterior surfaces intersected by an optical axis, the anterior and posterior surfaces being joined by a peripheral region, the peripheral region inclined posteriorly from the anterior surface, the angle of inclination of the peripheral region being greater than  $\sin^{-1}\left(\frac{n_2}{n_3} \sin r_1\right)$ , where  $n_3$  is the refractive index of the material of the intraocular lens,  $n_2$  is the refractive

index of aqueous humor and  $r_1$  is the angle of refraction at which the most peripheral rays are refracted into the eye by the cornea.

**[0013]** Details of one or more implementations of the subject matter described in this specification are set forth in the accompanying drawings and the description below. Other features, aspects, and advantages will become apparent from the description, the drawings, and the claims. Note that the relative dimensions of the following figures may not be drawn to scale.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0014]** Embodiments disclosed herein may be better understood from the following detailed description when read in conjunction with the accompanying drawings. Such embodiments, which are for illustrative purposes only, depict novel and non-obvious aspects of the inventions. The drawings include the following figures.

**[0015]** Figure 1 is a schematic representation of certain aspects of a human eye with an artificial IOL positioned therein configured such that the most peripheral rays that enter the eye are incident on and anterior optical surface of the IOL and not incident on a peripheral region, such as an edge of the IOL.

**[0016]** Figure 2 is a schematic perspective view of an implementation of the IOL depicted in Figure 1, showing a central optical axis.

**[0017]** Figure 3 is a cross-sectional view of another implementation of an IOL in which the most peripheral rays that enter the eye and are incident on and refracted by the IOL are not incident on an edge of the IOL.

**[0018]** Figures 4A through 4C are top plan views of substantially oval, elliptical, and rectangular preferred IOL embodiments.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

**[0019]** A human eye includes a transparent crystalline biconvex lens which can focus light from objects over a wide range of distances on the retina. The natural lens allows the eye to focus on the objects at various distances by changing its shape thereby changing its focal length. The ability of the lens to change its shape to adjust the focal length is known as accommodation. The lens is housed in a structure known as the capsular bag 102. During natural accommodation, the capsular bag is acted on by a ciliary muscle and zonular fibers (also known as zonules) in the eye, which can pull on the capsular bag to change its shape.

The motion of the capsular bag generally deforms the lens in order to change its power, so that the eye can focus on objects at varying distances away from the eye.

**[0020]** In a healthy human eye ambient light is refracted into the eye by the cornea 101 and focused by the lens on the retina to form an image. The image is produced by the combination of the optical powers of the cornea 101, the capsular bag 102 and the lens, all of which are generally disposed about a central optical axis OA. As used herein, an "anterior direction" is in the direction generally toward the cornea, while a "posterior direction" is generally in the direction toward the retina which is located rearward of the cornea 101. In a healthy human eye, an iris is disposed between the cornea 101 and the capsular bag 102 which provides a variable pupil that dilates under lower lighting conditions (scotopic vision) and constricts under brighter lighting conditions (photopic vision) to control the amount of ambient light that enters the eye.

**[0021]** The average diameter of the cornea in a human eye is between about 10 mm and 12 mm. The radius of curvature of the cornea is typically between about 6 mm and about 11.5 mm. The average distance between the mid-point of the cornea and the capsular bag is between about 2.0 mm and 5.0 mm. In general, the average horizontal diameter of the natural lens is between 9 – 10 mm and the average thickness of the natural lens is about 4.5 mm. The pupil diameter can vary between about 1.0 mm and about 8 mm.

**[0022]** Figure 1 illustrates a cross-sectional view of a human eye in which an IOL 103 is implanted in the capsular bag 102 to replace the natural lens. Figure 2 is a schematic perspective view of the implementation of the IOL 103 illustrated in Figure 1. Although, the IOL 103 is illustrated as being implanted in the evacuated capsular bag 102, it is understood by a person having ordinary skill in the art that the IOL 103 can be a phakic/piggy-back IOL which acts as a secondary lens in a phakic eye that includes the natural lens. Also, it will be understood that the IOL 103 may have haptics to mechanically position the optic in position in the eye, and as further described below. The IOL 103 has an anterior surface 201 and a posterior surface 203 that is intersected by the central optical axis OA. In use, the optical axis OA may extend from the fovea of the retina to an object being viewed. The central area of the anterior and/or posterior surface (about a 3 mm radius from the central optical axis) may be monofocal, aspheric, toric, diffractive, or any combination of the aforementioned. The IOL 103 also includes a peripheral region 205 that is disposed between the anterior



surface 201 and the posterior surface 203. The peripheral region 205 can join the anterior surface 201 and the posterior surface 203. In various implementations, the peripheral region 205 may comprise a circular, elliptical or other regular shaped peripheral zone that extends posteriorly from the anterior surface 201.

