

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
6 August 2009 (06.08.2009)

PCT

(10) International Publication Number
WO 2009/097255 A1

- (51) International Patent Classification: 61/053,734 16 May 2008 (16.05.2008) US
G02C 7/06 (2006.01) 61/054,379 19 May 2008 (19.05.2008) US
- (21) International Application Number: 61/056,663 28 May 2008 (28.05.2008) US
PCT/US2009/032086 61/078,986 8 July 2008 (08.07.2008) US
- (22) International Filing Date: 27 January 2009 (27.01.2009)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:

61/025,477	1 February 2008 (01.02.2008)	US
61/037,958	19 March 2008 (19.03.2008)	US
61/041,094	31 March 2008 (31.03.2008)	US
61/044,802	14 April 2008 (14.04.2008)	US
61/047,614	24 April 2008 (24.04.2008)	US
61/047,888	25 April 2008 (25.04.2008)	US
61/048,860	29 April 2008 (29.04.2008)	US
61/048,851	29 April 2008 (29.04.2008)	US
61/048,862	29 April 2008 (29.04.2008)	US
61/052,034	9 May 2008 (09.05.2008)	US
61/052,700	13 May 2008 (13.05.2008)	US
- (71) Applicant (for all designated States except US): **PIX-ELOPTICS INC.** [US/US]; 5241 Valleypark Drive, Roanoke, VA 24019 (US).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): **BLUM, Ronald, D.** [US/US]; 5320 Silver Fox Road, Roanoke, VA 24018 (US). **KOKONASKI, William** [US/US]; 1807 44th Street Court, NW, Gig Harbor, WA 98335 (US). **HADDOCK, Joshua, N.** [US/US]; 17 Church Avenue SW, Apt 202, Roanoke, VA 24011 (US). **IYER, Venkatramani, S.** [US/US]; 1932 Summerfield Drive, Roanoke, VA 24012 (US).
- (74) Agent: **NARCISSE, Claude, R.**; Pearl Cohen Zedek Latzer, LLP, 1500 Broadway, 12th Floor, New York, NY 10036 (US).
- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

[Continued on next page]

(54) Title: MULTIPLE LAYER MULTIFOCAL COMPOSITE LENS

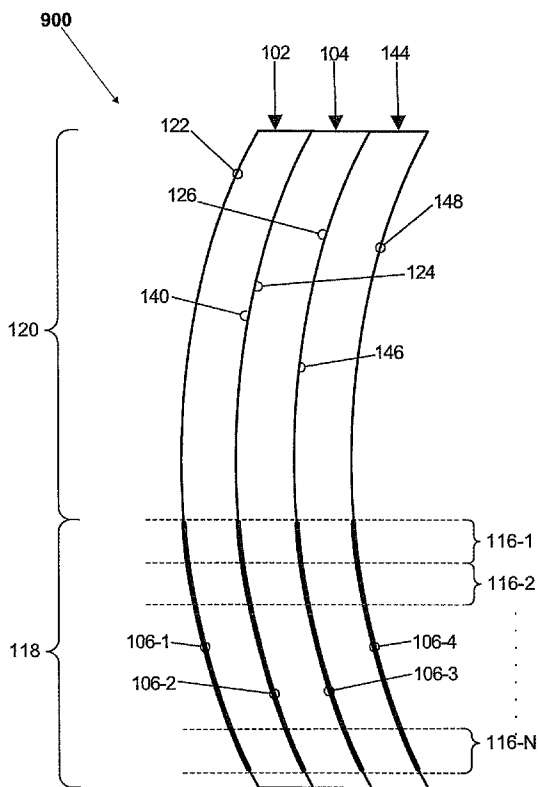


FIG. 9

(57) Abstract: Aspects of the present invention provide multiple-layer composite lenses comprising two or more materials and methods for making the same. A multi-layer composite lens of the present invention can use multiple surfaces to form optical elements that can contribute to a total desired add power. The multiple contributing elements can be aligned so as to be in optical communication to form multiple stable vision zones to enhance optical performance and vision experience of the wearer. Distributing the total desired add power across multiple appropriately aligned optical elements that are in optical communication with one another can reduce the total distortion of the lens, minimize the number of optical discontinuities introduced and reduce the visibility of any introduced optical discontinuity. A surface of the multiple-layer composite lens can comprise a combined progressive structure and substantially constant optical power structure or a cropped progressive structure.

WO 2009/097255 A1



AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM,

ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (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, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report*

MULTIPLE LAYER MULTIFOCAL COMPOSITE LENS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention generally relates to lenses. More specifically, the present invention provides lenses having multiple vision zones with reduced distortion and reduced visibility of any included discontinuities.

Background Art

Multifocal lenses generally have two or more adjacent regions of different optical power to provide multiple vision zones. Examples of traditional multifocal lenses include bifocals, trifocals, and progressive addition lenses. The multiple vision zones of a multifocal lens allow a wearer to more clearly view differently spaced objects using different vision zone correction prescriptions. A typical wearer of a multifocal lens may have a first vision correction prescription for viewing distant objects and a second vision correction prescription for viewing near objects.

Many multifocal lenses are lined lenses. That is, many multifocal lenses have a discontinuity separating each vision zone that can be seen by someone looking at a wearer of the lens. As a result, many individuals find lined multifocals to be cosmetically unappealing. Additionally, a wearer of a lined multifocal lens will perceive the effects of traversing the multiple discontinuities when the wearer's line of sight crosses the boundaries of the vision zones. The traversal of any such discontinuity can cause an image jump perceptible to the wearer. Experiencing an image jump can be visually disturbing and distracting to the wearer. Accordingly, experiencing multiple image jumps in a multifocal lens that provides two or more vision zones exacerbates the discomfort of the user.

Blended multifocals can reduce the effects of the abrupt discontinuity between two adjacent regions of different optical powers. Generally, a blend zone is provided between the two different optical power regions to provide a relatively smooth transition from the optical power of the initial zone to the optical power of the adjacent zone. Such blending can improve the aesthetics of a multifocal lens by reducing the visibility of the discontinuity between the adjacent regions. However, blend zones are typically unusable portions of a lens due to poor resulting optics associated with the blend zone. Therefore, using a blend zone to reduce the visibility of an optical discontinuity can reduce the usability of the vision zones of

a multifocal lens by reducing their size. Further, blend zones can introduce their own unique disturbances as experienced by a wearer when traversed by a wearer's line of sight. Such disturbances can be introduced by the blending of the optical power which can create unwanted astigmatism and distortion across the blend zone.

5 Due to the disadvantages of traditional multifocals (lined or blended), many individuals opt to wear multiple pairs of spectacle lenses or choose to wear a progressive lens. Progressive lenses generally provide a smooth continuous change in optical power between different regions of a lens. While many individuals find progressive lenses to be more appealing cosmetically, they too are often accompanied by many disadvantages. For example, many
10 progressive lenses have narrow channels or vision zones, cause wearers to experience an unpleasant visual motion known as swim, and have large amounts of distortion (e.g., unwanted astigmatism) in the periphery of the lens.

Many prior art lens designs have attempted to improve upon the deficiencies of traditional multifocal lenses yet continue to suffer from significant drawbacks. FIG. 11 illustrates a
15 front and side view of a prior art multifocal lens design described in U.S. Pat. No. 6,270,220 to Keren. Keren describes a multifocal lens having a progressive region 1104 and a diffractive segment 1102. The diffractive segment 1102 can be on the front or back surface of the multifocal lens. The multifocal lens is made up of a single material and comprises a single layer. The diffractive segment 1102 is limited to being positioned over the
20 intermediate region of the progressive region 1104 only. The diffractive segment 1102 does not contribute optical power to the far distance or near distance vision zones of the multifocal lens. Instead, the diffractive segment 1102 contributes multiple different optical powers to the intermediate region only. The multiple different optical powers are not additive and can make the intermediate region uncomfortable to a wearer. Overall, the multifocal lens
25 described in Keren provides only three vision zones with only two vision zones (the near vision and the distance vision zones) being stable.

FIG. 12 illustrates a front and side view of a prior art multifocal lens design described in U.S. Pat. No. 4,461,550 to Legendre. Legendre describes a multifocal lens having a progressive region 1202 and a refractive segment 1204 superposed in the near vision zone of the
30 progressive region 1202. The refractive segment 1204 can be placed on top of the multifocal lens or can be positioned within the multifocal lens. The refractive segment 1204, when buried, does not form a separate layer of the multifocal lens. The refractive segment 1204 introduces a discontinuity 1206 around the near vision zone which can be very disturbing to a

wearer. The refractive segment 1204 does not contribute to the optical power provided in the intermediate or far distance vision zones of the lens. Due to the increase in near vision power from the superposed refractive segment 1204, the power ramp up of the intermediate region of the progressive region 1202 must be increased significantly. As a result, unwanted
5 astigmatism is increased in the lens thereby reducing the sizes of the vision zones. Further, the multifocal lens described in Legendre provides only three vision zones of which only two vision zones (the near vision and distance vision zones) are stable.

FIG. 13 illustrates a front and side view of a prior art lens design described in U.S. Pat. No. 5,305,028 to Okano. Okano describes a multifocal lens having a fused segment that has a
10 first spherical segment 1302 and a second spherical segment 1306 joined by a progressive region 1304. The boundaries between the progressive region 1304 and the spherical regions 1302 and 1306 are transition regions 1308. These transition regions 1308 operate similarly to blend zones and therefore restrict the usefulness of the transition regions 1308 optically. The multifocal lens of Okano comprises a single material. Further, the multifocal lens of Okano
15 comprises multiple discontinuities which can be very discomforting to a wearer of the lens when the wearer's line of sight traverses the provided vision zones. The near vision zone of the multifocal lens described by Okano comprises the spherical region 1306 only such that the progressive region 1304 does not contribute to the total near add power of the lens.

FIG. 14 illustrates a front and side view of a prior art lens design described in U.S. Pat. No.
20 6,086,203 to Blum et al. Blum et al. describes a multifocal lens having a progressive region 1404 and various discontinuous elements 1402. The progressive region 1404 is limited to being placed on a perform lens 1406. Further, the multifocal lens is limited to having two or more of the discontinuous optical elements 1402 added to the perform 1402. Blum et al. provides multiple vision zones but at the cost of introducing multiple discontinuities which
25 results in significant discomfort for the wearer. Further, Blum et al. places the discontinuous elements below the start or top of the progressive region 1404. The discontinuities are therefore positioned in close proximity with one another which can exacerbate the discomfort of the wearer. As a result, the lens described by Blum is not viable for use when working on a computer.

30 Accordingly, what is needed is a lens that overcomes one or more deficiencies of prior art lenses. More specifically, a lens that provides multiple vision zones with low distortion and a minimum number of optical discontinuities while simultaneously remaining cosmetically pleasing is desired.

BRIEF DESCRIPTION OF THE DRAWINGS/FIGURES

FIG. 1 illustrates a side view of a two-layer composite lens according to an aspect of the present invention.

FIG. 2 illustrates a front view of the two-layer composite lens of FIG. 1 according to an aspect of the present invention.

FIG. 3 illustrates a side view of an implementation of the two-layer composite lens of FIG. 1 according to an aspect of the present invention.

FIG. 4A illustrates a front view of the two-layer composite lens of FIG. 3 according to an aspect of the present invention.

FIG. 4B illustrates a front view of a two-layer composite lens according to an aspect of the present invention.

FIG. 4C illustrates a front view of a two-layer composite lens according to an aspect of the present invention.

FIG. 5 illustrates a close-up view of enhanced optical regions depicted in FIG. 4A in accordance with an aspect of the present invention.

FIG. 6A illustrates an optical power profile of the two-layer composite lens depicted in FIG. 4A.

FIG. 6B illustrates an optical power profile of the two-layer composite lens depicted in FIG. 4B.

FIG. 6C illustrates an optical power profile of the two-layer composite lens depicted in FIG. 4C.

FIG. 7 illustrates a front view of the two-layer composite lens of FIG. 3 according to an aspect of the present invention.

FIG. 8 illustrates a front view of the two-layer composite lens of FIG. 3 according to an aspect of the present invention.

FIG. 9 illustrates a side view of a three-layer composite lens according to an aspect of the present invention.

FIG. 10 illustrates a front view of the three-layer composite lens of FIG. 9 according to an aspect of the present invention.

FIG. 11 illustrates a front and side view of a prior art multifocal lens design.

FIG. 12 illustrates a front and side view of a prior art multifocal lens design.

FIG. 13 illustrates a front and side view of a prior art multifocal lens design.

FIG. 14 illustrates a front and side view of a prior art multifocal lens design.

FIG. 15 illustrates a front view of the two-layer composite lens of FIG. 3 according to an aspect of the present invention.

FIG. 16 illustrates a front view of the two-layer composite lens of FIG. 3 according to an aspect of the present invention.

5 FIG. 17 illustrates a front view of the two-layer composite lens of FIG. 3 according to an aspect of the present invention.

FIG. 18 illustrates a front view of the two-layer composite lens of FIG. 3 according to an aspect of the present invention.

10 FIG. 19 provides a flowchart that illustrates operational steps for manufacturing a two-layer composite lens in accordance with an aspect of the present invention.

FIG. 20 illustrates an implementation of a surface of a multi-layer composite lens of the present invention with an enhanced optical region comprising a combined progressive structure and substantially constant optical power structure in accordance with an aspect of the present invention.

15 FIG. 21A illustrates a first optical power profile of the enhanced optical region depicted in FIG. 20.

FIG. 21B illustrates a second optical power profile of the enhanced optical region depicted in FIG. 20.

20 FIG. 22A illustrates an implementation of a surface of a multi-layer lens of the present invention that can be optically aligned with the surface depicted in FIG. 20.

FIG. 22B illustrates a front view of a multi-layer lens of the present invention that can comprise the surface of FIG. 22A aligned on top of the surface of FIG. 20.

FIG. 22C illustrates a side view of the multi-layer lens depicted in FIG. 22B.

FIG. 23A illustrates a lens surface comprising a progressive structure.

25 FIG. 23B illustrates a lens surface of the present invention with an enhanced optical region comprising a cropped progressive structure in accordance with an aspect of the present invention.

30 FIG. 24 illustrates a possible optical power progression of an enhanced optical region as a refractive progressive optical power region in accordance with an aspect of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Aspects of the present invention provide multiple-layer (multi-layer) composite lenses comprising two or more materials and methods for making the same. A multi-layer composite lens of the present invention can use multiple surfaces (internal or external) to form optical elements that can contribute to a total desired add power. The multiple contributing optical elements can be aligned so as to be in optical communication to form multiple distinct and stable vision zones. Distributing the total desired add power across multiple appropriately aligned optical elements that are in optical communication with one another can reduce the total distortion of the lens, minimize the number of optical discontinuities introduced, can reduce optical power jump as experienced by the wearer's eye when traversing any discontinuity, and can reduce the visibility of any introduced optical discontinuity as perceived by an observer looking at the wearer. A surface of the multiple-layer composite lens can comprise a combined progressive structure and substantially constant optical power structure. A surface of the multiple-layer composite lens can also comprise a cropped progressive structure.

FIG. 1 illustrates a side view of a two-layer composite lens 100 according to an aspect of the present invention. The two-layer composite lens 100 comprises a first layer 102 and a second layer 104. The first layer 102 can comprise a first material having a first index of refraction, n_1 . The second layer 104 can comprise a second material having a second index of refraction, n_2 . The first material and the second material can comprise different materials and can each be substantially homogeneous.

The first and second materials can be any materials such as, but not limited to, any plastic or glass. Depending upon the selection of the first and second materials, the first index of refraction, n_1 , can be different from the second index of refraction, n_2 . As shown in FIG. 1, the first layer 102 can form an anterior surface and the second layer 104 can form a posterior surface of the two-layer composite lens 100, such that the second layer 104 is intended to be located closer to a wearer's eye. In general, a surface of the two-layer composite lens 100 can be one or both of the external surfaces of the lens or an internal surface of the lens (not including any coatings such as, for example, hard coating).

An index matching layer can be positioned between the first layer 102 and the second layer 104. The index matching layer can also be considered to be an index mediating, mitigating or bridging layer. The index matching layer can be a thin layer of material having an index of refraction that is between the indices of refraction of the first and second layers 102 and 104

(e.g., an index of refraction equal to the arithmetic mean of the indices of refraction of the first and second layers 102 and 104. Either layer can also be coated or covered by a scratch resistant and index matching layer. Such a coating can be dipped or spin-coated onto a layer and can cover the entirety of a layer.

- 5 The two-layer composite lens 100 can represent a finished lens, a finished lens blank, a semi-finished lens blank or a non-finished lens blank. More specifically, the two-layer composite lens 100 can be a finished lens (edged and ready to mount in a frame), a finished lens blank (finished on both outer surfaces but not yet edged), a semi-finished lens blank (finished on a first outer surface and not finished on a second outer surface) or a non-finished lens blank
10 (having neither outer surface finished). The two-layer composite lens 100 can be subjected to any known lens treatments or coatings prior to forming a final ophthalmic lens as will be appreciated by one skilled in the pertinent art(s).

A final desired state, or a state prior to the final desired state, of any external or internal surface of the two-layer composite lens 100, or any portion thereof, can be shaped by one or
15 more molds. The shaping of any external or internal surface of the two-layer composite lens 100, or any portion thereof, can be the result of a lens blank fabrication process. Any and all known lens blank fabrication processes can be used to shape any external or internal surface of the two-layer composite lens 100, or any portion thereof, to a final desired state or a state prior to a final desired state.

- 20 Any internal surface, or portion thereof, of the two-layer composite lens 100 can be shaped to a final desired state prior to positioning the first layer 102 and the second layer 104 as shown in FIG. 1. The final desired state of any internal or external surface of the two-layer composite lens 100, or any portion thereof, can be shaped by the result of one or more processes appreciated by one skilled in the pertinent art(s) including, but not limited to,
25 stamping, thermoforming, molding, injection molding, free-forming, diamond turning, machining, and surfacing and polishing.

An upper portion or region 120 of the two-layer composite lens 100 can form a distance vision zone. The distance vision zone 120 can be considered a first vision zone of the two-layer composite lens 100.

- 30 A lower portion 118 of the two-layer composite lens 100 can comprise one or more enhanced optical regions 106. The optical regions 106 can be considered enhanced because they can have curvatures or structures, or can contribute to optical powers, that are different from corresponding portions of the upper region 120 of the two-layer composite lens. The

enhanced optical regions can contribute to the additive power of the two-layer composite lens 100 provided in the lower region 118.

As shown in FIG. 1, the upper region 120 is positioned relative to the lower region 118. The upper portion 120 can be a portion of the two-layer composite lens 100 positioned approximately above a fitting point or a geometric center of the two-layer composite lens 100. The lower portion 118 can be a portion of the two-layer composite lens 100 positioned approximately below a fitting point or a geometric center of the two-layer composite lens 100.

As shown in FIG. 1, the two-layer composite lens 100 can comprise a first enhanced optical region 106-1, a second enhanced optical region 106-2 and a third enhanced optical region 106-3. The first enhanced optical region 106-1 can be positioned on an external surface 122 of the first layer 102 (e.g., a first external surface 122 of the two-layer composite lens 100).

The second enhanced optical region 106-2 can be positioned on a surface 140 of the first layer 102 (e.g., on a back surface 140 of the first layer 102). The surface 140 can be an internal surface or an unexposed surface 140 of the first layer 102. Alternatively, the second enhanced optical region 106-2 can be positioned on a surface 124 of the second layer 104 (e.g., on a front surface 124 of the second layer 104). The surface 124 can be an internal surface or an unexposed surface 124 of the second layer 104.

As shown in FIG. 1, the surface 140 of the first layer 102 and the surface 124 of the second layer 104 can form a boundary separating the first layer 102 and the second layer 104. The two-layer composite lens 100 can be fabricated such that the surface 140 substantially overlaps or covers the surface 124 of the second layer 104, or any portion thereof. That is, the surfaces 140 and 124 can substantially complement one another such that no gap, void or space exists between the first layer 102 and the second layer 104.

The third enhanced optical region 106-3 can be positioned on an external finished surface of the second layer 104 (i.e., a second external surface 126 of the two-layer composite lens 100) when a curvature of the external surface is being finished. For purposes of illustration and clarity only, the first layer 102 and the second layer 104 are depicted as being of the same size or dimension but are not so limited. That is, the first layer 102 and the second layer 104 can each be of any size, height, width, thickness, shape and geometry. Further, the first layer 102 and the second layer 104 are not limited to extending across the entire vertical or horizontal dimensions of the two-layer composite lens 100. Any surface of either the first

layer 102 or the second layer 104 can be free-formed in accordance with any desired features as will be appreciated by one skilled in the pertinent art(s).

The enhanced optical regions 106 are each depicted as having approximately the same vertical dimensions, lengths or sizes for purposes of illustration and clarity only and are not so limited. That is, the enhanced optical regions 106-1, 106-2 and 106-3 can each be of any height or size. Additionally, the enhanced optical regions 106 are depicted as being approximately horizontally aligned for purposes of illustration and clarity only and are not so limited. That is, the enhanced optical regions 106-1, 106-2 and 106-3 can be positioned along any respective vertical portion of the two-layer composite lens 100. More specifically, the enhanced optical region 106-1 can be vertically positioned along any portion of the first external surface 122; the enhanced optical region 106-2 can be vertically positioned along any portion of the internal surface 140 or the internal surface 124; and the enhanced optical region 106-3 can be vertically positioned along any portion of the second external surface 126. Overall, any enhanced optical region 106 can be of any vertical dimension (or any horizontal dimension though not depicted in FIG. 1). Further, none of the enhanced optical regions 106 are limited to being positioned in the lower portion 118 of the two-layer composite lens 100.

The enhanced optical regions 106 can be aligned such that light passing through more than one of the enhanced optical regions 106 can experience a combined optical power equal to the sum of the optical powers contributed by each individual enhanced optical region 106 through which the light passes. When any two of the enhanced optical regions 106, or any portions thereof, are so aligned, they can be considered to be in optical communication with one another.

The enhanced optical regions 106 can be aligned to form multiple vision zones 116-1 through 116-N. Vision zone 116-N can be a near vision zone and can provide a total near add power of the two-layer composite lens 100. Each of the other vision zones 116 can provide a portion of the total near add power of the two-layer composite lens 100.

An enhanced optical region 106 can contribute to a constant, substantially constant, or variable optical power or any combination thereof, including plano or zero optical power and negative optical power. An optical discontinuity can occur at a boundary, or any portion thereof, of an enhanced optical region 106. An optical discontinuity can occur within an enhanced optical region 106.

An optical discontinuity can be considered to be a change in optical power that causes most individuals to perceive an image break when the change in optical power is traversed by an individual's line of sight. The change in optical power can occur at a boundary between two optical regions of different optical power. In many instances (but not all), a change in optical power (e.g., a step up in optical power or a step down in optical power) of approximately 0.12 diopters (D) or greater can cause most individual to perceive an image break that can be considered to be caused by an optical discontinuity.

An enhanced optical region 106 can comprise a refractive structure, a diffractive structure, a variable power structure, or a progressive structure (e.g., a progressive refractive structure) or any combination thereof. Any enhanced optical region 106 can be blended at its boundary, or any portion thereof, or within any portion of the enhanced optical region 106. As a refractive structure, an enhanced optical region 106 can comprise a refractive curve that is spherical, substantially spherical, aspheric, or any combination thereof. As a progressive structure, an enhanced optical region 106 can comprise a progressive structure that is cropped. Further, as will be appreciated by one skilled in the pertinent art(s), an enhanced optical region 106 as a progressive structure can comprise a region of continuously varying optical power ranging from a first optical power (e.g., a minimum optical power), typically in an upper portion of the progressive structure, to a second optical power (e.g., a maximum optical power), typically in a lower portion of the progressive structure. A progressive structure can be of a hard or soft design as will be appreciated by one skilled in the pertinent art(s).

As a progressive structure, an enhanced optical region 106 can be considered to begin or start when the optical power contributed by the progressive structure is increased above the optical power contributed by an adjacent region or vision zone (e.g., the distance vision zone) of the two-layer composite lens 100. Typically, this increase is a positive optical power of approximately +0.01 D or greater. The difference in optical power between a start of the progressive structure and the adjacent region or vision zone of the two-layer composite lens 100 can be formed by a mostly continuous increase in positive optical power (e.g., a slow ramp up in optical power).

Alternatively, the difference in optical power between a start of the progressive structure and the adjacent region or vision zone of the two-layer composite lens 100 can be caused by a step up in optical power which is either part of the progressive optical power region or part of a different optical power region. Such a step-up in optical power can form an optical discontinuity as previously described. Additionally, as will be appreciated by one skilled in

the pertinent art(s), the optical power of the progressive structure can decrease after reaching its maximum optical power (e.g., prior to reaching the end or bottom of the progressive structure). In general, an enhanced optical region 106 as a progressive structure can be of any size or shape and can contribute to any substantially continuous change in optical power and therefore any optical power profile.

