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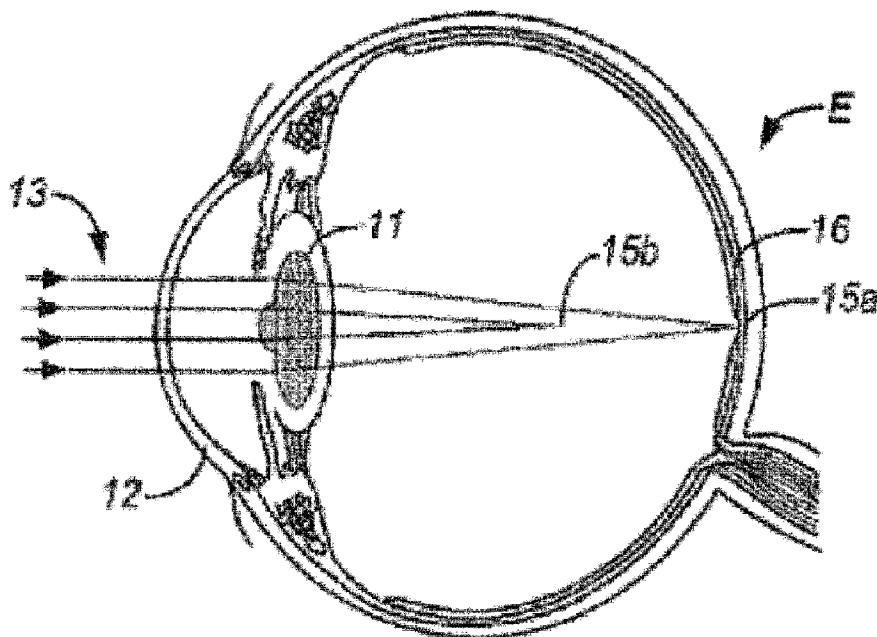
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(54) Titre : LENTILLES INTRAOCULAIRES DE TRAITEMENT CONTRE LA PRESBYTIE
(54) Title: INTRAOCULAR LENSES FOR PRESBYOPIA TREATMENT

FIG. 1A



(57) **Abrégé/Abstract:**

Apparatuses, systems and methods for providing improved ophthalmic lenses, particularly intraocular lenses (IOLs), include features for reducing dysphotopsia effects, such as haloes and glare. Exemplary ophthalmic lenses may include a central zone with a first set of two echelettes arranged around the optical axis, the first set having a profile in r-squared space. A middle zone includes a second set of two echelettes arranged around the optical axis, the second set having a profile in r-squared space that is different than the profile of the first set. A peripheral zone includes a third set of two echelettes arranged around the optical axis, the third set having a profile in r-squared space that is different than the profile of the first set and the profile of the second set, the third set being repeated in series on the peripheral zone.

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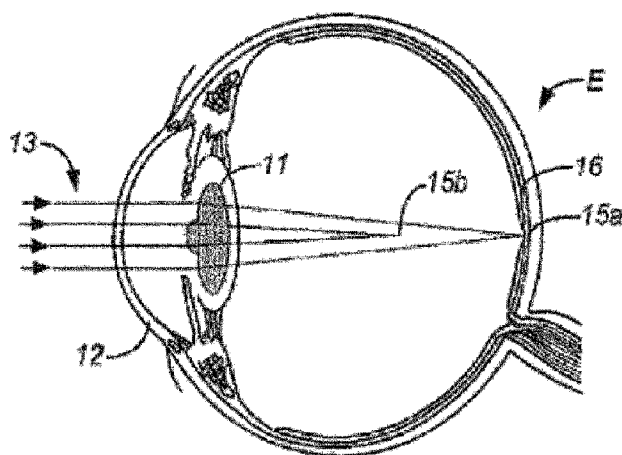
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(54) **Title:** INTRAOCULAR LENSES FOR PRESBYOPIA TREATMENT

FIG. 1A



(57) **Abstract:** Apparatuses, systems and methods for providing improved ophthalmic lenses, particularly intraocular lenses (IOLs), include features for reducing dysphotopsia effects, such as haloes and glare. Exemplary ophthalmic lenses may include a central zone with a first set of two echelettes arranged around the optical axis, the first set having a profile in r-squared space. A middle zone includes a second set of two echelettes arranged around the optical axis, the second set having a profile in r-squared space that is different than the profile of the first set. A peripheral zone includes a third set of two echelettes arranged around the optical axis, the third set having a profile in r-squared space that is different than the profile of the first set and the profile of the second set, the third set being repeated in series on the peripheral zone.



WO 2018/234552 A1

INTRAOCULAR LENSES FOR PRESBYOPIA TREATMENT

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CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of U.S. Provisional Application No. 62/524,128, filed June 23, 2017, the entire contents of which are incorporated herein by reference.

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BACKGROUND

[0002] Embodiments of the present disclosure relate generally to diffractive ophthalmic lenses, and particular embodiments provide methods, devices, and systems for mitigating or treating vision conditions such as presbyopia, often by determining a desired multifocal power profile and selecting a geometry of the diffractive profile that results in a diffractive lens shape according to the desired power profile and to various parameters of the patient's eye. Embodiments also relate to vision treatment techniques and in particular embodiments, to ophthalmic lenses such as, for example, contact lenses, corneal inlays or onlays, or intraocular lenses (IOLs) including, for example, phakic IOLs and piggyback IOLs (i.e. IOLs implanted in an eye already having an IOL).

[0003] Presbyopia is a condition that affects the accommodation properties of the eye. As objects move closer to a young, properly functioning eye, the effects of ciliary muscle contraction and zonular relaxation allow the lens of the eye to change shape, and thus increase its optical power and ability to focus at near distances. This accommodation can allow the eye to focus and refocus between near and far objects.

[0004] Presbyopia normally develops as a person ages, and is associated with a natural progressive loss of accommodation. The presbyopic eye often loses the ability to rapidly and easily refocus on objects at varying distances. The effects of presbyopia usually become noticeable after the age of 45 years. By the age of 65 years, the crystalline lens has often lost almost all elastic properties and has only limited ability to change shape.

[0005] Along with reductions in accommodation of the eye, age may also induce clouding of the lens due to the formation of a cataract. A cataract may form in the hard central nucleus of the lens, in the softer peripheral cortical portion of the lens, or at the back of the lens. Cataracts can be treated by the replacement of the cloudy natural lens with an artificial lens. An artificial lens
5 replaces the natural lens in the eye, with the artificial lens often being referred to as an intraocular lens or “IOL”.

[0006] Multifocal IOLs may, for example, rely on a diffractive optical surface to direct portions of the light energy toward differing focal distances, thereby allowing the patient to clearly see both near and far objects. Multifocal ophthalmic lenses (including contact lenses or
10 the like) have also been proposed for treatment of presbyopia without removal of the natural crystalline lens. Diffractive optical surfaces, either monofocal or multifocal, may also be configured to provide reduced chromatic aberration.

[0007] Diffractive monofocal and multifocal lenses can make use of a material having a given refractive index and a surface curvature which provide a refractive power. Diffractive lenses
15 have a diffractive profile which confers the lens with a diffractive power that contributes to the overall optical power of the lens. The diffractive profile is typically characterized by a number of diffractive zones. When used for ophthalmic lenses these diffractive zones are typically annular lens zones, or echelettes, spaced about the optical axis of the lens. Each echelette may be defined by an optical zone, a transition zone between the optical zone and an optical zone of
20 an adjacent echelette, and echelette geometry. The echelette geometry includes an inner and outer diameter and a shape or slope of the optical zone, a height or step height, and a shape of the transition zone. The surface area or diameter of the echelettes largely determines the diffractive power(s) of the lens and the step height of the transition between echelettes largely determines the light distribution between the different add powers. Together, these echelettes form a
25 diffractive profile.

[0008] A multifocal diffractive profile of the lens may be used to mitigate presbyopia by providing two or more optical powers; for example, one for near vision and one for far vision. The lenses may also take the form of an intraocular lens placed within the capsular bag of the eye, replacing the original lens, or placed in front of the natural crystalline lens. The lenses may

be in the form of a contact lens, most commonly a bifocal contact lens, or in any other form mentioned herein.

[0009] Multifocal (e.g. diffractive) intraocular lenses (IOLs) are intended to provide a patient with improved vision at different distances, such as near, intermediate and far. The near vision may generally correspond to vision provided when objects are at a distance of equal or less than 1.5 feet from a subject eye. Intermediate vision may generally correspond to vision for objects at a distance between about 1½ feet and about 5-6 feet from a subject eye. Far vision may generally correspond to vision for objects at any distance greater than about 5-6 feet from a subject eye. Such characterizations of near, intermediate, and far vision correspond to those addressed in Morlock R, Wirth RJ, Tally SR, Garufis C, Heichel CWD, Patient-Reported Spectacle Independence Questionnaire (PRSIQ): Development and Validation. Am J Ophthalmology 2017; 178:101-114.

[0010] Since multifocal IOLs provide multiple focal lengths, the focused image on the retina originating from the focal length that corresponds to the particular viewing distance is overlapping with unfocused images originating from the other focal lengths. This can create visual artifacts for the patient. Furthermore, conventional approaches typically provide for near and far vision, but achieve unsatisfactory visual performance at intermediate distances. Relatedly, increasing the number of focal lengths in an IOL can exacerbate the aforementioned visual artifacts. Therefore, multifocal conventional ophthalmic approaches may fail to adequately improve visual performance at intermediate distances.

BRIEF SUMMARY

[0011] Embodiments herein described include an ophthalmic lens with a first surface and a second surface disposed about an optical axis, and a diffractive profile imposed on one of the first surface or the second surface. The diffractive profile may include a central zone, a peripheral zone, and a middle zone positioned between the central zone and the peripheral zone. The central zone may include a first set of two echelettes arranged around the optical axis, the first set having a profile in r-squared space, the first set being repeated in series at least once on the central zone. The middle zone may include a second set of two echelettes arranged around the optical axis, the second set having a profile in r-squared space that is different than the profile of the first set. The peripheral zone may include a third set of two echelettes arranged around the

optical axis, the third set having a profile in r-squared space that is different than the profile of the first set and the profile of the second set, the third set being repeated in series at least once on the peripheral zone.

[0012] Embodiments herein described include an ophthalmic lens including a first surface and a second surface disposed about an optical axis. A diffractive profile is imposed on one of the first surface or the second surface. The diffractive profile includes a first set of two echelettes arranged around the optical axis, the first set having a profile in r-squared space, the first set being repeated to form a first repeated set. The diffractive profile includes a second set of two echelettes arranged around the optical axis, the second set being adjacent the first repeated set, the second set having a profile in r-squared space that is different than the profile of the first set. The diffractive profile includes a third set of two echelettes arranged around the optical axis, the third set being adjacent the second set, the third set having a profile in r-squared space that is different than the profile of the first set and the profile of the second set, the third set being repeated to form a second repeated set.

[0013] Embodiments herein described include an ophthalmic lens including a first surface and a second surface disposed about an optical axis. A diffractive profile is imposed on one of the first surface or the second surface. The diffractive profile includes a central zone and a peripheral zone. The central zone includes a first set of two echelettes arranged around the optical axis, the first set having a profile in r-squared space, the first set being repeated in series at least once on the central zone. The peripheral zone includes a second set of two echelettes arranged around the optical axis, the second set having a profile in r-squared space that is different than the profile of the first set, the second set being repeated in series at least once on the peripheral zone.

