(54) **METHOD FOR PROVIDING AN OPHTHALMIC PROGRESSIVE ADDITION LENS FOR A FARSIGHTED AND PRESBYOPIC WEARER**

VERFAHREN ZUR BEREITSTELLUNG EINER OPHTHALMISCHEN PROGRESSIVEN ZUSATZLINSE FÜR EINEN WEITSICHTIGEN UND ALTERSWEITSICHTIGEN TRÄGER

PROCÉDÉ PERMETTANT DE FABRIQUER UNE LENTILLE À ADDITION PROGRESSIVE OPHTALMIQUE POUR UN PORTEUR HYPERMÉTROPE ET PRESBYTE

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Description

[0001]   The invention relates generally to the field of vision improvement and more specifically concerns a method for providing an ophthalmic progressive addition lens for a farsighted and presbyopic wearer as defined in the claims.

[0002]   Conventionally, spectacles lenses are manufactured on request in accordance with specifications intrinsic to individual wearers. Such specifications generally encompass a medical prescription made by an ophthalmologist or an eye care practitioner.

[0003]   A farsighted wearer has a positive optical power correction for far vision. According to the present invention, one considers that a farsighted wearer has a prescribed far vision mean refractive power which is greater or equal to plus 1 Diopter. For presbyopic wearers, the value of the power correction is different for far vision and near vision, due to the difficulties of accommodation in near vision. The prescription thus comprises a far-vision power value and an addition representing the power increment between far vision and near vision. The addition is qualified as prescribed addition ADD_p.

[0004]   Progressive lenses are disclosed in WO2006/084986 A1, WO2011/042504 A1, EP1791014 A1, EP2506063 A1, EP2752703 A1, WO2015/074777 A1 and EP2211159 A1.

[0005]   The inventors have noticed that current ophthalmic progressive addition lens for a farsighted and presbyopic wearer can still be improved so as to enhance the wearer's visual comfort.

[0006]   A problem that the invention aims to solve is thus to enhance the wearer's visual comfort.

[0007]   For this purpose, a subject of the invention is a method for providing an ophthalmic progressive addition lens for a farsighted and presbyopic wearer which has a prescribed far vision mean refractive power greater or equal to plus 1 Diopter and a non nil prescribed addition, ADD_p, said lens having a mean refractive power, $PPO(\alpha, \beta)$, a module of resulting astigmatism, $ASR(\alpha, \beta)$, an acuity loss value $ACU(\alpha, \beta)$, where said (α, β) functions are determined in as-worn conditions of the lens by the wearer, and a first acuity criterion, AcuityCriterion1 which fulfils following requirement:

$$AcuityCriterion1 \geq 44 \ D^2.deg$$

and where, "D" refers to Diopter, "deg" to degree, AcuityCriterion1 is defined as a combination of $PPO(\alpha, \beta)$, $ASR(\alpha, \beta)$, ADD_p, and $ACU(\alpha, \beta)$.

[0008]   According to an embodiment, AcuityCriterion1 fulfils following requirement: AcuityCriterion 1 $\geq$ 46.5 D^2.deg.

[0009]   According to an embodiment, AcuityCriterion1 fulfils following requirement: AcuityCriterion1 $\geq$ 49 D^2.deg.

[0010]   The inventors have discovered that to defining a threshold value of an acuity criterion is suitable to characterize ophthalmic progressive addition lens for a farsighted and presbyopic wearer where the wearer's visual comfort is enhanced in view of known prior art ophthalmic progressive addition lens.

[0011]   The method according to the present invention provides a lens which is further characterized by a meridian line, $ML(\alpha, \beta)$, a fitting cross, $FC(\alpha_{FC}, \beta_{FC})$, said (α, β) functions being determined in as-worn conditions of the lens by the wearer for gaze directions (α, β) joining the center of rotation of the eye, CRE, and the lens, where α is a lowering angle in degree and β is an azimuth angle in degree and wherein:

- the acuity loss value $ACU(\alpha, \beta)$ is expressed in logMAR and defined according to following equation:

$$ACU(\alpha, \beta) = - \log (AC\%(\alpha, \beta)/100),$$

where :
- $AC\%(\alpha, \beta) = 100 - 63 \times P(\alpha, \beta) - 44.3 \times ASR(\alpha, \beta) + 7.2 \times P(\alpha, \beta)^2 + 19.5 \times P(\alpha, \beta) \times ASR(\alpha, \beta) + ASR(\alpha, \beta)^2$; when $P(\alpha, \beta) \geq 0$; and
- $AC\%(\alpha, \beta) = 100 - 44.3 \times ASR(\alpha, \beta) + ASR(\alpha, \beta)^2$; when $P(\alpha, \beta) < 0$;
- $P(\alpha, \beta) = PPO(\alpha, \beta) - PPO(\alpha, \beta\_\alpha\_mer)$;
- β_α_mer is the value of the azimuth angle β on the meridian line, $ML(\alpha, \beta)$, at the lowering angle α;
  and where AcuityCriterion1 = Numerator1 / Denominator;
- Numerator1 = LAcuSub85(0.1) x LAcuAlpha85(0.1) x ADD_p^4;
- Denominator = PeaksMean^2 x PVL^2;
- LAcuSub85(0.1) is the angular extent (in deg^2) of the zone where $ACU(\alpha, \beta) \leq 0.1$ logMAR, inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees, and where $\alpha \geq \alpha85\%$, $\alpha85\%$ being the lowering angle where 85% of the prescribed addition is perceived by the wearer on the meridian line;
- LAcuAlpha85(0.1) is the acuity width (in deg) at $\alpha85\%$ between two iso- acuity loss lines corresponding to 0.1 logMAR and is equal to $\beta_+(ACU(\alpha85\%, \beta)=0.1) - \beta_-(ACU(\alpha85\%, \beta)=0.1)$, where β_+ is greater than $\beta\_\alpha\_mer(\alpha85\%)$

and β_- is less than $\beta\_\alpha\_mer(\alpha 85\%)$;

- PVL is the power variation length is expressed in deg and defined as being equal to $(\alpha 85\% - \alpha 15\%)$, $\alpha 15\%$ being the lowering angle where 15% of the prescribed addition is perceived by the wearer on the meridian line;
- PeaksMean is the mean maximum module of resulting astigmatism (in Diopter,) which is equal to $[ASR_{max}(\alpha_L, \beta_L)$ $+ ASR_{max}(\alpha_R, \beta_R)]/2$, where $ASR_{max}(\alpha_L, \beta_L)$ is the maximum module of resulting astigmatism on a side (left side) of the meridian line, and $ASR_{max}(\alpha_R, \beta_R)$ is the maximum module of resulting astigmatism on the other side (right side) of the meridian line that are both determined inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees;

[0012] According to different embodiments of the present invention which can be combined, the method can provide a lens which fulfills at least one of the following requirements:

- a second acuity criterion, AcuityCriterion2, fulfils following requirement:

$$AcuityCriterion2 \geq 105\ D^2.deg,$$

where:

- AcuityCriterion2 = Numerator2 / Denominator;
- Numerator2 = LAcuSub85(0.2) x LAcuAlpha85(0.2) x ADD_p^4;
- LAcuSub85(0.2) is the angular extent (in deg^2) of the zone where $ACU(\alpha, \beta) \leq 0.2$ logMAR, inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees, and where $\alpha \geq \alpha 85\%$;
- LAcuAlpha85(0.2) is the acuity width (in deg) at $\alpha 85\%$ between two iso-acuity loss lines corresponding to 0.2 logMAR and is equal to $\beta_+(ACU(\alpha 85\%, \beta)=0.2) - \beta_-(ACU(\alpha 85\%, \beta)=0.2)$, where β_+ is greater than $\beta\_\alpha\_mer(\alpha 85\%)$ and β_- is less than $\beta\_\alpha\_mer(\alpha 85\%)$;
- According to an embodiment, AcuityCriterion2 fulfils following requirement: AcuityCriterion2 $\geq$ 115 D^2.deg.
- According to an embodiment, AcuityCriterion2 fulfils following requirement: AcuityCriterion2 $\geq$ 125 D^2.deg.

- a third acuity criterion, AcuityCriterion3, fulfils following requirement:

$$AcuityCriterion3 \geq 3.9\ D,$$

where:

- AcuityCriterion3 = Numerator3 / Denominator;
- Numerator3 = LAcuSubFC(0.1) x ADD_p^3;
- LAcuSubFC(0.1) is the angular extent (in deg^2) of the zone where $ACU(\alpha, \beta) \leq 0.1$ logMAR, inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees, and where $\alpha \geq \alpha_{FC}$;
- According to an embodiment, AcuityCriterion3 fulfils following requirement: AcuityCriterion3 $\geq$ 4.1 D.
- According to an embodiment, AcuityCriterion3 fulfils following requirement: AcuityCriterion3 $\geq$ 4.3 D.

- a fourth acuity criterion, AcuityCriterion4, fulfils following requirement:

$$AcuityCriterion4 \geq 6.1\ D,$$

where:

- AcuityCriterion4 = Numerator4 / Denominator;
- Numerator4 = LAcuSubFC(0.2) x ADD_p^3;
- LAcuSubFC(0.2) is the angular extent (in deg^2) of the zone where $ACU(\alpha, \beta) \leq 0.2$ logMAR, inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees, and where $\alpha \geq \alpha_{FC}$;
- According to an embodiment, AcuityCriterion4 fulfils following requirement: AcuityCriterion4 $\geq$ 6.5 D.
- According to an embodiment, AcuityCriterion4 fulfils following requirement: AcuityCriterion4 $\geq$ 7 D.