As previously mentioned, an optical discontinuity in a lens may result in a perceived image break when traversed by the line of sight of a wearer of the lens. Further, such an optical discontinuity may be visible to a person viewing the lens when the lens is being worn by a wearer. An example of a lens exhibiting this characteristic can be a traditional lined bifocal. In a traditional lined bifocal, a boundary separates a distance viewing zone and a near vision zone. This boundary is generally visible because of the large difference in the index of refraction between the material comprising the lens and the air surrounding or on top of the lens. This phenomenon can occur or can be found in many non-blended multifocal lenses that comprise one or more optical discontinuities.

An aspect of the present invention, in contrast to prior art lenses that contain multiple visible optical discontinuities, can reduce or remove the visibility of such an optical discontinuity as perceived by an observer of the lens. The visibility of an optical discontinuity can be reduced or removed entirely by positioning the optical discontinuity on a layer of material that is then covered by another layer of material having a similar index of refraction. Because the optical discontinuity is positioned behind another layer of material, and because the difference between the refractive indices of the two layers is less than the difference between the refractive indices of the layer containing the optical discontinuity and air, the visibility of the optical discontinuity can be reduced.

As an example, an optical discontinuity can be positioned on the front surface of the second layer 104 – e.g., by the boundary of the enhanced optical region 106-2. Because the first layer 102 has an index of refraction that is closer to the index of refraction of the second layer 104 as compared to air, the visibility of any optical discontinuity introduced by the enhanced optical region 106-2 can be removed or reduced as compared to a lens not having a first layer 102. As such, an aspect of the present invention enables the two-layer composite lens 100 to provide many of the benefits of a lined bifocal or multifocal (e.g., multiple distinct vision zones 116) while improving the cosmetics or aesthetics of the two-layer composite lens 100 as compared to prior art lens systems.

A further aspect of the present invention includes the design of the shape and profile of an optical element that contributes to the total add power of lens such that the visibility of any discontinuity associated with the optical element is substantially reduced.

Further, it should be noted that any layer of the two-layer composite lens 100 can comprise
5 one or more polarized layer or layers. Additionally, any layer of the two-layer composite lens 100 can be photochromic. For example, the first layer 102 can be photochromic. As another example, the second layer 104 can be photochromic and the first layer 102 can be formed to block or filter out as little Ultraviolet (UV) light as possible.

FIG. 2 illustrates a front view of the two-layer composite lens 100 according to an aspect of
10 the present invention. The front view of the two-layer composite lens 100 is a view directed at the front layer 102 of the two-layer composite lens 100. For purposes of illustration and clarity only, the enhanced optical region 106-1 is depicted as a first progressive surface, the enhanced optical region 106-2 is depicted as a round substantially spherical surface, and the enhanced optical region 106-3 is depicted as a second progressive surface. Accordingly, the
15 enhanced optical region 106-2 can be a spherical surface, an aspheric surface or any combination thereof.

As shown in FIG. 2, the enhanced optical regions 106 can be positioned below a fitting point
128 of the two-layer composite lens 100 but are not so limited. That is, as previously described, the enhanced optical regions 106 can be positioned anywhere in the upper region
20 120 or the lower region 118 of the two-layer composite lens 100. Further, the fitting point 128 is shown as being positioned in the geometric center of the two-layer composite lens 100 for purposes of illustration and clarity only. In general, the fitting point 128 of the two-layer composite lens 100 can be positioned at any point relative to the geometric center of the two-layer composite lens 100. For example, the fitting point can represent the approximate
25 location of a wearer's pupil when looking straight ahead through a lens once the lens is mounted in an eyeglass frame and positioned on the wearer's face. As further shown in FIG. 2, the enhanced optical regions 106 can be positioned to be horizontally centered with respect to the fitting point 128 (and with respect to each other) but are not so limited.

As progressive surfaces, the enhanced optical regions 106-1 and 106-3 can contribute to
30 variable optical powers that each range from a first value (e.g., a minimum value) to a second value (e.g., a maximum value) with respect to a top and bottom of the respective enhanced optical regions 106-1 and 106-3. When combined with the constant optical power contributed by the enhanced optical power region 106-2, the enhanced optical regions 106

can form the vision zones 116-1 through 116-N. As previously described, the visibility of any optical discontinuity that may be formed at the boundary of the enhanced optical region 106-2 can be reduced or removed by positioning of the first layer 102 over the second layer 104.

5 As depicted in FIG. 2, the enhanced optical regions 106-1 and 106-3 are positioned within a boundary of the enhanced optical region 106-2 but are not so limited. That is, the enhanced optical regions 106 can be positioned such that the enhanced optical regions 106 fully or partially overlap one another as may be desired to form the vision zones 116. Further, the enhanced optical regions 106 can be of any shape. For example, the enhanced optical regions
10 106 – e.g., as refractive segments – can be curved, elliptical, round, oval or can be of a flat-top design.

As used herein, refractive segments are not limited to fused, glued, adhered, or joined optical elements. Further, as used herein, refractive segments are not limited to optical elements that must extend across the entire surface of a lens. Instead, refractive segments as contemplated
15 by the present invention include regions having an enhanced or different (e.g., additive) optical power relative to an adjacent region. Accordingly, a refractive segment can be considered to be a portion of a lens surface having a curvature that is different from a remaining portion of the lens surface having a second, different curvature. Therefore, a refractive segment can comprise an additive power of a lens.

20 As shown in FIGs. 1 and 2, an aspect of the present invention enables multiple optical elements of the two-layer composite lens 100 to contribute to the total optical power provided by each vision zone 116. Further, an enhanced optical region 106, as a progressive structure, can enable the vision zones 116 to provide variable optical powers while minimizing the number of optical discontinuities introduced. Separating the total power required for a
25 particular vision zone across two or more optical elements, with at least one optical element comprising a progressive structure, the two-layer composite lens 100 can still provide the same optical powers zones 116 with same desired optical powers as a prior art single layer progressive lens. However, the two-layer composite lens 100 can provide this substantially identical performance with less distortion than a traditional single layer progressive lens.

30 Specifically, the distortion introduced by a progressive structure can exceed the maximum optical power contributed by the progressive structure for high optical power values. For example, a progressive structure providing a maximum add power of 1.00 D may introduce only 1.00 D of unwanted astigmatism; however, a progressive structure providing a

maximum add power of 2.00 D may introduce 2.25 D of unwanted astigmatism and a progressive structure providing a maximum add power of 3.00 D may introduce 3.75 D of unwanted astigmatism. As the maximum add power of a progressive structure is increased, the unwanted astigmatism introduced by the progressive structure can outpace the additive
5 power. Therefore, in accordance with an aspect of the present invention, by reducing the optical power to be contributed by an enhanced optical region as a progressive structure 106, the total distortion introduced in the lens can be reduced. Further, if more than one enhanced optical region 106 is formed as a progressive structure, then the progressive structures can be aligned to cancel out or reduce a portion of the unwanted astigmatism.

10 Accordingly, an aspect of the present invention can provide the same or more vision zones with the same optical powers as a traditional multifocal lens while simultaneously reducing the total introduced distortion and improving the cosmetics of the lens. This improvement can be achieved without blending and with minimizing the number of introduced optical discontinuities.

15 FIG. 3 illustrates a two-layer composite lens 300 according to an aspect of the present invention. The two-layer composite lens 300 can represent a particular implementation of the two-layer composite lens 100. The two-layer composite lens 300 can represent a finished lens, a finished lens blank, a semi-finished lens blank or a non-finished lens blank. More specifically, the two-layer composite lens 300 can be a finished lens (edged and ready to
20 mount in a frame), a finished lens blank (finished on both outer surfaces but not yet edged), a semi-finished lens blank (finished on a first outer surface and not finished on a second outer surface) or a non-finished lens blank (having neither outer surface finished).

The two-layer composite lens 300 can comprise two enhanced optical regions 106-1 and 106-2. The second external surface 126 (or back surface 126) of the two-layer composite lens 300
25 can be shaped to a final desired state. For example, the surface 126 can comprise a refractive surface having a substantially constant radius of curvature in both the upper region 120 and the lower region 118. The surface 126 can also comprise a toric surface. The surface 126 can also be shaped to include a progressive surface or structure in addition to a spherical, aspherical or toric surface. In general, the back surface 126 can be shaped in accordance with
30 a particular distance correction prescription.

The first external surface 122 (or front surface 122) in the upper region 120 can be shaped to a final desired state. For example, the surface 122 can comprise a refractive curve having a substantially constant radius of curvature. The internal surfaces 140 and 124 in the upper

region 120 can also comprise a refractive curve having a substantially constant radius of curvature. The front surface 122 and the internal surfaces 140 and 124 can be substantially parallel such that the radius of curvature of the surfaces 140 and 124 match, parallel or follow the radius of curvature of the surface 122.

5 The curvature of the back surface 126 can contribute to the distance power of the two-layer composite lens 300. During a finishing process, the radius of curvature and/or toric surfaces of the back surface 126 (in both the upper region 120 and the lower region 118) can be set to be substantially equal to establish a desired optical power in the upper region 120. Accordingly, the set desired optical power in the upper region 120 can form a far distance
10 vision zone 120 of the two-layer composite lens 300.

The enhanced optical region 106-1 can comprise a progressive addition surface. In particular, the enhanced optical region 106-1 can be a refractive progressive optical power structure. As such, the enhanced optical region 106-1 can contribute to a first progressive optical power ramp (i.e., change in optical power) between a start or top 130 of the enhanced
15 optical region 106-1 and a first boundary 134 of the enhanced optical region 106-1. The enhanced optical region 106-1 can contribute to a second progressive optical power ramp between the first boundary 134 and a second boundary 136 of the enhanced optical region. The enhanced optical region 106-1 can contribute to a constant optical power between the second boundary 136 and a bottom or end 132 of the enhanced optical region 106-1.

20 The first progressive optical power ramp contributed by the enhanced optical region 106-1 can contribute to the total optical power provided within the vision zone 116-1. The second progressive optical power ramp contributed by the enhanced optical region 106-1 can contribute to the total optical power provided within the vision zone 116-2. The constant optical power contributed by the enhanced optical region 106-1 can contribute to the total
25 optical power provided within the vision zone 116-3. The optical power contributed by the enhanced optical region 106-1 between the boundaries 130 and 136 can be a continuously increasing optical power that reaches a maximum at or near the boundary 136.

The enhanced optical region 106-2 can comprise a refractive surface having a substantially constant radius of curvature. Alternatively, the enhanced optical region 106-2 can comprise a
30 refractive surface having a changing radius of curvature as found in an aspheric lens. The enhanced optical region 106-2 can be of any shape including, but not limited to, round, oval, elliptical or rectangular and can comprise a refractive surface that is spherical, substantially spherical, aspheric, or any combination thereof. The enhanced optical region 106-2 can

contribute to an optical power that is substantially constant. The enhanced optical region 106-2 can be located on the interior surface 124 of the second layer 104 or the interior surface 140 of the first layer 102. Therefore, the interior surface 124 (and/or the interior surface 140) can comprise regions of at least two different curvatures – a first curvature in the upper portion
 5 120 and a second curvature in the lower region 118 that forms the enhanced optical region 106-2.

The first curvature of the surface 124 of the second layer 104 can contribute to a first optical power (in the upper region 120) and the second curvature of the surface 124 can contribute to a second optical power (in the lower region 118). The second optical power can be considered
 10 to be an additive optical power with respect to the first optical power. The difference in the radii of curvatures between the first curvature and the second curvature can form an optical discontinuity. That is, a boundary, or any portion thereof, between the first curvature of the interior surface 124 and the second curvature of the enhanced optical element 106-2 can form an optical discontinuity. The surface 124 and the enhanced optical region 106-2 can be
 15 formed by way of any known manufacturing process including, but not limited to, casting, stamping, thermoforming, molding, free-forming, diamond turning, and machining.

The optical power of a refractive surface having a substantially constant radius of curvature can be determined using the lens maker's formula:

$$P = \frac{n_x - n_y}{r} \quad (1)$$

20 where n_x represent the index of refraction of a material X immediately after the refractive surface with respect to the direction of light, n_y represents the index of refraction of a material Y immediately prior to the refractive surface, and r represents the radius of curvature of the refractive surface between materials X and Y. Generally, for a radius of curvature expressed in units of meters (m), optical power is expressed in units of diopters (m^{-1} or D). For the
 25 enhanced optical region 106-2, the optical power it contributes to is given by:

$$P = \frac{n_2 - n_1}{r_{124}} \quad (2)$$

where r_{124} represents the radius of curvature of the surface 124. Accordingly, it can be seen from equation (4) that as the difference in the refractive indices between the first layer 102 and the second layer 104 increases, optical power increases for a given radius of curvature.
 30 Further, the difference between refractive indices between the first layer 102 and the second layer 104 can be any value such as, but not limited to, at least 0.01.

The two-layer composite lens 300 can be designed such that the first layer 102 and the second layer 104 are each either positive or negative lenses and/or provide positive or negative add powers. For some implementations of the two-layer composite lens 300, the materials selected for the first layer 102 and the second layer 104 can be such that $n_2 > n_1$. Under such a scenario, a spherical segment positioned on the second layer 104 can protrude outward, thereby increasing the thickness of the second layer 104. For other implementations of the two-layer composite lens 300, the materials selected from the first layer 102 and the second layer 104 can be such that $n_1 > n_2$. Under such a scenario, a spherical segment positioned on the second layer 104 can protrude inward, thereby decreasing the thickness of the second layer 104.

The enhanced optical region 106-2, as a substantially spherical segment, can contribute a constant optical power that is additive with respect to the upper region 120 of the two-layer composite lens 300. The substantially spherical segment 106-2 can comprise an aspheric region. For example, the substantially spherical segment 106-2 can comprise an aspheric region in the periphery of the substantially spherical segment 106-2 that can form a boundary or intermediate region surrounding the substantially spherical segment 106-2 or any portion thereof.

The substantially spherical segment can increase the thickness of the second layer 104 beyond an initial thickness contributed by a first curvature of the upper region 120 of the surface 124. Generally, as the width of the spherical segment is increased, the thickness contributed by the spherical segment will increase if the optical power of the spherical segment is to remain substantially the same. Alternatively, as the width of the spherical segment is increased, the thickness contributed by the spherical segment can be held constant but at the expense of decreasing optical power.

For some implementations of the two-layer composite lens 300, it may be desirable to maintain or increase the optical power contributed by the spherical segment so that the optical power required to be contributed by the enhanced optical region 106-1 can be kept low. Also, for some implementations of the two-layer composite lens 300, it may be desirable to maintain or increase the width of the spherical segment to increase its radius of curvature. By doing so, any optical discontinuity associated with the spherical segment can be pushed out into the peripheral nasal directions such that any optical discontinuity is less noticeable. However, the desire to increase the optical power and width of the spherical segment should

be balanced against any increase in thickness contributed by the spherical segment as any such increase may increase the overall thickness of the two-layer composite lens 300.

Reducing the thickness of the two-layer composite lens 300 may be important for modifying the two-layer composite lens 300 to fit a particular eyeglass frame and/or to improve the cosmetics or aesthetics of the two-layer composite lens 300. As shown by equation (1), increasing the difference in the refractive index of the first layer 102 and the refractive index of the second layer 104 can increase the optical power contributed by the spherical segment 106-2. By increasing this difference in refractive index, the optical power contributed by the spherical segment 106-2 can be increased while maintaining the thickness contributed by the spherical segment 106-2. Overall, the refractive indices of the first layer 102 and the second layer 104, the width of the spherical segment 106-2, and the radius of curvature of the refractive curve can be varied to meet a variety of design constraints.

The enhanced optical region 106-2 can be considered to be a “buried segment” of the two-layer composite lens 300. That is, the front surface of the enhanced optical region 106-2 can be completely covered by another layer of material – specifically, the first layer of material 102. As a result, as previously discussed, the visibility of any optical discontinuity typically manifested as a lined discontinuity and introduced by a boundary of the enhanced optical region 106-2, can be greatly reduced, minimized or removed.

Further, as described above, the enhanced optical region 106-2 as a buried segment can contribute to one or more optical powers. As an example, the buried segment 106-2 can comprise one or more optical discontinuities (e.g., a lined multifocal design) separating or defining boundaries between different optical power zones. The visibility of any discontinuities positioned within the boundary of the buried segment 106-2 – as seen by an observer looking at a wearer of the two-layer composite lens 300 – can be reduced as a result of an aspect of the present invention as previously described. In a particular implementation, the buried segment 106-2 can have a round shape which can provide a significant reduction in the visibility of the buried segment 106-2 and a significant improvement in the overall aesthetics of the two-layer composite lens 300.

As shown in FIG. 3, the variable optical power contributed by the enhanced optical region 106-1 in conjunction with the constant optical power contributed by the enhanced optical region 106-2 can contribute to the formation of the three vision zones 116-1, 116-2 and 116-3 in the lower region 118 of the two-layer composite lens 300. The vertical sizes of the vision zones 116-1, 116-2 and 116-3 can be of any size such that any vision zone 116 can be of the

same size or of a different size with respect to any other vision zone 116. The optical powers of the vision zones 116 can be adapted or customized for a particular wearer or application (e.g., for use as an occupational lens or computer lens). Further, the optical powers of the vision zones 116 can be any value and can be adjusted by adjusting the values of the optical powers contributed by the respective portions of the enhanced optical regions 106-1 and 106-2.

The first vision zone of the overall two-layer composite lens 300 can be the distance zone 120. The distance zone 120 can allow a wearer of the two-layer composite lens 300 to see an object clearly that is approximately 5 feet to approximately 20 feet or more from the wearer's eyes. The vision zones 116-1, 116-2 and 116-3 can comprise second, third and fourth vision zones, respectively, of the overall two-layer composite lens 300. The vision zones 116-1, 116-2 and 116-3 can be considered to be first, second and third vision zones within the lower region 118 of the two-layer composite lens 300 and may be referred to as such in the discussion herein for purposes of clarity only.

The vision zone 116-1 can be considered to be a far intermediate vision zone. Such a far intermediate vision zone 116-1 can provide, for example, a vision correction for viewing objects that are in range of approximately twenty-nine inches to approximately four feet to five feet from the eye of the wearer. As a further example, the far intermediate vision zone 116-1 can provide a vision correction for viewing objects that are in range of approximately twenty-nine inches to approximately ten feet from the eye of the wearer.

The third vision zone 116-2 can be considered to be an intermediate vision zone. Such an intermediate vision zone 116-2 can provide, for example, a vision correction for viewing objects that are in a range approximately twenty-nine inches to approximately eighteen inches from the eye of the wearer.

The vision zone 116-3 can be considered to be a near vision zone. Such a near vision zone 116-3 can provide, as an example, a vision correction for viewing objects that are in a range approximately eighteen inches to approximately ten inches from the eye of the wearer.

Overall, in combination with the distance vision zone 120, the two-layer composite lens 300 can provide four vision zones. One or more of the four vision zones can be stable in a horizontal and/or in a vertical direction. A stable vision zone can be any region having optical power that varies no more than 0.20 D per millimeter (mm) – for example, no more than 0.10 D/mm or nor more than 0.05 D/mm – across the region in a particular direction. Stable vision zones can also include regions having somewhat varying optical power across

the region in particular direction but without introducing an optical discontinuity, swim or other distortion perceptible to a wearer. The sizes of the stable vision zones in both the vertical and horizontal directions can be designed to be of any shape and size.

In a particular implementation, the distance vision zone 120, the far-intermediate vision zone 5 116-1 and the near vision zone 116-3 can each be stable zones – either horizontally stable, vertically stable, or both – while the – intermediate vision zone 116-2 can be designed to not meet the aforementioned requirements of a stable zone. Further, according to an aspect of the present invention, based on the placement of an optical discontinuity associated with the enhanced optical region 106-2, the far-intermediate vision zone 116-1 can be perceived by a 10 wearer of the lens as being continuous with the intermediate zone 116-2 and discontinuous with the far distance zone 120. Alternatively, the far-intermediate vision zone 116-1 can be perceived by a wearer of the lens as being discontinuous with the intermediate zone 116-2 and discontinuous with the far distance zone 120.

The two-layer composite lens 300 can provide these four vision zones, in a particular 15 implementation, with as few as one optical discontinuity. As discussed above, the visibility of this single optical discontinuity, as observed by an individual looking at a wearer of the two-layer composite lens 300, can be significantly reduced or removed. Further, the enhanced optical region 106-1 as a refractive progressive optical power structure can be positioned or shaped to push any unwanted astigmatism (or at least an area of high unwanted 20 astigmatism) off to the periphery of the two-layer composite lens 300.

Based on the positioning of the refractive progressive optical power structure 106-1, a portion of any introduced unwanted astigmatism can be pushed to the bottom or below the distance vision zone 120. Additionally, the enhanced optical region 106-2 can be made wider to 25 further push into the periphery of the wearer's visual field the optical discontinuity as seen by the wearer when looking through the two-layer composite lens 300. By doing so, distortion introduced by the enhanced optical region 106-1 can be located off to the sides of a wearer's typical line of vision such that the distortion is less disturbing or noticeable to a wearer.

Each vision zone 116-1, 116-2 and 116-3 provides an additive power with respect to the optical power provided by the distance vision zone 120. The additive power of any vision 30 zone 116 is determined by the summation of the individual additive powers contributed by the corresponding portions of the enhanced optical regions 106-1 and 106-2. Specifically, the additive optical power provided by the vision zone 116-1 is determined by the optical power contributed by the refractive progressive optical power structure 106-1 in combination with

the optical power contributed by the substantially spherical segment 106-2 within the boundaries 130 and 134 (the additive optical powers of the first layer 102 and the second layer 104 between the boundaries 130 and 134); the additive optical power provided by the vision zone 116-2 is determined by the optical power contributed by the refractive progressive optical power structure 106-1 in combination with the optical power contributed by the substantially spherical segment 106-2 within the boundaries 134 and 136 (the additive optical powers of the first layer 102 and the second layer 104 between the boundaries 134 and 136); and the additive optical power provided by the vision zone 116-3 is determined by the optical power contributed by the refractive progressive optical power structure 106-1 in combination with the optical power contributed by the substantially spherical segment 106-2 within the boundaries 136 and 132 (the additive optical powers of the first layer 102 and the second layer 104 between the boundaries 136 and 132).

According to this partitioning of the additive powers of the two-layer lens 300 between separate additive optical powers contributed by the first layer 102 and the second layer 104, the optical powers contributed by the enhanced optical regions 106-1 and 106-2 provide the total or full near add power of the two-layer composite lens 300. In essence, the total near add power of the two-layer composite lens 300 is provided by a first component – the enhanced optical region 106-1 as a refractive progressive optical power structure – and a second component – the enhanced optical region 106-2 as a substantially spherical constant refractive optical power structure. Therefore, the optical power contribution of the enhanced optical region 106-1 can be considered to be a first incremental add power and the optical power contribution of the enhanced optical region 106-2 can be considered to be a second incremental add power. Therefore, in general, the enhanced optical region 106-1 can be considered to be a first incremental add power region (or zone) and the enhanced optical region 106-2 can be considered a second incremental add power region (or zone). Any additional enhanced optical regions can provide additional portions of the total add power of a lens of the present invention.

Together, the first and second incremental add powers provide the full or total add power of the lens desired for near distance vision as found in optical region 116-3. Since the enhanced optical region 106-1 contributes to an increasing progression of optical power between boundaries 130 and 136, the region between the boundaries 130 and 134 can provide an optical power that is a portion of the first incremental add power contributed by the enhanced optical region 106-1 in a region between the boundaries 136 and 132. Likewise, the region

between boundaries 134 and 136 can provide an optical power that is a portion of the first incremental add power contributed by the enhanced optical region 106-1 in a region between the boundaries 136 and 132.

The contribution of the first incremental add power – and likewise the contribution of the second incremental add power – can be any fractional split of the total add power of the two-layer composite lens 300 provided in the near vision zone 116-3. As an example, the first incremental add power can be two-thirds or approximately 67% of the total add power of the two-layer composite lens 300. Under this scenario, the second incremental add power can provide the remainder or balance of the total add power or one-third or approximately 33% of the total add power of the two-layer composite lens 300.

In general, the first and second incremental add powers can take on any values such that together they sum to a total desired add power for a particular wearer. That is, the first incremental add power (or maximum optical power contributed by the enhanced optical region 106-1) can be any fraction or percentage of the total desired add power. Consequently, the second incremental add power (or the optical power contributed by the enhanced optical region 106-2) can be any complementing fraction or percentage of the total desired add power given the value of the first incremental add power. As an example, the enhanced optical region 106-1 can contribute to a first incremental add power that is 20%-80% of a total desired add power.