**[0023]** The figures suggest that a very precise demarcation can be provided between discrete regions of the IOL 103, such as between the anterior zone 201 and the peripheral region 205. However, in some embodiments, a gradual transition can be provided between these and other zones. For example, in various implementations, the peripheral region 205 can include an inflection region 207 (illustrated in Figure 3) that forms a transition area between the anterior surface and the peripheral region 205. The inflection region 207 may be inclined posteriorly with respect to the anterior surface 201 as discussed above. In various implementations, the inflection region can include a peripheral surface which connects the anterior surface 201 to the peripheral region 205.

**[0024]** The IOL 103 is generally made of a transparent bio-compatible material that can be deformed. For example, in various implementations, the IOL 103 can be made of silicone or acrylic. The anterior and/or the posterior surface of the IOL 103 are curved such that the IOL 103 has optical power. The anterior and/or posterior surface may also be comprised of a diffractive surface or an extended depth of focus structure. Or, the lens may be moveable with respect to the retina or other surface or deform to have adjustable power, as in an accommodating IOL.

**[0025]** The field-of-view of an average human eye is about 110 degrees in the horizontal direction. Accordingly, the most peripheral rays of light are incident on the cornea 101 at a maximum angle  $i_1$  of about 110 degrees with respect to the central optical axis OA, as illustrated by ray 105, and are refracted by the cornea 101 into the eye, as illustrated by ray 107. Peripheral rays that are incident on the cornea 101 at an angle greater than about 110 degrees with respect to the central optical axis OA will not enter the eye, which is the reason for the limited field-of-view of the human eye. Rather, these rays will be reflected by or pass through the opposite side of the cornea. If the geometry of the cornea at the incident point of ray 105 and the refractive index of the cornea 101 and aqueous humor are known, the angle of refraction  $r_1$  of the refracted ray of light 107 can be determined from Snell's law of refraction. Mathematically, Snell's law of refraction is expressed as

$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$ , where  $i$  is the angle of incidence of a ray of light that is incident from a medium having a refractive index  $n_1$  onto a medium having refractive index  $n_2$  and  $r$  is the angle of refraction. With reference to Figure 1,  $n_1$  is the refractive index of air which is considered to be 1.0 and  $n_2$  is the combined refractive index of the cornea and the aqueous humor which is about 1.38. For a typical human eye, the most peripheral rays (e.g. ray 105) that are incident at an angle of about 110 degrees with respect to the central optical axis OA are refracted by the cornea 101 into the eye with an angle of about 80 degrees. In other words, for a typical human eye,  $r_1$  is about 80 degrees.

**[0026]** The most peripheral rays that are refracted into the eye by the cornea (e.g. ray 107) are incident on the anterior surface 201 of the IOL 103 and refracted into IOL 103 in accordance with Snell's law of refraction, as illustrated by ray 109. The angle  $r_2$  that ray 109 makes with respect to an axis parallel to the central optical axis OA, intersecting the peripheral region at the inflection point and extending in the posterior direction from the inflection point can be calculated from Snell's law of refraction if the geometry of the IOL 103 at the incidence point of ray 107 and the refractive index of the material of the IOL 103 is known. For the implementation illustrated in Figure 1, the angle  $r_2$  is given by  $\sin^{-1}\left(\frac{n_2}{n_3}\sin r_1\right)$ , where  $n_3$  is the refractive index of the material of the IOL 103. Generally, for an acrylic or silicone IOL with a low refractive index, the angle  $r_2$  is less than or equal to about 40 degrees for a typical human eye having  $r_1$  of about 80 degrees.