[0014] Embodiments herein described also include manufacturing systems for making an ophthalmic lens. Such manufacturing system can include an input that accepts an ophthalmic lens prescription for a patient eye. A first module is configured to generate a diffractive profile based on the ophthalmic lens prescription. The diffractive profile includes a central zone, a peripheral zone, and a middle zone positioned between the central zone and the peripheral zone. The central zone includes a first set of two echelettes arranged around an optical axis, the first set having a profile in r-squared space, the first set being repeated in series at least once on the

central zone. The middle zone includes a second set of two echelettes arranged around the optical axis, the second set having a profile in r-squared space that is different than the profile of the first set. The peripheral zone includes a third set of two echelettes arranged around the optical axis, the third set having a profile in r-squared space that is different than the profile of the first set and the profile of the second set, the third set being repeated in series at least once on the peripheral zone. The manufacturing system includes a manufacturing assembly that fabricates the ophthalmic lens based on the diffractive profile.

[0015] Embodiments herein described also include manufacturing systems for making an ophthalmic lens. Such manufacturing system can include an input that accepts an ophthalmic lens prescription for a patient eye. A first module is configured to generate a diffractive profile based on the ophthalmic lens prescription. The diffractive profile includes a central zone and a peripheral zone. The central zone includes a first set of two echelettes arranged around an optical axis, the first set having a profile in r-squared space, the first set being repeated in series at least once on the central zone. The peripheral zone includes a second set of two echelettes arranged around the optical axis, the second set having a profile in r-squared space that is different than the profile of the first set, the second set being repeated in series at least once on the peripheral zone. The manufacturing system includes a manufacturing assembly that fabricates the ophthalmic lens based on the diffractive profile.

[0016] Embodiments herein described also include methods of designing an intraocular lens. Such methods can include defining a diffractive profile and generating a diffractive lens surface based on the diffractive profile. The diffractive profile may include a central zone, a peripheral zone, and a middle zone positioned between the central zone and the peripheral zone. The central zone includes a first set of two echelettes arranged around the optical axis, the first set having a profile in r-squared space, the first set being repeated in series at least once on the central zone. The middle zone includes a second set of two echelettes arranged around the optical axis, the second set having a profile in r-squared space that is different than the profile of the first set. The peripheral zone includes a third set of two echelettes arranged around the optical axis, the third set having a profile in r-squared space that is different than the profile of the first set and the profile of the second set, the third set being repeated in series at least once on the peripheral zone.

[0017] Embodiments herein described also include methods of designing an intraocular lens. Such methods can include defining a diffractive profile and generating a diffractive lens surface based on the diffractive profile. The diffractive profile may include a central zone and a peripheral zone. The central zone includes a first set of two echelettes arranged around an optical axis, the first set having a profile in r-squared space, the first set being repeated in series at least once on the central zone. The peripheral zone includes a second set of two echelettes arranged around the optical axis, the second set having a profile in r-squared space that is different than the profile of the first set, the second set being repeated in series at least once on the peripheral zone.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIG. 1A illustrates a cross-sectional view of an eye with an implanted multifocal refractive intraocular lens;

[0019] FIG. 1B illustrates a cross-sectional view of an eye having an implanted multifocal diffractive intraocular lens;

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[0020] FIG. 2A illustrates a front view of a diffractive multifocal intraocular lens;

[0021] FIG. 2B illustrates a cross-sectional view of a diffractive multifocal intraocular lens;

[0022] FIGS. 3A and 3B are graphical representations of a portion of the diffractive profile of a conventional diffractive multifocal lens;

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[0023] FIG. 4 illustrates a cross-sectional view of an eye having an implanted multifocal diffractive intraocular lens having a far, a near, and an intermediate focal length;

[0024] FIG. 5 is a graphical representation illustrating a lens profile for a diffractive lens according to certain embodiments of this disclosure;

[0025] FIG. 6 is a graphical representation illustrating a lens profile for a diffractive lens according to certain embodiments of this disclosure;

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[0026] FIG. 7 is a simplified block diagram illustrating a system for generating a diffractive lens surface, in accordance with embodiments;

[0027] FIG. 8 illustrates an example process for generating a diffractive lens surface; and

[0028] FIG. 9 illustrates an example computing environment for facilitating the systems and processes of FIGS. 7 and 8.

DETAILED DESCRIPTION

[0029] Contemporary Lens Shapes and Diffractive Profiles

5 [0030] FIGS. 1A, 1B, 2A, 2B, 3A, and 3B, illustrate multifocal IOL lens geometries, aspects of which are described in U.S. Patent Publication No. 2014-0168602 A1 and U.S. Patent Publication No. 2011-0149236 A1, which are hereby incorporated by reference in their entireties.

10 [0031] FIG. 1A is a cross-sectional view of an eye E fit with a multifocal IOL 11. As shown, multifocal IOL 11 may, for example, comprise a bifocal IOL. Multifocal IOL 11 receives light from at least a portion of cornea 12 at the front of eye E and is generally centered about the optical axis of eye E. For ease of reference and clarity, FIGS. 1A and 1B do not disclose the refractive properties of other parts of the eye, such as the corneal surfaces. Only the refractive and/or diffractive properties of the multifocal IOL 11 are illustrated.

15 [0032] Each major face of lens 11, including the anterior (front) surface and posterior (back) surface, generally has a refractive profile, e.g. biconvex, plano-convex, plano-concave, meniscus, etc. The two surfaces together, in relation to the properties of the surrounding aqueous humor, cornea, and other optical components of the overall optical system, define the effects of the lens 11 on the imaging performance by eye E. Conventional, monofocal IOLs have a refractive
20 power based on the refractive index of the material from which the lens is made, and also on the curvature or shape of the front and rear surfaces or faces of the lens.

[0033] Multifocal lenses may optionally also make special use of the refractive properties of the lens. Such lenses generally include different powers in different regions of the lens so as to mitigate the effects of presbyopia. For example, as shown in FIG. 1A, a perimeter region of
25 refractive multifocal lens 11 may have a power which is suitable for viewing at far viewing distances. The same refractive multifocal lens 11 may also include an inner region having a higher surface curvature and a generally higher overall power (sometimes referred to as a positive add power) suitable for viewing at near distances.

[0034] Rather than relying entirely on the refractive properties of the lens, multifocal diffractive IOLs or contact lenses can also have a diffractive power, as illustrated by the IOL 18 shown in FIG. 1B. The diffractive power can, for example, comprise positive or negative power, and that diffractive power may be a significant (or even the primary) contributor to the overall optical power of the lens. The diffractive power is conferred by a plurality of concentric diffractive zones which form a diffractive profile. The diffractive profile may either be imposed on the anterior face or posterior face or both.

[0035] The diffractive profile of a diffractive multifocal lens directs incoming light into a number of diffraction orders. As light enters from the front of the eye, the multifocal lens 18 directs light to form a far field focus 15a on retina for viewing distant objects and a near field focus 15b for viewing objects close to the eye. Depending on the distance from the source of light 13, the focus on retina 16 may be the near field focus 15b instead. Typically, far field focus 15a is associated with 0th diffractive order and near field focus 15b is associated with the 1st diffractive order, although other orders may be used as well as seen in embodiments below.

[0036] Bifocal ophthalmic lens 18 typically distributes the majority of light energy into two viewing orders, often with the goal of splitting imaging light energy between the 2 viewing orders about evenly (50%:50%), one viewing order corresponding to far vision and one viewing order corresponding to near vision, although typically, some fraction goes to non-viewing orders.

[0037] Corrective optics may be provided by phakic IOLs, which can be used to treat patients while leaving the natural lens in place. Phakic IOLs may be angle supported, iris supported, or sulcus supported. The phakic IOL can be placed over the natural crystalline lens or piggy-backed over another IOL. It is also envisioned that the present disclosure may be applied to inlays, onlays, accommodating IOLs, spectacles, and even laser vision correction.

[0038] FIGS. 2A and 2B show aspects of a conventional diffractive multifocal lens 20. Multifocal lens 20 may have certain optical properties that are generally similar to those of multifocal IOLs 11, 18 described above. Multifocal lens 20 has an anterior lens face 21 and a posterior lens face 22 disposed about optical axis 24.

[0039] When fitted onto the eye of a subject or patient, the optical axis of lens 20 is generally aligned with the optical axis of eye E. The curvature of lens 20 gives lens 20 an anterior

refractive profile and a posterior refractive profile. Although a diffractive profile may also be imposed on either anterior face 21 and posterior face 22 or both, FIG. 2B shows posterior face 22 with a diffractive profile. The diffractive profile is characterized by a plurality of annular diffractive zones or echelettes 23 spaced about optical axis 24. While analytical optics theory generally assumes an infinite number of echelettes, a standard multifocal diffractive IOL typically has at least 9 echelettes, and may have over 30 echelettes. For the sake of clarity, FIG. 2B shows only 4 echelettes. Typically, an IOL is biconvex, or possibly plano-convex, or convex-concave, although an IOL could be plano-plano, or other refractive surface combinations.

[0040] FIGS. 3A and 3B are graphical representations of a portion of a typical diffractive profile of a multifocal lens. While the graph shows only 3 echelettes, typical diffractive lenses extend to at least 9 echelettes to over 32 echelettes. In FIG. 3A, the height 32 of the surface relief profile (from a plane perpendicular to the light rays) of each point on the echelette surface is plotted against the square of the radial distance (r^2 or ρ) from the optical axis of the lens (referred to as r-squared space). In multifocal lenses, each echelette 23 may have a diameter or distance from the optical axis which is often proportional to $\sqrt{n}$, n being the number of the echelette 23 as counted from optical axis 24. Each echelette has a characteristic optical zone 30 and transition zone 31. Optical zone 30 typically has a shape or downward slope that is parabolic as shown in FIG. 3B. The slope of each echelette in r-squared space (shown in FIG. 3A), however, is the same. As for the typical diffractive multifocal lens, as shown here, all echelettes have the same surface area. The area of echelettes 23 determines the diffractive power of lens 20, and, as area and radii are correlated, the diffractive power is also related to the radii of the echelettes. The physical offset of the trailing edge of each echelette to the leading edge of the adjacent echelette is the step height. An exemplary step height between adjacent echelettes is marked as reference number 33 in FIG. 3A. The step heights remain the same in r-squared space (FIG. 3A) and in linear space (FIG. 3B). The step offset is the height offset of the transition zone from the underlying base curve. An exemplary step offset is marked as reference number 526 in FIG. 5.

[0041] Conventional multifocal diffractive lenses typically provide for near and far vision, neglecting visual performance at intermediate distances. It is possible to produce a lens having a

far focal length, an intermediate focal length and a near focal length by having repeated sets of two echelettes that focus light to different focal lengths. This can help to improve the visual performance at intermediate distances. However, as the number of optical zones increases, the risk of visual artifacts also increases. For example, in a trifocal diffractive lens having near, intermediate, and far focal lengths, light from the near focal length may be visible, albeit out of focus, to a user looking at an object in the intermediate or far distance.