The optical powers provided in the far-intermediate vision zone 116-1 and the intermediate vision zone 116-2 can be any respective percentages of the total near add power provided by the near vision zone 116-3. For example, the far-intermediate vision zone 116-1 can provide an optical power that is approximately 20% to 44% of the total add power of the two-layer composite lens 300. Also as an example, the intermediate vision zone 116-2 can provide an optical power that is approximately 45% to 55% of the total add power of the two-layer composite lens 300.

In general, the portions of the enhanced optical regions 106-1 and 106-2 of the far-intermediate vision zone 116-1 and the portions of the enhanced optical regions 106-1 and 106-2 of the intermediate vision zone 116-2 and the portions of the enhanced optical regions 106-1 and 106-2 of the near vision zone 116-3 can contribute to optical powers that are any percentage or fraction of the total near add power of the two-layer composite lens 300. Further, the range of optical powers contributed by the enhanced optical region 106-1 (e.g., the power profile of the enhanced optical region 106-1) can be varied in accordance with any

desired optical power to be provided by the far-intermediate vision zone 116-1 and the intermediate vision zone 116-2.

The two-layer composite lens 300, having the first enhanced optical region as a refractive progressive optical power structure and the second enhanced optical region as a refractive substantially spherical incremental add power segment can be considered to be a refractive-
5 refractive two-layer composite multifocal lens. As described herein, the first and second incremental add power regions can be positioned on different surfaces – i.e., on discontinuous surfaces or surfaces that are discontinuous with respect to one another – yet still provide vision zones that are perceived by a wearer of the lens as continuous.

10 For example, the additive powers provided by the intermediate vision zone 116-2 and the near vision zone 116-3 of the two-layer composite lens 300 are provided by the first and second incremental add power regions 106-1 and 106-2. The first and second incremental add power regions 106-1 and 106-2 are located on separate surfaces of the two-layer composite lens 300. Therefore, the first and second incremental add power regions 106-1 and
15 106-2 are discontinuous with respect to one another. However, to a wearer of the two-layer composite lens 300, the intermediate vision zone 116-2 and the near vision zone 116-3 appear to be continuous.

As previously described, an aspect of the present invention enables the two-layer composite lens 300 to provide at least three stable vision zones with only one optical discontinuity (with
20 at least two stable vision zones located below the fitting point 128 and a third stable vision zone above the only one optical discontinuity – e.g., the distance zone 120). Further, an aspect of the present invention enables the two-layer composite lens 300 to introduce less distortion than a traditional multifocal lens or progressive addition lens having the same total near add power. More specifically, providing substantially the same add power in a single
25 layer progressive addition lens requires that more distortion (e.g., unwanted astigmatism) be introduced. By spreading a desired add power over multiple optical elements, the two-layer composite lens 300 reduces the distortion contribution from the enhanced optical region 106-1 as a refractive progressive optical power structure while providing a desired number of vision zones 120 and 116 with desired associated optical powers.

30 FIG. 4A illustrates a front view of the two-layer composite lens 300 according to an aspect of the present invention. The front view of the two-layer composite lens 300 is a view directed at the front layer 102 of the two-layer composite lens 300. As shown in FIG. 2, the enhanced optical regions 106-1 and 106-2 are positioned below the fitting point 128 of the two-layer

composite lens 300. The fitting point 128 can be located at a geometric center of the two-layer composite lens 300 but is not so limited (e.g., the fitting point can be a reference point on a lens that represents the approximate location of a wearer's pupil when looking straight ahead through the lens once the lens is mounted in an eyeglass frame and positioned on the
5 wearer's face). Further, the fitting point 128 can be offset to the left or right of the geometric center of the two-layer composite lens 300. The fitting point 128 can also be offset above or below the geometric center of the two-layer composite lens 300. The enhanced optical regions 106-1 and 106-2 can be horizontally aligned with the fitting point 128. The tops of the enhanced optical regions 106-1 and 106-2 can be aligned vertically but are not so limited.
10 Rather, the tops can begin at any distance below the fitting point 128 such as, for example, 4 mm.

The positioning and alignment of the enhanced optical regions 106-1 and 106-2 as depicted in FIG. 4 results in an improved visual experience by a wearer of the two-layer composite lens 300. Specifically, the location of any discontinuity introduced at a top boundary of the
15 enhanced optical region 106-2 will not be too low below the fitting point as to be overly disturbing to a wearer of the two-layer composite lens 300. Specifically, if such a discontinuity were positioned too low below the fitting point, then the discontinuity could greatly interfere with a user's comfort when working on a computer screen since the discontinuity could cut across the computer screen and be seen and be perceived by the
20 wearer as that of an aggravating image break. Further, if the discontinuity is located too close to the fitting point 128 then the discontinuity could be perceived as a disturbing image break in the line of sight of the wearer when the wearer looks straight ahead.

The enhanced optical region 106-2 can be substantially round in shape and can have a diameter 142. The diameter 142 of the enhanced optical region 106-2 can be any value such
25 as, but not limited to, greater than 22 mm (e.g., 25 mm or larger – 28 mm, 30 mm, 35 mm, 40 mm or larger). The enhanced optical region 106-1 can be positioned entirely within the boundary of the enhanced optical region 106-2. Alternatively, any portion of the enhanced optical region 106-1 can overlap any portion of the enhanced optical region 106-2 (i.e., the enhanced optical region 106-1 can begin above or below a top of the enhanced optical region
30 106-2). As such, any portion of the enhanced optical region 106-1 can extend beyond any portion of the boundary of the enhanced optical region 106-2.

FIG. 5 illustrates a close-up view of the alignment and positioning of the enhanced optical regions 106-1 and 106-2 shown in FIG. 4. Specifically, FIG. 5 depicts a possible overlap

between the upper portions of the enhanced optical region 106-1 and the enhanced optical region 106-2. As shown in FIG. 5, the top 130 of the enhanced optical region 106-1 is aligned with the top of the enhanced optical region 106-2. A first distance 502 can correspond to a first change in the optical power provided by the enhanced optical region 5 106-1. Specifically, the first change can be from a beginning optical power value (e.g., zero D) to a first optical power value. A second distance 504 can correspond to a second change in the optical power provided by the enhanced optical region 106-1. Specifically, the second change can be from the first optical power value to a second optical power value. A third distance 506 can correspond to a third change in the optical power provided by the enhanced 10 optical region 106-1. Specifically, the change can be from a second optical power value to a third optical power. Accordingly, as shown in FIG. 5, the enhanced optical region 106-1 can change from a starting optical power at the top 130 of the enhanced optical power region 106-1 to a third optical power value by the end of a third distance 506.

The end of the third distance 506 can correspond to the boundary 134. In this way, the 15 distance between the boundary 130 and the end of the third distance 506 can correspond to the far-intermediate vision zone 116-1.

The length of the first, second and third distances 502, 504 and 506, as well as the corresponding first, second and third optical power values can be adjusted and modified to accommodate any ramp-up in optical power within the enhanced optical region 106-1. For a 20 sharp ramp up in optical power, the distances 502, 504 and 506 can be designed to be short and/or the power changes within each zone can be high. For a slow ramp up in optical power, the distances 502, 504 and 506 can be designed to be extended and/or the power changes within each zone can be low. In general, the distances 502, 504 and 506 and corresponding power change values can be designed to be any value.

25 As an example, each of the distances 502, 504 and 506 can be 1 mm in length and the changes in optical power can be +0.03 D in the first distance 502, +0.03 D in the second distance 504, and +0.04 D in the third distance 506. Under this scenario, the total optical power of the first distance 502 is +0.03 D, the total optical power of the second distance 504 is +0.06 D, and the total optical power of the third distance 506 is +0.1D. This enables the 30 distance between the boundary 130 and the end of the third distance 506 to be a stable vision zone that can form the far-intermediate vision zone 116-1 of the two-layer composite lens 300.

FIG. 6A illustrates a possible optical power profile 602 of the multi-layer composite lens 300. Specifically, FIG. 6A depicts an optical power profile resulting from the alignment shown in FIGs. 3 and 4A between the spherical incremental add power segment 106-2 and the progressive optical power region 106-1. As shown in FIG. 6A, the constant optical power contributed in part by the spherical incremental add power segment 106-2 begins at approximately the boundary 130. The boundary 130 can be positioned below the fitting point 128 of the two-layer composite lens 300. As an example, the boundary 130 can be posited approximately 4 mm below the fitting point 128. The positioning of the spherical incremental add power segment 106-2 at the boundary 130 can introduce a discontinuity at the boundary 130. Overall, the boundary 130 can be positioned between 1 mm and 10 mm below the fitting point 128.

The optical power contributed in part by the spherical incremental add power segment 106-2 (when substantially spherical) can be substantially constant across the vision zones 116-1, 116-2 and 116-3. Further, the optical power contributed in part by the progressive optical power region 106-1 can begin at approximately the boundary 130. Accordingly, between the fitting point 128 and the boundary 130, approximately 0 D of additive optical power can be provided by the two-layer composite lens 300. The distance viewing zone 120 of the two-layer composite lens 300 can therefore extend below the fitting point 128 of the two-layer composite lens 300.

Between the boundary 130 and 134, the progressive optical power region 106-1 can have a slow ramp up of optical power. Specifically, the progressive optical power region 106-1 can increase from approximately 0 D of optical power to approximately 0.1 D of optical power at the boundary 134 in accordance with the power ramp described above in relation to FIG. 5. The distance between the boundary 130 and the boundary 134 can be, for example, approximately 3 mm. In general, the distance between the boundary 130 and the boundary 134 can be between 1 mm to 10 mm.

Between the boundary 134 and 136, the progressive optical power region 106-1 can have a sharper ramp up in optical power. Specifically, the progressive optical power region 106-1 can increase from approximately 0.1 D of optical power at approximately the boundary 134 to its approximately maximum optical power at approximately the boundary 136. As mentioned previously, the maximum optical power contributed by the progressive optical power region 106-1 can be considered to be the first incremental add power of the two-layer composite lens 300. The distance between the boundary 134 and the boundary 136 can be,

for example, approximately 9 mm. In general, the distance between the boundary 134 and the boundary 136 can be between 3 mm and 15 mm. The progressive optical power region 106-1 can contribute to a substantially constant optical power between the boundary 136 and the boundary 132.

5 The distance between the boundary 136 and the boundary 132 can be designed to be any desired distance. Further, the progressive optical power region 106-1 can provide a decrease in optical power at or near the boundary 132 if desired.

As shown in FIG. 6A and as an example only, the optical power contributed in part by the spherical incremental add power segment 106-2 is approximately one-third of the total incremental add power provided by the two-layer composite lens 300. Consequently, the
10 optical power contributed in part by the progressive optical power region 106-1 can be approximately two-thirds of the total incremental add power provided by the two-layer composite lens 300. The profile curve 604 represents the overall optical power profile resulting from the spherical incremental add power segment 106-2 being in optical
15 communication with the progressive optical power region 106-1 as described above in relation to FIG. 4A.

The incremental add powers contributed in part by the spherical incremental add power region 106-2 and the progressive addition optical power region 106-2 can form two stable vision zones – vision zones 116-1 and 116-3 – and one non-stable vision zone 116-2 as
20 described above.

FIG. 4B illustrates an alternative alignment of the spherical incremental add power region 106-2 and the progressive addition optical power region 106-2. Specifically, FIG. 4B depicts the progressive additional optical power region 106-2 starting or beginning approximately 3 mm below a top or start of the spherical incremental add power segment 106-1 which can
25 begin approximately 4 mm below the fitting point 128. This possible alignment of the spherical incremental add power region 106-2 and the progressive additional optical power region 106-2 can also provide two stable vision zones – vision zones 116-1 and 116-3. Vision zone 116-2 can have any height defined by the distance between the boundaries 134 and 136 such as, for example, 9 mm.

30 FIG. 6B illustrates a possible optical power profile 606 of the multi-layer composite lens 300 as depicted in FIG. 4B. As shown, the optical power provided by the vision zone 116-1 is contributed by the spherical incremental add power segment 106-2 alone as the optical power contributed in part by the progressive optical power region 106-1 does not begin until

approximately the boundary 134. The optical power contributed by the progressive optical power region 106-1 can be a sharp ramp up between the boundaries 134 and 136. The optical power contributed by the spherical incremental add power segment 106-2 can form a discontinuity at approximately the boundary 130. The profile curve 608 represents the overall optical power profile resulting from the spherical incremental add power segment 106-2 being in optical communication with the progressive optical power region 106-1 as described above in relation to FIG. 4B.

FIG. 4C illustrates another alternative alignment of the spherical incremental add power region 106-2 and the progressive addition optical power region 106-2. Specifically, FIG. 4C depicts the progressive additional optical power region 106-2 starting or beginning approximately 4 mm below the fitting point 128. The spherical incremental add power segment 106-2 can begin approximately 3 mm below the top or start of the progressive addition optical power region 106-1. This possible alignment of the spherical incremental add power region 106-2 and the progressive additional optical power region 106-2 can also provide two stable vision zones – vision zones 116-1 and 116-3. Vision zone 116-2 can have any height defined by the distance between the boundaries 134 and 136 such as, for example, 9 mm.

FIG. 6C illustrates a possible optical power profile 610 of the multi-layer composite lens 300 as depicted in FIG. 4C. As shown, the optical power provided by the vision zone 116-1 is contributed by the progressive optical power region 106-1 alone as the optical power contributed in part by the spherical incremental add power segment 106-2 does not begin until approximately the boundary 134. The progressive additional optical power region 106-1 can have a small ramp up in optical power (e.g., 0.1 D) between the boundary 130 and the boundary 134 and can have a larger ramp up in optical power between the boundary 134 and the boundary 136. The placement of the spherical incremental add power segment 106-2 at the boundary 134 can introduce a discontinuity at approximately the boundary 134. The profile curve 612 represents the overall optical power profile resulting from the spherical incremental add power segment 106-2 being in optical communication with the progressive optical power region 106-1 as described above in relation to FIG. 4C.

FIG. 6A depicts an example optical power profile with a far-intermediate vision zone 116-1 that can be perceived by a wearer of the lens as being continuous with the intermediate zone 116-2 and discontinuous with the far distance zone 120. Alternatively, FIG. 6C depicts an example optical power profile with a far-intermediate vision zone 116-1 that can be perceived

by a wearer of the lens as being discontinuous with the intermediate zone 116-2 and discontinuous with the far distance zone 120.

FIG. 7 illustrates a front view of the two-layer composite lens 300 according to an aspect of the present invention. In particular, FIG. 7 illustrates a possible orientation and positioning of the enhanced optical regions 106-1 and 106-2 de-centered nasally relative to a geometric center 706 of the two-layer composite lens 300 intended for use as a left eye lens. As show in
5 of the enhanced optical regions 106-1 and 106-2 de-centered nasally relative to a geometric center 706 of the two-layer composite lens 300 intended for use as a left eye lens. As show in FIG. 7, the geometric center 706 of the two layer composite lens 300 is defined by the intersection of a vertical axis of symmetry 702 and a horizontal axis of symmetry 704. The fitting point 128 is located on the horizontal axis of symmetry but is not so limited. The
10 fitting point 128 can be offset from the geometric center 706 of the two-layer composite lens 300. As an example, the fitting point 128 can be offset to the left of the geometric center 706. Further, the fitting point 128 can be offset above or below the geometric center 706.

FIG. 8 illustrates a front view of the two-layer composite lens 300 according to an aspect of the present invention. In particular, FIG. 8 illustrates a possible orientation and positioning of the enhanced optical regions 106-1 and 106-2 de-centered nasally relative to a geometric center 706 of the two-layer composite lens 300 intended for use as a right eye lens. As show
15 in FIG. 8, the geometric center 706 of the two layer composite lens 300 is defined by the intersection of the vertical axis of symmetry 702 and the horizontal axis of symmetry 704. The fitting point 128 is located on the horizontal axis of symmetry but is not so limited. The fitting point 128 can be offset from the geometric center 706 of the two-layer composite lens 300. As an example, the fitting point can be offset to the right of the geometric center 706.

FIGs. 15-18 illustrate possible variations in the orientations of the enhanced optical region 106-1 and the enhanced optical region 106-2 relative to one another and relative to the geometric center 702. Specifically, FIG. 15 depicts an example of a left-eye lens of the present invention with the enhanced optical region 106-1 offset from the geometric center
25 702 and the enhanced optical region 106-2 offset relative to a center of the enhanced optical region 106-1. As an example, the enhanced optical region 106-2 can be offset relative to the center of the enhanced optical region 106-1 by 2.5 mm. FIG. 16 depicts an example of a right-eye lens of the present invention corresponding to the lens depicted in FIG. 15. FIG. 16 shows the enhanced optical region 106-1 offset from the geometric center 702 and the enhanced optical region 106-2 offset relative to a center of the enhanced optical region 106-1.
30 As an example, the enhanced optical region 106-2 can be offset relative to the center of the enhanced optical region 106-1 by 2.5 mm.

FIG. 17 depicts an example of a left-eye lens of the present invention with the enhanced optical region 106-1 centered about the geometric center 702 and the enhanced optical region 106-2 offset relative to a center of the enhanced optical region 106-1. As an example, the enhanced optical region 106-2 can be offset relative to the center of the enhanced optical region 106-1 by 2.5 mm. FIG. 18 depicts an example of a right-eye lens of the present invention corresponding to the lens depicted in FIG. 17. FIG. 18 shows the enhanced optical region 106-1 centered about the geometric center 702 and the enhanced optical region 106-2 offset relative to a center of the enhanced optical region 106-1. As an example, the enhanced optical region 106-2 can be offset relative to the center of the enhanced optical region 106-1 by 2.5 mm. As discussed above, for each of the lenses depicted in FIGs. 7-8 and 15-18, the fitting point 128 of the lens can be positioned anywhere on the lens including above, below or to the left or right of the geometric center 702 with the enhanced optical regions 106-1 and 106-2 positioned below the fitting point 128 as desired.

As will be appreciated by one skilled in the pertinent art(s), variations in form and detail of the two-layer composite lens 100 and the three-layer composite lens 300 can be made without departing from the spirit and scope of the invention. For purposes of clarity, non-limiting variations in several design parameters of the two-layer composite lens 100/300 are given in the following table.

Parameter(s)	Possible Non-Limiting Variation(s)
n ₁ /n ₂ combinations	In general, any combination is possible. Example n ₁ /n ₂ combinations: -1.50/1.60 -1.53/1.60 -1.53/1.67 -1.53/1.71 -1.60/1.71 -1.53/1.74 -1.60/1.74 -1.60/1.67
Types of materials (e.g., for the first layer 102 and/or the second layer 104)	Generally, any first substantially homogeneous material having a first index of refraction that can bond to a second substantially homogenous material having a second index of refraction different from the first index of refraction. Such materials can include, but are not limited to, glass and plastics. Specific optical grade materials that are commercially available are:

Parameter(s)	Possible Non-Limiting Variation(s)
	-PPG CR39 -PPG HiRi -Polycarbonate -PPG Trivex 1.53 and 1.60 -Nouryset 200 -Rav-7 -MR-6 -MR-7 -MR-8 -MR-10 -MR-20 -MR-90 -Brite-5 -Brite-60 -Brite-Super -TS216 -UDEL P-1700 NT-06 -Radel A-300 NT -Radel R-5000 NT -1.7 Mitsui -1.74 MGC -1.74 Mitsui (MR-174) -High-refractive index episulfide resin monomer (HIE) -Polysulfone -Polyimide -Polyetherimide
Width of the second enhanced optical region 106-2 as a substantially spherical or aspherical segment	Generally, any diameter is possible. Example widths: -any diameter from ~20 mm to ~40 mm in ~0.25 mm increments
Thickness of first layer – unfinished (e.g., the first layer 102)	~0.2mm or greater
Thickness of first layer – finished (e.g., the first layer 102)	~0.2 mm to ~1.0 mm or greater
Thickness of second layer – unfinished (e.g., the second layer 104)	~3.0 mm to ~7.0 mm or greater
Thickness of second layer – finished (e.g., the second layer 104)	.2mm to 2mm or greater
Overall thickness of two-layer composite lens – unfinished or semi-finished	Semi-finished: ~4.0 mm to ~8.0 mm or greater Unfinished: ~2.5 mm to ~12 mm
Center thickness of two-layer composite lens – finished, myopic prescription	Minimum range: ~0.5 mm to ~2.0 mm Maximum range: ~1.0 to ~3.0 mm
Optical power of the of the second enhanced optical region 106-2 (e.g., as a substantially spherical or aspherical segment)	Generally, any optical power is possible. Example optical powers: -any optical power from ~+0.12 D to ~+6.0 D

Parameter(s)	Possible Non-Limiting Variation(s)
	in air in +0.12 D increments
Maximum optical power of the first enhanced optical region 106-1 (e.g., as a progressive structure)	<p>Generally, any maximum optical power is possible.</p> <p>Typical optical powers: -any optical power from ~+0.50 D to ~+2.75 D in air in +0.12 D increments</p>
Shape of curve of second enhanced optical region 106-2 as a refractive curve	<p>Generally, any shape is possible.</p> <p>Example shapes: -spherical -substantially spherical -aspheric</p>
Minimum difference in refractive indices between first and second layers (e.g., minimum Δn , where $\Delta n = n_2 - n_1$)	<p>Generally, any non-zero difference is possible. As an example, $\Delta n \geq 0.01$. Preferably greater than or equal to $\sim .05$.</p>
Shape of covered refractive surface (e.g., shape of the second enhanced optical region 106-2 as a refractive surface having substantially constant radius of curvature)	<p>Generally, any shape is possible.</p> <p>Example shapes: -round - oval -substantially round -elliptical -flat-top -curved</p>
Horizontal position of the top of the second enhanced optical region 106-2 relative to fitting point 128	<p>Generally, any positioning is possible.</p> <p>Example positioning: ~2.0mm – ~4.0mm de-centered nasally</p>
Horizontal position of the top of the first enhanced optical region 106-1 relative to fitting point 128.	<p>Generally, any positioning is possible.</p> <p>Example positioning: ~2.0mm – ~4.0mm decentered nasally</p>
Vertical position of the top of the second enhanced optical region 106-2 relative to fitting point 128	<p>Generally, any positioning is possible.</p> <p>Example positioning: Starts ~2.0 mm – ~6.0mm below fitting point 128 Preferred is ~3.0mm to ~5.0mm below</p>
Vertical position of the top of the first enhanced optical region 106-1 relative to fitting point 128.	<p>Generally, any positioning is possible.</p> <p>Example positioning: Starts ~0mm – ~10.0mm below fitting point 128</p>
Power of far-intermediate zone as percentage of total add power	<p>Generally, any optical power is possible.</p> <p>Example optical power ranges:</p>

Parameter(s)	Possible Non-Limiting Variation(s)
	~20% - ~44%
Power of intermediate zone as percentage of total add power	Generally, any optical power is possible. Example optical power ranges: ~45% - ~55%
Power split between 1 st and 2 nd incremental add power contributors	Generally, any power split is possible. Percentage contribution of second enhanced optical power region 106-2 (e.g., as a substantially spherical segment): -20% to 95%, more typically ~20% - ~44% Percentage contribution of first enhanced optical power region 106-1 (e.g., as a progressive structure): -5% to 80%, more typically ~80% - ~56%

- Table I -

FIG. 9 illustrates a side view of a three-layer composite lens 900 according to an aspect of the present invention. The three-layer composite lens 900 comprises the first layer 102, the second layer 104 and a third layer 144. As shown in FIG. 9, the three-layer composite lens 900 comprises elements at least depicted and described in relation to the two-layer composite lens 100 of FIGs. 1 and 2. Accordingly, it is intended that like reference numbers indicate substantially the same components as will be appreciated by one having skill in the pertinent art(s). As such, any previous description of characteristics of any identical elements is intended to be incorporated into the description of features of the three-layer composite lens 900.

The third layer 144 can comprise a third material having a third index of refraction, n_3 . The third material can comprise a material that is different from the first material of the first layer 102 and the second material of the second layer 104. Alternatively, the third material of the third layer 144 can comprise a material that is substantially the same as first material of the first layer 102 or the second material of the second layer 102. Further, the third material can be substantially homogeneous.

The third material can be any material such as, but not limited to, any plastic or glass. Depending upon the selection of the third material, the third index of refraction, n_3 , can be the same as either the first index of refraction, n_1 , or the second index of refraction, n_2 . Alternatively, the third index of refraction can be different from the first index of refraction, n_1 , and the second index of refraction, n_2 .

As shown in FIG. 9, the first layer 102 can form an anterior surface and the third layer 144 can form a posterior surface of the three-layer composite lens 900, such that the third layer 144 is intended to be located closer to a wearer's eye.