- a fifth acuity criterion, AcuityCriterion5, fulfils following requirement:

$$\text{AcuityCriterion5} \geq 8.5 \text{ D},$$

where:

- AcuityCriterion5 = Numerator5 / Denominator;
- Numerator5 = LAcuDomain(0.1) x ADD_p^3;
- LAcuDomain(0.1) is the angular extent (in deg^2) of the zone where $ACU(\alpha, \beta) \leq 0.1$ logMAR, inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees;
- According to an embodiment, AcuityCriterion5 fulfils following requirement: AcuityCriterion5 $\geq$ 8.7 D.
- According to an embodiment, AcuityCriterion5 fulfils following requirement: AcuityCriterion5 $\geq$ 8.9 D.

- a sixth acuity criterion, AcuityCriterion6, fulfils following requirement:

$$\text{AcuityCriterion6} \geq 12.5 \text{ D},$$

where:

- AcuityCriterion6 = Numerator6 / Denominator;
- Numerator6 = LAcuDomain(0.2) x ADD_p^3;
- LAcuDomain(0.2) is the angular extent (in deg^2) of the zone where $ACU(\alpha, \beta) \leq 0.2$ logMAR, inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees.
- According to an embodiment, AcuityCriterion6 fulfils following requirement: AcuityCriterion6 $\geq$ 13.1 D.
- According to an embodiment, AcuityCriterion6 fulfils following requirement: AcuityCriterion6 $\geq$ 13.7D.

[0013]   In another aspect, the present invention also provides a method implemented by computer means for providing an ophthalmic progressive addition lens to a farsighted and presbyopic wearer having a prescribed far vision mean refractive power greater or equal to plus 1 Diopter and a non nil prescribed addition, ADD_p, comprising the step of calculating a mean refractive power repartition, $PPO(\alpha, \beta)$, a module of resulting astigmatism repartition, $ASR(\alpha, \beta)$, an acuity loss value repartition $ACU(\alpha, \beta)$, where said (α, β) functions are calculated in as-worn conditions of the lens by the wearer, so as to fulfil following requirement of a first acuity criterion, AcuityCriterion1:

$$\text{AcuityCriterion1} \geq 44 \text{ D}^2.\text{deg};$$

Where, "D" refers to Diopter, "deg" to degree, AcuityCriterion1 is defined as a combination of $PPO(\alpha, \beta)$, $ASR(\alpha, \beta)$, ADD_p, and $ACU(\alpha, \beta)$.

[0014]   The method claimed further comprises the following steps:

- Calculating or defining a meridian line, $ML(\alpha, \beta)$,
- Calculating or defining a fitting cross, $FC(\alpha_{FC}, \beta_{FC})$,
- Calculating the mean refractive power, $PPO(\alpha, \beta)$, and the module of resulting astigmatism, $ASR(\alpha, \beta)$, determined in as-worn conditions of the lens by the wearer for gaze directions (α, β) joining the center of rotation of the eye, CRE, and the lens, where α is a lowering angle in degree and β is an azimuth angle in degree, an acuity loss value $ACU(\alpha, \beta)$ is expressed in logMAR and defined according to following equation:

$$ACU(\alpha, \beta) = -\log (AC\%(\alpha, \beta)/100),$$

where :

- $AC\%(\alpha, \beta) = 100 - 63 \times P(\alpha, \beta) - 44.3 \times ASR(\alpha, \beta) + 7.2 \times P(\alpha, \beta)^2 + 19.5 \times P(\alpha, \beta) \times ASR(\alpha, \beta) + ASR(\alpha, \beta)^2$; when $P(\alpha, \beta) \geq 0$; and
- $AC\%(\alpha, \beta) = 100 - 44.3 \times ASR(\alpha, \beta) + ASR(\alpha, \beta)^2$; when $P(\alpha, \beta) < 0$;
- $P(\alpha, \beta) = PPO(\alpha, \beta) - PPO(\alpha, \beta\_\alpha\_mer)$;
- β_α_mer is the value of the azimuth angle β on the meridian line, $ML(\alpha, \beta)$, at the lowering angle α;

and where AcuityCriterion1 = Numerator1 / Denominator;

- Numerator1 = LAcuSub85(0.1) x LAcuAlpha85(0.1) x ADD_p;
- Denominator = $PeaksMean^2$ x PVL^2;
- LAcuSub85(0.1) is the angular extent (in deg^2) of the zone where $ACU(\alpha, \beta) \leq 0.1$ logMAR, inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees, and where $\alpha \geq \alpha85\%$, $\alpha85\%$ being the lowering angle where 85% of the prescribed addition is perceived by the wearer on the meridian line;
- LAcuAlpha85(0.1) is the acuity width (in deg) at $\alpha85\%$ between two iso-acuity loss lines corresponding to 0.1 logMAR and is equal to:
  $\beta_+(ACU(\alpha85\%, \beta)=0.1) - \beta_-(ACU(\alpha85\%, \beta)=0.1)$, where β_+ is greater than $\beta\_\alpha\_mer(\alpha85\%)$ and β_- is less than $\beta\_\alpha\_mer(\alpha85\%)$;
- PVL is the power variation length is expressed in deg and defined as being equal to $(\alpha85\% - \alpha15\%)$, $\alpha15\%$ being the lowering angle where 15% of the prescribed addition is perceived by the wearer on the meridian line;
- PeaksMean is the mean maximum module of resulting astigmatism (in Diopter) which is equal to $[ASR_{max}(\alpha_L, \beta_L) + ASR_{max}(\alpha_R, \beta_R)]/2$, where $ASR_{max}(\alpha_L, \beta_L)$ is the maximum module of resulting astigmatism on a side (left side) of the meridian line, and $ASR_{max}(\alpha_R, \beta_R)$ is the maximum module of resulting astigmatism on the other side (right side) of the meridian line that are both determined inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees;

[0015] According to different embodiments of the method of the present invention, that may be combined:

- the method further comprising following steps: calculates the lens so as to fulfil following requirement of a second acuity criterion, AcuityCriterion2:

$$AcuityCriterion2 \geq 105\ D^2.deg,$$

where:

- AcuityCriterion2 = Numerator2 / Denominator;
- Numerator2 = LAcuSub85(0.2) x LAcuAlpha85(0.2) x ADD_p^4;
- LAcuSub85(0.2) is the angular extent (in deg^2) of the zone where $ACU(\alpha, \beta) \leq 0.2$ logMAR, inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees, and where $\alpha \geq \alpha85\%$;
- LAcuAlpha85(0.2) is the acuity width (in deg) at $\alpha85\%$ between two iso-acuity loss lines corresponding to 0.2 logMAR and is equal to $\beta_+(ACU(\alpha85\%, \beta)=0.2) - \beta_-(ACU(\alpha85\%, \beta)=0.2)$, where β_+ is greater than $\beta\_\alpha\_mer(\alpha85\%)$ and β_- is less than $\beta\_\alpha\_mer(\alpha85\%)$;

- one calculates the lens so as to fulfil following requirement of a third acuity criterion, AcuityCriterion3:

$$AcuityCriterion3 \geq 3.9\ D,$$

where:

- AcuityCriterion3 = Numerator3 / Denominator;
- Numerator3 = LAcuSubFC(0.1) x ADD_p^3;
- LAcuSubFC(0.1) is the angular extent (in deg^2) of the zone where $ACU(\alpha, \beta) \leq 0.1$ logMAR, inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees, and where $\alpha \geq \alpha_{FC}$;

- one calculates the lens so as to fulfil following requirement of a fourth acuity criterion, AcuityCriterion4:

$$AcuityCriterion4 \geq 6.1\ D,$$

where:

- AcuityCriterion4 = Numerator4 / Denominator;
- Numerator4 = LAcuSubFC(0.2) x ADD_p^3;
- LAcuSubFC(0.2) is the angular extent (in deg^2) of the zone where $ACU(\alpha, \beta) \leq 0.2$ logMAR, inside a circle, CIR,

centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees, and where $\alpha \geq \alpha_{FC}$;

- one calculates the lens so as to fulfil following requirement of a fifth acuity criterion, AcuityCriterion5:

$$AcuityCriterion5 \geq 8.5 \ D,$$

where:

- • AcuityCriterion5 = Numerator5 / Denominator;
- • Numerator5 = LAcuDomain(0.1) x ADD_p^3;
- • LAcuDomain(0.1) is the angular extent (in deg^2) of the zone where $ACU(\alpha, \beta) \leq 0.1$ logMAR, inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees;

- one calculates the lens so as to fulfil following requirement of a sixth acuity criterion, AcuityCriterion6:

$$AcuityCriterion6 \geq 12.5 \ D,$$

where:

- • AcuityCriterion6 = Numerator6 / Denominator;
- • Numerator6 = LAcuDomain(0.2) x ADD_p^3;
- • LAcuDomain(0.2) is the angular extent (in deg^2) of the zone where $ACU(\alpha, \beta) \leq 0.2$ logMAR, inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees;

- here above requirements of preferred embodiments directed to AcuityCriterion1 and/or AcuityCriterion2 and/or AcuityCriterion3 and/or AcuityCriterion4 and/or AcuityCriterion5 and/or AcuityCriterion6 may be chosen within the scope of the method of the present invention.
- the method comprises an optimization routine where at least a target is chosen within requirement of an acuity criterion chosen in the list consisting of AcuityCriterion1, AcuityCriterion2, AcuityCriterion3, AcuityCriterion4, AcuityCriterion5, AcuityCriterion6.

Description of the drawings

[0016]   The features of the present invention, as well as the invention itself, both as to its structure and its operation, will be best understood from the accompanying non limiting drawings and examples, taken in conjunction with the accompanying description, in which :

- figures 1 and 2 show, diagrammatically, optical systems of eye and lens and ray tracing from the center of rotation of the eye ;
- figure 3 shows field vision zones of an ophthalmic progressive addition lens;
- figures 4 to 13 show diagrams helping understanding the definitions of the criteria used within the frame of the present invention;
- figures 14 to 17 give optical characteristics of an ophthalmic progressive addition lens according to the prior art;
- figures 18 to 21 give optical characteristics of an ophthalmic progressive addition lens provided by the method according to the invention.