[0042] FIG. 4 shows a diffractive multifocal IOL 30 having a third, intermediate focal length 15c. The addition of the third, intermediate focal length 15c can increase the performance of the IOL 30 for users by providing improved visual acuity at the intermediate distances, i.e. for viewing objects in the range of about 1.5 feet to about 5-6 feet from the eye. The diffractive profile of the diffractive multifocal IOL 30 may be configured to possess additional focal lengths beyond the near focal length and far focal lengths described above.

[0043] FIG. 5 shows a graphical representation illustrating an embodiment of a diffractive profile 500. The diffractive profile 500 may result in a lens having at least two foci, and may include a lens having at least three foci (a trifocal lens). The foci may include a near, a far, and an intermediate focus.

[0044] The diffractive profile 500, in the form of a sag profile, is shown extending outward from an optical axis 502. The diffractive zones, or echelettes, are shown extending radially outward from the optical axis 502, and would be arranged around the optical axis 502 (the other half of the diffractive profile 500 is not shown). The diffractive profile 500 is shown relative to the Y axis 504, which represents the height or phase shift of the diffractive profile 500. The height is shown in units of micrometers, and may represent the distance from the base curve of the lens. In other embodiments, other units or scalings may be utilized.

[0045] The height or phase shift of the diffractive profile 500 is shown in relation to the radius on the X axis 506 from the optical axis 502. The radius is shown in units of millimeters, although in other embodiments, other units or scalings may be utilized. The diffractive profile 500 may extend outward from the optical axis 502 for a radius of 3.0 millimeters (diameter of 6.0 millimeters), although in other embodiments the diffractive profile 500 may extend for a lesser or greater radius.

[0046] The diffractive profile 500 includes three sets 508, 510, 512 of diffractive zones or echelettes. The three sets 508, 510, 512 include a first set 508 positioned at a central zone 514 of the lens. The first set 508 may be repeated once on the central zone 514 (to form two first sets 508 on the central zone). The second set 510 is positioned at a middle zone 516 of the lens. The third set 512 is positioned at a peripheral zone 518 of the lens. The third set 512 may be repeated in series on the peripheral zone 518.

[0047] The first set 508 is adjacent the optical axis 502. The first set 508 includes two diffractive zones or echelettes 520a, 522a. The echelettes 520a, 522a are connected by a transition zone 524a having a step height and a step offset (marked with reference number 526). Each of the echelettes 520a, 522a of the first set may be configured to have a different profile than each other.

[0048] The first set 508 has a profile defined by the shape or slope of the echelettes 520a, 522a, and the step height and step offsets (as discussed previously) at the transition zone 524a, and the height of the first echelette 520a at the optical axis 502, and the height of the trailing end of second echelette 522a at the transition zone 528. The first echelette 520a of the first set 508 has a negative slope extending from its leading end to its trailing edge or end at the transition zone 524a. The trailing end has a height corresponding to the step offset at the transition zone 524a. The leading end of the second echelette 522a is separated from the trailing end of the first echelette 520a by the step height corresponding to the transition zone 524a.

[0049] The second echelette 522a extends from its leading end to the trailing end at transition zone 528 and has a negative slope. The slope of the second echelette 522a may be different than the slope of the first echelette 520a.

[0050] The profiles of each of the echelettes 520a, 522a, are different from each other. The different profiles are due to the differing step heights, step offsets, and slopes of each echelette 520a, 522a. In r-squared space (discussed previously), the profiles of the echelettes 520a, 522a, are different from each other, due to the differing step heights, step offsets, and slopes of each echelette 520a, 522a.

[0051] The first set 508 may be disposed twice in series on the central zone 514. The first set 508 may be repeated to form a repeated set 530 on the central zone 514. The other first set may

include echelettes 520b, 522b, and transition zone 524b. The first set 508 may connect to the other first set at transition zone 528. The other first set may have the same profile at the first set 508 in r-squared space.

[0052] Using the scaling shown in FIG. 5, the repeated first set 530, and the central zone 514, may end at the radial distance of about 1.1 millimeters.

[0053] The second set 510 may be adjacent the repeated first set 530. The second set 510 includes two diffractive zones or echelettes 532, 534. The echelettes 532, 534 may be connected by a transition zone 536 having a step height and step offset. The second set 510 may occur once on the middle zone 516 (and the optical surface overall), and thus may not be repeated on the middle zone 516. The second set 510 may connect to the repeated first set 530 via the transition zone 538.

[0054] The second set 510 has a profile defined by the shape or slope of the echelettes 532, 534, and the step height and step offsets (as discussed previously) at the transition zones 536, 538, and the height of the trailing end of second echelette 534 at the transition zone 540. The first echelette 532 of the second set 510 has a negative slope extending from its leading end to its trailing edge or end at the transition zone 536. The trailing end has a height corresponding to the step offset at the transition zone 536. The leading end of the second echelette 534 is separated from the trailing end of the first echelette 532 by the step height corresponding to the transition zone 536.

[0055] The second echelette 534 extends from its leading end to the trailing end at transition zone 540 and has a negative slope. The slope of the second echelette 534 may be different than the slope of the first echelette 532.

[0056] The profiles of each of the echelettes 532, 534, are different from each other. The different profiles are due to the differing step heights, step offsets, and slopes of each echelette 532, 534. In r-squared space (discussed previously), the profiles of the echelettes 532, 534, are different from each other, due to the differing step heights, step offsets, and slopes of each echelette 532, 534.

[0057] The profile of the second set 510 is different than the profile of the first set 508. The different profiles are due to the differing step heights, step offsets, and slopes of the echelettes

within the respective set 508, 510. In r-squared space, the profile of the second set 510 is different than the profile of the first set 508 due to the differing step heights, step offsets, and slopes of the echelettes within the respective set 508, 510.

[0058] Using the scaling shown in FIG. 5, the second set 510, and the central zone 516, may end at the radial distance of about 1.25 millimeters.

[0059] The third set 512 may be adjacent the second set 510. The third set 512 includes two diffractive zones or echelettes 542a, 544a.

[0060] The echelettes 542a, 544a may be connected by a transition zone 546a having a step height and step offset. The third set 512 may connect to the second set 510 via the transition zone 540.

[0061] The third set 512 has a profile defined by the shape or slope of the echelettes 542a, 544a, and the step height and step offsets (as discussed previously) at the transition zones 540, 546a, and the height of the trailing end of second echelette 544a at the transition zone 548. The first echelette 542a of the third set 512 has a negative slope extending from its leading end to its trailing edge or end at the transition zone 546a. The trailing end has a height corresponding to the step offset at the transition zone 546a. The leading end of the second echelette 544a is separated from the trailing end of the first echelette 542a by the step height corresponding to the transition zone 546a.

[0062] The second echelette 544a extends from its leading end to the trailing end at transition zone 548 and has a negative slope. The slope of the second echelette 544a may be different than the slope of the first echelette 542a.

[0063] The profiles of each of the echelettes 542a, 544a are different from each other. The different profiles are due to the differing step heights, step offsets, and slopes of each echelette 542a, 544a. In r-squared space (discussed previously), the profiles of the echelettes 542a, 544a, are different from each other, due to the differing step heights, step offsets, and slopes of each echelette 542a, 544a.

[0064] The profile of the third set 512 is different than the profile of the first set 508 and the profile of the second set 510. The different profiles are due to the differing step heights, step

offsets, and slopes of the echelettes within the respective set 508, 510, 512. In r-squared space, the profile of the third set 512 is different than the profile of the first set 508 and the second set 510 due to the differing step heights, step offsets, and slopes of the echelettes within the respective set 508, 510, 512. Notably, the third set 512 includes step offsets that are greater than
 5 either the first set 508 or the second set 510.

[0065] The third set 512 may be repeated in series on the peripheral zone 518. The third set 512 may be repeated multiple times in series on the peripheral zone 518. The third set 512 may be repeated to form a repeated set 550 on the peripheral zone 518. An adjacent third set may include echelettes 542b, 544b, and transition zone 546b. The adjacent third set may connect to
 10 the third set 512 at transition zone 548. The adjacent third set may have the same profile as the third set 512 in r-squared space. The third sets may be repeated to form twelve sets, as shown in FIG. 5, and in other embodiments may be repeated a greater or lesser number of times.

[0066] Using the scaling shown in FIG. 5, the repeated third set 550, and the peripheral zone 518, may end at the radial distance of about 3 millimeters.

[0067] The first set 508 repeats in series once. The optical characteristics of the repeated first set may be defined by at least three diffractive orders corresponding to at least three diffractive powers. The repeated first set may produce three diffractive orders that are useful for a patient's vision, corresponding to three diffractive powers that are useful for a patient's vision. The diffractive orders may include a 0th order and orders 1st through 4th. The orders 2nd through 4th
 20 may be useful for a patient's vision. The 0th and 1st orders may be hyperopic (beyond far).

[0068] The repeated first set may distribute light to three diffractive orders, with the following light distribution of incident light to each of the three diffractive orders, and the diffractive power shown in Table 1 below:

Diffractive order	Diffractive power	Light distribution
2 nd	4.0D (Far)	36%
3 rd	6.0 D (2 D add)	23%
4 th	8.0D (4 D add)	26%

TABLE 1

[0069] The repeated first set may result in a light distribution with more than 20% of incident light distribution toward a first diffractive power, and more than 20% of incident light distribution towards a second diffractive power. The first diffractive power may be between about 1.75 and 2.25 diopter, and the second diffractive power may be between about 3.75 and 4.25 diopter. The first diffractive power may correspond to a 3rd diffractive order and the second diffractive power may correspond to a 4th diffractive order.

[0070] In one embodiment, the first set 508 may be repeated at least once on the central zone 514.

[0071] The second set 510 does not repeat. If the second set 510 were to repeat, then the optical characteristics may be defined by at least three diffractive orders corresponding to at least three diffractive powers. The repeated second set 510 may produce three diffractive orders that are useful for a patient's vision, corresponding to three diffractive powers that are useful for a patient's vision. The diffractive orders may include a 0th order and orders 1st through 4th. The orders 2nd through 4th may be useful for a patient's vision. The 0th and 1st orders may be hyperopic (beyond far).

[0072] If the second set 510 were to repeat, the repeated second set 510 may distribute light to three diffractive orders, with the following light distribution of incident light to each of the three diffractive orders, and the diffractive power shown in Table 2 below:

Diffractive order	Diffractive power	Light distribution
2 nd	4D (Far)	41%
3 rd	6D (2D add)	15%
4 th	8D (4D addd)	28%

TABLE 2

[0073] In one embodiment, the second set 510 may be repeated at least once.

[0074] The third set 512 repeats to form a repeated set. The optical characteristics of the repeated third set may be defined by at least three diffractive orders corresponding to at least three diffractive powers. The repeated third set may produce three diffractive orders that are useful for a patient's vision, corresponding to three diffractive powers that are useful for a patient's vision. The diffractive orders may include a 0th order and orders 1st through 4th. The

orders 2nd through 4th may be useful for a patient's vision. The 0th and 1st orders may be hyperopic (beyond far).