The three-layer composite lens 900 can represent a finished lens, a finished lens blank, a semi-finished lens blank or a non-finished lens blank. More specifically, the two-layer composite lens 900 can be a finished lens (edged and ready to mount in a frame), a finished lens blank (finished on both outer surfaces but not yet edged), a semi-finished lens blank (finished on a first outer surface and not finished on a second outer surface) or a non-finished lens blank (having neither outer surface finished). The two-layer composite lens 900 can be subjected to any known lens treatments or coatings prior to forming a final ophthalmic lens as will be appreciated by one skilled in the pertinent art(s).

The three-layer composite lens 900 can comprise four enhanced optical regions 106-1, 106-2, 106-3 and 106-4. The enhanced optical region 106-3 can be positioned on the surface 126 or on a surface 146 of the third layer 144. The enhanced optical region 106-4 can be positioned on a surface 146. The enhanced optical regions 106 can be aligned in any desired manner to be in optical communication with one another to form vision zones 116-1 through 116-N. The three layers 102, 104 and 144 can also form a first distance zone (e.g., a far distance vision zone) 120. Variations in the optical powers contributed by and the positioning and sizing of the enhanced optical regions can be varied as was discussed in relation to the two-layer composited lenses 100 and 300 discussed above and as one skilled in the pertinent art(s) would appreciate.

As will be appreciated by one skilled in the pertinent art(s), the distance power of the three-layer composite lens 900 can be determined by a curvature of the surface 146 and 148. In particular, when the first layer 102 and the second layer 104 are conformal – i.e., the surfaces 122, 140, 124 and 126 have curvatures that are substantially the same as the curvature of the surface 146 in the distance zone 120 – then the back layer 144 can determine the distance power of the three-layer composite lens 900. As will be appreciated by one skilled in the pertinent art(s), this result is applicable to the two-layer composite lens 100 – i.e., when the surfaces 122 and 140 have curvatures that are substantially the same as the curvature of the surface 124 in the distance zone 120 – then the back layer 104 can determine the distance power of the three-layer composite lens 100.

FIG. 10 illustrates a front view of the three-layer composite lens 900 according to an aspect of the present invention. The front view of the three-layer composite lens 900 is a view

directed at the front layer 102 of the three-layer composite lens 900. For purposes of illustration and clarity only, the enhanced optical region 106-1 is depicted as a first progressive surface, the enhanced optical region 106-2 is depicted as a round substantially spherical surface, the enhanced optical region 106-3 is depicted as a second progressive surface and the enhanced optical region 106-4 is depicted as a third progressive surface. As shown, the enhanced optical regions 106 can be positioned to be in optical communication with one another so as to form vision zones 116 in the lower portion 118 of the three-layer composite lens 900.

Overall, the multiple layer multifocal composite lens of the present invention provides numerous advantages over prior art lenses. The multiple layer multifocal composite lens of the present invention can provide multiple stable vision zones. For example, as described in relation to FIG. 4A above, the multiple layer multifocal composite lens of the present invention can provide a total of four distinct vision zones with three of the zones providing stable vision. Further, these vision zones, as an example, can be provided with as few as only one discontinuity. The introduced discontinuity, due to the composite structure of the lens and placement of the spherical add power segment behind a first layer of the lens, can have a reduced visibility when seen by an observer looking at a wearer of the lens.

Any introduced discontinuity can be positioned well below the fitting point of the lens to increase the cosmetic appeal of the lens while not interfering with distance vision gaze. In addition, the positioning of the discontinuity enables a lens of the present invention to be used as an occupational or computer lens. This is generally due to the discontinuity not being positioned neither too high nor too low – e.g., 3-5 mm below the fitting point of the lens – and acceptable for most applications of the lens. In particular, any introduced discontinuity can be positioned no greater than 10 mm below the fitting point (approximately 4 mm below the fitting point as described in relation to FIG. 4A). This positioning enables a buried constant optical add power segment to contribute to the add power of the lens while not being positioned where it would interfere with a wearer's line of sight.

The multiple layer multifocal composite lens of the present invention can also exploit the benefits of a refractive progressive optical power structure while minimizing any unwanted astigmatism introduced by such a structure. As an example, the multiple layer multifocal composite lens of the present invention as described in relation to FIG. 4A, can position a progressive optical power region to begin or start at or near a discontinuity introduced by a buried spherical add power segment. Overall, the start of the progressive structure can begin

at any position greater than 2 mm below the fitting point of the lens. This is contrary to traditional progressive lenses which begin progressive structures within 1 mm of the fitting point. By positioning the progressive structure lower than prior art lenses, the multiple layer multifocal composite lens of the present invention can push any unwanted astigmatism down
5 and into the periphery of the lens and therefore the wearer's field of vision so as to be less disruptive.

Further, the multiple layer multifocal composite lens of the present invention can use a progressive structure that provides a slow ramp up in power to help provide a stable vision zone. A progressive structure used by the multiple layer multifocal composite lens of the present invention, as described in relation to FIG. 4A, can reach an optical power of
10 approximately 0.1D 7 mm or below the fitting point of the lens. This slow ramp of power limits the introduction of unwanted astigmatism and therefore widens the channel of the progressive structure relative to prior art lenses. Lastly, because the progressive structure provides only a portion of the total near add power of the multiple layer multifocal composite
15 lens of the present invention, unwanted astigmatism is reduced as compared to a traditional progressive lens providing the same add power.

As will be appreciated by one skilled in the pertinent art(s), the principles described herein with respect to a multiple-layer lens are applicable to a single layer lens. That is, the present invention includes a single layer lens comprising a first incremental add power region – e.g.,
20 a refractive progressive optical power region – and a second incremental add power region – e.g., a spherical, substantially spherical, aspheric or any combination thereof segment – that are positioned to be in optical communication to obtain the beneficial lens characteristics described herein. As an example, a single layer lens of the present invention can include a substantially spherical segment positioned on a front surface (e.g., an anterior surface) of the
25 lens and a refractive progressive optical power region positioned on a back surface (e.g., a posterior surface) of the lens. The spherical segment can be fabricated by mold while the progressive region can be fabricated by mold or by free-forming.

Combined Progressive and Substantially Constant Power Regions

30 An enhanced optical power region 106 of the present invention can comprise a combined progressive optical power region and a substantially constant optical power region in accordance with an aspect of the present invention. More specifically, an aspect of the present invention enables a progressive optical power region and a substantially constant

optical power region to partially or fully overlap (e.g., be joined) according to any orientation to form a combined optical power region. Such a combined region can form an incremental add power region (e.g., either a first or second incremental add power region) of a lens of the present invention.

5 An enhanced optical power region 106 comprising a combined progressive optical power region and a substantially constant optical power region can be located on any surface of a multi-layer composite lens of the present invention. Further, an enhanced optical power region 106 comprising a combined progressive optical power region and a substantially constant optical power region can be located on an external surface of a single layer or a
10 single material lens as will be understood by one skilled in the pertinent art(s). An enhanced optical power region 106 comprising a combined progressive optical power region and a substantially constant optical power region can form an incremental add power region of a lens of the present invention (e.g., a second incremental add power region).

An enhanced optical power region 106 comprising a combined progressive optical power
15 region and a substantially constant optical power region can be used to provide a clear line of vision between a distance zone and a near vision zone of a lens as perceived by a wearer of the lens. That is, an enhanced optical power region 106 comprising a combined progressive optical power region and a substantially constant optical power region can provide a wearer's line of sight with a smooth transition when moving between a far and near distance zone of a
20 lens of the present invention.

FIG. 20 illustrates an implementation of a surface 2000 of a multi-layer composite lens of the present invention. For purposes of illustration and clarity only, the surface 2000 is depicted as an internal surface (e.g., the surface 124) of a multi-layer composite lens of the present invention. The surface 2000 can comprise an enhanced optical region of the present
25 invention (e.g., the enhanced optical region 106-2). In general, the surface 2000 can be any surface of a multi-layer composite lens or single layer lens of the present invention as will be understood by one skilled in the pertinent art(s).

As shown in FIG. 20, the enhanced optical region 106-2 can comprise a combined substantially constant optical power region 2002 and a progressive optical power region
30 2004. A lower portion of the progressive optical power region 2004 is shown in phantom to depict this lower portion of the progressive optical power region 2004 as being removed or replaced by the overlapping substantially constant optical power region 2002. That is, the enhanced optical region 106-2 comprises an upper portion of a progressive optical power

region 2004 that can provide a continuous change or ramp up in optical power that leads into a substantially constant optical power region 2002. The effect of any optical power provided by the lower portion of the progressive optical power region 2004 is eliminated by introducing the substantially constant optical power region 2002.

5 The substantially constant optical power region 2002 can be any optical structure or region that provides a constant or substantially constant optical power. For example, the substantially constant optical power region 2002 can be a refractive surface having a substantially constant radius of curvature. As such, the substantially constant optical power region 2002 can comprise a refractive curve that is spherical, substantially spherical, 10 aspherical or any combination thereof. The substantially constant optical power region 2002 is depicted as having a curved shape but is not so limited. That is, the substantially constant optical power region 2002 can be of any shape such as, but not limited to, round, curved, elliptical, flat on the top, curved on the top, oval, and square, or any combination thereof. Further, any initial shape of the substantially constant optical power region 2002 can be 15 modified during any finishing or edging process as will be appreciated by one skilled in the pertinent art(s).

The substantially constant optical power region 2002 is depicted as overlapping and replacing a lower portion of the progressive optical power region 2004 but is not so limited. That is, the substantially constant optical power region 2002 can be positioned anywhere on the 20 surface 124 with respect to the progressive optical power region 2004. Accordingly, any or all portions of the substantially constant optical power region 2002 can overlap (either fully or partially) any portion of the progressive optical power region 2004. As shown in FIG. 20, the substantially constant optical power region 2002 replaces the lower portion of the progressive optical power region 2004 such that the lower portion of the progressive optical 25 power region 2004 no longer exists on the surface 2000. More specifically, the lower portion of the enhanced optical region 106-2 has an optical power contributed by the substantially constant optical power region 2002 only.

Any portion of a boundary 2006 (e.g., left and right boundary portions 2006-1 and 2006-2) of the substantially constant optical power region 2002 can comprise an optical discontinuity. 30 An optical discontinuity can result due to a difference in optical power between a distance zone of the surface 2000 and the substantially constant optical power region 2002. For example, an optical discontinuity can be caused by a step-up in optical power from the

distance zone of the surface 2000 to the substantially constant optical power region 2004. Such an optical discontinuity can comprise a slope or sag discontinuity.

The progressive optical power region 2004 can comprise any progressive region as previously described. As shown in FIG. 20, the progressive optical power region 2004 is positioned above the substantially constant optical power region 2004. For purposes of illustration and clarity only, a top of the channel of the progressive optical power region 2004 begins below the fitting point 128 but is not so limited. That is, the progressive optical power region 2004 (and therefore the substantially constant optical power region 2002 and the enhanced optical region 106-2) can be positioned anywhere on the surface 2000 with respect to the fitting point 128. Accordingly, the progressive optical power region 2004 (and therefore the substantially constant optical power region 2002 and the enhanced optical region 106-2) can be aligned with a vertical center of the fitting point 128 as depicted but is not so limited.

As previously described, the lower portion of the progressive optical power region 2004 can be replaced or removed due to the introduction or positioning of the substantially constant optical power region 2002. Accordingly, areas of relatively higher astigmatism, 2008-1 and 2008-2, associated with that of the progressive optical power region 2004 are removed and therefore no longer exist. As an example, prior to introducing the substantially constant optical power region 2002, the enhanced optical region 106-2 can initially comprise the progressive optical power region 2004 only. As such, the progressive optical power region 2004 can be initially associated with a first area of relatively higher astigmatism 2008-1 and a second area of relatively higher astigmatism 2008-1 as compared to associated areas of relatively lower astigmatism 2010-1 and 2010-2 located near a top or start of the progressive optical power region 2004. This can be due to the slope of the progressive optical power region 2004 being less near the top or start of the progressive optical power region 2004 as compared to the middle or bottom of the progressive optical power region 2004. The substantially constant optical power region 2002 can be added in such a manner during fabrication so as to effectively eliminate the first and second areas of relatively higher astigmatism 2008-1 and 2008-2.

Further, during introduction of the substantially constant optical power region 2002, the substantially constant optical power region 2002 can also remove or replace the lower portion or lower channel of the progressive optical power region 2004. Consequently, the initial maximum optical power area of the progressive optical power region 2004 is eliminated. The

progressive optical power region 2004 can therefore be left to comprise the upper region or the top of the channel of the progressive optical power region 2004. The first area of relatively lower astigmatism 2010-1 and the second area of relatively lower astigmatism 2010-2 can remain and can continue to be associated with the remaining progressive optical power region 2004.

The remaining upper portion of the progressive optical power region 2004 can provide progressive optical power ranging from an initial value (e.g., a minimum optical power) to a final value (e.g., a maximum optical power). The final value can be realized at a boundary 2012 distinguishing the progressive optical power region 2004 and the substantially constant optical power region 2002. Depending upon the optical power provided by the progressive optical power region 2004 at the boundary 201 and the optical power provided by the substantially constant optical power region 2002, the boundary 2012 can be designed to comprise an optical discontinuity or to not comprise an optical discontinuity. If the optical power of the progressive optical power region 2004 and the substantially constant optical power region 2002 are of substantially the same value at the boundary 2012, then no optical discontinuity may result. Consequently, the effects of an optical discontinuity are unlikely to be experienced when a wearer's line of sight travels between a far distance zone and a near distance zone of the surface 2000 (i.e., traverses the boundary 2012). However, an optical discontinuity may be introduced or remain at a peripheral boundary 2006-1 and/or 2006-2 of the substantially constant optical power region 2002 under such a scenario.

The enhanced optical region 106-2, as previously described, can be positioned to be in optical communication with any other enhanced optical region 106 of a multi-layer composite lens or single layer lens of the present invention. Accordingly, the enhanced optical region 106-2, as a combined substantially constant optical power region 2002 and a progressive optical power region 2004, can provide a first portion of a total desired add power. The enhanced optical region 106-2 can be designed to provide any optical power value whether located on an internal or external surface of a lens of the present invention.

Additionally, as previously discussed, the enhanced optical region 106-2 can contribute to the formation of multiple vision zones. The vision zones can provided a clear line of sight from an upper region to a lower region of a lens of the present invention if the enhanced optical region 106-2 is designed to not introduce an optical discontinuity at the boundary 2012. When combined with one or more enhanced optical regions 106, the astigmatism regions

2010-1 and 2010-2 can be positioned to overlap or not overlap any portion of any other astigmatism regions that may be associated with another enhanced optical region 106.

FIG. 21A illustrates an optical power profile 2100 of the enhanced optical region 106-2 depicted in FIG. 20. The optical power profile 2100 can be an optical power profile provided
5 by the combined substantially constant optical power region 2002 and progressive optical power region 2004. The optical power profile 2100 can be the optical power provided from a top to a bottom of the enhanced optical region 106-2. As shown in FIG. 21A, a first portion of the optical power profile 2104 can be contributed by the progressive optical power region 2004. The optical power of the progressive optical power region 2004 can progress
10 continuously from a minimum value 2112 (e.g., plano) to a maximum value 2110. The maximum value 2110 need not be the maximum optical power value of the original, pre-modified progressive optical power region 2004. That is, the maximum value 2110 can be a value that is less than an original maximum optical power of the progressive optical power region 2004.

15 As further shown in FIG. 21A, a second portion of the optical power profile 2106 can be contributed by the substantially constant optical power region 2002. The substantially constant optical power region 2002 can provide a substantially constant optical power value 2108. The first portion of the optical power profile 2104 can begin at a top of the progressive optical power region 2004 (e.g., the top of the enhanced optical region 106-2) and can end or
20 terminate at approximately the boundary 2012. Likewise, the second portion of the optical power profile 2106 can begin at approximately the boundary 2012 and can end or terminate at the bottom of the substantially constant optical power region 2002 (e.g., the bottom of the enhanced optical region 106-2).

Depending on the optical power values 2110 and 2108 provided by the progressive optical
25 power region 2004 and the substantially constant optical power region 2002, respectively, an optical discontinuity may or may not be introduced at the boundary 2012. As shown in FIG. 21A, the optical power values 2110 and 2108 can be of different values such that an optical discontinuity may occur at the boundary 2012. That is, a step up in optical power may exist at the boundary 2012 between the first portion of the optical power profile 2104 and the
30 second portion of the optical power profile 2106. In general, the first portion of the optical power profile 2104 and the second portion of the optical power profile 2106 can be of any values or power gradient to provide any desired optical power profile of the enhanced optical

region 106-2 as a combined substantially constant optical power region 2002 and progressive optical power region 2004.

FIG. 21B illustrates an alternative optical power profile 2102 of the enhanced optical region 106-2 depicted in FIG. 20. As shown in FIG. 21B, the maximum optical power value 2110 provided by the progressive optical power region 2004 can be substantially equal to the substantially constant optical power 2108 provided by the substantially constant optical power region 2002. As such, a relatively smooth change in optical power may occur at the boundary 2012 between the first portion of the optical power profile 2104 and the second portion of the optical power profile 2106. Accordingly, the second optical power profile 2102 may not result in the formation of an optical discontinuity at the boundary 2012.

Example Implementation of a Combined Progressive and a Substantially Constant Power Region

The following example implementation of an enhanced optical region 106 as a combined progressive optical power region and substantially constant optical power region are for illustration purposes only are not intended to limit the spirit and scope of this aspect of the present invention as will be appreciated by one skilled in the pertinent art(s).

FIG. 22A illustrates an implementation of a surface 2200 of a multi-layer lens of the present invention that can be optically aligned with the surface 2000 depicted in FIG. 20. As an example, the surface 2200 can be a front external surface (e.g., the surface 122) of a multi-layer composite lens of the present invention. The surface 2200 can include an enhanced optical region (e.g., the enhanced optical region 106-1). As an example, the enhanced optical region 106-1 can comprise a progressive optical power region 2206 having a maximum optical power region 2204. The region can provide, as an example, +1.25 D of optical power. The maximum optical power region 2204 can provide a first portion of a total desired add power.

A top or start 130 of the progressive optical power region 2206 can begin with, for example, plano optical power. The progressive optical power region 2206 can begin, for example, approximately 7 mm below the fitting point 128. The progressive optical power region 2206 can be associated with, for example, approximately 1.00 D of maximum unwanted astigmatism in regions 2202-1 and 2202-2. When in optical communication with the surface 2000 as an example implementation, the progressive optical power region 2004 depicted in FIG. 20 can ramp from a plano optical power to +0.50 D of optical power at the boundary

2012. As such, the progressive optical power region 2004 can be associated with approximately 0.50 D of astigmatism in the regions 2010-1 and 2010-2.

Continuing with an example implementation of the surface 2000 depicted in FIG. 20, the substantially constant optical power region 2002 can be a spherical segment comprising
5 substantially spherical optical power. The spherical segment 2002 can provide, for example, a substantially constant +0.75 D of optical power. Accordingly, an optical discontinuity can result at the boundary 2012 due to a step up in optical power of 0.25 D between the maximum optical power provided by the progressive optical power region 2004 and the substantially constant optical power provided by the spherical segment 2002. The +0.75 D of
10 substantially constant optical power provided by the spherical segment 2002 can provide a second portion of the total desired add power of a final lens.

The spherical segment 2002 of this example implementation can begin, for example, approximately 6 mm below the fitting point 128. The progressive optical power region 2004 therefore ends approximately 6 mm below the fitting point 128. As such, the associated
15 astigmatism regions 2202-1 and 2202-2 of the progressive optical power region 2206 are positioned to not be in optical communication with the associated astigmatism regions 2010-1 and 2010-2, respectively, of the progressive optical power region 2004. Consequently, the distortion introduced by these astigmatism regions will not be fully additive. However, this particular alignment and positioning of the two enhanced regions 106-1 and 106-2 will allow
20 the first portion of the add power contributed by the progressive optical power region 2206 to combine with the second portion of the add power contributed by the spherical segment 2002 to provide the total desired add power.

FIG. 22B illustrates a front view of a multi-layer lens 2208 of the present invention that can comprise the surface 2200 overlaid or aligned on top of the surface 2000. The combined
25 alignment of the enhanced optical regions 106-1 and 106-2 are shown. The enhanced optical region 106-1 can be considered to be a first incremental add power region and can provide approximately +1.25 D of additive optical power. The enhanced region 106-2 can be considered to be a second incremental add power region and can provide approximately +0.75 D of additive optical power. Further, the enhanced optical regions 106-1 and 106-2
30 can be aligned such that +0.50 D of optical power is provided prior to an optical discontinuity at the boundary 2012. Below the boundary 2012, +0.75 D of optical power is provided to approximately a top 130 of the progressive optical power region 2206. Approximately 0.5 D of astigmatism is associated with the regions 2010-1 and 2010-2. The combined additive

power of the enhanced optical regions 106-1 and 106-2 can be +2.00 D. This maximum additive power can be provided with reduced maximum astigmatism in accordance with an aspect of the present invention. Specifically, the combined progressive optical power region 2004 and substantially constant optical power region 2002 limits the maximum astigmatism to approximately 1.00 D of astigmatism in the regions 2202-1 and 2202-2. For this example, the maximum unwanted astigmatism (1.00 D) is one-half of the maximum astigmatism associated with a traditional progressive lens that provides the same amount of total desired add power (+2.00 D).

FIG. 22C illustrates a side view of the multi-layer lens 2208 depicted in FIG. 22B. The multi-layer lens 2208 is depicted as a two-layer lens for purposes of illustration and clarity only and is not so limited. As shown in FIG. 22C, the enhanced optical region 106-1, as a progressive optical power region 2206, is positioned on a front surface 122 of the multi-layer lens 2208. The enhanced optical region 106-2, comprising a progressive optical power region 2004 and a spherical segment 2002, is positioned on an inner surface 124 of the multi-layer lens 2208.

Due to the positioning of the progressive optical power region 2004, the progressive optical power region 2004 is not in optical communication with any portion of the enhanced optical region 106-1. Accordingly, the residual astigmatism regions 2010-1 and 2010-2 are not combined with any astigmatism region associated with the progressive optical power region 2206. A top portion of the spherical segment 2002 is not in optical communication with the progressive optical power region 2206. A lower portion of the spherical segment 2002 is in optical communication with the progressive optical power region 2206. The alignment of such an example implementation can provide multiple vision zones with a single discontinuity (other example implementations can include no discontinuities). Further, a total maximum astigmatism associated with a total desired add power can be reduced by approximately 50% as compared to prior art lens systems.

A combined progressive region and substantially constant optical power region of the present invention can be fabricated according to all previously described techniques. For example, an enhanced optical power region 106 comprising a combined progressive optical power region and substantially constant optical power region can be fabricated using a mold (e.g., a consumable mold, a non-consumable mold) or an optical perform. Additionally, an enhanced optical power region 106 comprising a combined progressive optical power region and substantially constant optical power region can be free-formed into an unfinished surface of a

lens of the present invention. Accordingly, aspects of the present invention include methods for fabricating an enhanced optical power region 106 comprising a combined progressive optical power region and substantially constant optical power region.

Accordingly, aspects of the present invention include methods for fabricating a mold to
5 produce such a combined structure. For example, an aspect of the present invention provides a method for fabricating a mold that can be used to form the enhanced optical region 106-2 depicted in FIG. 20. According to an aspect of the present invention, fabrication of such a mold can occur in two primary steps. In a first step, a mold is formed that comprises a progressive optical power region. Alternatively, a performed mold having a desired initial
10 progressive optical power region can be selected for further modification.

The mold can comprise any material such as, but not limited to, any type of metal, glass or plastic. For example, a mold can be formed that can be used to form the full progressive optical power region 2004 depicted in FIG. 20. In a second step, a substantially constant optical power region can be formed over the existing progressive optical power region and
15 into the mold. For example, a mold shaped to produce the progressive optical power region 2004 can be further shaped to introduce the substantially constant optical power region 2002. Any known technique for shaping or tooling a mold to fabricate desired shaping can be used including, but not limited to, diamond turning or grinding and polishing. Shaping the substantially constant power region can introduce sag and/or slope discontinuities at any
20 boundary of the substantially constant power region.

As an alternative, a mold of the present invention can be formed in a single step. Specifically, a desired combined shaping of the progressive and substantially constant power optical power regions can be shaped into a mold in a single combined step.

A mold, appropriately shaped to form an enhanced optical region comprising a combined
25 progressive optical power region and substantially constant optical power region, can be used to form an internal or external surface of a multi-layer composite lens of the present invention. Further, such a mold can be used to shape an external surface of a single layer or a single material lens contemplated by the present invention. This mold of the present invention can be fabricated to be a consumable mold or a non-consumable mold. The mold
30 of the present invention can also be fabricated as an optical perform.