[0017]   On the figures, following references correspond to followings:

- • MER is the meridian line;
- • NVGD is the near vision gaze direction;
- • FVGD is the far vision gaze direction;
- • FCGD is the fitting cross gaze direction

Definitions

[0018]   The following definitions are provided so as to define the wordings used within the frame of the present invention.

[0019] The wordings *"wearer's prescription"*, also called *"prescription data"*, are known in the art. Prescription data refers to one or more data obtained for the wearer and indicating for at least an eye, preferably for each eye, a prescribed sphere SPH_p, and/or a prescribed astigmatism value CYL_p and a prescribed axis $AXIS_p$ suitable for correcting the ametropia of each eye for the wearer and, if suitable, a prescribed addition ADD_p suitable for correcting the presbyopia of each of his eyes.

[0020] *"Progressive ophthalmic addition lenses"* are known in the art. According to the invention, the lens may be a standard lens but also a lens for information glasses, wherein the lens comprises means for displaying information in front of the eye. The lens may also be suitable for sunglasses or not. All ophthalmic lenses provided by the method of the invention may be paired so as to form a pair of lenses (left eye LE, right eye RE).

[0021] A *"gaze direction"* is identified by a couple of angle values (α, β), wherein said angles values are measured with regard to reference axes centered on the center of rotation of the eye, commonly named as "CRE". More precisely, figure 1 represents a perspective view of such a system illustrating parameters α and β used to define a gaze direction. Figure 2 is a view in the vertical plane parallel to the antero-posterior axis of the wearer's head and passing through the center of rotation of the eye in the case when the parameter β is equal to 0. The center of rotation of the eye is labeled CRE. The axis CRE-F', shown on Figure 2 in a dot-dash line, is the horizontal axis passing through the center of rotation of the eye and extending in front of the wearer - that is the axis CRE-F' corresponding to the primary gaze direction. The lens is placed and centered in front of the eye such that the axis CRE-F' cuts the front surface of the lens on a point called the fitting cross, which is, in general, present on lenses to enable the positioning of lenses in a frame by an optician. The point of intersection of the rear surface of the lens and the axis CRE-F' is the point, O. A vertex sphere, which center is the center of rotation of the eye, CRE, and has a radius q' = O-CRE, intercepts the rear surface of the lens in a point of the horizontal axis. A value of radius q' of 25.5 mm corresponds to a usual value and provides satisfying results when wearing the lenses. Other value of radius q' may be chosen. A given gaze direction, represented by a solid line on figure 1, corresponds to a position of the eye in rotation around CRE and to a point J (see figure 2) of the vertex sphere; the angle β is the angle formed between the axis CRE-F' and the projection of the straight line CRE-J on the horizontal plane comprising the axis CRE-F'; this angle appears on the scheme on Figure 1. The angle α is the angle formed between the axis CRE-J and the projection of the straight line CRE-J on the horizontal plane comprising the axis CRE-F'; this angle appears on the scheme on Figures 1 and 2. A given gaze view thus corresponds to a point J of the vertex sphere or to a couple (α, β). The more the value of the lowering gaze angle is positive, the more the gaze is lowering and the more the value is negative, the more the gaze is rising. In a given gaze direction, the image of a point M in the object space, located at a given object distance, is formed between two points S and T corresponding to minimum and maximum distances JS and JT, which would be the sagittal and tangential local focal lengths. The image of a point in the object space at infinity is formed, at the point F'. The distance D corresponds to the rear frontal plane of the lens.

[0022] For each gaze direction (α, β), a mean refractive power $PPO(\alpha, \beta)$, a module of astigmatism $ASR(\alpha, \beta)$ and an axis $AXE(\alpha, \beta)$ of this astigmatism, and a module of resulting (also called residual or unwanted) astigmatism $ASR(\alpha, \beta)$ are defined.

[0023] *"Astigmatism"* refers to astigmatism generated by the lens, or to residual astigmatism (resulting astigmatism) which corresponds to the difference between the prescribed astigmatism (wearer astigmatism) and the lens-generated astigmatism; in each case, with regards to amplitude or both amplitude and axis;

[0024] *"Ergorama"* is a function associating to each gaze direction the usual distance of an object point. Typically, in far vision following the primary gaze direction, the object point is at infinity. In near vision, following a gaze direction essentially corresponding to an angle α of the order of 35° and to an angle β of the order of 5° in absolute value towards the nasal side, the object distance is of the order of 30 to 50 cm. For more details concerning a possible definition of an ergorama, US patent US-A-6,318,859 may be considered. This document describes an ergorama, its definition and its modeling method. For a method of the invention, points may be at infinity or not. Ergorama may be a function of the wearer's ametropia. Using these elements, it is possible to define a wearer optical power and astigmatism, in each gaze direction. An object point M at an object distance given by the ergorama is considered for a gaze direction (α, β). An object proximity ProxO is defined for the point M on the corresponding light ray in the object space as the inverse of the distance MJ between point M and point J of the vertex sphere:

$$ProxO = 1/MJ$$

[0025] This enables to calculate the object proximity within a thin lens approximation for all points of the vertex sphere, which is used for the determination of the ergorama. For a real lens, the object proximity can be considered as the inverse of the distance between the object point and the front surface of the lens, on the corresponding light ray. For the same gaze direction (α, β), the image of a point M having a given object proximity is formed between two points S and T which correspond respectively to minimal and maximal focal distances (which would be sagittal and tangential focal distances). The quantity ProxI is called image proximity of the point M:

$$\mathrm{Pr}\, oxI \;=\; \frac{1}{2}\left(\frac{1}{JT} + \frac{1}{JS}\right)$$

[0026]   By analogy with the case of a thin lens, it can therefore be defined, for a given gaze direction and for a given object proximity, i.e. for a point of the object space on the corresponding light ray, an optical power PPO as the sum of the image proximity and the object proximity.

$$PPO = ProxO + ProxI$$

The optical power is also called refractive power.

[0027]   With the same notations, an astigmatism AST is defined for every gaze direction and for a given object proximity as:

$$AST = \left|\frac{1}{JT} - \frac{1}{JS}\right|$$

[0028]   This definition corresponds to the astigmatism of a ray beam created by the lens. The resulting astigmatism ASR is defined for every gaze direction through the lens as the difference between the actual astigmatism value AST for this gaze direction and the prescribed astigmatism for the same lens. The residual astigmatism (resulting astigmatism) ASR more precisely corresponds to module of the vectorial difference between actual (AST, AXE) and prescription data (CYL$_p$, AXIS$_p$).

[0029]   When the characterization of the lens is of optical kind, it refers to the ergorama-eye-lens system described above. For simplicity, the term 'lens' is used in the description but it has to be understood as the 'ergorama-eye-lens system'. The values in optic terms can be expressed for gaze directions. Conditions suitable to determine of the ergorama-eye-lens system are called in the frame present invention "as-worn conditions".

[0030]   In the remainder of the description, terms like «up », « bottom », « horizontal », « vertical », « above », « below », or other words indicating relative position may be used. These terms are to be understood in the wearing conditions of the lens. Notably, the "upper" part of the lens corresponds to a negative lowering angle α <0° and the "lower" part of the lens corresponds to a positive lowering angle α >0°.

[0031]   A *"far-vision gaze direction"*, referred as FVGD, is defined for a lens, as the vision gaze direction corresponding to the far vision (distant) reference point and thus (α_{FV}, β_{FV}), where the mean refractive power is substantially equal to the mean prescribed power in far vision, the mean prescribed power being equal to SPH$_p$+(CYL$_p$/2). Within the present disclosure, far-vision is also referred to as distant-vision.

[0032]   A *"near-vision gaze direction"*, referred as NVGD, is defined for a lens, as the vision gaze direction corresponding to the near vision (reading) reference point, and thus (α_{NV}, β_{NV}), where the refractive power is substantially equal to the prescribed power in far vision plus the prescribed addition, ADD$_p$.

[0033]   A *"fitting-cross gaze direction"*, referred as FCGD, is defined for a lens, as the vision gaze direction corresponding to the fitting cross reference point and thus (α_{FC}, β_{FC}).

[0034]   The *"meridian line"*, referred as M$_L$(α,β), of a progressive lens is a line defined from top to bottom of the lens and passing through the fitting cross where one can see clearly an object point. Said meridian line is defined on the basis of the repartition of module of resulting astigmatism, ASR, over the (α, β) domain and substantially correspond to the center of the two central iso-module of resulting astigmatism values which value is equal to 0.25 Diopter. To be more specific and according to the present invention the meridian line is calculated according to following method:

- One defines the gaze direction, FCGD, corresponding to the fitting cross (α_{FC}, β_{FC});
- One calculates the lowering angle α_{NV} corresponding to the near vision gaze direction;
- For each lowering angle α comprised between α_{FC} and α_{NV}, one calculates the azimuth angle β corresponding to the midway direction between the two central iso-module of resulting astigmatism values which value is equal to 0.25 Diopter; said calculated directions are referred as (α_i, β_i); one calculates a straight line, d2, so as to minimizes the deviation of (α_i, β_i) to said straight line, according to following equation:

$$d2 : \beta(\alpha) = a_2\alpha + b_2 ; \alpha_{FC} < \alpha < \alpha_{NV}$$

$$a_2, b_2 : \min \left\{ \sum_i \left(a_2 \alpha_i + b_2 - \beta_i \right)^2 \right\}$$

where « min » function relates to determining the a_2 and b_2 parameters so as to minimize the equation between brackets.