**[0027]** In the embodiment of Figure 1, the IOL 103 is configured such that the peripheral region 205 is disposed laterally of the point of incidence of the ray 107 with the anterior surface 201 of the IOL 103. Additionally, the peripheral region 205 is disposed away from the trajectory of the refracted ray 109. In other words, the ray 109 may be refracted by the IOL 103 along a path therethrough but the path does not intersect the peripheral region 205. In one embodiment, the region 205 may be inclined posteriorly from the anterior surface 201 and is at an angle  $\theta$  greater than or equal to about 40 degrees and is preferably greater than or equal to about 55 degrees, and more preferably greater than or equal to about 60 degrees. The peripheral region may be substantially straight thus maintaining this angle. Or if the peripheral region is comprised of a curved portion, it may

be configured such that light rays will not strike the peripheral region of the IOL. In other words, the most peripheral rays that enter the eye and are refracted into the IOL 103 would not be incident on peripheral region 205 and also would not be refracted by the IOL to pass through the peripheral region 205. Thus, the interaction between the light that is refracted into the IOL 103 and the peripheral region 205 can be reduced or eliminated which can prevent aberrant optical effects such as positive and/or negative dysphotopsia. Since, the angle of inclination  $\theta$  of the peripheral region 205 depends on the phenomenon of refraction, in various implementations of the IOL 103, the angle of inclination  $\theta$  of the peripheral region 205 is determined by the refractive index of the material of the IOL 103 and the geometry of the portion of the anterior surface 103 at which the most peripheral rays that enter the eye are incident. For a typical silicone or acrylic IOL, the angle  $\theta$  may be in the range of about 40 degrees and 120 degrees, and is preferably in the range of about 40 degrees and 60 degrees, and more preferably in the range of about 55 degrees and 60 degrees.

**[0028]** As discussed above, one of the causes for negative dysphotopsia in some IOL designs is the creation of a shadow in the eye. The shadow can be in a region of the retina between two groups of rays that are incident on the retina. The first group of rays pass laterally of the IOL are not refracted at all by the lens. The second group of rays, which are immediately adjacent to the first group, are incident on the lens and are refracted at an angle away from the first group. This causes the two groups of rays to diverge, with little or no light being present in the region between the diverging rays. Thus, the region between the diverging rays is darker, i.e., a shadow is cast on the retina. The IOL 103 is configured such that the inflection region or the transition area 207 that is inclined posteriorly from the anterior surface 201 is disposed at a distance L from the central optical axis OA. If angle  $\theta$  is greater than 90 degrees, then at least a portion of the inflection region or the transition area is inclined anteriorly. The distance L is selected to be equal to or greater than the outermost point of incidence of the ray 107. This ensures that the most peripheral rays that enter the eye are incident on the anterior surface and not on the peripheral zone 205. In such implementations, negative dysphotopsia can also be reduced or mitigated since all light that enters the eye is incident on the anterior surface of the IOL 103 and refracted in the preferred

way. In various implementations, the inflection region can be disposed at a distance L of about 2-5 mm from the central optical axis OA.

**[0029]** Although Figures 1 and 2 illustrate the IOL 103 to be polygonal in shape, a person having ordinary skill in the art would understand that the anterior surface 201, the posterior surface 203 and the peripheral region 205 can be curved to produce the desired power. In various implementations, the anterior surface 201 or the inflection region can have some curvature. In those implementations, where the peripheral region 205 is arcuate, the angle of the inclination of the peripheral region 205 can be taken as the angle between an anterior-posterior line parallel to the central optical axis and a line connecting a point of inflection of the peripheral region 205 closer to the anterior surface and a point located at the boundary between the peripheral zone 205 and the posterior surface 203. In some implementations, where the peripheral region 205 is arcuate, the angle of inclination of the peripheral region 205 can be taken as the angle between the largest chord of the peripheral region 205 and an axis that is parallel to the central optical axis and extends posteriorly from the point of inflection.

**[0030]** In various implementations, the IOL 103 can be designed by selecting parameters such as the lateral distance of the peripheral region 205 from the central optical axis, the curvature of the peripheral region 205, the angle of inclination of the peripheral region 205 such that the most peripheral rays that enter an average human eye are incident on the anterior surface of the IOL 103 and do not intersect the peripheral region 205 after being refracted by the IOL 103. In some implementations, the IOL 103 can be designed specifically for a patient's eye by taking the patient's pupil diameter, depth of the capsular bag from a mid-point of the cornea into consideration such that most peripheral rays that enter the patient's eye are incident on the anterior surface of the IOL and do not intersect the peripheral region 205 after being refracted by the IOL. In other implementations, a set of IOLs designed for different pupil diameters and different depth of the capsular bag from a mid-point of the cornea can be provided to suit the needs of the general population.