The mold can be used in conjunction with any of the previously described fabrication methods for generating a multi-layer composite lens of the present invention. For example, the mold can be used for fabricating an implementation of the two-layer composite lens 100

of the present invention. Further, as will be appreciated by one skilled in the pertinent art(s), these techniques can be modified to fabricate a single layer and/or single material lens (e.g., a homogenous monolithic lens) having at least one surface comprising an enhanced optical region 106 that comprises a combined progressive and substantially constant optical power region. Such a single material lens can have an enhanced optical region 106 that comprises a combined progressive and substantially constant optical power region on a first external surface (e.g., the surface shown in FIG. 20) and a properly aligned low power progressive on a second external surface (e.g., the surface shown in FIG. 22A). In this way, FIG. 22B can represent a single layer lens in accordance with an aspect of the present invention.

As an example, FIG. 19 provides a flowchart 1900 that illustrates operational steps for manufacturing an implementation of the two-layer composite lens 100 (e.g., the two-layer lens 300), or a portion thereof, having a combined progressive and substantially constant optical power region in accordance with an aspect of the present invention. The two-layer composite lens 100 can be fabricated as a finished, semi-finished or unfinished lens blank according to the operation steps depicted in the flowchart 1900. The invention is not limited to this operational description. Rather, it will be apparent to persons skilled in the relevant art(s) from the teachings herein that other operational control flows are within the scope and spirit of the present invention. In the following discussion, the steps in FIG. 19 are described. At step 1902, a first mold is placed in a first mold assembly. The first mold can be used to shape a portion of a first surface of the second layer 104. In particular, the first mold can be used to shape the upper region 120 of the surface 124 of the second layer 104 and/or the enhanced optical region 106-2 of the second layer 104. The mold can form the enhanced optical region 106-2 to be a combined progressive and substantially constant optical power region. The first mold can therefore determine the shape of the entire surface of the second layer 104 that will be covered by the first layer 102. Alternatively, the first mold can be used to shape the upper region 120 of the surface 124 of the second layer 104 only. Under this scenario, subsequent manufacturing steps can be implemented to fabricate the enhanced optical region 106-2 prior to being covered by the first layer 102.

At step 1904, a second mold is placed in the first mold assembly. The second mold can be used to shape a portion of a second surface of the second layer 104. In particular, the second mold can be used to shape the upper region 120 of the surface 126 of the second layer 104 and/or the enhanced optical region 106-3 of the second layer 104. In this way, the second mold can determine the shape of the entire surface of the second layer 104 that will not be

covered by the first layer 102. Alternatively, the second mold can be used to shape the upper region 120 of the surface 126 of the second layer 104 only or the enhanced optical region 106-3 only. Subsequent manufacturing steps can be implemented to fabricate the enhanced optical region 106-3 or to shape the upper region 120 of the surface 126 to a final desired state. Accordingly, the second mold need not necessarily shape any portion of the surface 126 to its final desired state. That is, the second mold can shape any or all portions of the surface 126 in a way that subsequent fabrication steps (e.g., free-forming) or finishing steps (e.g., traditional surfacing and polishing) can be used to shape portions of the surface 126 to a final desired state.

5
10
15
At step 1906, the first and second molds in the first mold assembly are properly positioned and aligned within the first mold assembly. In particular, the first and second molds are spaced a predetermined distance apart that can determine a thickness of the second layer 104. The predetermined distance or spacing can be greater than the final thickness of the second layer 104 and can take into account any shrinkage of the material used to form the second layer 104. The alignment and spacing of the first and second molds can be secured using tape and/or a gasket.

At step 1908, a first monomer resin is poured into a cavity of the first mold assembly. That is, a first monomer resin which when cured (polymerized) becomes the first material comprising the second layer 104 is provided to the spacing between the first and second molds. The first resin fills the space or void between the separated first and second molds of the first mold assembly.

20
25
At step 1910, the first resin is cured. The resin can be cured using any known curing techniques including, but not limited to, thermal curing, photo-curing, or any combination thereof. The first resin can be hardened to form the second layer 104 and can comprise a material and be cured in a way that the second layer 104 is substantially homogenous. The first resin, when cured to a solid state, can form the second layer 104.

30
As shown in FIG. 19, steps 1902-1910 are indicated to be a first portion 1912 of a manufacturing process for producing the two-layer composite lens 100. That is, the first portion 1912 of the manufacturing process can produce one of the layers of the two-layer composite lens 100 (i.e., either the first layer 102 or the second layer 104 as will be appreciated by one skilled in the pertinent art(s)). Alternatively, the output of steps 1902-1910 can be a single layer lens of the present invention having an external surface comprising a combined progressive and substantially constant optical power region.

For use in fabricating a multiple layer lens, the output of this first portion 1912 of the fabrication process can be considered to be an optical perform. As will be appreciated by one skilled in the pertinent art(s), such an optical perform can be a preformed optical component that is used or combined with other optical components to form a lens blank. In general, an optical perform can be an initial or early stage component of a lens system such that additional material is added to an optical perform to form the lens blank (e.g., a finished, semi-finished or unfinished lens blank). A first layer 102 of the two-layer composite lens 100, as an optical perform, can therefore be produced according to steps 1902-1910 or any similar fabrication process as will be understood by one skilled in the pertinent art(s).

At step 1914, a third mold is placed in a second mold assembly. The third mold can be used to shape any portion of a first surface of the first layer 102. In particular, the third mold can be used to shape the upper region 120 of the surface 122 of the first layer 102 and/or the enhanced optical region 106-1 of the first layer 104. The third mold can shape any portion of the surface 122 as a finished or unfinished surface. Further, the third mold can be used to shape the upper region 120 of the surface 122 of the first layer 102 only. Under this scenario, subsequent manufacturing steps can be implemented to fabricate the enhanced optical region 106-2.

At step 1916, the second layer 104, produced by steps 1902-1910 and outputted after step 1910, can be placed in the second mold assembly. The second layer 104 can be used to shape a second surface of the first layer 102. In particular, the second layer 104 can be used to shape the surface 140 of the first layer 102. In this way, the second layer 104 can determine the shape of the surface of the first layer 102 that will cover by the second layer 104. In doing so, a curvature of the upper region 120 of the surface 140 can be made to substantially match a curvature of the upper region 120 of the surface 124. As described above, one skilled in the pertinent art(s) will understand that any portion of the surface 140 can be shaped by an optical perform (e.g., the second layer 104 as an optical perform).

At step 1918, the third mold and the second layer 104 of the second mold assembly are properly positioned and aligned within the second mold assembly. In particular, the third mold and the second layer 104 are spaced a predetermined distance apart that can determine a thickness of the first layer 102. The predetermined distance or spacing can be greater than the final thickness of the first layer 102 and can take into account any shrinkage of the material used to form the second layer 102. The alignment and spacing of the third mold and the second layer 104 can be secured using tape and/or a gasket. Measures can be taken to

ensure that any of the enhanced optical regions 106-2 and 106-3 of the second layer 104 are optimally optically aligned in relation to the enhanced optical region 106-1. This alignment can be provided through optical recognition and alignment systems and/or power measurement systems. If the output of flowchart 1900 is to be a lens having only the enhanced optical region 106-2 (e.g., with one or more of the enhanced optical regions 106-1 and 106-3 to be added in later finishing steps), then such alignment steps may not be necessary.

At step 1920, a second resin is poured into a cavity of the second mold assembly. That is, a second monomer resin which when cured (polymerized) becomes the material comprising the first layer 102 is provided to the spacing between the third mold and the second layer 104. The second resin fills the space or void between the separated third mold and the second layer 104 of the second mold assembly. Additionally, prior to injecting the second resin, any portion of the second layer 104 can be treated or coated with one or more materials to increase or strengthen the bonding between the second layer 104 and the resin.

At step 1922, the second resin is cured. The second resin can be cured using any known curing techniques including, but not limited to, thermal curing, photo-curing, or any combination thereof. The second resin can be hardened to form the first layer 102 and can comprise a material and be cured in a way that the first layer 102 is substantially homogenous. The second resin, when cured to a solid state, can form the first layer 102. Further, curing the second resin can bond the first layer 102 and the second layer 104. As will be appreciated by one skilled in the pertinent art(s), the second layer 104 can be considered to be a consumable mold. That is, the second layer 104 output after step 1910 or the second layer 104 as an optical perform can be used to shape a portion of the first layer 102 while also forming a portion of a lens blank once bonded to the first layer 102.

As shown in FIG. 19, steps 1914-1922 are indicated to be a second portion 1924 of a manufacturing process for producing the two-layer composite lens 100. That is, the second portion 1924 of the manufacturing process can produce the first layer 102 of the two-layer composite lens 100 while simultaneously adhering/bonding the first layer 102 or combining the first layer 102 and the second layer 104. Alternatively, as will be appreciated by one skilled in the pertinent art(s), the second portion 1924 of the manufacturing process can produce the second layer 104 of the two-layer composite lens 100 while simultaneously adhering/bonding the second layer 104 or combining the first layer 102 and the second layer 104.

The output of step 1922 can be the two-layer composite lens 100 depicted in FIGs. 1 and 2. The output of step 1922 can be a lens blank that is either unfinished or semi-finished. Alternatively, the output of step 1922 can be a finished lens. The output can be of any thickness and can be subject to additional processing steps 1926 to achieve a desired
5 thickness, base power, and distance power. Further, the additional processing steps 1926 can include adding enhanced optical regions 106-1 and 106-3 to the output if they are not already included. At step 1926, the lens blank can be subjected to lens coating or other treatments, including further curing or hardening steps.

A multi-layer composite lens of the present invention can also be fabricated by
10 manufacturing each layer separately and then adhering/adhesively bonding each layer together during subsequent manufacturing steps.

Cropped Progressive Regions

An enhanced optical power region 106 of the present invention can comprise a cropped
15 progressive optical power region in accordance with an aspect of the present invention. The cropped progressive optical power region can be a progressive region that has a portion of any associated astigmatism regions removed. For example, the cropped progressive optical power region of the present invention can be disassociated with regions of maximum unwanted astigmatism traditionally associated with prior art progressive regions.

FIG. 23A illustrates a lens surface 2300 comprising a progressive optical power region 2302.
20 The progressive region is positioned below the fitting point of the lens surface 2300. The progressive region is associated with multiple regions of astigmatism 2304. The regions of astigmatism 2304 are located to the sides of the channel of the progressive region 2302. The regions of astigmatism 2304 are generally symmetric. A first region of astigmatism, 2304-1, is located closest to the progressive region 2302. A second region of astigmatism, 2304-2, is
25 located adjacent to the first region of astigmatism 2304-1. A third region of astigmatism, 2304-3, is located adjacent to the second region of astigmatism 2304-2. A fourth region of astigmatism, 2304-4, is located adjacent to the third region of astigmatism 2304-3. The fourth region of astigmatism 2304-4 is located furthest from the progressive region 2302 and to the periphery of the lens surface 2300.

30 The level of distortion associated with the regions of astigmatism 2304 can increase from the first region of astigmatism 2304-1 to the sixth region of astigmatism 2304-6. For example, for a progressive region providing 1.50 D of maximum optical power, the first region of astigmatism 2304-1 can introduce approximately 0.25 D of astigmatism; the second region of

astigmatism 2304-2 can introduce approximately 0.50 D of astigmatism; the third region of astigmatism 2304-3 can introduce approximately 0.75 D of astigmatism; the fourth region of astigmatism 2304-4 can introduce approximately 1.00 D of astigmatism; the fifth region of astigmatism 2304-5 can introduce approximately 1.25 D of astigmatism; and the sixth region of astigmatism 2304-6 can introduce approximately 1.50 D of astigmatism. The distortion associated with the regions of astigmatism 2304 can reduce the usability of the progressive region 2302. That is, the distortion associated with the regions of astigmatism 2304 can reduce the channel width of the progressive region 2302 and can introduce perceptible effects that can be distracting and dissatisfying to a wearer of a lens comprising the lens surface 2300.

A region 2306 indicates a portion of the progressive region 2302 that is to be cropped. That is, the region 2306 indicates the portion of the progressive region 2302 that is desired to be kept. An aspect of the present invention enables the progressive region 2302 within the region 2306 to be captured and used without being adversely influenced by the astigmatism regions 2304-03 and 2304-4 outside of the region 2306.

FIG. 23B illustrates a lens surface 2308 of the present invention. The lens surface 2308 can be any internal or external surface of a multi-layer lens of the present invention. The lens surface 2308 can also be any external surface of a single layer or single material lens contemplated by the present invention.

As shown in FIG. 23B, the lens surface 2308 comprises an enhanced optical region 106 that comprises a cropped progressive region 2310 of the present invention. The region 2306 indicates where the progressive region 2310 has been cropped. Because the progressive region 2310 has been cropped, the astigmatism regions 2304-4, 2304-5 and 2304-6 are no longer associated with the progressive region 2310. As such, only the astigmatism regions 2304-1, 2304-2 and 2304-3 remain associated with the cropped progressive region 2310.

In effect, the astigmatism regions 2304 that introduce higher levels of astigmatism have been removed from the lens surface 2308. Therefore, in accordance with an aspect of the present invention, an enhanced optical region 106 of the present invention can comprise a cropped progressive region 2310 that provides a high maximum optical power without suffering from the high astigmatism regions usually associated with the high optical power value. The enhanced optical region 106 as a cropped progressive region 2310 can be made by using a mold or by free-forming. Such a cropped progressive region 2310 can be used as an

incremental add power region to be combined or placed in optical communication with another incremental power region as discussed herein.

FIG. 24 illustrates a possible optical power progression 2400 of an enhanced optical region 106 as a refractive progressive optical power region. The optical power progression 2400 can represent the change in optical power down a channel of a progressive region that can begin at or near a fitting point of a lens. Over a first distance 2402, a first optical power 2410 can be achieved with a ramp of optical power that can be faster than that of conventional progressive lenses. The first optical power 2410 over the first distance 2402 can be in a range of between 10% and 30% of a full addition power 2414. The distance 2402 can be within a range of approximately 2 to 5 mm.

Proceeding further down the channel there can be only a slight increase in the optical power such that the optical power over a second distance 2404 can be stable and can form a plateau of optical power providing vertical stability of vision. The second distance 2404 can be in a range of 3 to 6 mm. Proceeding still further down the channel, the slope in optical power (the ramp of optical power) can increase until the optical power begins to reach a second power 2412. The optical power 2412 can be within a range of between 40% to 60% of the full addition power 2414. The optical power 2412 can be achieved over a third distance 2406. The third distance 2406 can be in a range of approximately of 4 to 6 mm.

By having a small or slight change in optical power along the distance 2406 the channel width of the progressive optical power region can be made much wider and can provide more vertical stability of vision than normal progressive addition lenses. Proceeding still further down the channel along a final fourth distance 2408, the full addition power 2414 can be achieved. The rapid rise in power (optical power ramp) along the distance 2408 can produce unwanted astigmatism, but this astigmatism can occur on the sides of the reading zone which – because the power is stabilized beyond 2408 – can be wide and clear. The distance 2408 can be between 2 to 6 mm long.

Overall, the optical powers 2410, 2412 and 2414 and the distances 2402, 2404, 2406 and 2408 can be varied over any values to realize a wide range of progressive addition designs that provide substantially stable far-intermediate distance, intermediate distance, and near distance vision correction.

Conclusion

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example and not limitation. As such, all optical powers, add powers, incremental add powers, optical power ranges, refractive indices, 5 refractive index ranges, thicknesses, thickness ranges, distances from the fitting point of the lens, and diameter measurements that have been provided are examples only and are not intended to be limiting. It will be apparent to one skilled in the pertinent art that various changes in form and detail can be made therein without departing from the spirit and scope of the invention. Therefore, the present invention should only be defined in accordance with the 10 following claims and their equivalents.

WHAT IS CLAIMED IS:

1. A lens, comprising:
 - a first surface comprising a first incremental add power region comprising a combined progressive optical power region and a substantially constant optical power region,
 - wherein the first surface comprises one or more optical discontinuities,
 - wherein at least one optical discontinuity is adjacent to a distance vision zone of the lens,
 - wherein the progressive optical power region is positioned above the at least one optical discontinuity.
2. The lens of claim 1, further comprising a second surface comprising a second incremental add power region.
3. The lens of claim 2, wherein the second incremental add power region comprises a refractive progressive optical power region.
4. The lens of claim 2, wherein the second incremental add power region comprises one of a spherical, a substantially spherical, and an aspheric optical power region.
5. The lens of claim 2, wherein the first surface comprises an external surface of a first layer of the lens.
6. The lens of claim 5, wherein the second surface comprises an internal surface of a second layer of the lens.
7. The lens of claim 6, wherein a portion of a boundary of the second incremental add power forms an optical discontinuity adjacent to the distance vision zone of the lens.
8. The lens of claim 6, wherein the first layer comprises a first index of refraction and the second layer comprises a second index of refraction.

9. The lens of claim 2, wherein the first and second incremental add power regions are positioned to be in optical communication so as to form a far-intermediate vision zone, an intermediate vision zone and a near vision zone.

10. A lens, comprising:

a first surface comprising a first incremental add power region; and
a second surface comprising a second incremental add power region,
wherein a portion of a boundary of the first incremental add power region forms an optical discontinuity adjacent to a distance vision zone of the lens,
wherein the second incremental add power region comprises one of a spherical, a substantially spherical, and an aspheric optical power region,
wherein the first incremental add power region comprises a combined progressive optical power region and a substantially constant optical power region.

11. The lens of claim 10, wherein a portion of a boundary of the second incremental add power region forms an optical discontinuity.

12. The lens of claim 11, wherein the optical discontinuity formed by the portion of the boundary between the progressive optical power region and the substantially constant optical power region of the first incremental add power region is aligned with the optical discontinuity formed by the portion of the boundary of the second incremental add power region.

13. A method, comprising:

forming a first layer of a lens from a first material having a first index of refraction, the first layer having a first curvature and a second curvature, wherein the second curvature comprises a combined progressive curvature and a substantially spherical curvature;

shaping a first surface of a second layer of the lens using the first layer, the second layer comprising a second material having a second index of refraction different from the first index of refraction;

shaping a second surface of the second layer using a non-consumable mold to have a first curvature and second curvature, wherein the second curvature of the second layer

provides a progression of optical power and optically communicates with the second curvature of the first layer for providing a combined optical power for correcting near distance vision; and

 bonding the first layer to the second layer, the second surface of the second layer forming an external surface of the lens.