- One calculates a pivot direction (α_{piv}, β_{piv}) defined as the intersection between the straight line d2 and a line corresponding to $\beta = \beta_{FC}$, where

$$: \begin{cases} \alpha_{PIV} = \dfrac{(\beta_{FC} - b_2)}{a_2} \\ \beta_{PIV} = \beta_{FC} \end{cases}$$

- One calculates a straight line, d1, where: $d1 : \beta(\alpha) = \beta_{PIV}$; $\alpha < \alpha_{PIV}$;
- One determines β_{NV} as being the azimuth angle β of straight line d2 for α_{NV}; where : $\beta_{NV} = a_2 \alpha_{NV} + b_2$;
- For each lowering angle α greater than α_{NV}, one determines the azimuth angle β corresponding to the midway direction between the two central iso-module of resulting astigmatism values which value is equal to 0.25 Diopter; said calculated directions are referred as (α_j, β_j); one calculates a straight line, d3, so as to minimizes the deviation of (α_j, β_j) to said straight line and that passes at the direction (α_{NV}, β_{NV}); if the calculated slope is negative, the sloped is chosen to be nil; d3 is thus defined according to following equation :

$$d3 : \beta(\alpha) = a_3 (\alpha - \alpha_{NV}) + \beta_{NV} ; \alpha_{NV} < \alpha$$

$$a_3 : \min \left\{ \sum_j \left(a_3 (\alpha_j - \alpha_{NV}) + \beta_{NV} - \beta_j \right)^2 ; a_3 \geq 0 \right\}$$

[0035] - The meridian line is finally defined as being the line built when following the three segments d1, d2, d3.

[0036] *"Micro-markings"* also called *"alignment reference marking"* have been made mandatory on progressive lenses by the harmonized standards ISO 13666:2012 ("Alignment reference marking: permanent markings provided by the manufacturer to establish the horizontal alignment of the lens or lens blank, or to re-establish other reference points") and ISO 8990-2 ("Permanent marking: the lens has to provide at least following permanent markings: alignment reference markings comprising two markings distant from 34 mm one of each other, equidistant from a vertical plane passing through the fitting cross or the prism reference point"). Micro-markings that are defined the same way are also usually made on complex surfaces, such as on a front surface of a lens with a front surface comprising a progressive or regressive front surface.

[0037] *"Temporary markings"* may also be applied on at least one of the two surfaces of the lens, indicating positions of control points (reference points) on the lens, such as a control point for far-vision, a control point for near-vision, a prism reference point and a fitting cross for instance. The prism reference point PRP is considered here at the midpoint of the straight segment which connects the micro-markings. If the temporary markings are absent or have been erased, it is always possible for a skilled person to position the control points on the lens by using a mounting chart and the permanent micro-markings. Similarly, on a semi-finished lens blank, standard ISO 10322-2 requires micro-markings to be applied. The centre of the aspherical surface of a semi-finished lens blank can therefore be determined as well as a referential as described above.

[0038] Figure 3 shows field vision zones of an ophthalmic progressive addition lens 30 where said lens comprises a far vision (distant vision) zone 32 located in the upper part of the lens, a near vision zone 36 located in the lower part of the lens and an intermediate zone 34 situated between the far vision zone 32 and the near vision zone 36. The meridian line is referred as 38.

[0039] A plurality of criteria has been defined in the scope of the present invention and there definitions are illustrated by figures 4 to 12.

[0040] In the background of figures 4 to 11, the acuity loss contour plot of a same example of an ophthalmic progressive addition lens is represented.

[0041] In the background of figure 12, the module of resulting astigmatism contour plot of the same example of an ophthalmic progressive addition lens is represented.

[0042] The acuity loss contour shows the variations over the (α, β) domain of the acuity loss value $ACU(\alpha, \beta)$; the acuity loss value is expressed in logMAR.

[0043] The acuity loss value $ACU(\alpha, \beta)$ is defined according to following equation:

$$ACU(\alpha, \beta) = - \log (AC\%(\alpha, \beta)/100);$$

[0044] $AC\%(\alpha, \beta)$ is an acuity function defined as a function of both mean refractive power, $PPO(\alpha, \beta)$, and module of resulting astigmatism, $ASR(\alpha, \beta)$; where:

- one defines a mean refractive power difference function, $P(\alpha, \beta)$, where:

$$P(\alpha, \beta) = PPO(\alpha, \beta) - PPO(\alpha, \beta\_\alpha\_mer);$$

β_α_mer being the value of the azimuth angle β on the meridian line, $ML(\alpha, \beta)$, at the lowering angle α;
- if $P(\alpha, \beta) \geq 0$, $AC\%(\alpha, \beta)$ is defined according to following equation:

$$AC\%(\alpha, \beta) = \{100 - 63 \times P(\alpha, \beta) - 44.3 \times ASR(\alpha, \beta) + 7.2 \times P(\alpha, \beta)^2 + 19.5 \times P(\alpha, \beta) \times ASR(\alpha, \beta) + ASR(\alpha, \beta)^2\}$$

- if $P(\alpha, \beta) < 0$, $AC\%(\alpha, \beta)$ is defined according to following equation:

$$AC\%(\alpha, \beta) = 100 - 44.3 \times ASR(\alpha, \beta) + ASR(\alpha, \beta)^2.$$

[0045] Bibliographical reference of such an acuity loss definition can be found in following document: Fauquier, C., et al. "Influence of combined power error and astigmatism on visual acuity." Vision Science and Its Applications, OSA Technical Digest Series. Washington, DC: Optical Society of America (1995): 151-4.

[0046] Acuity loss values $ACU(\alpha, \beta)$ of the example lens are plotted in the background of figures 4 to 11 and curves indicates iso-acuity loss values where there is an increment of 0.1 logMAR between neighbouring curves of different acuity loss values. On all these figures, a circle, referred as CIR, is represented; said circle is centered on $(\alpha, \beta) = (12,0)$ and its radius is equal to 35 degree. Said circle represent the angular zone within which the criteria of the invention are defined.

[0047] Figure 4 shows how to calculate criterion LAcuSub85(0.1); LAcuSub85(0.1) is the angular extent (in deg^2) of the zone (in grey on the figure) between the two central neighbouring curves of acuity loss equal to 0.1 logMAR, said angular extent being calculated inside the circle CIR, and for lowering angle α more than $\alpha85\%$ (i.e. for $\alpha \geq \alpha85\%$), where $\alpha85\%$ is defined as the lowering angle where 85% of the prescribed addition is perceived by the wearer on the meridian line. The lowering angle of the meridian line where 85% of the prescribed addition is perceived by the wearer is defined in the frame of the present invention as being the angle lowering α where the mean refractive power, $PPO(\alpha85\%)$, fulfills following equation:

$$PPO(\alpha85\%) = PPO(FVGD) + 0.85 \times ADD_p,$$

and where $PPO(FVGD)$ is the mean refractive power according to the far-vision gaze direction, FVGD.

[0048] Similar definition is used for "a lowering angle of the meridian line where 15% of the prescribed addition is perceived by the wearer" which corresponds to the lowering angle α where the mean refractive power, $PPO(\alpha15\%)$, fulfills following equation:

$$PPO(\alpha15\%) = PPO(FVGD) + 0.15 \times ADD_p.$$

[0049] Figure 5 shows how to calculate criterion LAcuSub85(0.2); LAcuSub85(0.2) is the angular extent (in deg^2) of the zone (in grey on the figure) between the two central neighbouring curves of acuity loss equal to 0.2 logMAR, said angular extent being calculated inside the circle CIR, and for lowering angle α more than $\alpha85\%$ (i.e. for $\alpha \geq \alpha85\%$).

[0050] Figure 6 shows how to calculate criterion LAcuAlpha85(0.1); LAcuAlpha85(0.1) is the acuity width (in deg) at $\alpha85\%$ between the two central neighbouring curves of acuity loss equal to 0.1 logMAR; it is equal to $\beta_+(ACU(\alpha85\%,$

β)=0.1) - β_(ACU(α85%, β)=0.1), where $β_+$ is greater than β_α_mer(α85%) and β_ is less than β_α_mer(α85%).

[0051] Figure 7 shows how to calculate criterion LAcuAlpha85(0.2); LAcuAlpha85(0.2) is the acuity width (in deg) at α85% between the two central neighbouring curves of acuity loss equal to 0.2 logMAR; it is equal to $β_+$(ACU(α85%, β)=0.2) - β_(ACU(α85%, β)=0.2), where $β_+$ is greater than β_α_mer(α85%) and β_ is less than β_α_mer(α85%).

[0052] Figure 8 shows how to calculate criterion LAcuSubFC(0.1); LAcuSubFC(0.1) is the angular extent (in deg^2) of the zone (in grey on the figure) between the two central neighbouring curves of acuity loss equal to 0.1 logMAR, said angular extent being calculated inside the circle CIR, and for α more than $α_{FC}$ (i.e. for $α ≥ α_{FC}$).

[0053] Figure 9 shows how to calculate criterion LAcuSubFC(0.2); LAcuSubFC(0.2) is the angular extent (in deg^2) of the zone (in grey on the figure) between the two central neighbouring curves of acuity loss equal to 0.2 logMAR, said angular extent being calculated inside the circle CIR, and for α more than $α_{FC}$ (i.e. for $α ≥ α_{FC}$).

[0054] Figure 10 shows how to calculate criterion LAcuDomain(0.1); LAcuDomain(0.1) is the angular extent (in deg^2) of the zone (in grey on the figure) between the two central neighbouring curves of acuity loss equal to 0.1 logMAR, said angular extent being calculated inside the whole circle CIR.

[0055] Figure 11 shows how to calculate criterion LAcuDomain(0.2); LAcuDomain(0.2) is the angular extent (in deg^2) of the zone (in grey on the figure) between the two central neighbouring curves of acuity loss equal to 0.2 logMAR, said angular extent being calculated inside the whole circle CIR.