**[0031]** Figures 4A and 4B depict the present invention (as seen from a top plan view) as an elliptical IOL with an optic which has a width W (measured in the nasal-temporal direction), that is greater than its height H (measured in the superior-inferior direction). Figure 4C depicts an optic that is generally rectangular in shape with the width W

again greater than its height H. The width of the optic as measured on the anterior side of the optic is in the range of about 6.25 mm-10 mm and is preferably about 8-10 mm or more preferably between about 9-10 mm. Though the upper limit of width of the capsular bag is typically about 10 mm, it is envisioned that the width of the optic as disclosed herein may be configured to match the capsular bag. The height of the optic as measured on the anterior side of the optic is in the range of about 4.5 mm-9 mm and is preferably about 7-9 mm, or more preferably about 7-8 mm. The thickness of the central area of the optic will depend on the optical characteristics (e.g. refractive versus diffractive) desired for the central and as known to those skilled in the art. The thickness of the noncentral area may be between 0.01 mm and 1.0 mm. This thickness may be constant or may vary, for example, by tapering toward the peripheral zone. In certain preferred embodiments, the thickness at the edge of the IOL (as measured from the point of inflection to the posterior surface in a line parallel to the optical axis) on the nasal and/or temporal sides will be less than or about 0.03 mm or preferably less than or about 0.02 mm or even more preferably less than or about 0.01 mm (though the superior and inferior sides may also be so dimensioned). Such embodiments may allow the IOL to be folded/ compressed in such a manner to allow the IOL through a small diameter inserter using less force. While substantially oval, elliptical and rectangular embodiments are depicted in Figures 4A through 4C, other shapes encompassed herein include substantially poly-angle shapes such as a triangle, square, and other poly-angle basic shapes. At least two haptics are coupled to the optic at opposing ends, on the superior and inferior sides of the optic. As in the embodiments disclosed above, these configurations provide stability while substantially reducing or eliminating dysphotopsia and increasing field of view.

**[0032]** The above described design considerations can also be used to design implementations or contact lenses, spectacles or other ophthalmologic visual aid devices to avoid aberrant optical effects.

**[0033]** The description of the invention and its applications as set forth herein is illustrative and is not intended to limit the scope of the invention. Variations and modifications of the embodiments disclosed herein are possible, and practical alternatives to and equivalents of the various elements of the embodiments would be understood to those of ordinary skill in the art upon study of this patent document. These and other variations and

modifications of the embodiments disclosed herein may be made without departing from the scope and spirit of the invention.

WHAT IS CLAIMED IS:

1. A intraocular lens comprising:  
an optic and a plurality of haptics coupled to the optic wherein the optic comprises:  
an anterior optical surface extending peripherally from a central optical axis of the intraocular lens;  
a posterior optical surface extending peripherally from the central optical axis;  
and  
a peripheral zone disposed about and extending laterally from the anterior optical surface, the peripheral zone being inclined posteriorly from the anterior optical surface;  
wherein the extent of the posterior incline of the peripheral zone is sufficient to prevent aberrant optical effects from high angle optical rays directed posteriorly toward the intraocular lens and refracted by the anterior surface.
2. The intraocular lens of Claim 1, wherein the peripheral zone comprises a peripheral surface extending laterally and posteriorly from a point of inflection disposed between the anterior surface and the peripheral zone.
3. The intraocular lens of Claim 2, wherein the point of inflection is disposed laterally from the central optical axis by a distance greater than the distance to the location of the optic where the rays of greatest divergence refracted into the eye by the cornea strike the anterior surface of the lens when implanted in the capsular bag of a patient's eye.
4. The intraocular lens of Claim 3, wherein an angle is provided between the peripheral surface and an axis extending posteriorly from the point of inflection disposed between the anterior surface and the peripheral zone, the angle being greater than or equal to a maximum angle of refraction by the anterior surface of the rays of greatest divergence refracted into the eye by the cornea.
5. The intraocular lens of Claim 4, wherein the angle is greater than or equal to about 40 degrees.
6. The intraocular lens of Claim 4, wherein the angle is greater than or equal to about 55 degrees.