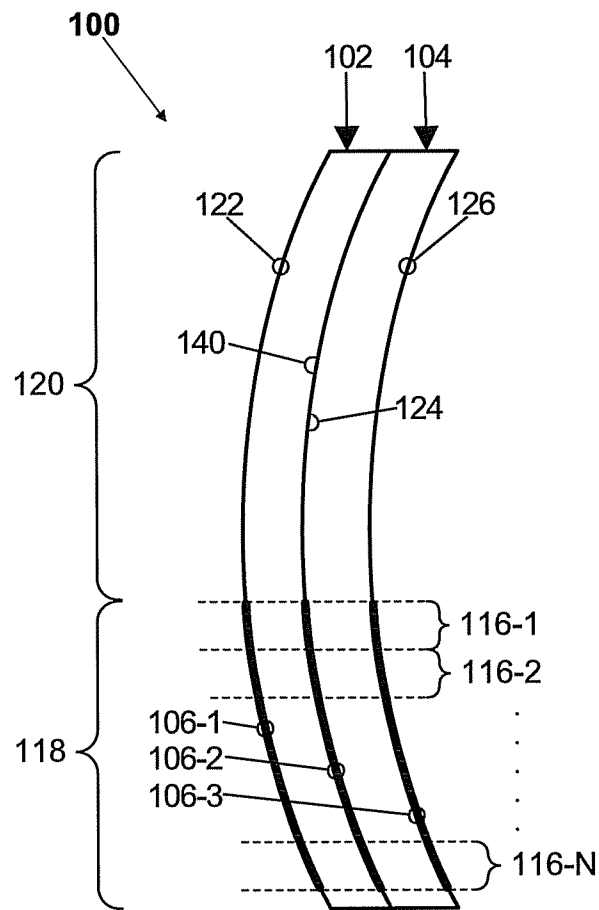


FIG. 1

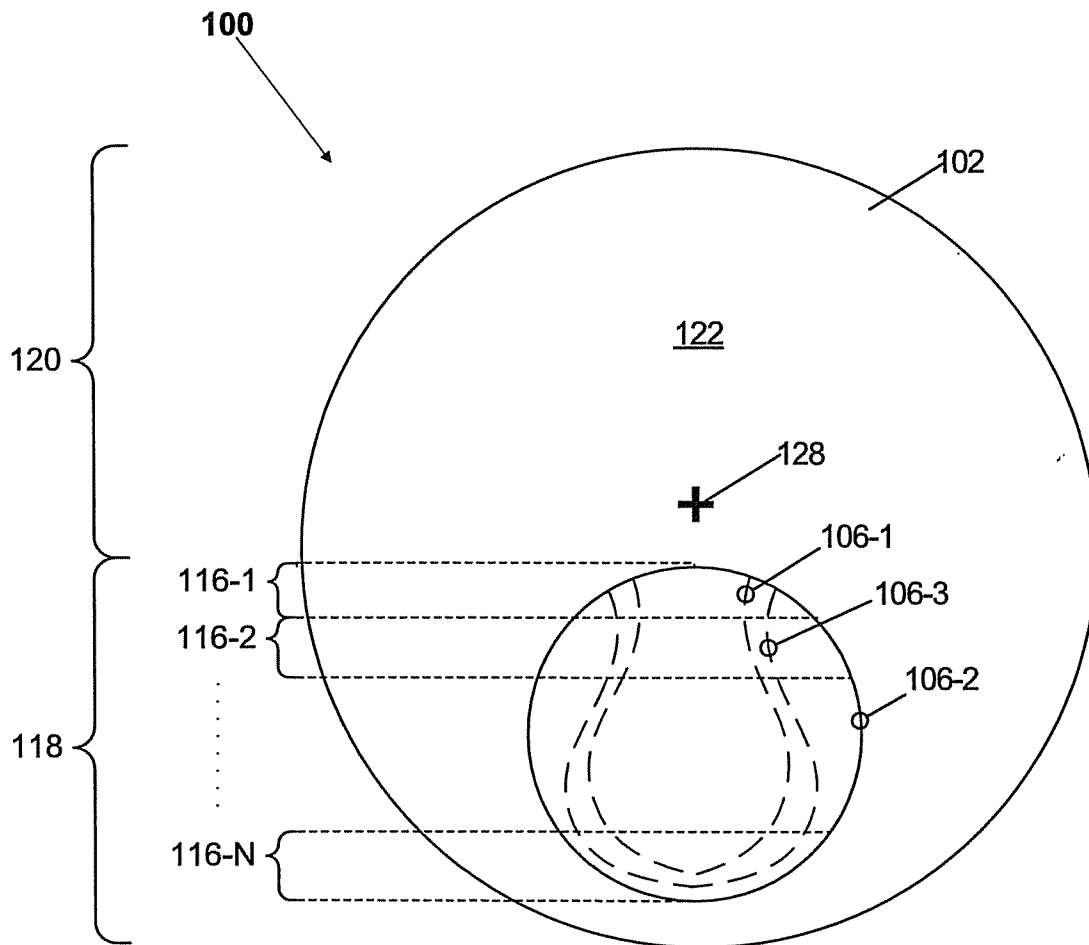


FIG. 2

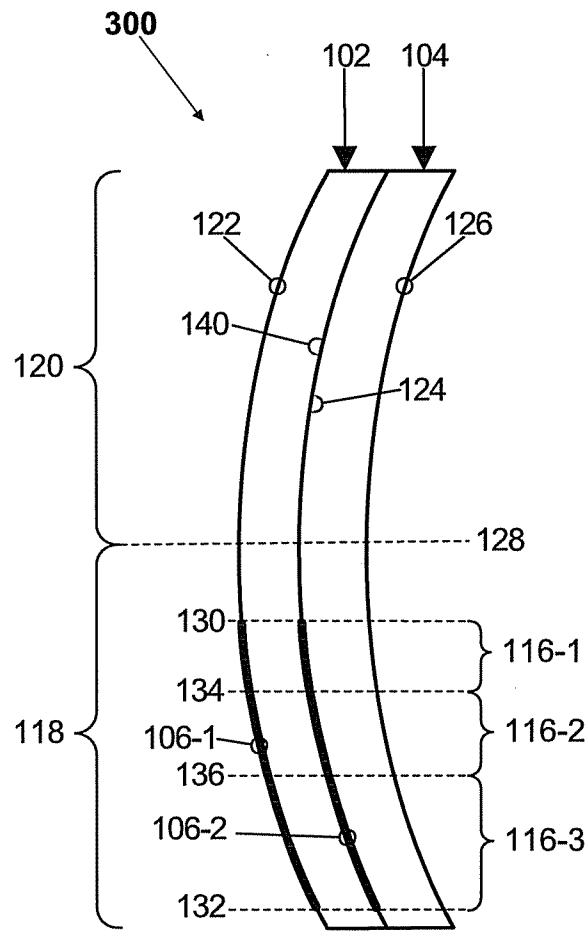


FIG. 3

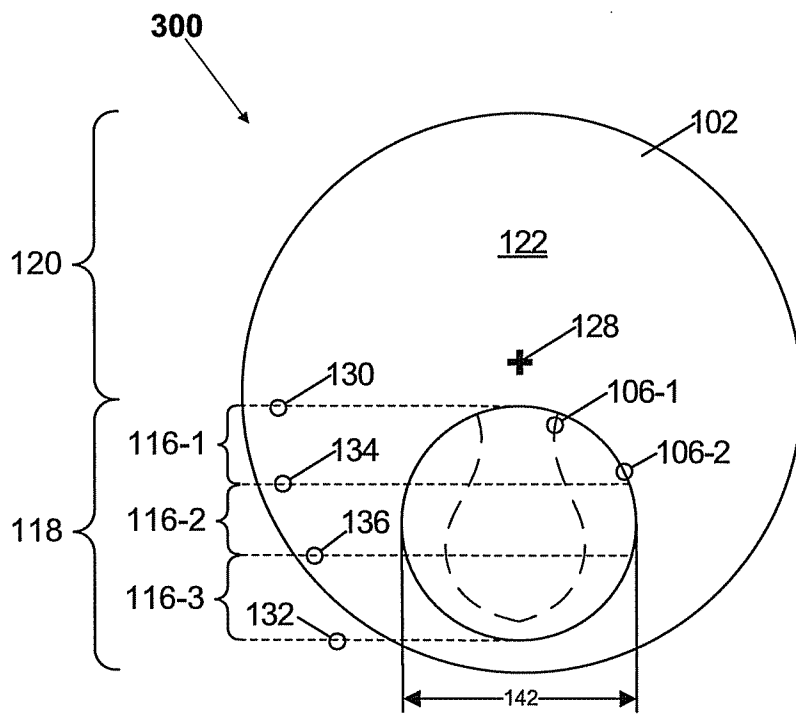


FIG. 4A

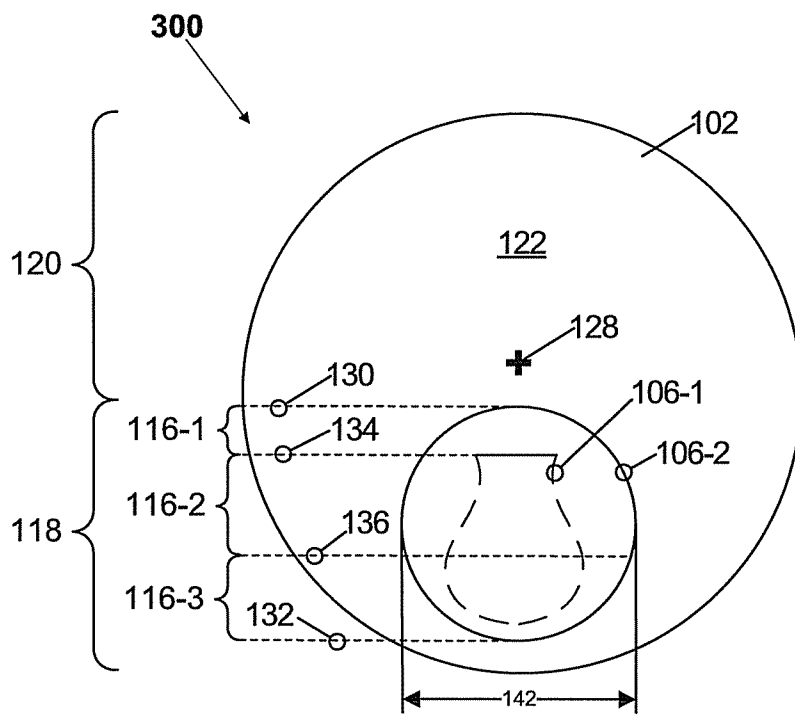


FIG. 4B

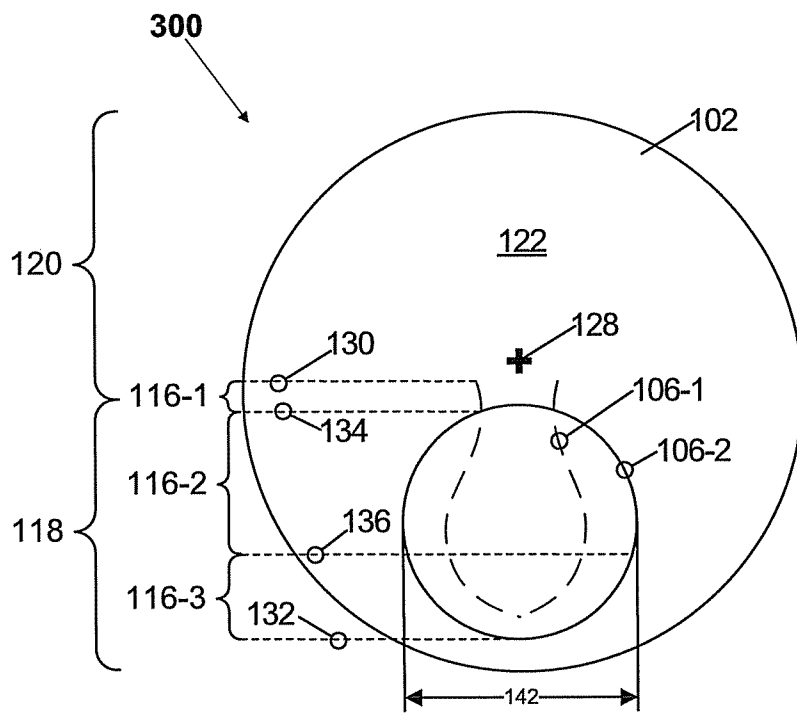


FIG. 4C

7/32

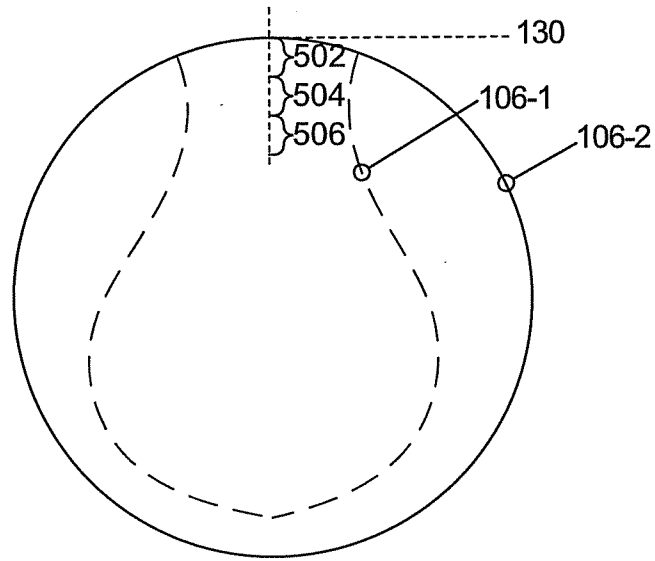


FIG. 5

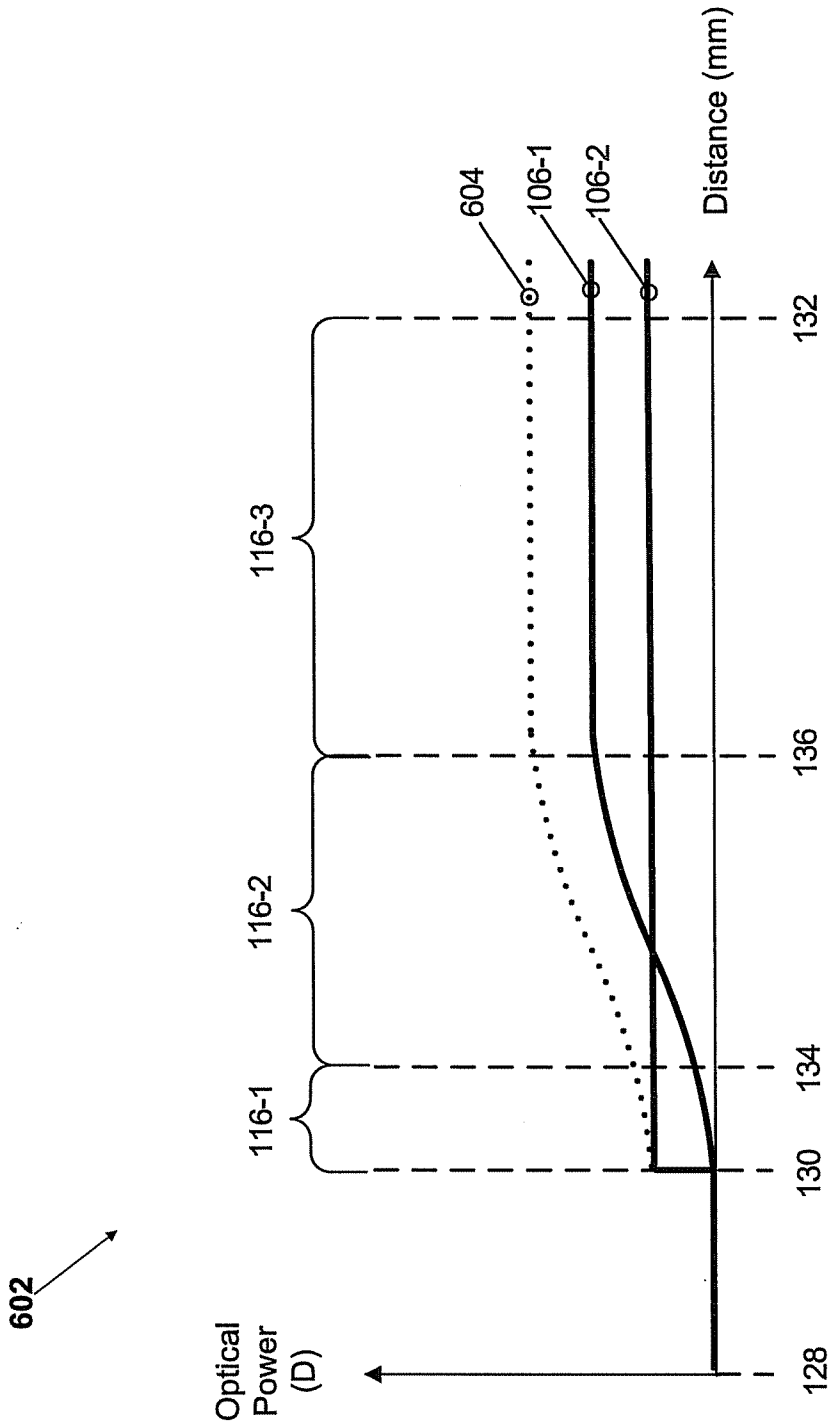


FIG. 6A

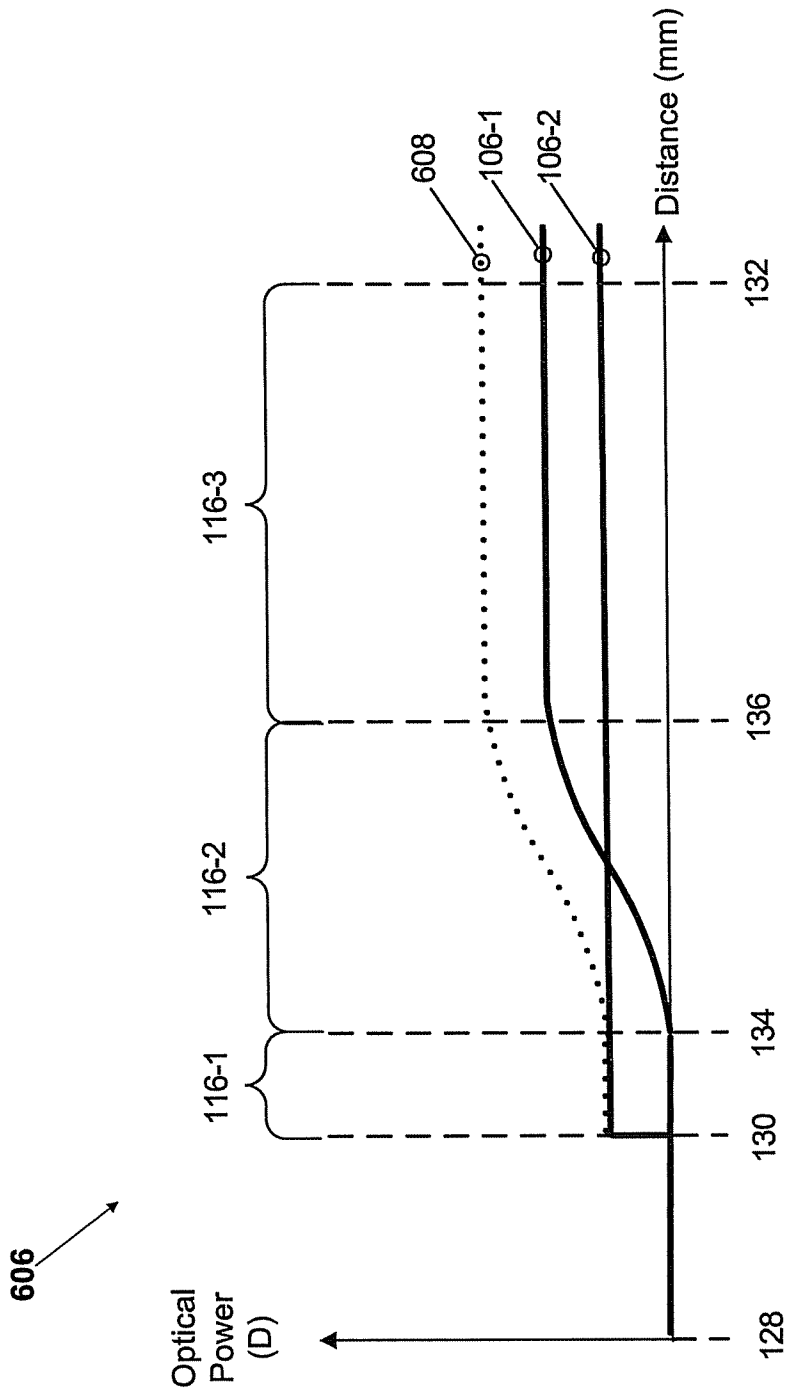


FIG. 6B

10/32

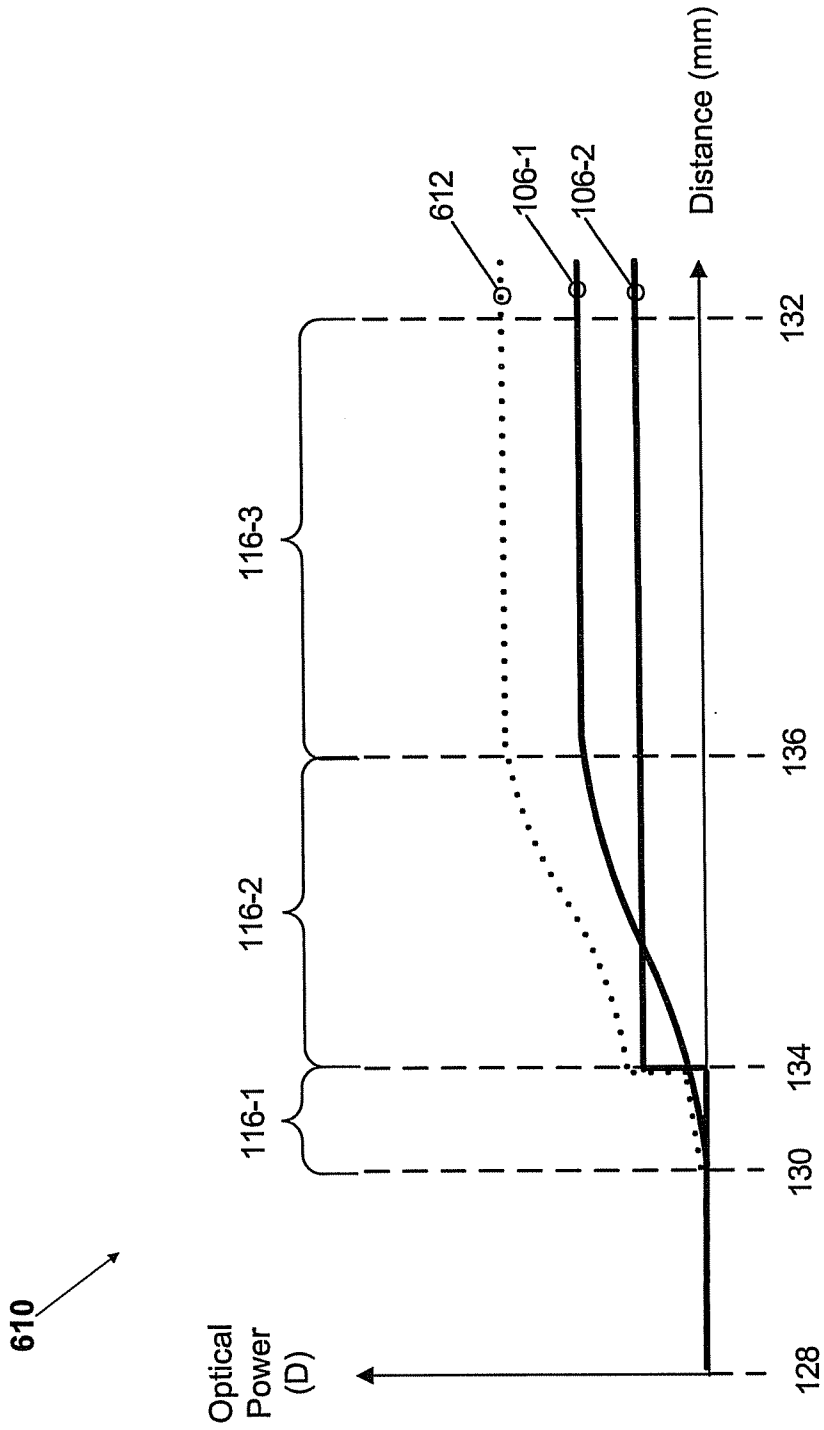


FIG. 6C

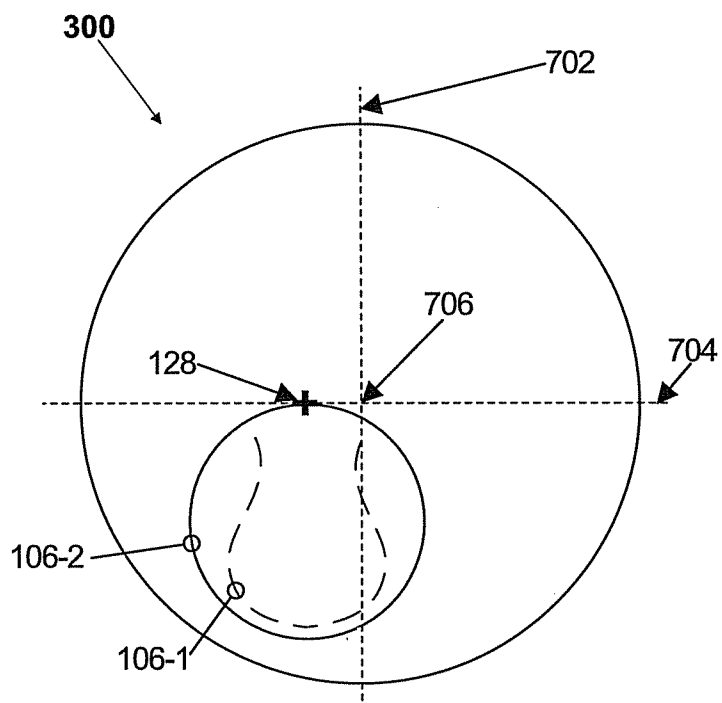


FIG. 7

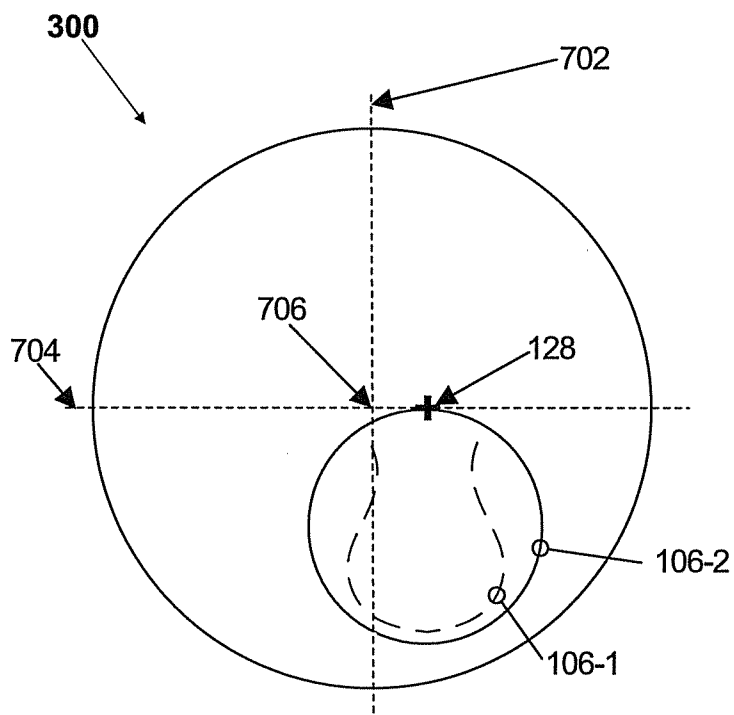


FIG. 8

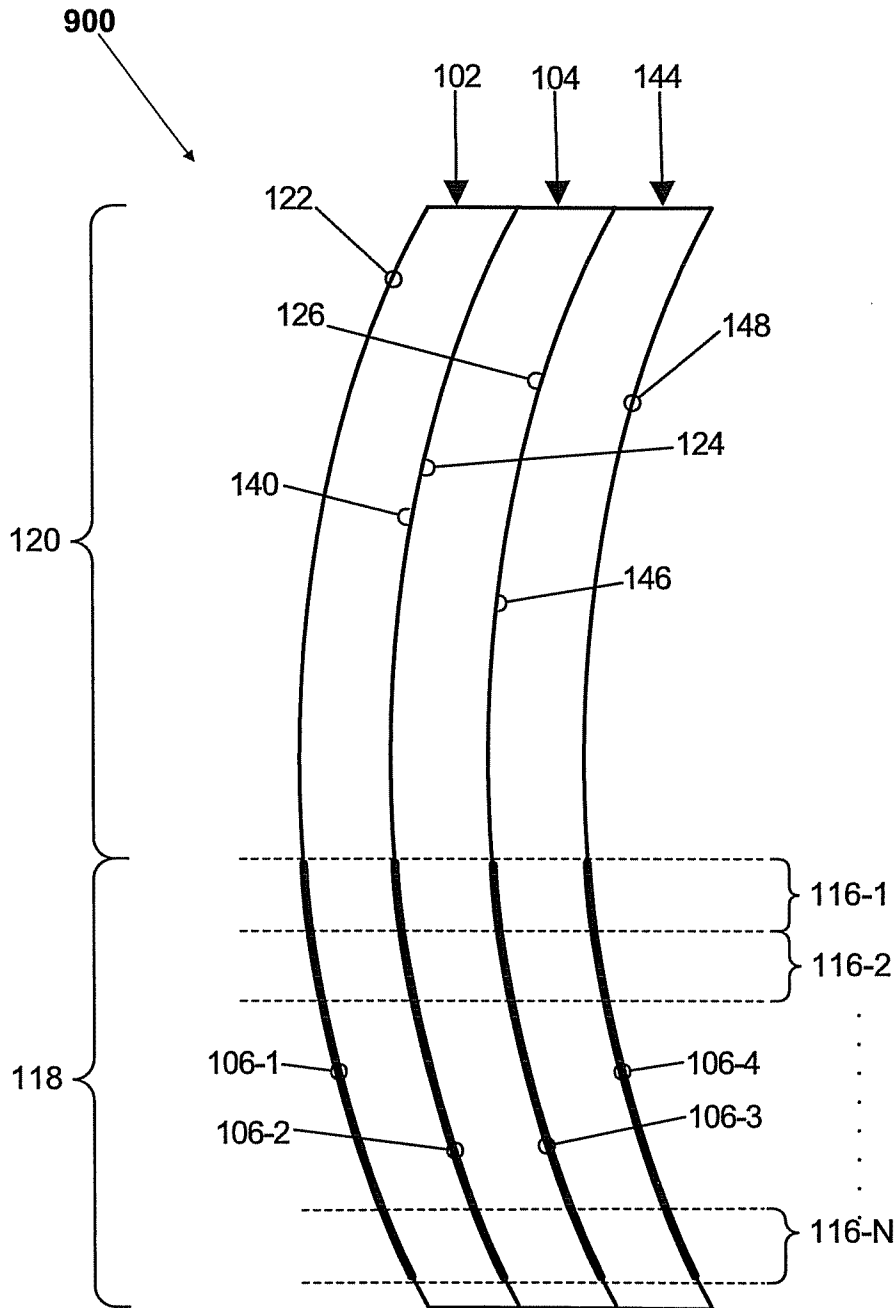


FIG. 9

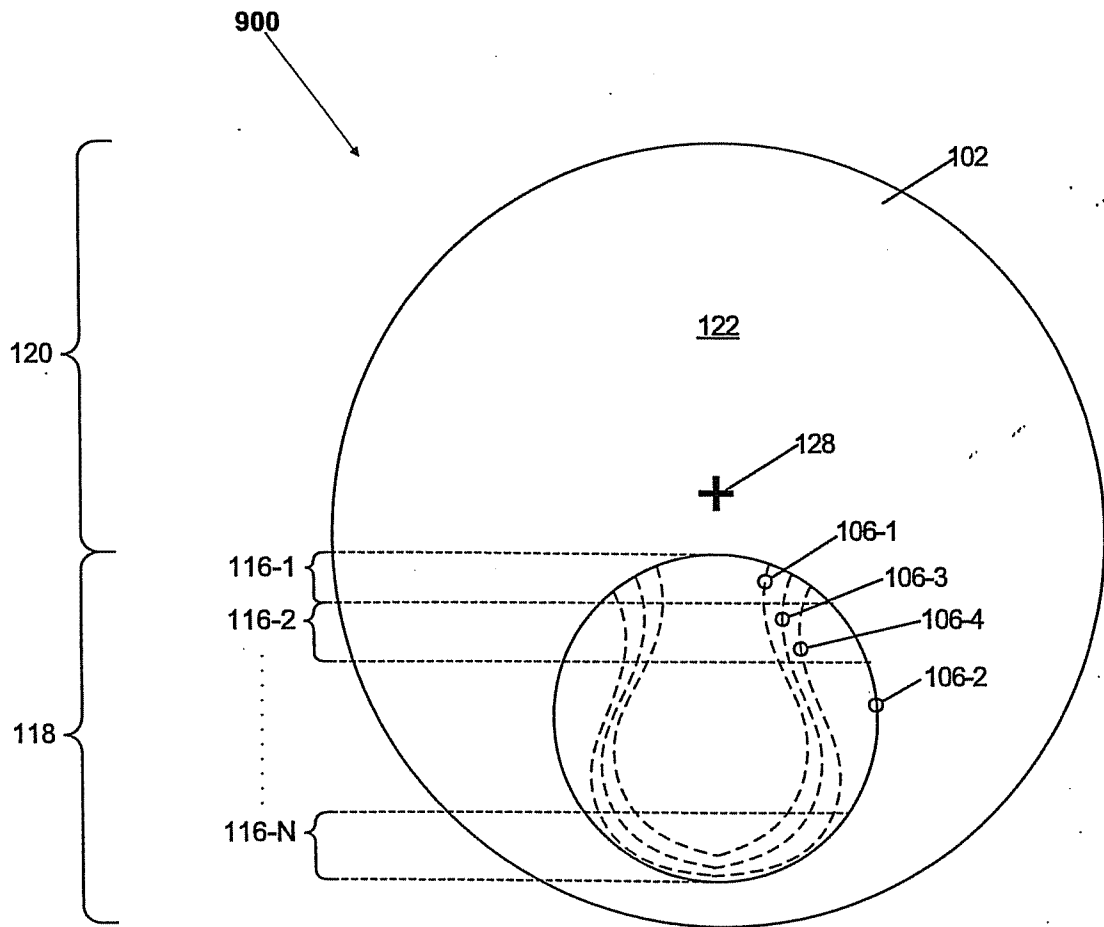
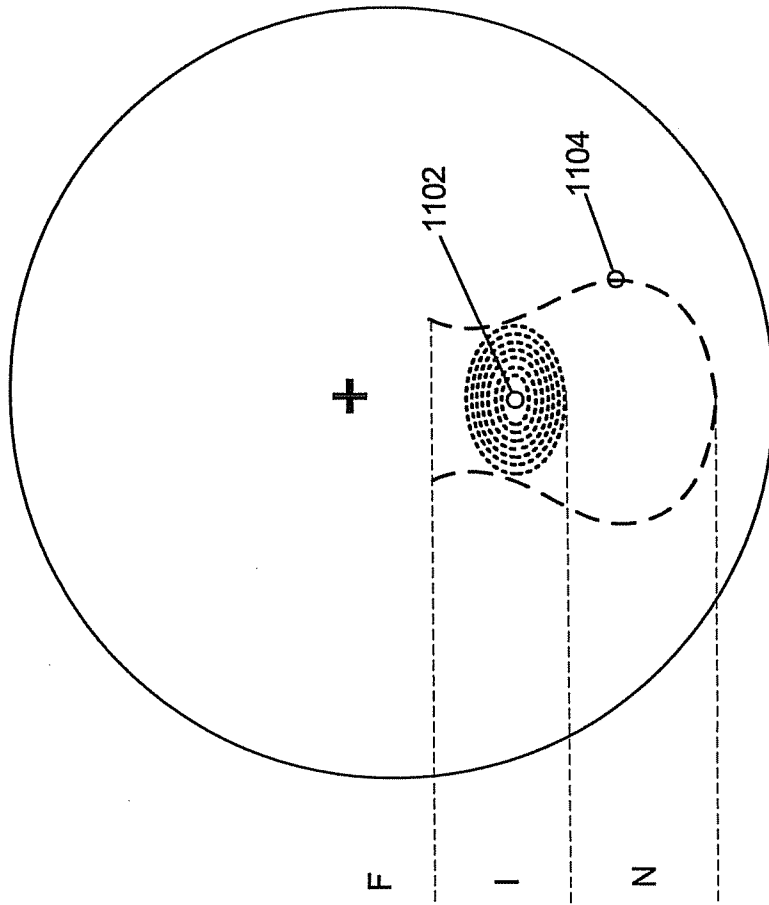
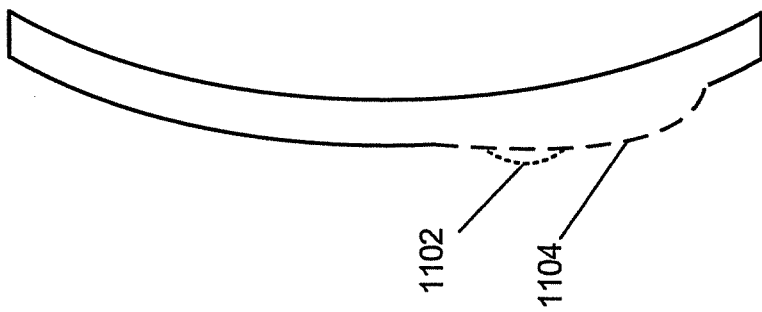