[0056] Figure 12 shows how to calculate criterion PeaksMean; the module of resulting astigmatism values of the example lens are plotted in the background of figure 12 and curves indicates iso-module of resulting astigmatism values where there is an increment of 0.25 Diopter between neighbouring curves of different module of resulting astigmatism values. Previously defined Circle, CIR, is represented; PeaksMean is the mean maximum module of resulting astigmatism (in Diopter) which is equal to $[ASR_{max}(α_L, β_L) + ASR_{max}(α_R, β_R)]/2$, where $ASR_{max}(α_L, β_L)$ is the maximum module of resulting astigmatism on a side (left side) of the meridian line, and $ASR_{max}(α_R, β_R)$ is the maximum module of resulting astigmatism on the other side (right side) of the meridian line that are both determined inside the circle, CIR.

[0057] Figure 13 shows the variation of object proximity ProxO as a function of the lowering angle α used to define the ergorama in view of US patent US-A-6,318,859.

[0058] The ergorama used in the frame of the present invention is defined thanks to following data, where object proximity values are given for lowering angles α:

Alpha [deg]	ProxO [D]
-50	0
-40	0
-30	0
-20	0
-10	0
0	0
10	1.65
20	2.54
30	2.78
40	2.93
50	2.98

Examples

[0059] Figures 14 to 17 give optical characteristics of an ophthalmic progressive addition lens according to the prior art, hereafter referred as "PA_lens".

[0060] Figures 18 to 21 give optical characteristics of an ophthalmic progressive addition lens provided by the method according to the invention, hereafter referred as "INV_lens".

[0061] Said both ophthalmic progressive addition lenses have been designed so as to fulfil following prescribed features:

- prescribed sphere SPH_p = + 4 Diopter
- prescribed astigmatism value CYL_P = 0 Diopter
- prescribed axis $AXIS_p$ = 0°
- prescribed addition ADD_p = 2 Diopter

[0062] Figures 14 and 18 represent the mean refractive power repartition profile, PPO, as a function of the lowering

angle α, along the meridian line, for respectively the prior art ophthalmic progressive addition lens and the ophthalmic progressive addition lens provided by the method according to the present invention. Lowering angles corresponding to α85% and to α15% are indicated.

[0063] Figures 15 and 19 represent the mean refractive power repartition, PPO, over the (α, β) domain, for respectively the prior art ophthalmic progressive addition lens and the ophthalmic progressive addition lens provided by the method according to the present invention. Curves indicates iso-mean refractive power values where there is an increment of 0.25 Diopter between neighbouring curves of different module of resulting astigmatism values.

[0064] Figures 16 and 20 represent respectively the module of resulting astigmatism repartition, ASR, over the (α, β) domain, for respectively the prior art ophthalmic progressive addition lens and the ophthalmic progressive addition lens provided by the method according to the present invention. Curves indicates iso-module of resulting astigmatism values where there is an increment of 0.25 Diopter between neighbouring curves of different module of resulting astigmatism values.

[0065] Figures 17 and 21 represent respectively the acuity loss value repartition ACU, over the (α, β) domain, for respectively the prior art ophthalmic progressive addition lens and the ophthalmic progressive addition lens provided by the method according to the present invention. Curves indicates iso-acuity loss values where there is an increment of 0.1 logMAR between neighbouring curves of different module of resulting astigmatism values.

[0066] Here above defined acuity criteria have been calculated for the said both ophthalmic progressive addition lenses. Results are reported here bellow.

Lens	PA_lens	INV_lens
AcuityCriterion1	43	56
AcuityCriterion2	104	139
AcuityCriterion3	3.8	4.7
AcuityCriterion4	6	7.4
AcuityCriterion5	8.4	9.4
AcuityCriterion6	12.4	14.5

[0067] The inventors have done tests that demonstrate that the chosen threshold value of AcuityCriterion 1, and optionally the chosen threshold values of AcuityCriterion2 and/or AcuityCriterion3 and/or AcuityCriterion4 and/or AcuityCriterion5 and/or AcuityCriterion6, is (are) suitable for providing to a farsighted and presbyopic wearer an ophthalmic progressive addition lens where the wearer's visual comfort is enhanced in view of known prior art ophthalmic progressive addition lens.

Claims

1. A method implemented by computer means for providing an ophthalmic progressive addition lens to a farsighted and presbyopic wearer having a prescribed far vision mean refractive power greater or equal to plus 1 Diopter and a non nil prescribed addition, ADD_p, comprising the step of calculating a mean refractive power repartition, PPO(α, β), a module of resulting astigmatism repartition, ASR(α, β), an acuity loss value repartition ACU(α, β), where said (α, β) functions are calculated in as-worn conditions of the lens by the wearer, so as to fulfil following requirement of a first acuity criterion, AcuityCriterion1:

$$\text{AcuityCriterion1} \geq 44 \text{ D}^2.\text{deg};$$

"D" refers to Diopter, "deg" to degree, AcuityCriterion1 is defined as a combination of PPO(α, β), ASR(α, β), ADD_p, and ACU(α, β) and wherein the method further comprises following steps:

• Calculating or defining a meridian line, ML(α, β),
• Calculating or defining a fitting cross, FC($α_{FC}$, $β_{FC}$),
• Calculating the mean refractive power, PPO(α, β), and the module of resulting astigmatism, ASR(α, β), determined in as-worn conditions of the lens by the wearer for gaze directions (α, β) joining the center of rotation of the eye, CRE, and the lens, where α is a lowering angle in degree and β is an azimuth angle in degree, an acuity loss value ACU(α, β) is expressed in logMAR and defined according to following equation:

$$ACU(\alpha, \beta) = -\log(AC\%(\alpha, \beta)/100),$$

where :

- $AC\%(\alpha, \beta) = 100 - 63 \times P(\alpha, \beta) - 44.3 \times ASR(\alpha, \beta) + 7.2 \times P(\alpha, \beta)^2 + 19.5 \times P(\alpha, \beta) \times ASR(\alpha, \beta) + ASR(\alpha, \beta)^2$; when $P(\alpha, \beta) \geq 0$; and
- $AC\%(\alpha, \beta) = 100 - 44.3 \times ASR(\alpha, \beta) + ASR(\alpha, \beta)^2$; when $P(\alpha, \beta) < 0$;
- $P(\alpha, \beta) = PPO(\alpha, \beta) - PPO(\alpha, \beta\_\alpha\_mer)$;
- β_α_mer is the value of the azimuth angle β on the meridian line, $ML(\alpha, \beta)$, at the lowering angle α; and where AcuityCriterion1 = Numerator1 / Denominator;
- Numerator1 = LAcuSub85(0.1) x LAcuAlpha85(0.1) x ADD_p^4;
- Denominator = $PeaksMean^2$ x PVL^2;
- LAcuSub85(0.1) is the angular extent (in deg^2) of the zone where $ACU(\alpha, \beta) \leq 0.1$ logMAR, inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees, and where $\alpha \geq \alpha85\%$, $\alpha85\%$ being the lowering angle where 85% of the prescribed addition is perceived by the wearer on the meridian line;
- LAcuAlpha85(0.1) is the acuity width (in deg) at $\alpha85\%$ between two iso-acuity loss lines corresponding to 0.1 logMAR and is equal to:
$\beta_+(ACU(\alpha85\%, \beta)=0.1) - \beta_-(ACU(\alpha85\%, \beta)=0.1)$, where β_+ is greater than $\beta\_\alpha\_mer(\alpha85\%)$ and β_- is less than $\beta\_\alpha\_mer(\alpha85\%)$;
- PVL is the power variation length is expressed in deg and defined as being equal to $(\alpha85\% - \alpha15\%)$, $\alpha15\%$ being the lowering angle where 15% of the prescribed addition is perceived by the wearer on the meridian line;
- PeaksMean is the mean maximum module of resulting astigmatism (in Diopter) which is equal to $[ASR_{max}(\alpha_L, \beta_L) + ASR_{max}(\alpha_R, \beta_R)]/2$, where $ASR_{max}(\alpha_L, \beta_L)$ is the maximum module of resulting astigmatism on a side (left side) of the meridian line, and $ASR_{max}(\alpha_R, \beta_R)$ is the maximum module of resulting astigmatism on the other side (right side) of the meridian line that are both determined inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees.

2. The method for providing an ophthalmic progressive addition lens as claimed in claim 1, according to which one calculates the lens so as to fulfil following requirement of a second acuity criterion, AcuityCriterion2:

$$\text{AcuityCriterion2} \geq 105 \text{ D}^2.\text{deg},$$

where:

- AcuityCriterion2 = Numerator2 / Denominator;
- Numerator2 = LAcuSub85(0.2) x LAcuAlpha85(0.2) x ADD_p^4;
- LAcuSub85(0.2) is the angular extent (in deg^2) of the zone where $ACU(\alpha, \beta) \leq 0.2$ logMAR, inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees, and where $\alpha \geq \alpha85\%$;
- LAcuAlpha85(0.2) is the acuity width (in deg) at $\alpha85\%$ between two iso-acuity loss lines corresponding to 0.2 logMAR and is equal to $\beta_+(ACU(\alpha85\%, \beta)=0.2) - \beta_-(ACU(\alpha85\%, \beta)=0.2)$, where β_+ is greater than $\beta\_\alpha\_mer(\alpha85\%)$ and β_- is less than $\beta\_\alpha\_mer(\alpha85\%)$.