7. The intraocular lens of Claim 4, wherein the angle is greater than or equal to about 60 degrees.

8. The intraocular lens of Claim 4, wherein the point of inflection is disposed laterally of the optical axis by at least about 2 mm.

9. The intraocular lens of Claim 1, wherein the optic is substantially elliptical, substantially oval, or substantially poly-angle in shape.

10. The intraocular lens of Claim 9, wherein a width of the optic is in the range of about 6.25 mm to 10 mm.

11. The intraocular lens of Claim 9, wherein a width of the optic is in the range of about 8 mm to 10 mm.

12. The intraocular lens of Claim 9, wherein a width of the optic is in the range of about 9 mm to 10 mm.

13. The intraocular lens of Claim 9, wherein a height of the optic is in the range of about 4.5 mm to 9 mm.

14. The intraocular lens of Claim 9, wherein a height of the optic is in the range of about 7 mm to 9 mm.

15. The intraocular lens of Claim 20, wherein the height of the optic is in the range of about 7 mm to 8 mm.

16. The intraocular lens of Claim 9, wherein a height of the optic is in the range of about 7 mm to 8 mm.

17. The intraocular lens of Claim 9, wherein an edge of the optic is less than or about 0.03 mm.

18. The intraocular lens of Claim 9, wherein an edge of the optic is less than or about 0.02 mm.

19. The intraocular lens of Claim 9, wherein an edge of the optic is less than or about 0.01 mm.

20. A dysphotopsia reducing intraocular lens comprising:

an optic and a plurality of haptics coupled to the optic wherein the optic comprises:

an optic configured for implantation in the eye of a patient, the optic having anterior surface and posterior surfaces intersected by an optical axis, the anterior and posterior surfaces being joined by a transition area disposed about the optical axis,



wherein the transition area inclines posteriorly from the anterior surface and intersects the anterior surface at an angle greater than approximately 55 degrees with respect to the optical axis.

21. The intraocular lens of claim 20, wherein rays of greatest divergence refracted into the eye by the cornea strike the anterior surface of the lens when implanted in the capsular bag of a patient's eye at the intersection of the first edge and the anterior surface.

22. The intraocular lens of Claim 21, wherein rays of greatest divergence refracted into the eye by the cornea is refracted by the anterior surface such that they are not incident on the first edge.

23. The intraocular lens of Claim 20, wherein the optic is substantially elliptical, substantially oval, or substantially poly-angle in shape.