[0075] The repeated third set may distribute light to three diffractive orders, with the following light distribution of incident light to each of the three diffractive orders, and the diffractive power shown in Table 3 below:

Diffractive order	Diffractive power	Light distribution
2 nd	4D (Far)	88%
3 rd	6D (2D add)	1%
4 th	8D (4D add)	4%

TABLE 3

[0076] The repeated third set may be configured to result in a light distribution with less than 2% of incident light distribution toward a first diffractive power, and less than 5% of incident light distribution toward a second diffractive power. The first diffractive power may be between about 1.75 and 2.25 diopter, and the second diffractive power may be between about 3.75 and 4.25 diopter. The first diffractive power may correspond to a 3rd diffractive order, and the second diffractive power may correspond to a 4th diffractive order.

[0077] In one embodiment, the third set 512 may be repeated at least once on the peripheral zone 518.

[0078] The diffractive powers and light distributions listed in each of Tables 1, 2, and 3 may vary to an amount that is "about" the listed amount. In other embodiments, the diffractive orders, powers and light distributions, listed in each of Tables 1, 2, and 3 may be varied as desired.

[0079] The add power listed in Tables 1-3 corresponds to 4 diopter of near add power and 2 diopter of intermediate add power. As such, the "Far" power by itself constitutes 4 diopter of diffractive power. This feature may provide improved correction of chromatic aberration for distance.

[0080] The diffractive powers of the lens may vary, depending on the desired performance of the design. The diffractive powers as listed in Tables 1-3 are intended for a design that provides adequate visual performance over the entire range of vision from far to intermediate distances

and near. Lower diffractive powers may be beneficial if the desired performance is to emphasize good far and intermediate vision, while vision at near distances may be slightly reduced. Such lens design may have a second diffractive add power of 0.58D, a third diffractive add power of 1.17D and a fourth diffractive add power of 1.75D. Some embodiments have diffractive add powers in-between these and those in Tables 1-3.

[0081] The combination of the repeating first set 508, non-repeating second set 510, and the repeated third set 512, may result in a diffractive profile producing at least two foci, and at least three foci, for the patient.

[0082] In one embodiment, the diffractive profile 500 may be positioned on a surface of a lens that is opposite an aspheric surface. The aspheric surface on the opposite side of the lens may be designed to reduce corneal spherical aberration of the patient.

[0083] In one embodiment, one or both optical surfaces may be aspherical, or include a refractive surface designed to extend the depth of focus, or create multifocality.

[0084] In one embodiment, a refractive zone on one or both optical surfaces may be utilized that may be the same size or different in size as one of the diffractive zones. The refractive zone includes a refractive surface designed to extend the depth of focus, or create multifocality.

[0085] FIG. 6 shows a graphical representation illustrating an embodiment of a diffractive profile 600. The diffractive profile 600 may result in a lens having at least two foci, and may include a lens having at least three foci (a trifocal lens). The foci may include a near, a far, and an intermediate focus.

[0086] The diffractive profile 600 is configured similarly as the diffractive profile 500 shown in FIG. 5. However, the diffractive profile 600 includes a second set 610 of echelettes in a middle zone 616 that has a profile in r-squared space that is substantially identical to the profile of a first set 608 of echelettes in r-squared space.

[0087] Similar to the diffractive profile 500 shown in FIG. 5, the diffractive profile 600 is shown extending outward from an optical axis 602. The diffractive profile 600 is shown relative to the Y axis 604, which represents the height or phase shift of the diffractive profile 600, and is shown in units of micrometers, and may represent the distance from the base curve of the lens.

[0088] The height or phase shift of the diffractive profile 600 is shown in relation to the radius on the X axis 606 from the optical axis 602.

[0089] The diffractive profile 600 includes three sets 608, 610, 612 of diffractive zones or echelettes. The three sets include a first set 608 positioned at a central zone 614 of the lens. The second set 610 is positioned at a middle zone 616 of the lens. The third set 612 is positioned at a peripheral zone 618 of the lens. The third set 612 may be repeated in series on the peripheral zone 618.

[0090] The first set 608 may include two diffractive zones or echelettes 620a, 622a, which may be connected by transition zone 624a. The reference number 626 represents the step offset at the transition zone 624a. The profile of the first set 608 may be the same as the profile of the first set 508 shown in FIG. 5. In addition, similar to the first set 508 shown in FIG. 5, the first set 608 may be repeated on the central zone once (to form two first sets 608 on the central zone). The repeated sets may form a repeated first set 630. The properties of the first set 608 and the repeated first set may be the same as the properties of the first set 508 and the repeated first set shown in FIG. 5. The other first set may include echelettes 620b, 622b, which may be connected by transition zone 624b. The other first set may connect to the first set 608 with transition zone 628. The first set 608 may be repeated at least once on the central zone 614.

[0091] The second set 610 may include two diffractive zones or echelettes 632, 634, which may be connected by transition zone 636. The second set 610 may be adjacent the repeated first set 608 and may be connected to the repeated first set 608 with a transition zone 638. The profile of the second set 610 in r-squared space is substantially identical to the profile of a first set 608 of echelettes in r-squared space. The step height and offset at transition zone 636 may be substantially identical to the step height and offset at transition zone 624a, and the slopes of the echelettes 632, 634 may be substantially identical to those of the echelettes 620a, 622a. In one embodiment, the second set 610 may not be repeated. In one embodiment, the second set 610 may be repeated at least once.

[0092] The third set 612 may include two diffractive zones or echelettes 642a, 644a, which may be connected by a transition zone 646a. The third set 612 may be adjacent the second set 610 and may be connected to the second set 610 with transition zone 640.

[0093] The profile of the third set 612 may be same as the profile of the third set 512 shown in FIG. 5. In addition, similar to the third set 512 shown in FIG. 5, the third set 612 may be repeated on the peripheral zone. The repeated sets may form a repeated third set 650. The properties of the third set 612 and the repeated third set may be the same as the properties of the third set 512 and the repeated third set shown in FIG. 5. One such repeated third set may include echelettes 642b, 644b, which may be connected by transition zone 646b. The third set may connect to the other third set 612 with transition zone 648. The third set 612 may be repeated at least once on the peripheral zone 618.

[0094] In one embodiment, the second set 610 may be excluded, such that only echelettes on a central zone and echelettes on a peripheral zone may be utilized in a diffractive profile. The echelettes on the central zone may be adjacent the echelettes on the peripheral zone.

[0095] In one embodiment, a diffractive profile may be configured such that the second set of echelettes in the middle zone has a profile that is the same as the second set 510 of echelettes shown in FIG. 5, and a first set of echelettes in a central zone has a profile in r-squared space that is substantially identical to the profile in r-squared space as the second set 510 of echelettes shown in FIG. 5.

[0096] The diffractive profiles disclosed herein may produce at least two foci, and at least three foci, for the patient.

[0097] The embodiments of diffractive profiles disclosed herein may be positioned on a surface of a lens that is opposite an aspheric surface. The aspheric surface on the opposite side of the lens may be designed to reduce corneal spherical aberration of the patient.

[0098] The embodiments of diffractive profiles disclosed herein may be utilized with one or both surfaces of the lens that may be aspherical, or include a refractive surface designed to extend the depth of focus, or create multifocality.

[0099] The embodiments of diffractive profiles disclosed herein may be utilized with a refractive zone on one or both surfaces of the lens, that may be the same size or different in size as one of the diffractive zones. The refractive zone includes a refractive surface designed to extend the depth of focus, or create multifocality.

[0100] Any of the embodiments of lens profiles discussed herein may be apodized to produce a desired result. The apodization may result in the step heights and step offsets of the repeated sets being varied according to the apodization. The sets, however, are still considered to be repeating sets over the optic of the lens.

5 [0101] Systems and Methods for determining lens shape:

[0102] FIG. 7 is a simplified block diagram illustrating a system 700 for generating an ophthalmic lens based on a user input.

[0103] The system 700 includes a user input module 702 configured to receive user input defining aspects of the user and of a lens. The input may accept an ophthalmic lens prescription
10 for a patient eye. Aspects of a lens may include a multifocal lens prescription, anatomical dimensions like a pupil size performance, and lens dimensions, among other attributes. A multifocal lens prescription can include, for example, a preferred optical power or optical power profile for correcting far vision and an optical power or optical power profile for near vision. In some cases, a multifocal lens prescription can further include an optical power or optical power
15 profile for correcting intermediate vision at two, or in some cases more than two intermediate foci, which may fall between the optical powers or ranges of optical powers described above. A pupil size performance can include a pupil radius of a patient and the visual field to be optimized. These parameters can also be related to patient's life style or profession, so that the design incorporates patient's visual needs as a function of the pupil size. Lens dimensions can
20 include a preferred radius of the total lens, and may further include preferred thickness, or a preferred curvature of one or the other of the anterior surface and posterior surface of the lens.

[0104] A multizonal diffractive surface modeling module 704 can receive information about the desired lens from the user input module 702, and can determine aspects of a multizonal lens. For example, the modeling module 704 can determine the shape of one or more echelettes of the
25 diffractive profile of a diffractive multifocal lens, including the positioning, width, step height, and curvature needed to fulfill the multifocal prescription for each subset of the echelettes, as well as the positioning of each subset of echelettes. The multizonal diffractive surface modeling module 704 can further determine the shapes of transition steps between echelettes. For example, transition steps may be smoothed or rounded to help mitigate optical aberrations caused
30 by light passing through an abrupt transition. Such transition zone smoothing, which may be

referred to as a low scatter profile, can provide for reductions in dysphotopsia by reducing the errant concentration of incident light behind the lens by the transition zones. By way of further example, echelette ordering, echelette offsets, and echelette boundaries may be adjusted to adjust the step heights between some adjacent echelettes. The generated diffractive profile may be any
5 of the diffractive profiles disclosed in this application.

[0105] The multizonal diffractive surface modeling module 704 can be configured to generate performance criteria 712, e.g. via modeling optical properties in a virtual environment. Performance criteria can include the match of the optical power profile of the multizonal lens with the desired optical power profile based on the extended range of vision prescription. The
10 performance criteria can also include the severity of diffractive aberrations caused by lens surface. In some cases, the multizonal surface modeling module 704 can provide a lens surface to a lens fabrication module 708 for facilitating the production of a physical lens, which can be tested via a lens testing module 710 for empirically determining the performance criteria 712, so as to identify optical aberrations and imperfections not readily discerned via virtual modeling,
15 and to permit iteration. The lens fabrication module may comprise a manufacturing assembly that may fabricate the ophthalmic lens based on the diffractive profile.

[0106] A refractive surface modeling module 706 can receive information from the user input 702 and multizonal surface modeling modules 704 in order to determine refractive aspects of the lens. For example, provided with a multifocal prescription and a set of add powers that can be
20 generated by a diffractive profile, the refractive surface modeling module 706 can provide a refractive geometry configured to provide a base power which, when combined with the diffractive surface, meets the requirements of the multifocal lens prescription. The refractive surface modeling module 706 can also generate performance criteria 712, and can contribute to providing a lens surface to a lens fabrication module 708 for facilitating the production of the
25 physical lens.