3. The method for providing an ophthalmic progressive addition lens as claimed in any of claims 1 to 2, according to which one calculates the lens so as to fulfil following requirement of a third acuity criterion, AcuityCriterion3:

$$\text{AcuityCriterion3} \geq 3.9 \text{ D},$$

where:

- AcuityCriterion3 = Numerator3 / Denominator;
- Numerator3 = LAcuSubFC(0.1) x ADD_p^3;
- LAcuSubFC(0.1) is the angular extent (in deg^2) of the zone where $ACU(\alpha, \beta) \leq 0.1$ logMAR, inside a circle, CIR, centered on $(\alpha, \beta) = (12,0)$, which radius is 35 degrees, and where $\alpha \geq \alpha_{FC}$.

4. The method for providing an ophthalmic progressive addition lens as claimed in any of claims 1 to 3, according to which one calculates the lens so as to fulfil following requirement of a fourth acuity criterion, AcuityCriterion4:

$$\text{AcuityCriterion4} \geq 6.1 \text{ D},$$

where:

- AcuityCriterion4 = Numerator4 / Denominator;
- Numerator4 = LAcuSubFC(0.2) x ADD_p^3;
- LAcuSubFC(0.2) is the angular extent (in deg^2) of the zone where ACU(α, β) $\leq$ 0.2 logMAR, inside a circle, CIR, centered on (α, β) = (12,0), which radius is 35 degrees, and where $\alpha \geq \alpha_{FC}$.

5. The method for providing an ophthalmic progressive addition lens as claimed in any of claims 1 to 4, according to which one calculates the lens so as to fulfil following requirement of a fifth acuity criterion, AcuityCriterion5:

$$\text{AcuityCriterion5} \geq 8.5 \text{ D},$$

where:

- AcuityCriterion5 = Numerator5 / Denominator;
- Numerator5 = LAcuDomain(0.1) x ADD_p^3;
- LAcuDomain(0.1) is the angular extent (in deg^2) of the zone where ACU(α, β) $\leq$ 0.1 logMAR, inside a circle, CIR, centered on (α, β) = (12,0), which radius is 35 degrees.

6. The method for providing an ophthalmic progressive addition lens as claimed in any of claims 1 to 5, according to which one calculates the lens so as to fulfil following requirement of a sixth acuity criterion, AcuityCriterion6:

$$\text{AcuityCriterion6} \geq 12.5 \text{ D},$$

where:

- AcuityCriterion6 = Numerator6 / Denominator;
- Numerator6 = LAcuDomain(0.2) x ADD_p^3;
- LAcuDomain(0.2) is the angular extent (in deg^2) of the zone where ACU(α, β) $\leq$ 0.2 logMAR, inside a circle, CIR, centered on (α, β) = (12,0), which radius is 35 degrees.

7. The method for providing an ophthalmic progressive addition lens as claimed in any of claims 1 to 6, according to which the method comprises an optimization routine where at least a target is chosen within requirement of an acuity criterion chosen in the list consisting of AcuityCriterion1, AcuityCriterion2, AcuityCriterion3, AcuityCriterion4, AcuityCriterion5, AcuityCriterion6.

Patentansprüche

1. Verfahren, das durch ein Computermittel implementiert wird, zum Bereitstellen einer ophthalmischen progressiven Zusatzlinse für einen weitsichtigen und altersweitsichtigen Träger, der eine verschriebene mittlere Weitsichtbrechkraft von größer oder gleich plus 1 Dioptrien und einen verschriebenen Zusatz ungleich null, ADD_p, aufweist, umfassend den Schritt des Berechnens einer mittleren Brechkraftverteilung, PPO(α, β), eines Moduls einer resultierenden Astigmatismusverteilung, ASR(α, β), einer Sehschärfeverlustwertverteilung ACU(α, β), wobei die (α, β)-Funktionen im Tragezustand der Linse durch den Träger berechnet werden, um die folgende Anforderung eines ersten Sehschärfekriteriums, SehschärfeKriterium1, zu erfüllen:

SehschärfeKriterium1 $\geq$ 44 D^2.gr;
"D" steht für Dioptrien, "gr" für Grad, SehschärfeKriterium1 ist als eine Kombination von PPO(α, β), ASR(α, β), ADD_p und ACU(α, β) definiert, und wobei das Verfahren ferner folgende Schritte umfasst:

• Berechnen oder Definieren einer Meridianlinie, ML(α, β),
• Berechnen oder Definieren eines Passkreuzes, FC(α_{FC}, β_{FC}),
• Berechnen der mittleren Brechkraft, PPO(α, β), und des Moduls eines resultierenden Astigmatismus, ASR(α, β), bestimmt im Tragezustand der Linse durch den Träger für Blickrichtungen (α, β), wobei das Rotationszentrum des Auges, CRE, und die Linse verbunden werden, wobei α ein Absenkwinkel in Grad ist und β ein Azimutwinkel in Grad ist, wobei ein Sehschärfeverlustwert ACU(α, β) in logMAR ausgedrückt und gemäß der folgenden Gleichung definiert wird:

$$\mathtt{ACU(\alpha,\ \beta)\ =\ -\ log\ (AC\%(\alpha,\ \beta)/100),}$$

wobei:

• AC%(α, β) = 100 - 63 x P(α, β) - 44,3 x ASR(α, β) + 7,2 x P(α, β)^2 + 19, 5 x P (α, β) x ASR(α, β) + ASR(α, β)^2; wenn P(α, β) $\geq$ 0; und
• AC%(α, β) = 100 - 44,3 x ASR(α, β) + ASR(α, β)^2; wenn P (α, β) < 0;
• P(α, β) = PPO(α, β) - PPO(α, β_α_mer);
• β_α_mer der Wert des Azimutwinkels β auf der Meridianlinie, ML(α, β), beim Absenkwinkel α ist;

und wobei SehschärfeKriterium1 = Numerator1/Denominator;

• Numerator1 = LAcuSub85(0,1) x LAcuAlpha85(0,1) x ADD$_p^4$;
• Denominator = PeaksMean^2 x PVL^2;
• LAcuSub85(0,1) die Winkelausdehnung (in gr^2) der Zone ist, wobei ACU(α, β) $\leq$ 0,1 logMAR, innerhalb eines Kreises, CIR, zentriert auf (α, β) = (12,0), dessen Radius 35 Grad ist, und wobei $\alpha \geq \alpha$85 %, wobei α85 % der Absenkwinkel ist, wobei 85 % des verschriebenen Zusatzes durch den Träger auf der Meridianlinie wahrgenommen werden;
• LAcuAlpha85(0,1) die Sehschärfebreite (in Grad) bei α85 % zwischen zwei Isosehschärfeverlustlinien entsprechend 0,1 logMAR ist und gleich Folgendem ist:
β_+(ACU(α85 %, β)=0,1) - β_-(ACU(α85 %, β)=0,1), wobei β_+ größer als β_α_mer(α85 %) ist und β_- kleiner als β_α_mer(α85 %) ist;
• PVL die Leistungsschwankungslänge ist, in Grad ausgedrückt wird und als gleich (α85 % - α15 %) definiert ist, wobei α15 % der Absenkwinkel ist, wobei 15 % des verschriebenen Zusatzes durch den Träger auf der Meridianlinie wahrgenommen werden;
• PeaksMean das mittlere maximale Modul eines resultierenden Astigmatismus (in Dioptrien) ist, das gleich [ASRmax (α_L, β_L) + ASRmax(α_R, β_R)]/2 ist, wobei ASRmax(α_L, β_L) das maximale Modul eines resultierenden Astigmatismus auf einer Seite (linke Seite) der Meridianlinie ist und ASRmax(α_R, β_R) das maximale Modul eines resultierenden Astigmatismus auf der anderen Seite (rechte Seite) der Meridianlinie ist, die beide innerhalb eines Kreises, CIR, zentriert auf (α, β) = (12,0), dessen Radius 35 Grad ist, bestimmt werden.

2. Verfahren zum Bereitstellen einer ophthalmischen progressiven Zusatzlinse nach Anspruch 1, gemäß dem die Linse berechnet wird, um die folgende Anforderung eines zweiten Sehschärfekriteriums, SehschärfeKriterium2, zu erfüllen: SehschärfeKriterium2 $\geq$ 105 D^2.gr, wobei:

• SehschärfeKriterium2 = Numerator2/Denominator;
• Numerator2 = LAcuSub85(0,2) x LAcuAlpha85(0,2) x ADD$_p^4$;
• LAcuSub85(0,2) die Winkelausdehnung (in gr^2) der Zone ist, wobei ACU(α, β) $\leq$ 0,2 logMAR, innerhalb eines Kreises, CIR, zentriert auf (α, β) = (12,0), dessen Radius 35 Grad ist, und wobei $\alpha \geq \alpha$85 %;
• LAcuAlpha85(0,2) die Sehschärfebreite (in Grad) bei α85 % zwischen zwei Isosehschärfeverlustlinien entsprechend 0,2 logMAR ist und gleich β_+(ACU(α85 %, β)=0,2) - β_-(ACU(α85 %, β)=0,2) ist, wobei β_+ größer als β_α_mer(α85 %) ist und β_- kleiner als β_α_mer(α85 %) ist.

3. Verfahren zum Bereitstellen einer ophthalmischen progressiven Zusatzlinse nach einem der Ansprüche 1 bis 2, gemäß dem die Linse berechnet wird, um die folgende Anforderung eines dritten Sehschärfekriteriums, SehschärfeKriterium3, zu erfüllen:
SehschärfeKriterium3 $\geq$ 3,9 D, wobei:

• SehschärfeKriterium3 = Numerator3/Denominator;

• Numerator3 = LAcuSubFC(0,1) x ADD_p^3;
• LAcuSubFC(0,1) die Winkelausdehnung (in gr^2) der Zone ist, wobei $ACU(\alpha, \beta) \leq 0,1$ logMAR, innerhalb eines Kreises, CIR, zentriert auf $(\alpha, \beta) = (12,0)$, dessen Radius 35 Grad ist, und wobei $\alpha \geq \alpha_{FC}$.