24. The intraocular lens of Claim 23, wherein the width of the optic is in the range of about 6.25 mm to 10 mm.

25. The intraocular lens of Claim 23, wherein the width of the optic is in the range of about 8 mm to 10 mm.

26. The intraocular lens of Claim 23, wherein the width of the optic is in the range of about 9 mm to 10 mm.

27. The intraocular lens of Claim 23, wherein the height of the optic is in the range of about 4.5 mm to 9 mm.

28. The intraocular lens of Claim 23, wherein the height of the optic is in the range of about 7 mm to 9 mm.

29. The intraocular lens of Claim 23, wherein the height of the optic is in the range of about 7 mm to 8 mm.

30. The intraocular lens of Claim 23, wherein an edge of the optic is less than or about 0.03 mm.

31. The intraocular lens of Claim 23, wherein an edge of the optic is less than or about 0.02 mm.

32. The intraocular lens of Claim 23, wherein an edge of the optic is less than or about 0.01 mm.

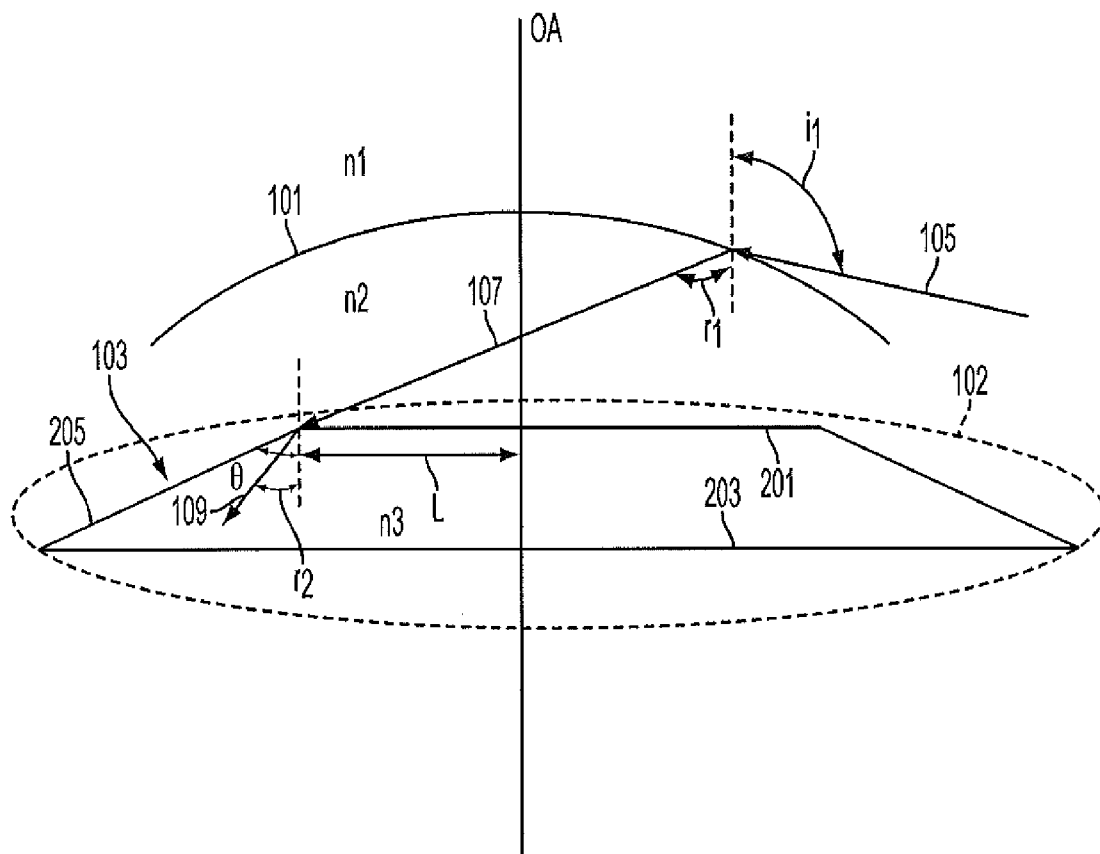


FIG. 1

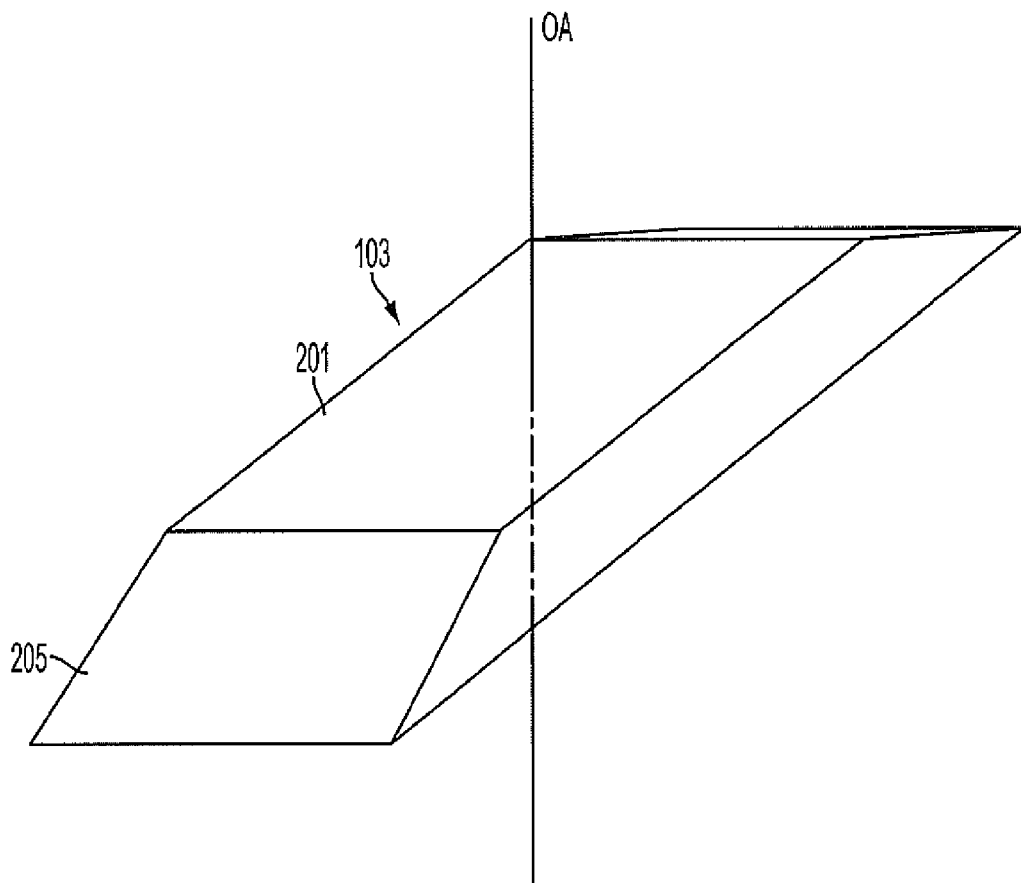


FIG. 2

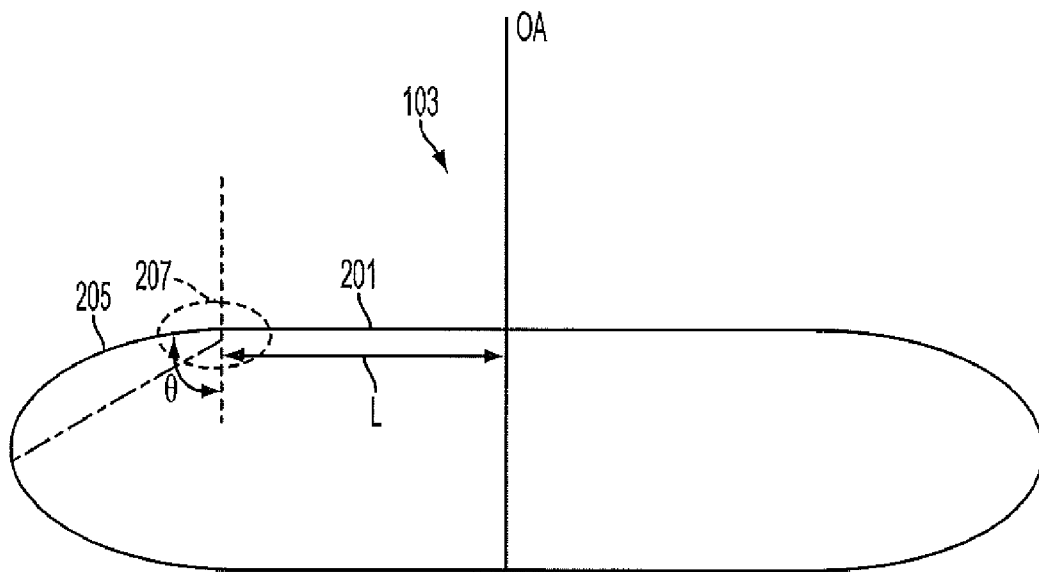


FIG. 3

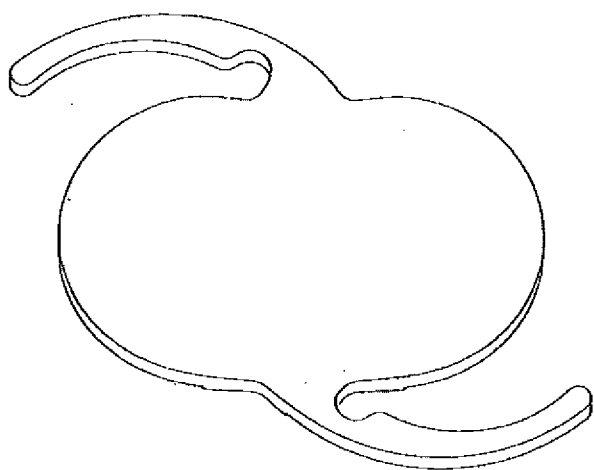