[0107] FIG. 8 is an example process 800 for generating a diffractive lens surface, in accordance with embodiments. The process 800 may be implemented in conjunction with, for example, the system 700 shown in FIG. 7. Some or all of the process 800 (or any other processes described herein, or variations, and/or combinations thereof) may be performed under
30 the control of one or more computer systems configured with executable instructions and may be

implemented as code (e.g., executable instructions, one or more computer programs, or one or more applications) executing collectively on one or more processors, by hardware or combinations thereof. The code may be stored on a computer-readable storage medium, for example, in the form of a computer program comprising a plurality of instructions executable by one or more processors. The computer-readable storage medium may be non-transitory.

[0108] The process 800 may include a method of designing an intraocular lens and may include receiving an input of an ophthalmic lens prescription, which may be a multifocal lens prescription (act 802). The input can include, e.g., a desired optical power profile for correcting impaired distance vision, a desired optical power profile for correcting impaired intermediate distance vision, a desired optical power profile for accommodating near vision, and any suitable combination of the above. Based on a desired optical power profile, a diffractive profile can be defined and generated including a central zone, a peripheral zone, and a middle zone positioned between the central zone and the peripheral zone. The generated diffractive profile may include a central zone including a first set of two echelettes arranged around the optical axis, the first set having a profile in r-squared space, the first set being repeated once in series on the central zone (act 804). The generated diffractive profile may include a middle zone including a second set of two echelettes arranged around the optical axis, the second set having a profile in r-squared space that is different than the profile of the first set (act 806). The generated diffractive profile may include a peripheral zone including a third set of two echelettes arranged around the optical axis, the third set having a profile in r-squared space that is different than the profile of the first set and the profile of the second set, the third set being repeated in series on the peripheral zone (act 808).

[0109] In one embodiment, the diffractive profile may be generated and utilized that includes a central zone and a peripheral zone. The central zone may include a first set of two echelettes arranged around an optical axis, the first set having a profile in r-squared space, the first set being repeated in series at least once on the central zone. The peripheral zone may include a second set of two echelettes arranged around the optical axis, the second set having a profile in r-squared space that is different than the profile of the first set, the second set being repeated in series at least once on the peripheral zone.

[0110] In one embodiment, the diffractive profile may include a middle zone positioned between the central zone and the peripheral zone. The middle zone may include a third set of two echelettes arranged around the optical axis, the third set having a profile in r-squared space that is substantially identical to the profile of the first set (in the central zone).

5 [0001] The diffractive lens profile of the multizonal diffractive lens surface may be used in combination with a known refractive base power. To that end, a refractive lens surface may be generated having a base power that, in combination with the diffractive lens surface, meets the multifocal lens prescription (act 810). A total lens surface can be generated based on both the refractive lens surface and the diffractive lens surface (act 812). The refractive lens surface can
10 include a refractive lens curvature on the anterior surface of the lens, the posterior surface of the lens, or both. Instructions can be generated to fabricate an intraocular lens based on the generated total lens surface (act 814). A manufacturing assembly may fabricate the ophthalmic lens based on the instructions. The methods herein are not limited to the examples of diffractive profiles discussed here, and may extend to any of the diffractive lens profiles and ophthalmic
15 lenses disclosed in this application.

[0111] Computational Methods:

[0112] FIG. 9 is a simplified block diagram of an exemplary computing environment 900 that may be used by systems for generating the the diffractive profiles and ophthalmic lenses of the present disclosure. Computer system 922 typically includes at least one processor 952 which
20 may communicate with a number of peripheral devices via a bus subsystem 954. These peripheral devices may include a storage subsystem 956 comprising a memory subsystem 958 and a file storage subsystem 960, user interface input devices 962, user interface output devices 964, and a network interface subsystem 966. Network interface subsystem 966 provides an interface to outside networks 968 and/or other devices, such as the lens fabrication module 708
25 or lens testing module 710 of FIG. 7.

[0113] User interface input devices 962 may include a keyboard, pointing devices such as a mouse, trackball, touch pad, or graphics tablet, a scanner, foot pedals, a joystick, a touchscreen incorporated into the display, audio input devices such as voice recognition systems, microphones, and other types of input devices. User input devices 962 will often be used to
30 download a computer executable code from a tangible storage media embodying any of the

methods of the present disclosure. In general, use of the term “input device” is intended to include a variety of conventional and proprietary devices and ways to input information into computer system 922.

[0114] User interface output devices 964 may include a display subsystem, a printer, a fax machine, or non-visual displays such as audio output devices. The display subsystem may be a cathode ray tube (CRT), a flat-panel device such as a liquid crystal display (LCD), a projection device, or the like. The display subsystem may also provide a non-visual display such as via audio output devices. In general, use of the term “output device” is intended to include a variety of conventional and proprietary devices and ways to output information from computer system 922 to a user.

[0115] Storage subsystem 956 can store the basic programming and data constructs that provide the functionality of the various embodiments of the present disclosure. For example, a database and modules implementing the functionality of the methods of the present disclosure, as described herein, may be stored in storage subsystem 956. These software modules are generally executed by processor 952. In a distributed environment, the software modules may be stored on a plurality of computer systems and executed by processors of the plurality of computer systems. Storage subsystem 956 typically comprises memory subsystem 958 and file storage subsystem 960. Memory subsystem 958 typically includes a number of memories including a main random access memory (RAM) 970 for storage of instructions and data during program execution and/or a read only member (ROM) 982.

[0116] Various computational methods discussed above, e.g. with respect to generating a multizonal lens surface, may be performed in conjunction with or using a computer or other processor having hardware, software, and/or firmware. The various method steps may be performed by modules, and the modules may comprise any of a wide variety of digital and/or analog data processing hardware and/or software arranged to perform the method steps described herein. The modules optionally comprising data processing hardware adapted to perform one or more of these steps by having appropriate machine programming code associated therewith, the modules for two or more steps (or portions of two or more steps) being integrated into a single processor board or separated into different processor boards in any of a wide variety of integrated and/or distributed processing architectures. These methods and systems will often

employ a tangible media embodying machine-readable code with instructions for performing the method steps described above. Suitable tangible media may comprise a memory (including a volatile memory and/or a non-volatile memory), a storage media (such as a magnetic recording on a floppy disk, a hard disk, a tape, or the like; on an optical memory such as a CD, a CD-R/W, a CD-ROM, a DVD, or the like; or any other digital or analog storage media), or the like.

WHAT IS CLAIMED IS:

1. An ophthalmic lens, comprising:
a first surface and a second surface disposed about an optical axis; and
a diffractive profile imposed on one of the first surface or the second surface, the diffractive profile including a central zone, a peripheral zone, and a middle zone positioned between the central zone and the peripheral zone, wherein:
the central zone includes a first set of two echelettes arranged around the optical axis, the first set having a profile in r-squared space, the first set being repeated in series at least once on the central zone;
the middle zone includes a second set of two echelettes arranged around the optical axis, the second set having a profile in r-squared space that is different than the profile of the first set; and
the peripheral zone includes a third set of two echelettes arranged around the optical axis, the third set having a profile in r-squared space that is different than the profile of the first set and the profile of the second set, the third set being repeated in series at least once on the peripheral zone.
2. The lens of claim 1, wherein the second set of the middle zone is repeated at least once.
3. The lens of claim 1, wherein each of the two echelettes of the first set have a different profile than each other in r-squared space.
4. The lens of claim 3, wherein each of the two echelettes of the second set have a different profile than each other in r-squared space.
5. The lens of claim 4, wherein each of the two echelettes of the third set have a different profile than each other in r-squared space.

6. The lens of claim 1, wherein the first set being repeated in series on the central zone forms a repeated set that is configured to result in a light distribution with more than 20% of incident light distribution toward a first diffractive power, and more than 20% of incident light distribution toward a second diffractive power.

7. The lens of claim 6, wherein the first diffractive power is between about 1.75 and 2.25 diopter, and the second diffractive power is between about 3.75 and 4.25 diopter.

8. The lens of claim 7, wherein the first diffractive power corresponds to a 3rd diffractive order, and the second diffractive power corresponds to a 4th diffractive order.

9. The lens of claim 1, wherein the third set being repeated in series on the peripheral zone forms a repeated set that is configured to result in a light distribution with less than 2% of incident light distribution toward a first diffractive power, and less than 5% of incident light distribution toward a second diffractive power.

10. The lens of claim 9, wherein the first diffractive power is between about 1.75 and 2.25 diopter, and the second diffractive power is between about 3.75 and 4.25 diopter.

11. The lens of claim 10, wherein the first diffractive power corresponds to a 3rd diffractive order, and the second diffractive power corresponds to a 4th diffractive order.

12. An ophthalmic lens, comprising:
a first surface and a second surface disposed about an optical axis; and
a diffractive profile imposed on one of the first surface or the second surface, the diffractive profile including:

a first set of two echelettes arranged around the optical axis, the first set having a profile in r-squared space, the first set being repeated to form a first repeated set;

a second set of two echelettes arranged around the optical axis, the second set being adjacent the first repeated set, the second set having a profile in r-squared space that is different than the profile of the first set; and

a third set of two echelettes arranged around the optical axis, the third set being adjacent the second set, the third set having a profile in r-squared space that is different than the profile of the first set and the profile of the second set, the third set being repeated to form a second repeated set.

13. The lens of claim 12, wherein the second set is repeated.

14. The lens of claim 12, wherein each of the two echelettes of the first set have a different profile than each other in r-squared space.

15. The lens of claim 12, wherein each of the two echelettes of the second set have a different profile than each other in r-squared space.

16. The lens of claim 12, wherein each of the two echelettes of the third set have a different profile than each other in r-squared space.

17. The lens of claim 12, wherein the first set is repeated once to form the first repeated set.

18. The lens of claim 12, wherein the first repeated set is configured to result in a light distribution with more than 20% of incident light distribution toward a first diffractive power, and more than 20% of incident light distribution toward a second diffractive power.

19. The lens of claim 18, wherein the first diffractive power is between about 1.75 and 2.25 diopter, and the second diffractive power is between about 3.75 and 4.25 diopter.

20. The lens of claim 19, wherein the first diffractive power corresponds to a 3rd diffractive order, and the second diffractive power corresponds to a 4th diffractive order.

21. A manufacturing system for making an ophthalmic lens, the system comprising:
an input that accepts an ophthalmic lens prescription for a patient eye;
a first module configured to generate a diffractive profile based on the ophthalmic lens prescription, wherein:

the diffractive profile includes a central zone and a peripheral zone,

the central zone includes a first set of two echelettes arranged around an optical axis, the first set having a profile in r-squared space, the first set being repeated in series at least once on the central zone, and

the peripheral zone includes a second set of two echelettes arranged around the optical axis, the second set having a profile in r-squared space that is different than the profile of the first set, the second set being repeated in series at least once on the peripheral zone; and

a manufacturing assembly that fabricates the ophthalmic lens based on the diffractive profile.

22. The system of claim 21, wherein the diffractive profile includes a middle zone positioned between the central zone and the peripheral zone, and the middle zone includes a third set of two echelettes arranged around the optical axis, the third set having a profile in r-squared space that is substantially identical to the profile of the first set.

23. The system of claim 21, wherein each of the two echelettes of the first set have a different profile than each other in r-squared space, and each of the two echelettes of the second set have a different profile than each other in r-squared space.