FIG. 10

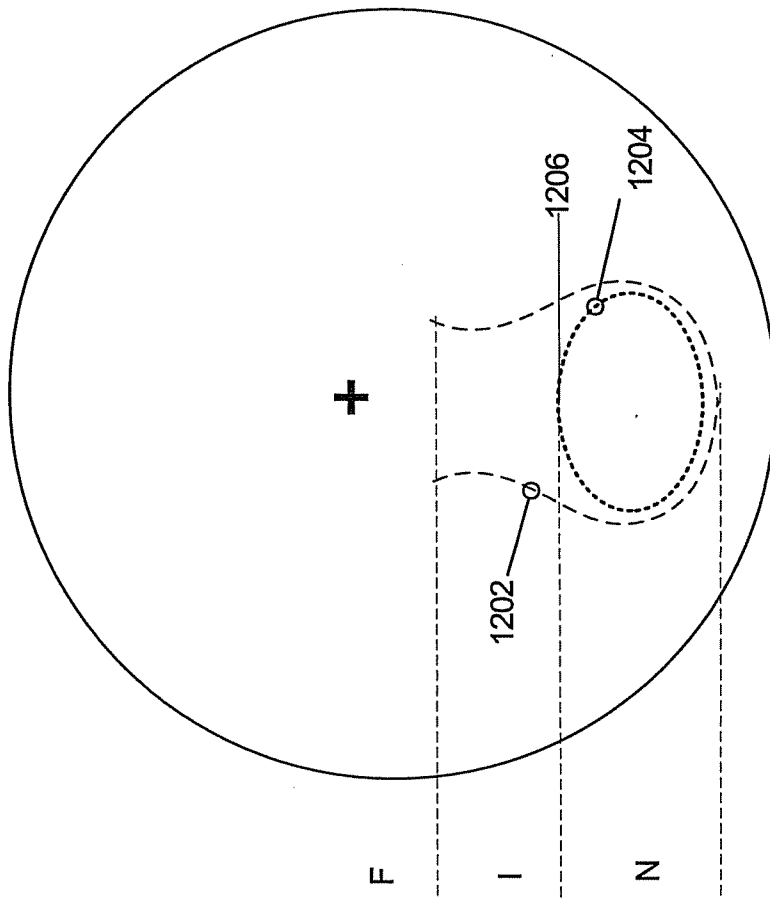


FRONT VIEW

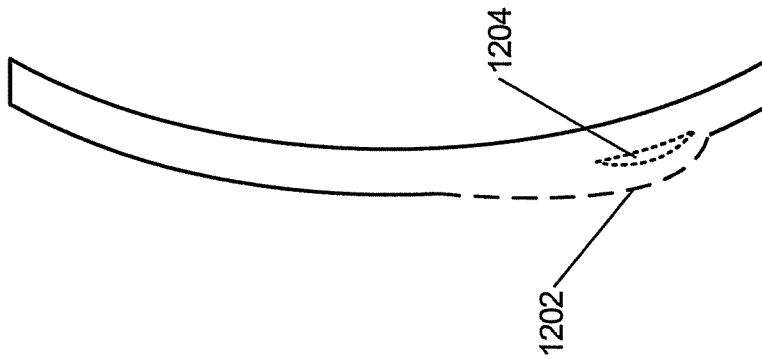


SIDE VIEW

PRIOR ART
FIG. 11



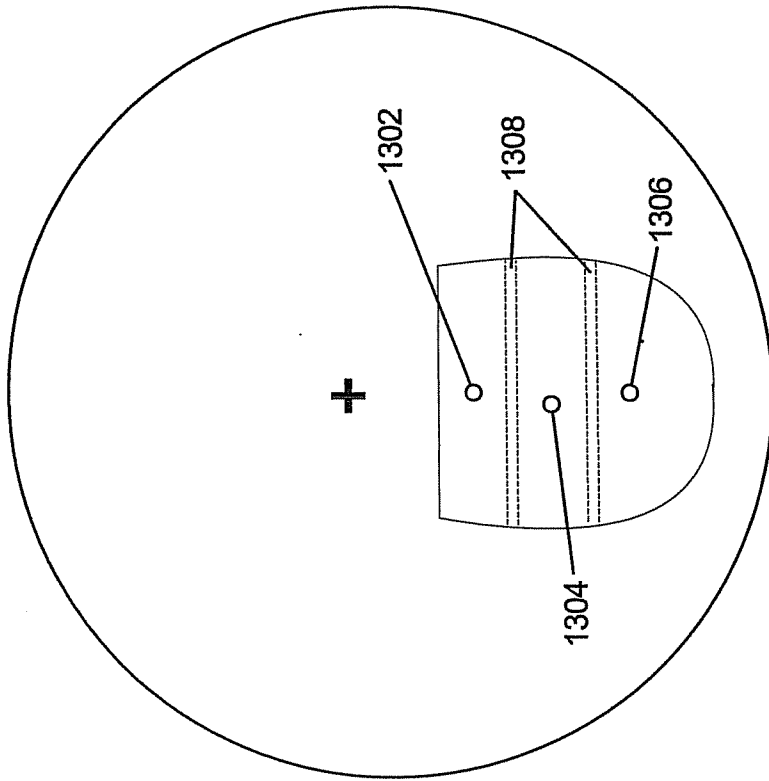
FRONT VIEW



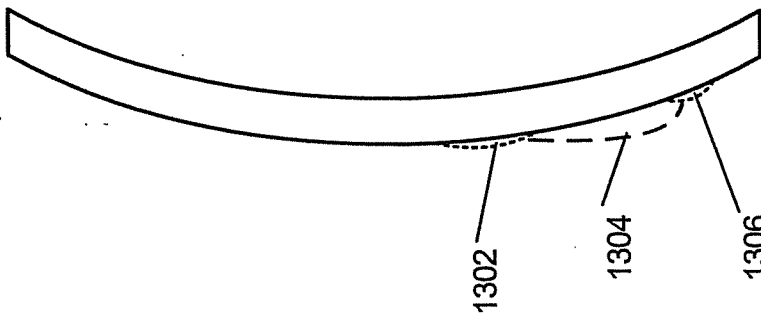
SIDE VIEW

PRIOR ART
FIG. 12

17/32

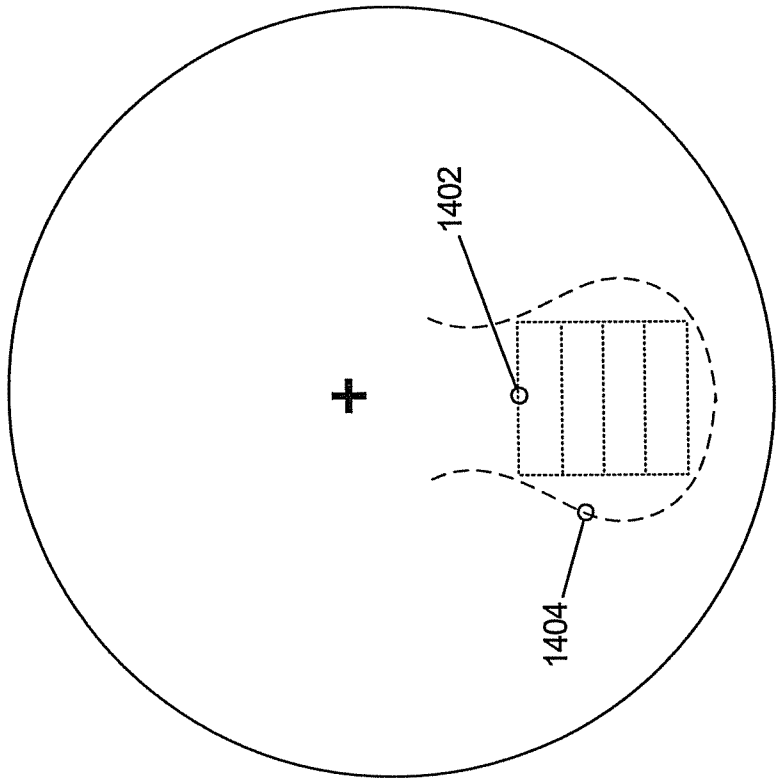


FRONT VIEW

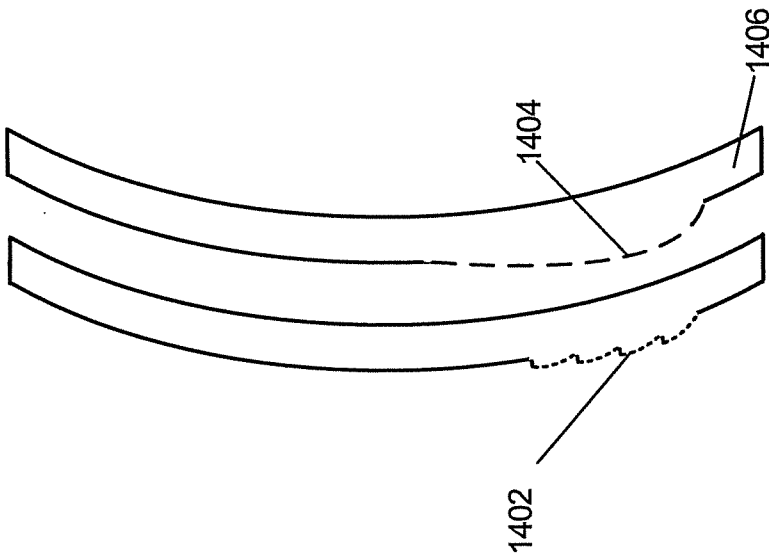


SIDE VIEW

PRIOR ART
FIG. 13



FRONT VIEW



SIDE VIEW

PRIOR ART
FIG. 14

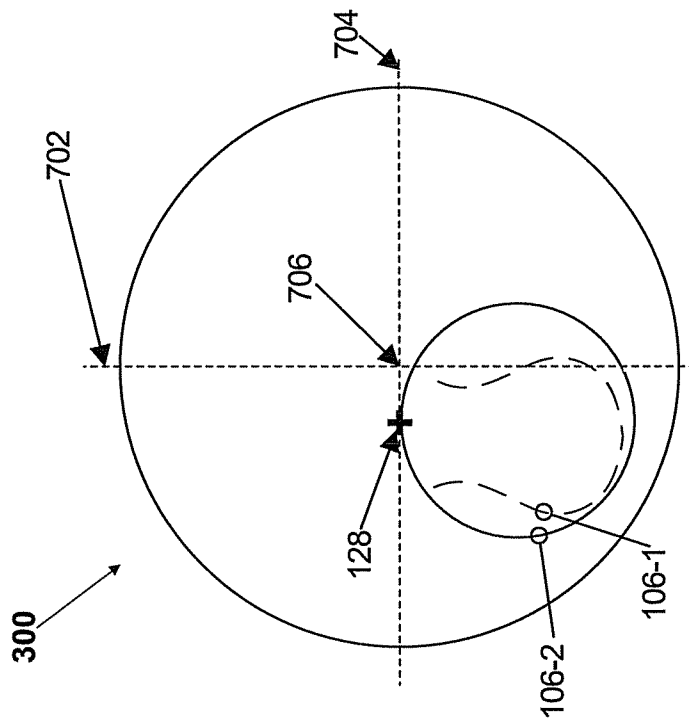


FIG. 15

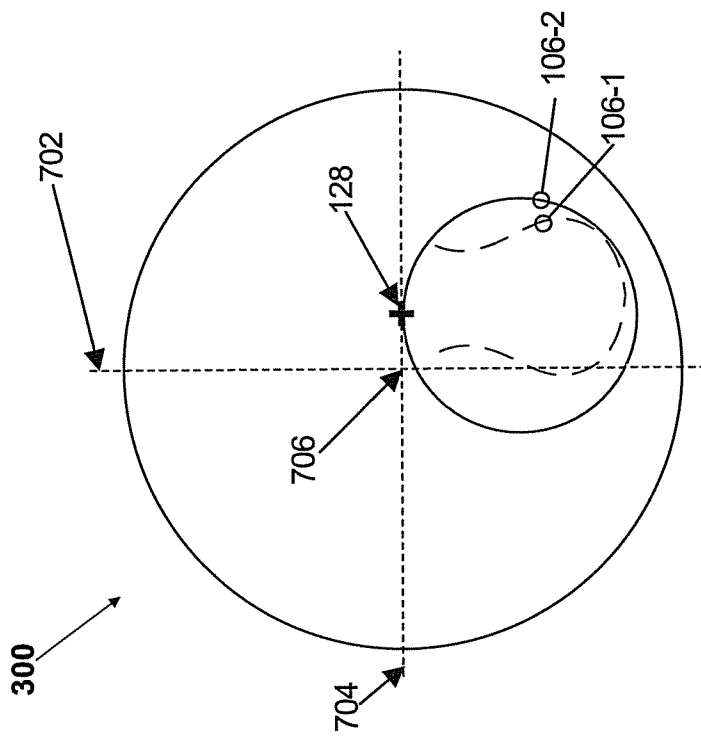


FIG. 16

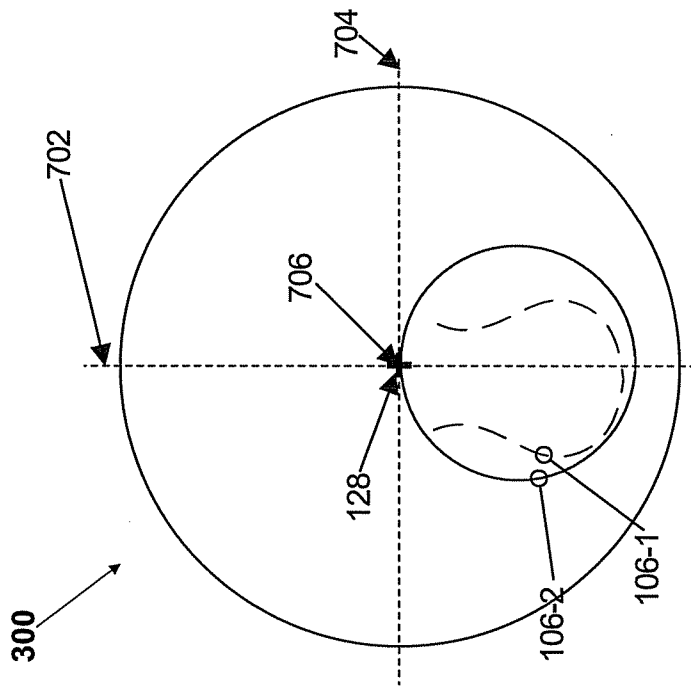


FIG. 17

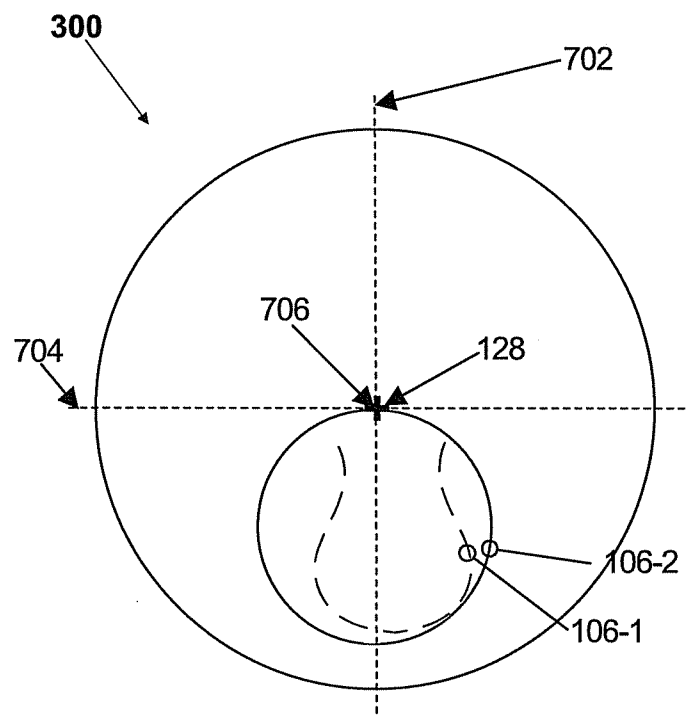


FIG. 18

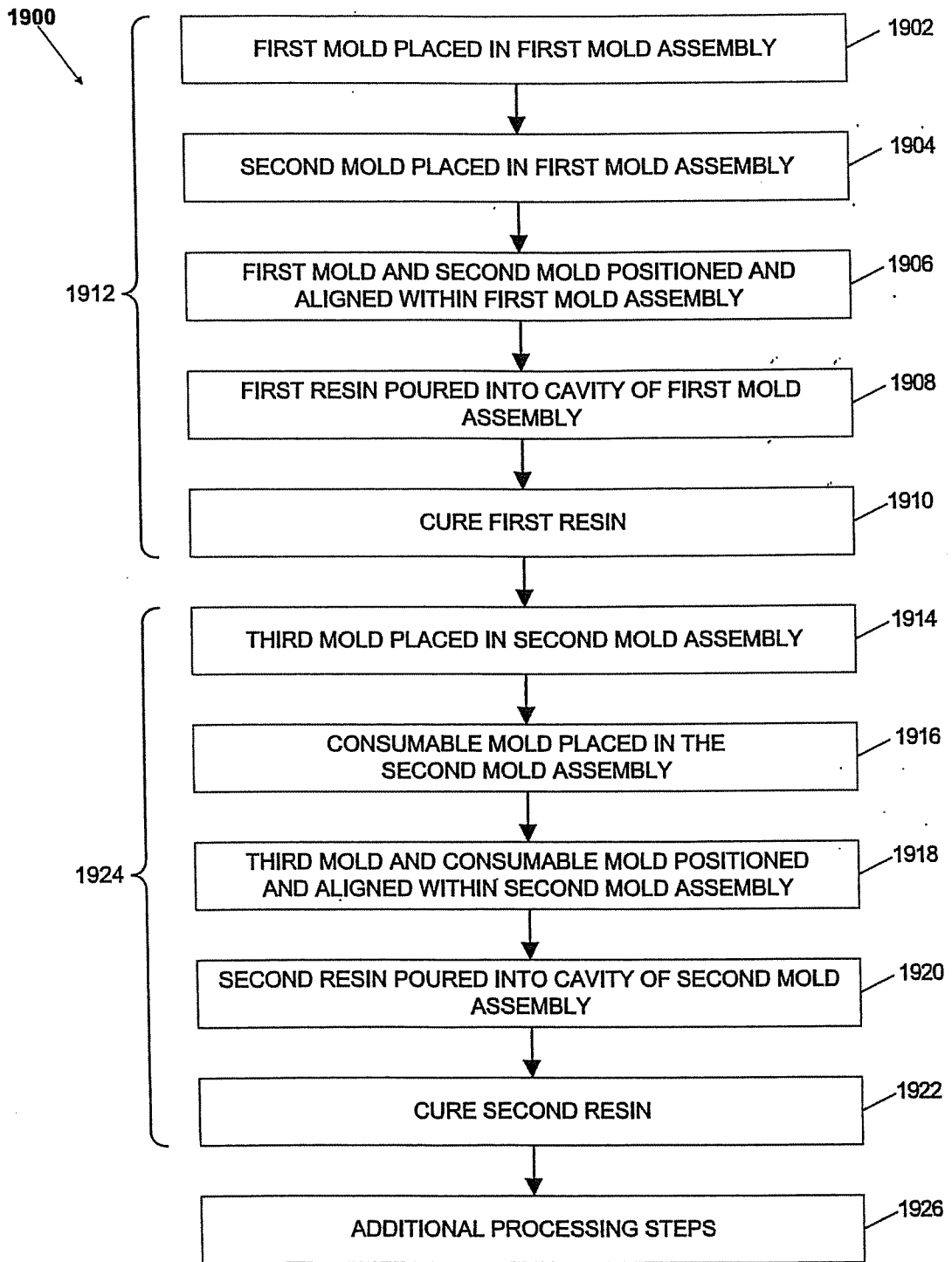


FIG. 19

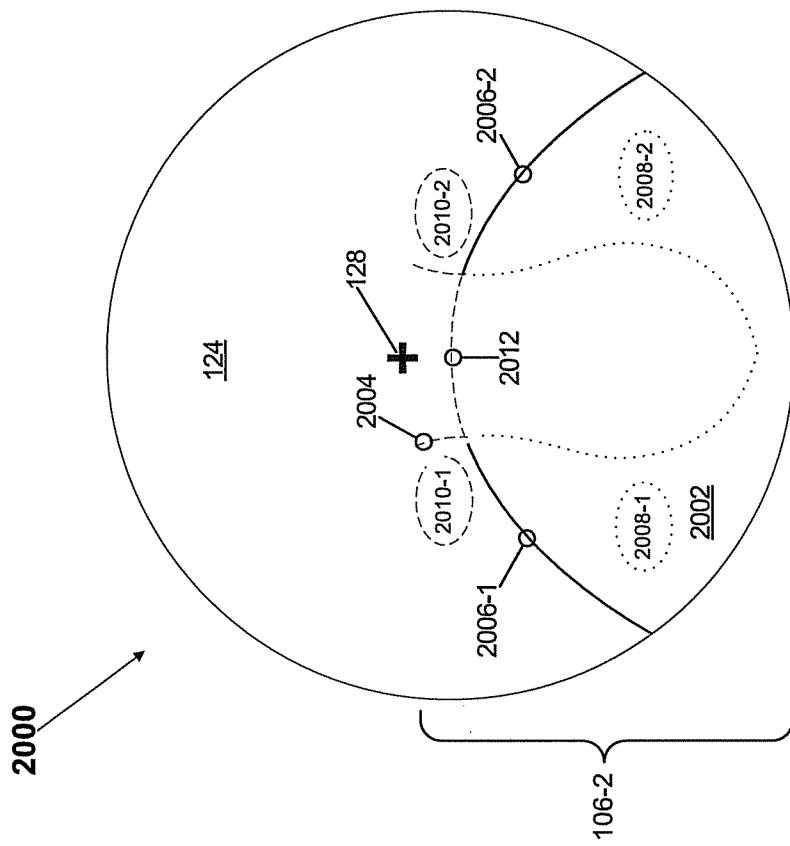


FIG. 20

2100 →

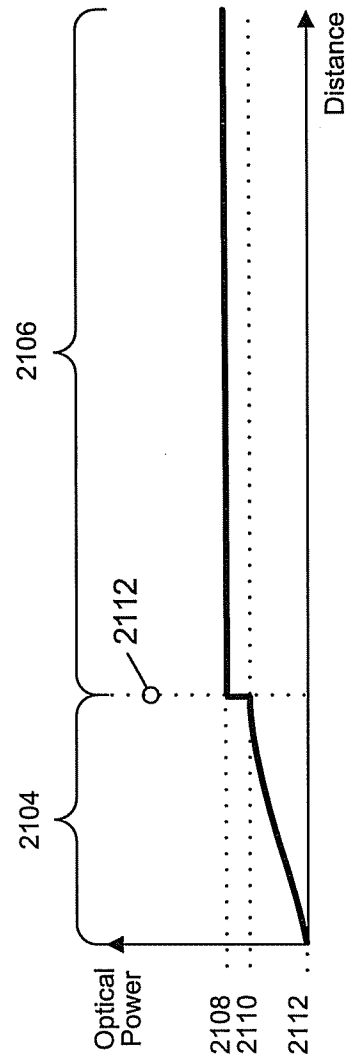


FIG. 21A

2102 →

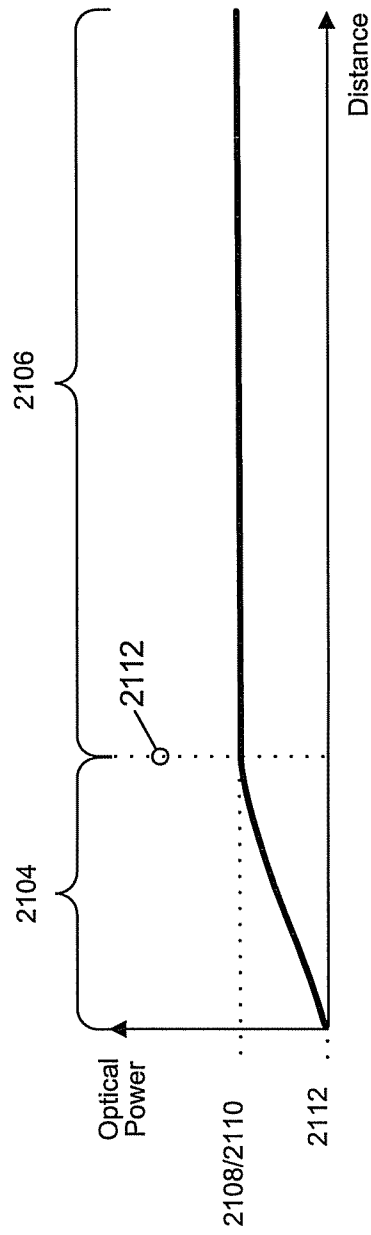


FIG. 21B

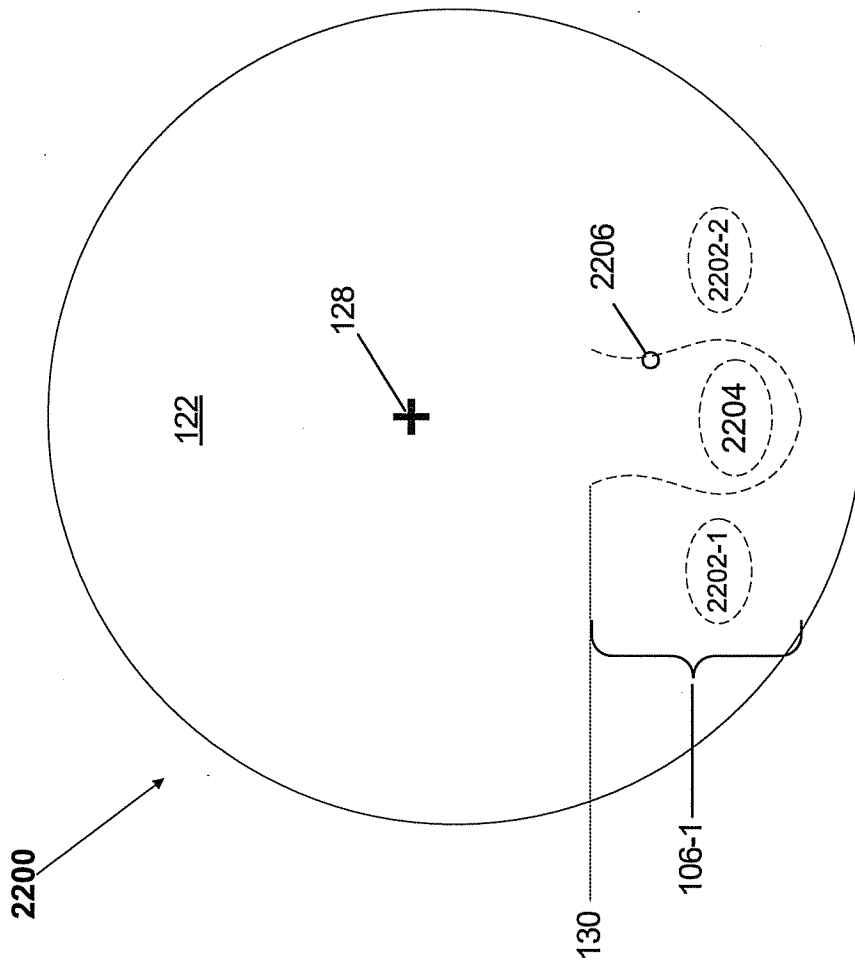


FIG. 22A

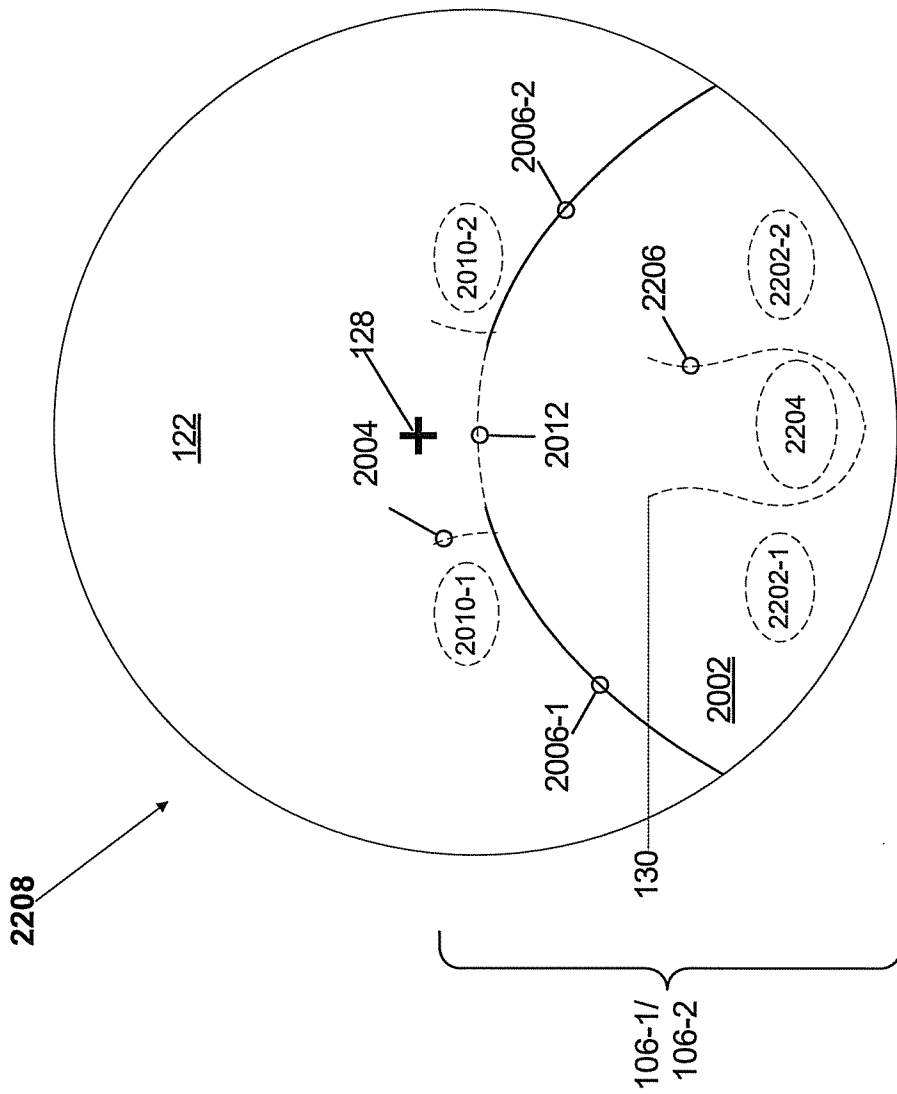


FIG. 22B

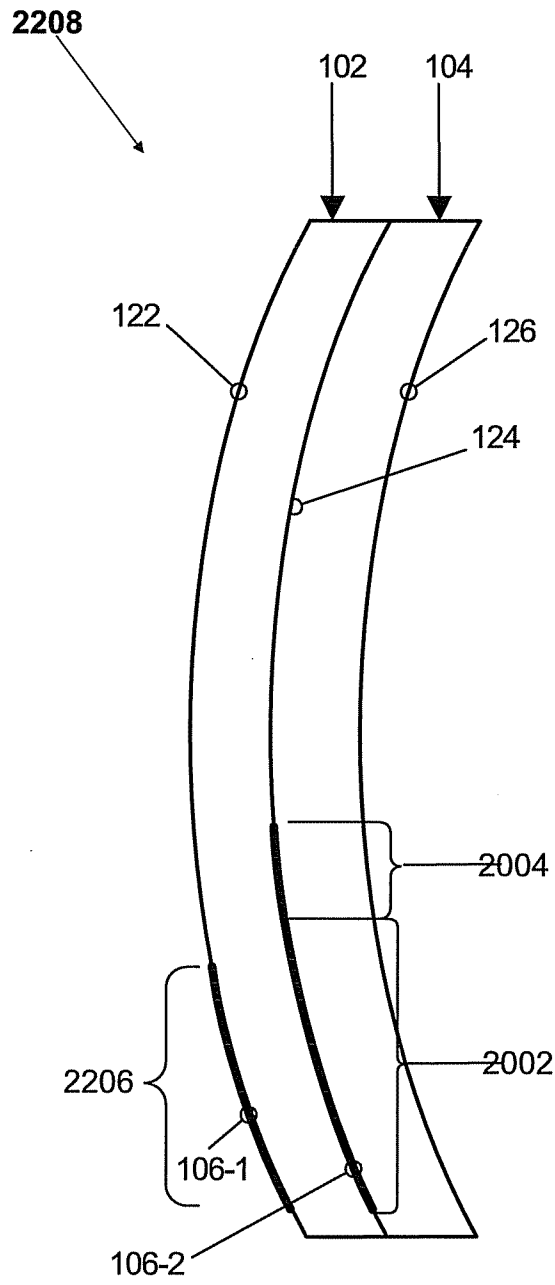


FIGURE 22C

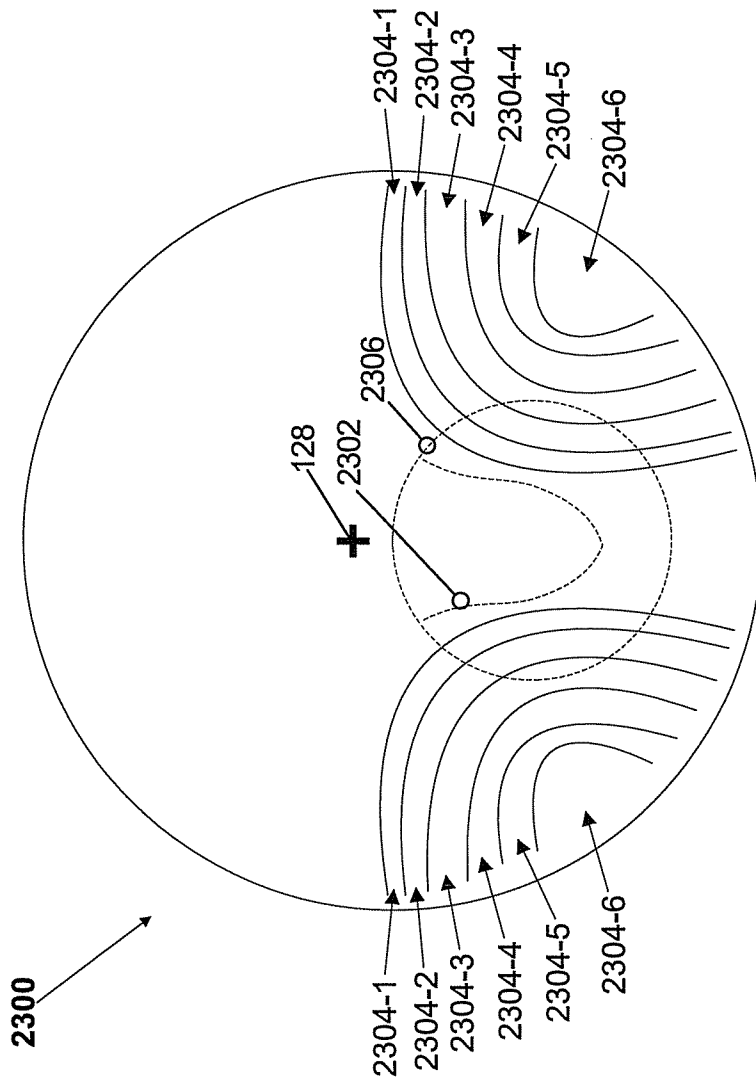


FIG. 23A

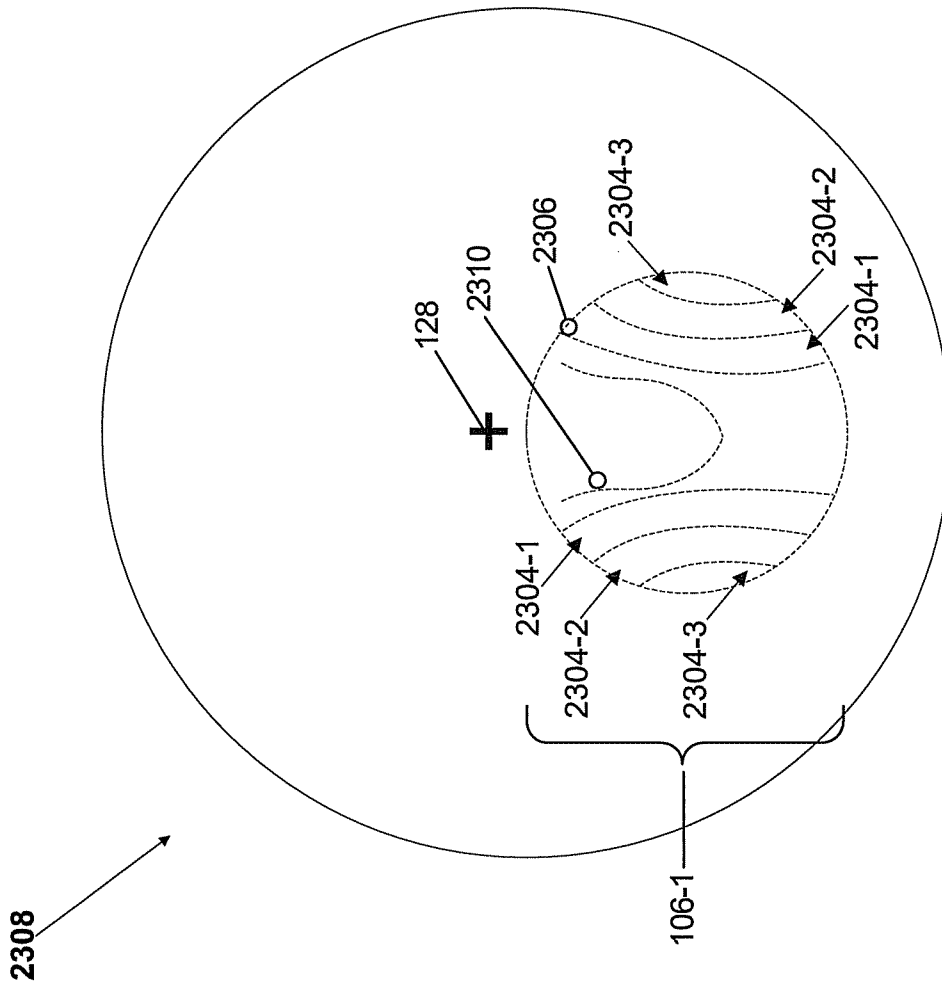


FIG. 23B

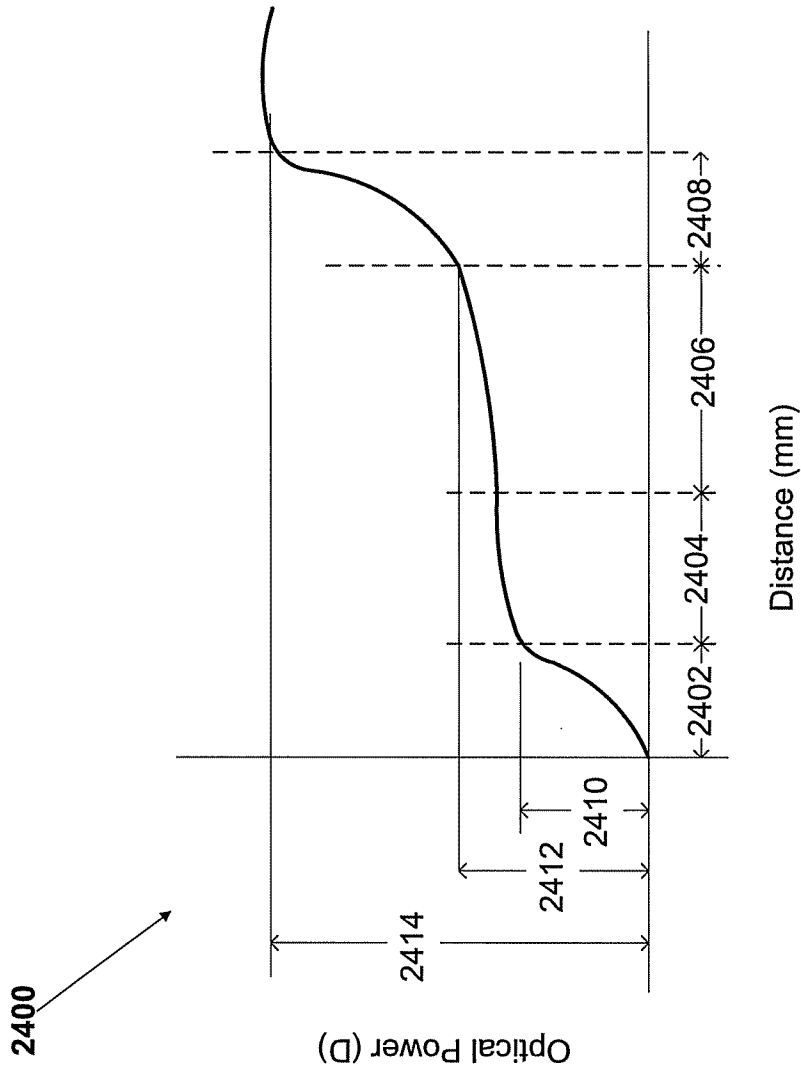


Figure 24

INTERNATIONAL SEARCH REPORT

International application No. PCT/US 09/32086
--

A. CLASSIFICATION OF SUBJECT MATTER
 IPC(8) - G02C 7/06 (2009.01)
 USPC - 351/168
 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)
 351/168

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
 351/159; 351/165; 351/166; 351/168; 351/172; 359/642

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 PubWEST(USPT,PGPB,EPAB,JPAB); Google Scholar; Google Patents
 Search Terms Used: lens, contacts, incremental, progressive, constant, discontinuities, distance, multi-focal, bi-focal, refractive, spherical, aspheric, refraction, intermediate, near

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ----- Y	US 4,062,629 A (WINTHROP) 13 December 1977 (13.12.1977), entire document especially Fig. 3, Fig. 14, col 7 ln 4-26, and col 15 ln 32-55.	1 ----- 2-12
X ----- Y	US 6,086,203 A (BLUM et al.) 11 July 2000 (11.07.2000), entire document especially Fig. 2-7, Fig. 9a, Fig. 10a, col 2 ln 1 -24, col 3 ln 31-51, col 5 ln 23-67, col 6 ln 69-67, and col 7 ln 1-49.	13 ----- 2-12

Further documents are listed in the continuation of Box C.

* 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
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"&" document member of the same patent family
"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 03 March 2009 (03.03.2009)	Date of mailing of the international search report 13 MAR 2009
---	--

Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774
---	--