Figure 4A

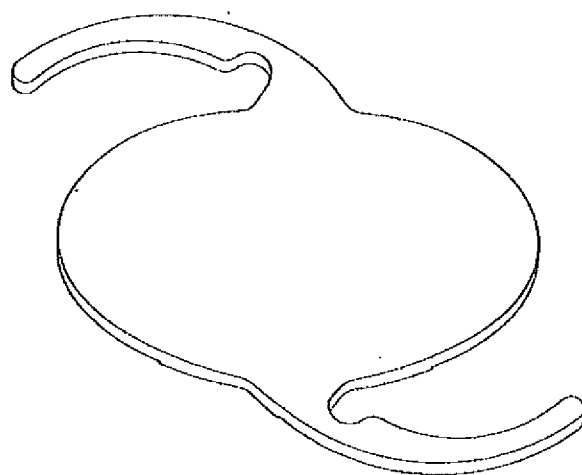


Figure 4B

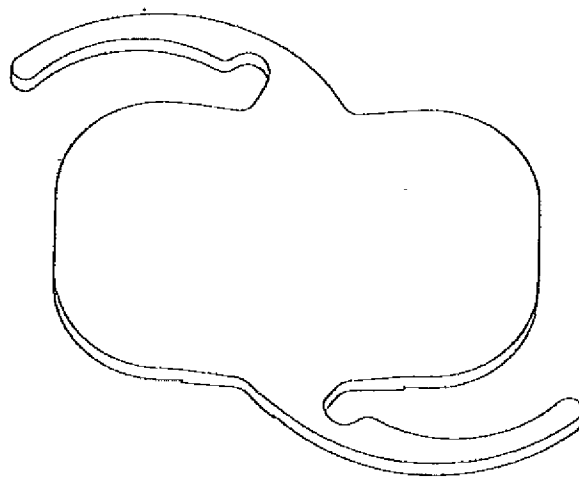


Figure 4C

# INTERNATIONAL SEARCH REPORT

International application No

PCT/US2013/048682

## A. CLASSIFICATION OF SUBJECT MATTER

INV. A61F2/16

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61F

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

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

EP0-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 755 786 A (WOFFINDEN GEORGE J [US] ET AL) 26 May 1998 (1998-05-26) column 5, line 44 - column 6, line 65 column 7, line 57 - line 59; figures 5B,6-8	1-10, 20-24
X	----- US 2003/144733 A1 (BRADY DANIEL G [US] ET AL) 31 July 2003 (2003-07-31)  paragraph [0010] paragraph [0067] - paragraph [0081] paragraph [0088] - paragraph [0093]; figures 4-9,14a-17 paragraph [0023]  ----- -/--	1-10, 17-24, 30-32



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

23 September 2013

Date of mailing of the international search report

30/09/2013

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040,  
Fax: (+31-70) 340-3016

Authorized officer