24. A method of designing an intraocular lens, the method comprising:
defining a diffractive profile including:

a central zone and a peripheral zone,

the central zone includes a first set of two echelettes arranged around an optical axis, the first set having a profile in r-squared space, the first set being repeated in series at least once on the central zone, and

the peripheral zone includes a second set of two echelettes arranged around the optical axis, the second set having a profile in r-squared space that is different than the profile of the first set, the second set being repeated in series at least once on the peripheral zone; and
generating a diffractive lens surface based on the diffractive profile.

25. The system of claim 24, wherein the diffractive profile includes a middle zone positioned between the central zone and the peripheral zone, and the middle zone includes a third set of two echelettes arranged around the optical axis, the third set having a profile in r-squared space that is substantially identical to the profile of the first set.

26. The system of claim 24, wherein each of the two echelettes of the first set have a different profile than each other in r-squared space, and each of the two echelettes of the second set have a different profile than each other in r-squared space.

27. An ophthalmic lens, comprising:
a first surface and a second surface disposed about an optical axis; and
a diffractive profile imposed on one of the first surface or the second surface, the diffractive profile including a central zone and a peripheral zone, wherein:

the central zone includes a first set of two echelettes arranged around the optical axis, the first set having a profile in r-squared space, the first set being repeated in series at least once on the central zone; and

the peripheral zone includes a second set of two echelettes arranged around the optical axis, the second set having a profile in r-squared space that is different than the profile of the first set, the second set being repeated in series at least once on the peripheral zone.

28. The lens of claim 27, wherein the diffractive profile includes a middle zone positioned between the central zone and the peripheral zone, and the middle zone includes a third set of two echelettes arranged around the optical axis, the third set having a profile in r-squared space that is substantially identical to the profile of the first set.

29. The lens of claim 27, wherein each of the two echelettes of the first set have a different profile than each other in r-squared space, and each of the two echelettes of the second set have a different profile than each other in r-squared space.

FIG. 1A

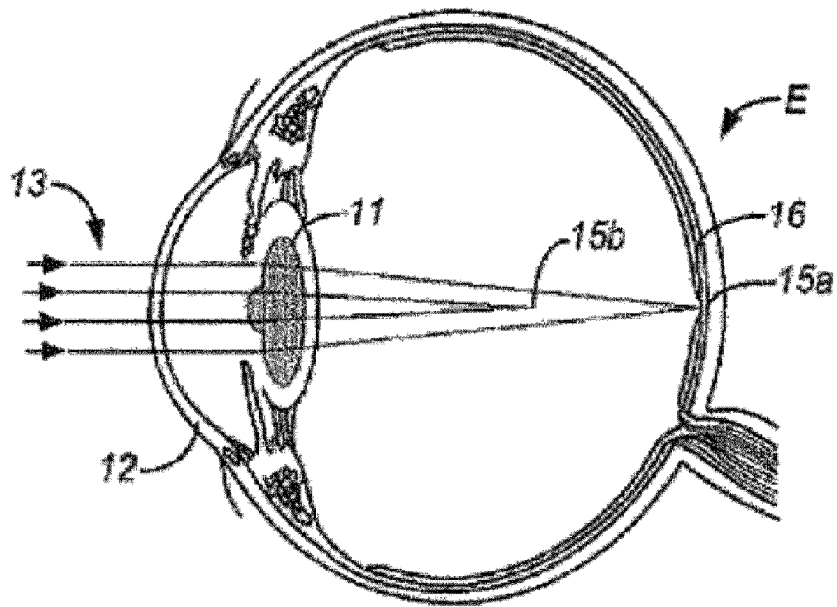


FIG. 1B

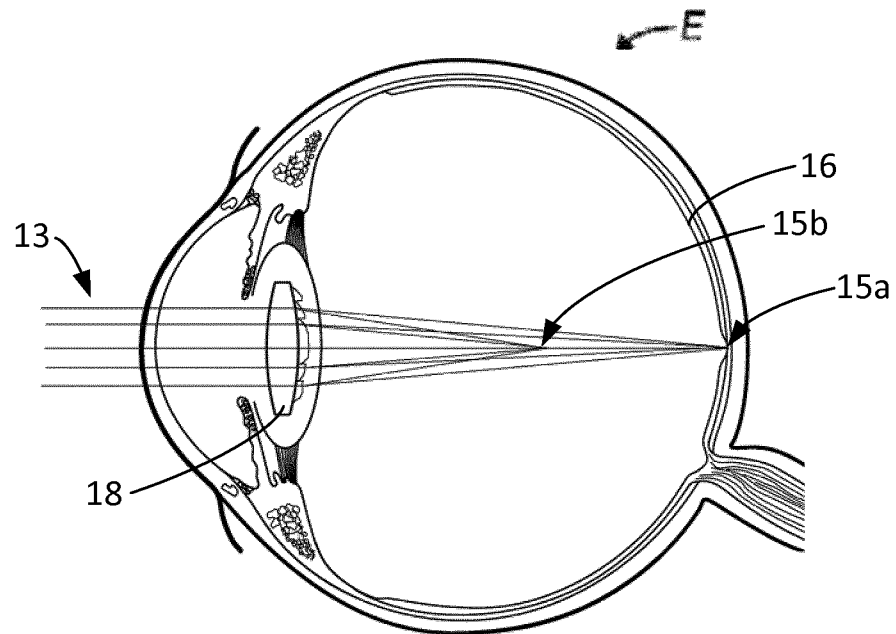


FIG. 2A

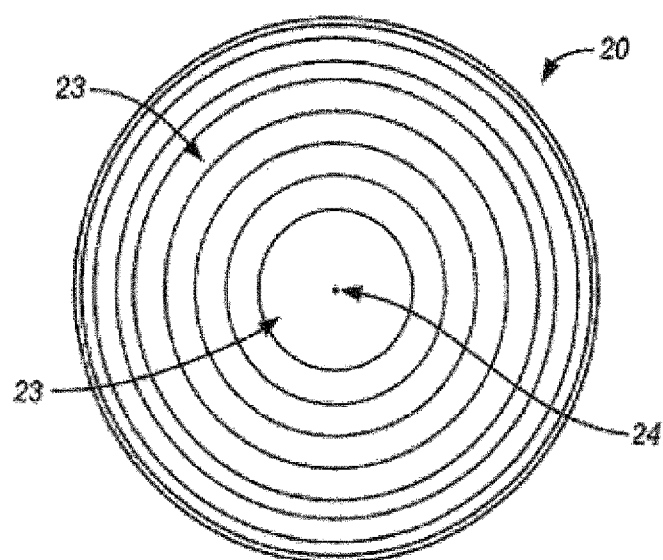
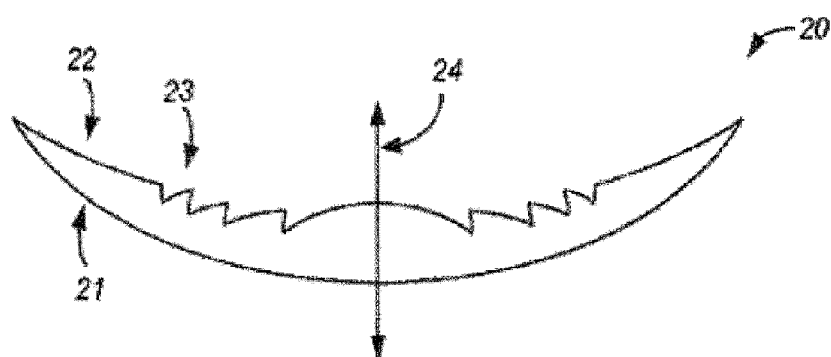


FIG. 2B



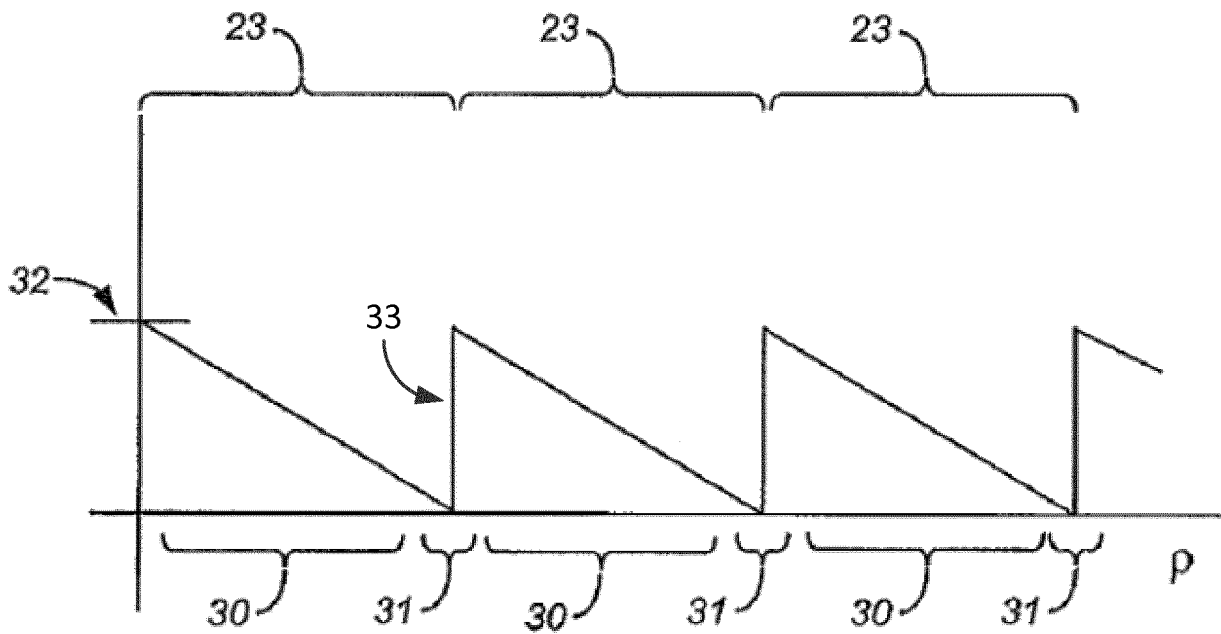
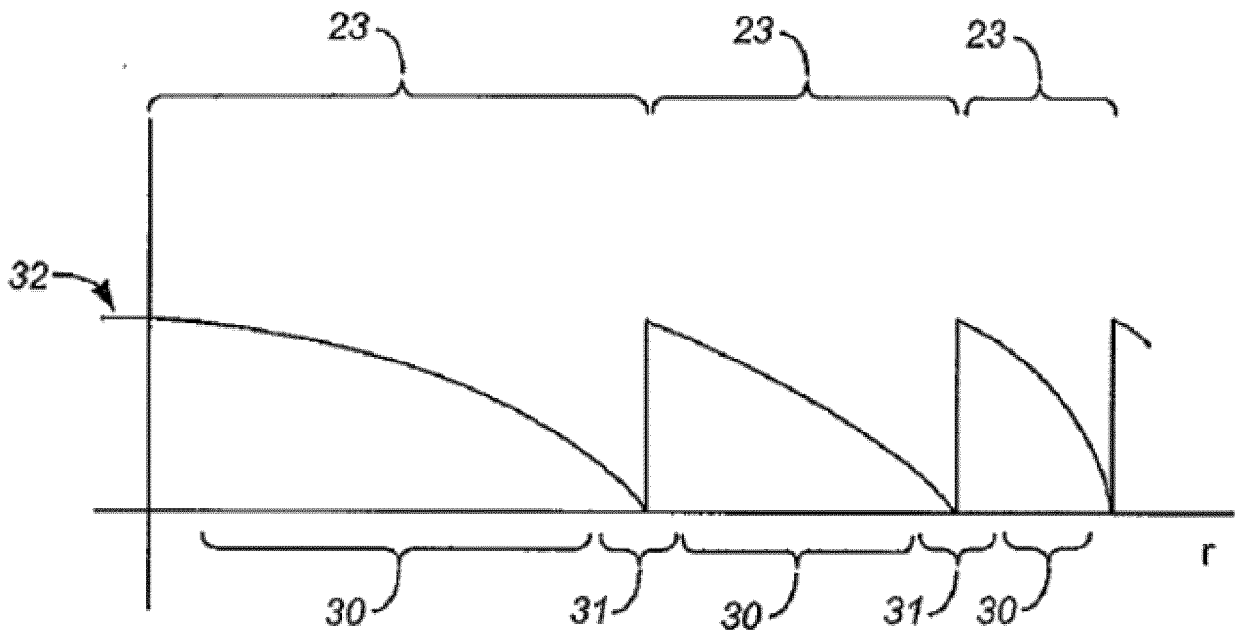
**FIG. 3A****FIG. 3B**