4. Verfahren zum Bereitstellen einer ophthalmischen progressiven Zusatzlinse nach einem der Ansprüche 1 bis 3, gemäß dem die Linse berechnet wird, um die folgende Anforderung eines vierten Sehschärfekriteriums, SehschärfeKriterium4, zu erfüllen:
SehschärfeKriterium4 $\geq 6,1$ D, wobei:

• SehschärfeKriterium4 = Numerator4/Denominator;
• Numerator4 = LAcuSubFC(0,2) x ADD_p^3;
• LAcuSubFC(0,2) die Winkelausdehnung (in gr^2) der Zone ist, wobei $ACU(\alpha, \beta) \leq 0,2$ logMAR, innerhalb eines Kreises, CIR, zentriert auf $(\alpha, \beta) = (12,0)$, dessen Radius 35 Grad ist, und wobei $\alpha \geq \alpha_{FC}$.

5. Verfahren zum Bereitstellen einer ophthalmischen progressiven Zusatzlinse nach einem der Ansprüche 1 bis 4, gemäß dem die Linse berechnet wird, um die folgende Anforderung eines fünften Sehschärfekriteriums, SehschärfeKriterium5, zu erfüllen:
SehschärfeKriterium5 $\geq 8,5$ D, wobei:

• SehschärfeKriterium5 = Numerator5/Denominator;
• Numerator5 = LAcuDomain(0,1) x ADD_p^3;
• LAcuDomain(0,1) die Winkelausdehnung (in gr^2) der Zone ist, wobei $ACU(\alpha, \beta) \leq 0,1$ logMAR, innerhalb eines Kreises, CIR, zentriert auf $(\alpha, \beta) = (12,0)$, dessen Radius 35 Grad ist.

6. Verfahren zum Bereitstellen einer ophthalmischen progressiven Zusatzlinse nach einem der Ansprüche 1 bis 5, gemäß dem die Linse berechnet wird, um die folgende Anforderung eines sechsten Sehschärfekriteriums, SehschärfeKriterium6, zu erfüllen:
SehschärfeKriterium6 $\geq 12,5$ D, wobei:

• SehschärfeKriterium6 = Numerator6/Denominator;
• Numerator6 = LAcuDomain(0,2) x ADD_p^3;
• LAcuDomain(0,2) die Winkelausdehnung (in gr^2) der Zone ist, wobei $ACU(\alpha, \beta) \leq 0,2$ logMAR, innerhalb eines Kreises, CIR, zentriert auf $(\alpha, \beta) = (12,0)$, dessen Radius 35 Grad ist.

7. Verfahren zum Bereitstellen einer ophthalmischen progressiven Zusatzlinse nach einem der Ansprüche 1 bis 6, gemäß dem das Verfahren eine Optimierungsroutine umfasst, wobei zumindest ein Ziel innerhalb einer Anforderung eines Sehschärfekriteriums ausgewählt wird, das ausgewählt wird in der Liste bestehend aus SehschärfeKriterium1, SehschärfeKriterium2, SehschärfeKriterium3, SehschärfeKriterium4, SehschärfeKriterium5, SehschärfeKriterium6.

Revendications

1. Procédé mis en œuvre par des moyens informatiques permettant de fournir une lentille ophtalmique à addition progressive à un porteur presbyte et hypermétrope ayant une puissance de réfraction moyenne de vision de loin prescrite supérieure ou égale à plus 1 dioptries et une addition prescrite non nulle, ADD_p, comprenant l'étape de calcul d'une répartition de puissance de réfraction moyenne, $PPO(\alpha, \beta)$, un module de répartition de l'astigmatisme résultant, $ASR(\alpha, \beta)$, une répartition de valeur de perte d'acuité $ACU(\alpha, \beta)$, où lesdites fonctions (α, β) sont calculées dans des conditions de port de la lentille par le porteur, de façon à remplir l'exigence suivante d'un premier critère d'acuité, AcuityCriterion1 :

AcuityCriterion1 ≥ 44 D^2.deg ;
« D » fait référence à dioptrie, « deg » à degré, AcuityCriterion1 est défini en tant que combinaison de $PPO(\alpha, \beta)$, $ASR(\alpha, \beta)$, ADD_p et $ACU(\alpha, \beta)$ et dans lequel le procédé comprend en outre les étapes suivantes :

. le calcul ou la définition d'une ligne méridienne, $ML(\alpha, \beta)$,
. le calcul ou la définition d'une croix d'ajustement, $FC(\alpha_{FC}, \beta_{FC})$,
. le calcul de la puissance de réfraction moyenne, $PPO(\alpha, \beta)$, et du module d'astigmatisme résultant, $ASR(\alpha, \beta)$, déterminé dans des conditions de port de la lentille par le porteur pour des directions de regard (α, β)

rejoignant le centre de rotation de l'œil, CRE, et la lentille, où α est un angle d'abaissement en degré et β est un angle d'azimut en degré, une valeur de perte d'acuité ACU(α, β) est exprimée en logMAR et définie en fonction de l'équation suivante :

$$\text{ACU}(\alpha, \beta) = -\log (\text{AC\%}(\alpha, \beta)/100),$$

où :

. AC%(a, β) = 100 - 63 x P(α, β) - 44,3 x ASR(α, β) + 7,2 x P(α, β)^2 + 19,5 x P(α, β) x ASR(α, β) + ASR(α, β)^2 ; lorsque P(α, β) $\geq$ 0 ; et
. AC%(a, β) = 100 - 44,3 x ASR(α, β) + ASR(α, β)^2 ; lorsque P(α, β) < 0 ;
. P(α, β) = PPO(α, β) - PPO(α, β_α_mer) ;
. β_α_mer est la valeur de l'angle d'azimut β sur la ligne méridienne, ML(α, β), au niveau de l'angle d'abaissement α ;

et où AcuityCriterion1 = Numerator1/Denominator ;

. Numerator1 = LAcuSub85(0,1) x LAcuAlpha85(0,1) x ADD$_p$^{4} ;
. Denominator = PeaksMean^2 x PVL^2 ;
. LAcuSub85(0,1) est l'extension angulaire (en deg^2) de la zone où ACU(α, β) $\leq$ 0,1 logMAR, à l'intérieur d'un cercle, CIR, centré sur (α, β) = (12,0), dont le rayon est de 35 degrés, et où $\alpha \geq \alpha$85%, α85% étant l'angle d'abaissement où 85% de l'addition prescrite est perçue par le porteur sur la ligne méridienne ;
. LAcuAlpha85(0,1) est la largeur d'acuité (en deg) à α85% entre deux lignes de perte d'iso-acuité correspondant à 0,1 logMAR et est égal à :
β_+(ACU(α85%, β) = 0,1) - β_-(ACU(α85%, β) = 0,1), où β_+ est supérieur à β_α_mer(α85%) et β_- est inférieur à β_α_mer(α85%) ;
. PVL est la longueur de variation de puissance est exprimée en deg et définie comme étant égale à (α85% - α15%), α15% étant l'angle d'abaissement où 15% de l'addition prescrite est perçue par le porteur sur la ligne méridienne ;
. PeaksMean est le module maximum moyen de l'astigmatisme résultant (en dioptrie) qui est égal à [ASR$_{max}$(α_L, β_L) + ASR$_{max}$(α_R, β_R)]/ 2, où ASR$_{max}$(α_L, β_L) est le module maximum de l'astigmatisme résultant sur un côté (côté gauche) de la ligne méridienne, et ASR$_{max}$(α_R, β_R) est le module maximum de l'astigmatisme résultant sur l'autre côté (côté droit) de la ligne méridienne qui sont toutes les deux déterminées à l'intérieur d'un cercle, CIR, centré sur (α, β) = (12,0), dont le rayon est de 35 degrés.

2. Procédé permettant de fournir une lentille ophtalmique à addition progressive selon la revendication 1, selon laquelle on calcule la lentille de façon à remplir l'exigence suivante d'un deuxième critère d'acuité, AcuityCriterion2 : AcuityCriterion2 $\geq$ 105 D^2.deg, où :

•

$$\text{AcuityCriterion2} = \text{Numerator2/Denominator} ;$$

•

Numerator2 = LAcuSub85 (0,2) x LAcuAlpha85(0,2) x ADD$_{p4}$

• LAcuSub85(0,2) est l'extension angulaire (en deg^2) de la zone où ACU(α, β) $\leq$ 0,2 logMAR, à l'intérieur d'un cercle, CIR, centré sur (α, β) = (12,0), dont le rayon est de 35 degrés, et où $\alpha \geq \alpha$85% ;
• LAcuAlpha85(0,2) est la largeur d'acuité (en deg) à α85% entre deux lignes de perte d'iso-acuité correspondant à 0,2 logMAR et est égal à β_+(ACU(α85%, β) = 0,2) - β_-(ACU(α85%, β) = 0,2), où β_+ est supérieur à β_α_mer(α85%) et β_- est inférieur à β_α_mer(α85%).

3. Procédé permettant de fournir une lentille ophtalmique à addition progressive selon l'une quelconque des revendications 1 à 2, selon laquelle on calcule la lentille de façon à remplir l'exigence suivante d'un troisième critère d'acuité,

AcuityCriterion3 :
AcuityCriterion3 ≥ 3,9 D, où :

-

$$AcuityCriterion3 = Numerator3/Denominator ;$$

-

$$Numerator3 = LAcuSubFC(0,1) \times ADD_p^3 ;$$

- LAcuSubFC(0,1) est l'extension angulaire (en deg^2) de la zone où $ACU(\alpha, \beta) \leq 0,1$ logMAR, à l'intérieur d'un cercle, CIR, centré sur $(\alpha, \beta) = (12,0)$, dont le rayon est de 35 degrés, et où $\alpha \geq \alpha_{FC}$.