Lega, A

# INTERNATIONAL SEARCH REPORT

International application No

PCT/US2013/048682

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/244560 A1 (OSSIPOV ALEXEI [US] ET AL) 18 October 2007 (2007-10-18) paragraph [0039] - paragraph [0060]; figures 1-9	1-16, 20-29
X	----- US 2005/060031 A1 (CORONEO MINAS THEODORE [AU] CORONCO MINAS THEODORE [AU]) 17 March 2005 (2005-03-17) paragraph [0010] - paragraph [0018] paragraph [0027] - paragraph [0028] paragraph [0035] - paragraph [0054]; claims 1-6,8-19; figure 5 -----	1-3,9, 10,20-23

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2013/048682

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5755786 A	26-05-1998	US 5755786 A	26-05-1998
		US 6264692 B1	24-07-2001
US 2003144733 A1	31-07-2003	US 2003144733 A1	31-07-2003
		US 2005154456 A1	14-07-2005
US 2007244560 A1	18-10-2007	AU 2007238068 A1	25-10-2007
		CA 2649317 A1	25-10-2007
		EP 2004094 A2	24-12-2008
		JP 2009533186 A	17-09-2009
		KR 20090005168 A	12-01-2009
		US 2007244560 A1	18-10-2007
		WO 2007121296 A2	25-10-2007
US 2005060031 A1	17-03-2005	US 2005060031 A1	17-03-2005
		US 2007276482 A1	29-11-2007