FIG. 4

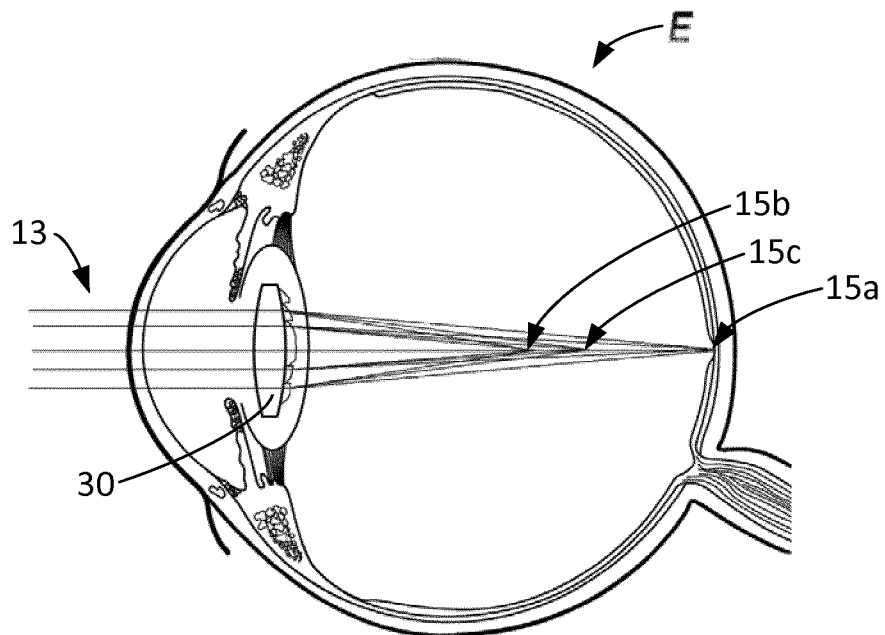


FIG. 5

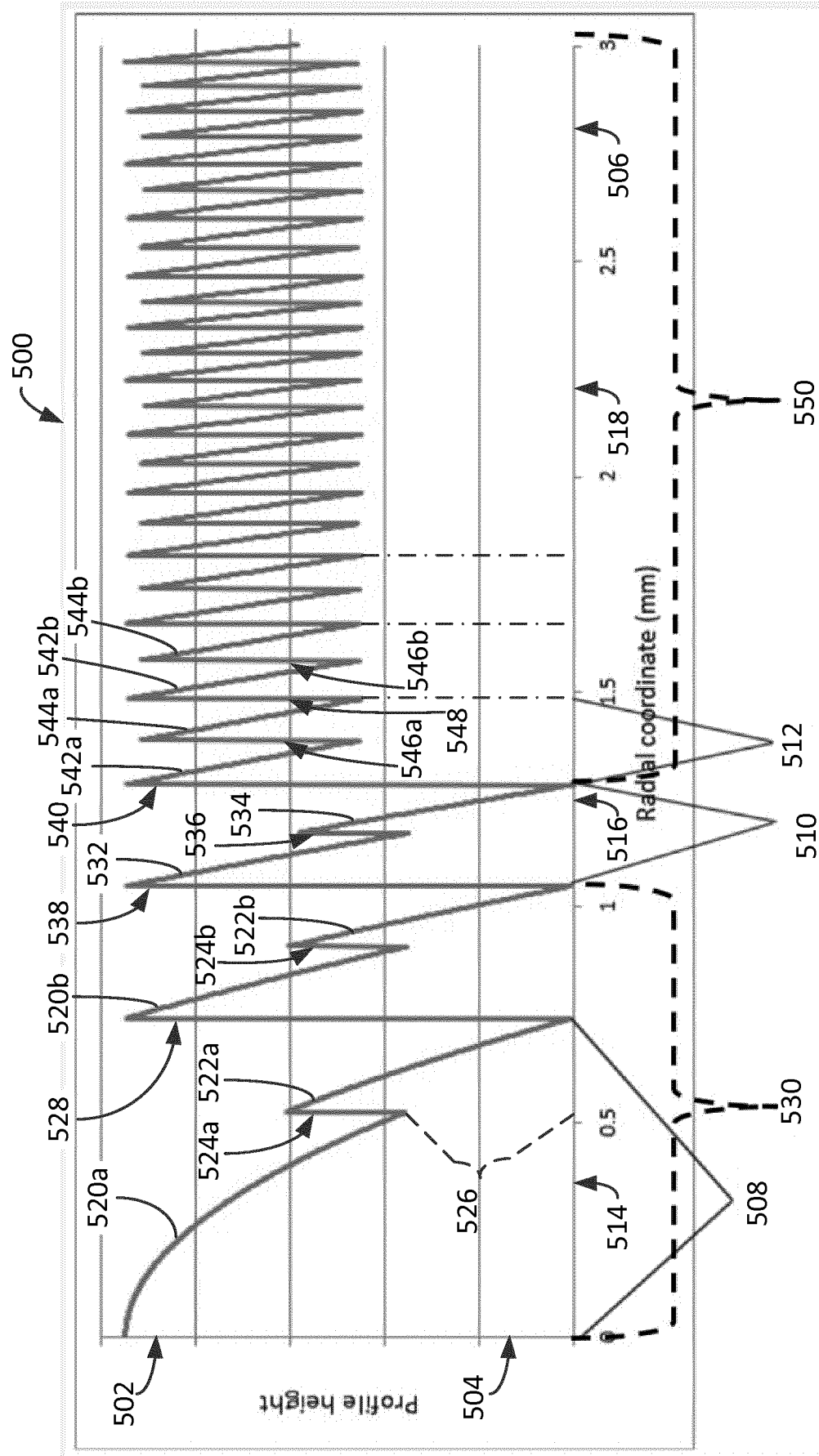


FIG. 6

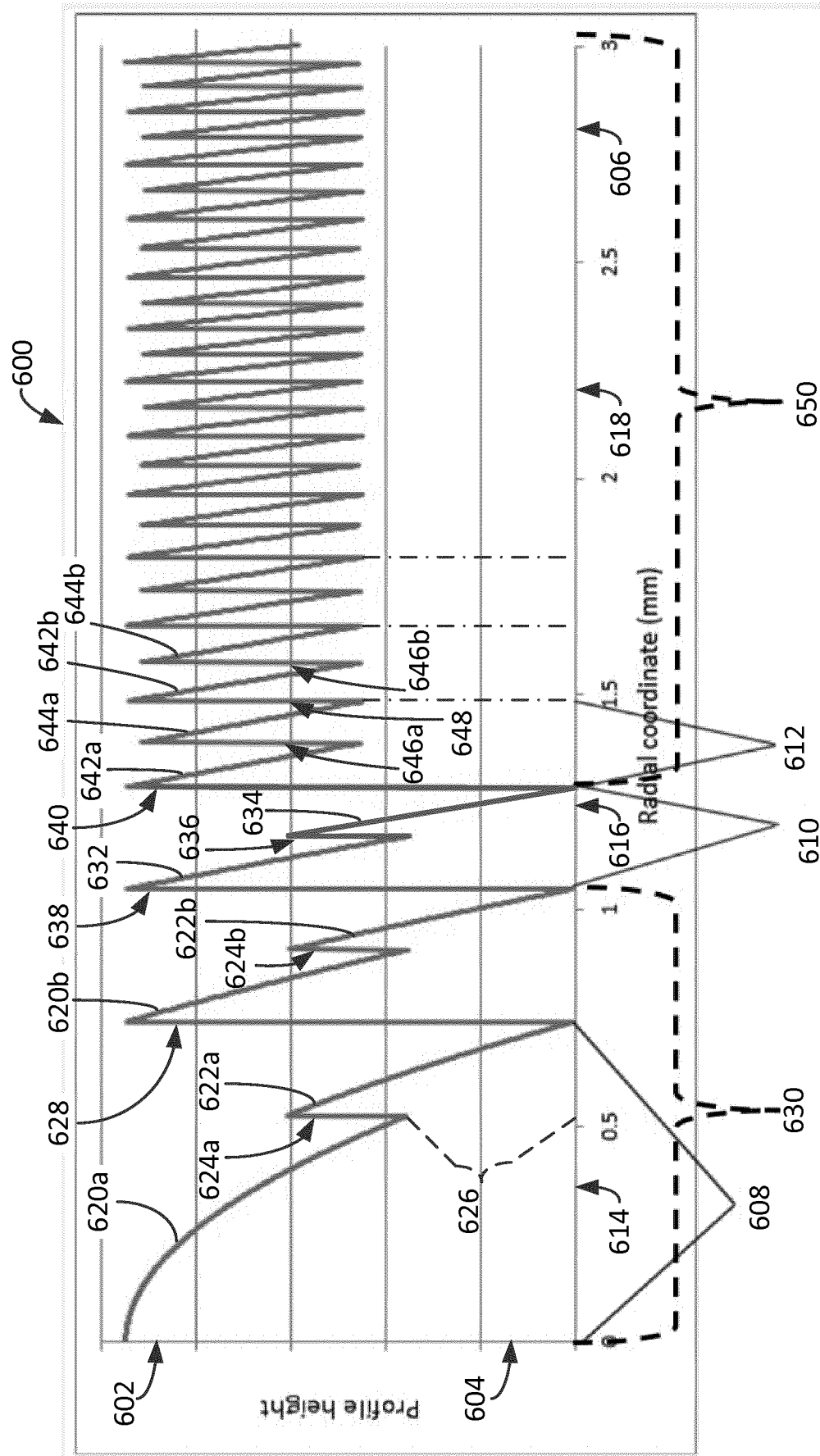


FIG. 7

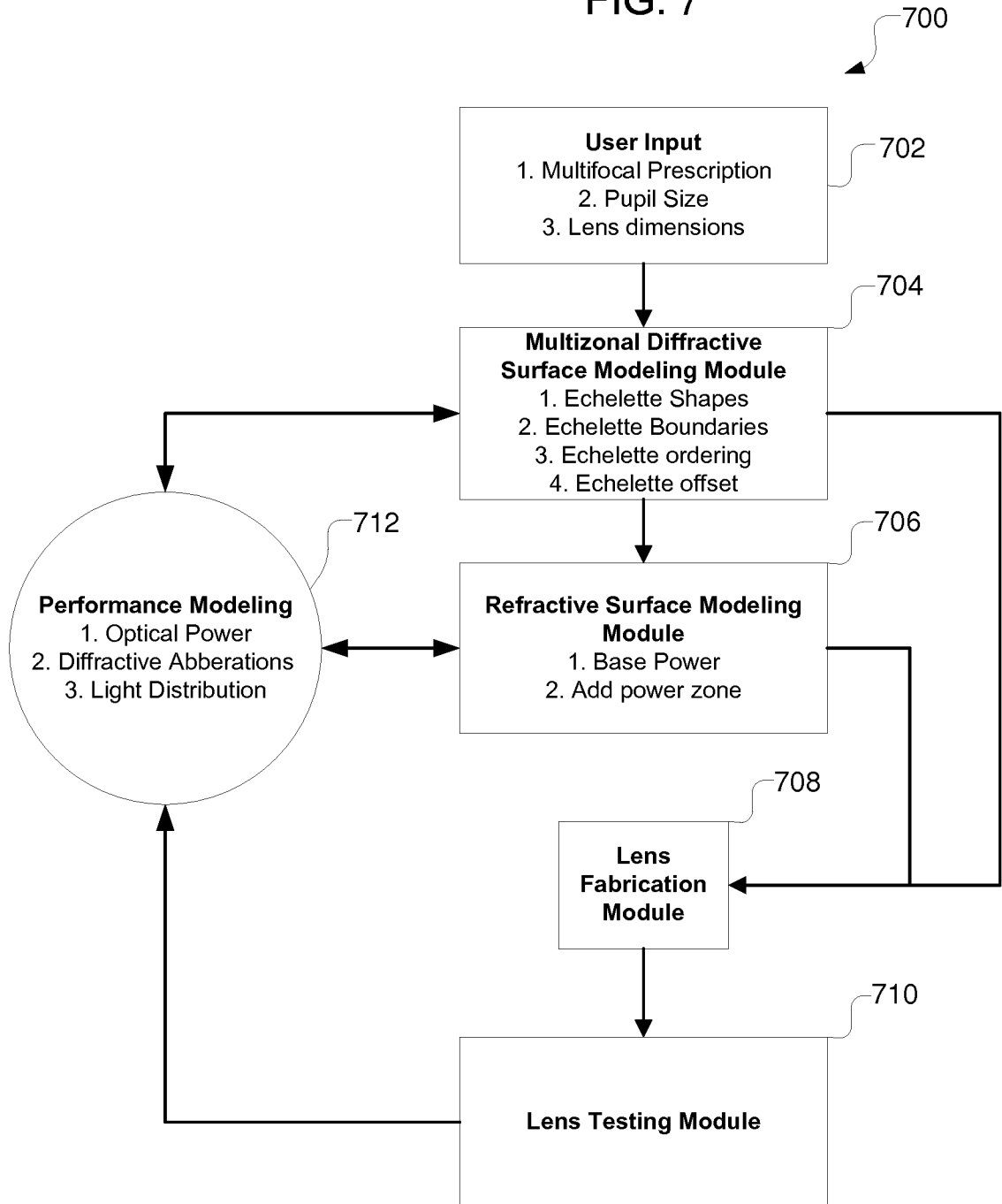


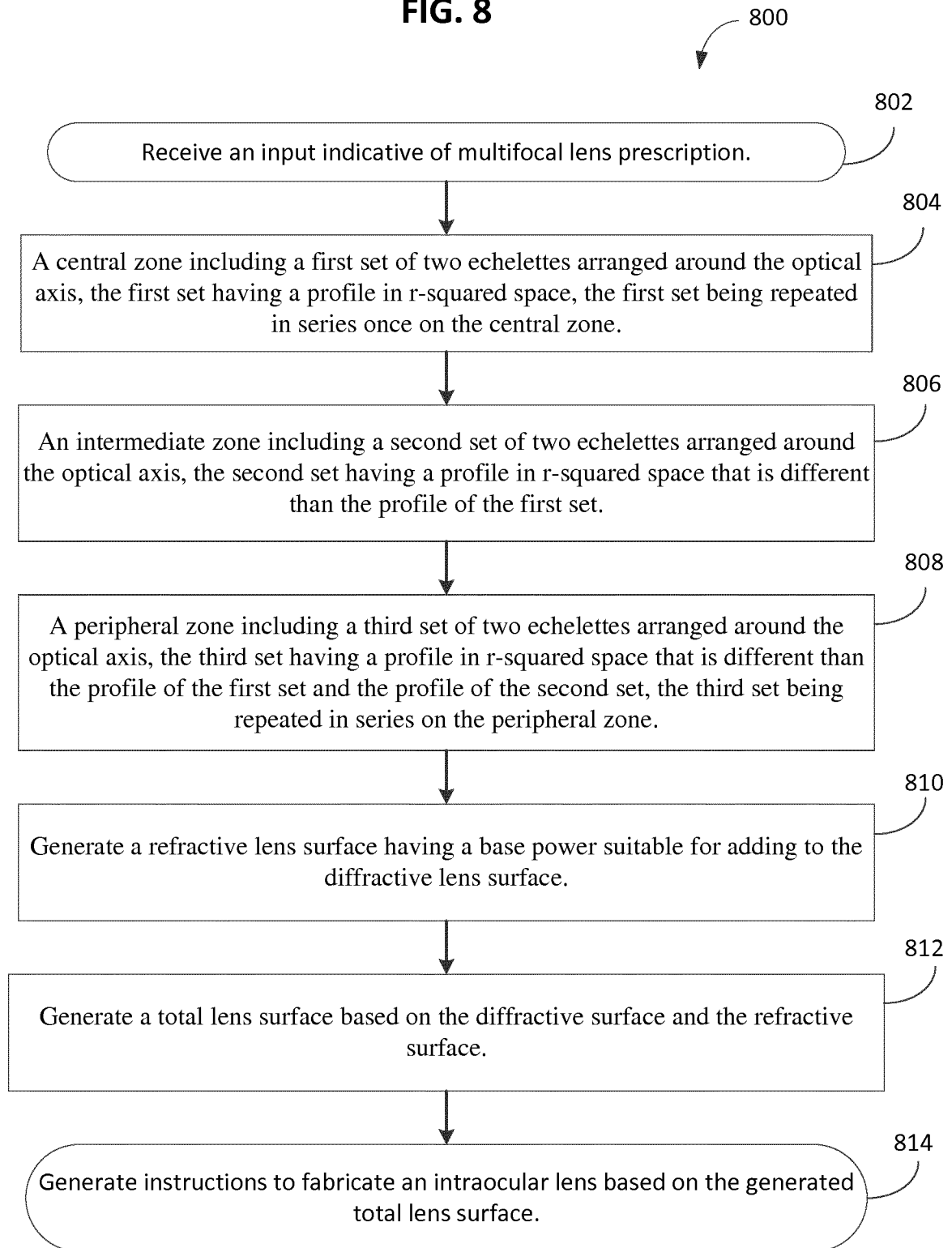
FIG. 8

FIG. 9

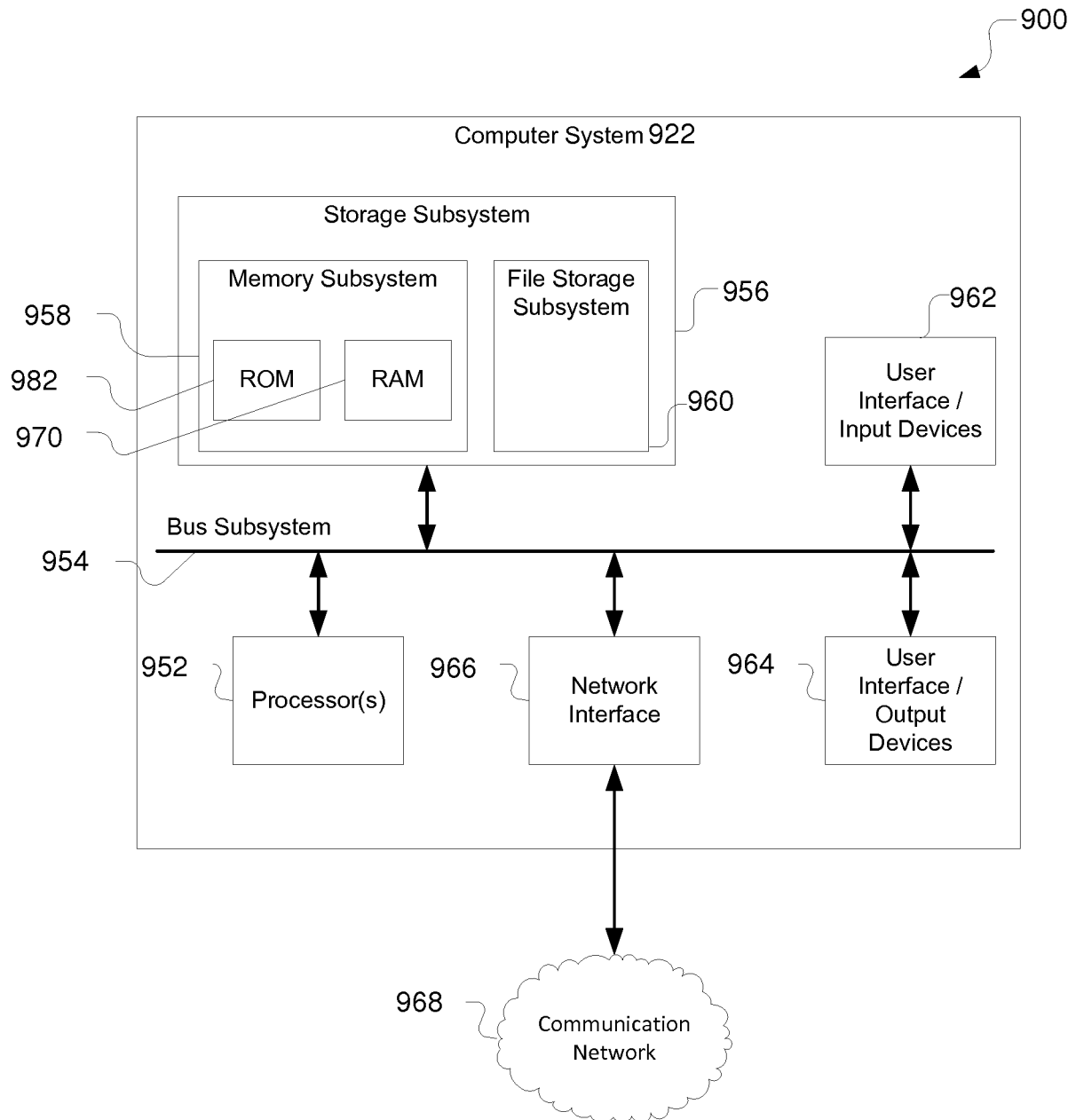


FIG. 1A