4. Procédé permettant de fournir une lentille ophtalmique à addition progressive selon l'une quelconque des revendications 1 à 3, selon laquelle on calcule la lentille de façon à remplir l'exigence suivante d'un quatrième critère d'acuité, AcuityCriterion4 :
AcuityCriterion4 ≥ 6,1 D, où :

-

$$AcuityCriterion4 = Numerator4/Denominator ;$$

- Numerator4 = $LAcuSubFC(0,2) \times ADD_p^3$;
- LAcuSubFC(0,2) est l'extension angulaire (en deg^2) de la zone où $ACU(\alpha, \beta) \leq 0,2$ logMAR, à l'intérieur d'un cercle, CIR, centré sur $(\alpha, \beta) = (12,0)$, dont le rayon est de 35 degrés, et où $\alpha \geq \alpha_{FC}$.

5. Procédé permettant de fournir une lentille ophtalmique à addition progressive selon l'une quelconque des revendications 1 à 4, selon laquelle on calcule la lentille de façon à remplir l'exigence suivante d'un cinquième critère d'acuité, AcuityCriterion5 :
AcuityCriterion5 ≥ 8,5 D, où :

-

$$AcuityCriterion5 = Numerator5/Denominator ;$$

-

$$Numerator5 = LAcuDomain(0,1) \times ADD_p^3 ;$$

- LAcuDomain(0,1) est l'extension angulaire (en deg^2) de la zone où $ACU(\alpha, \beta) \leq 0,1$ logMAR, à l'intérieur d'un cercle, CIR, centré sur $(\alpha, \beta) = (12,0)$, dont le rayon est de 35 degrés.

6. Procédé permettant de fournir une lentille ophtalmique à addition progressive selon l'une quelconque des revendications 1 à 5, selon laquelle on calcule la lentille de façon à remplir l'exigence suivante d'un sixième critère d'acuité, AcuityCriterion6 :
AcuityCriterion6 ≥ 12,5 D, où :

-

$$AcuityCriterion6 = Numerator6/Denominator ;$$

-

$$\texttt{Numerator6 = LAcuDomain(0,2) x ADD}_\texttt{p}^3 \texttt{;}$$

- LAcuDomain(0,2) est l'extension angulaire (en deg^2) de la zone où ACU(α, β) $\leq$ 0,2 logMAR, à l'intérieur d'un cercle, CIR, centré sur (α, β) = (12,0), dont le rayon est de 35 degrés.

7. Procédé permettant de fournir une lentille ophtalmique à addition progressive selon l'une quelconque des revendications 1 à 6, selon laquelle le procédé comprend une routine d'optimisation où au moins une cible est choisie au sein de l'exigence d'un critère d'acuité choisi dans la liste se composant de AcuityCriterion1, AcuityCriterion2, AcuityCriterion3, AcuityCriterion4, AcuityCriterion5, AcuityCriterion6.

FIG. 1

FIG. 2

FIG. 3
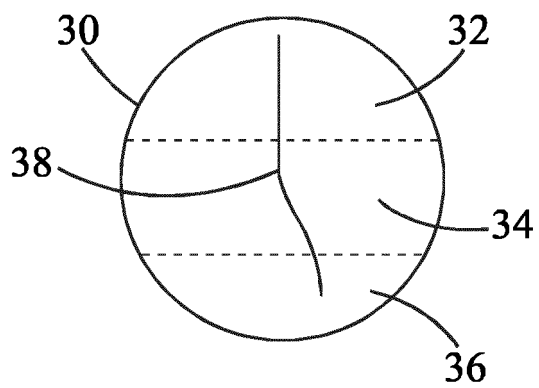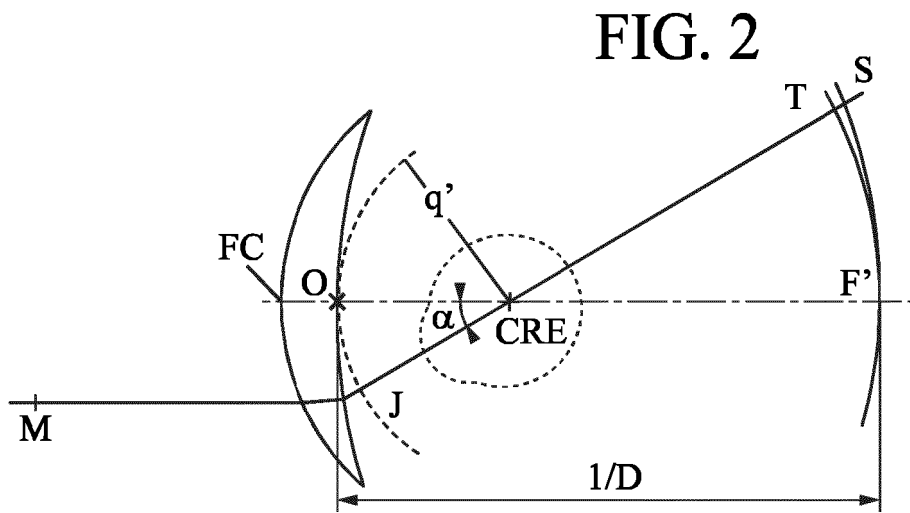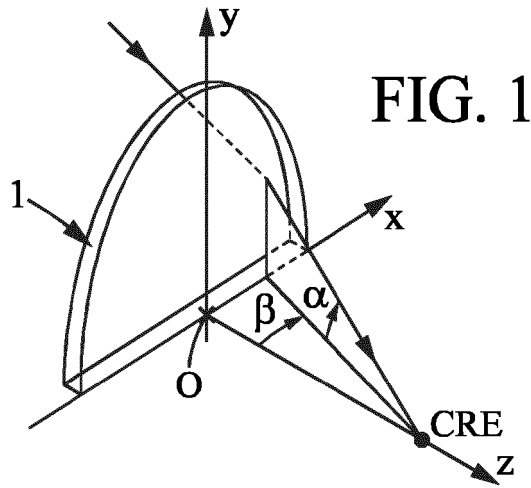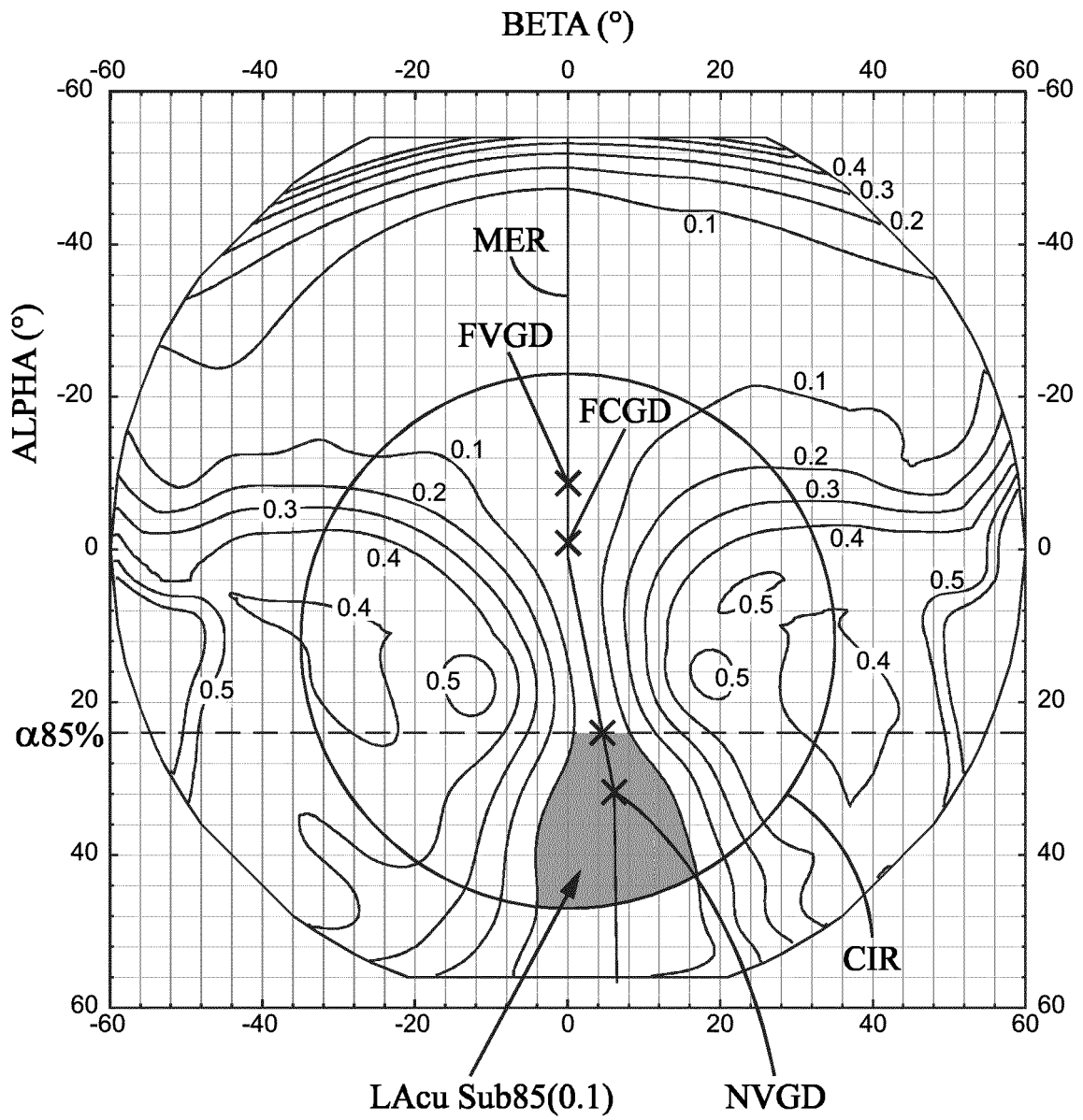
FIG. 4
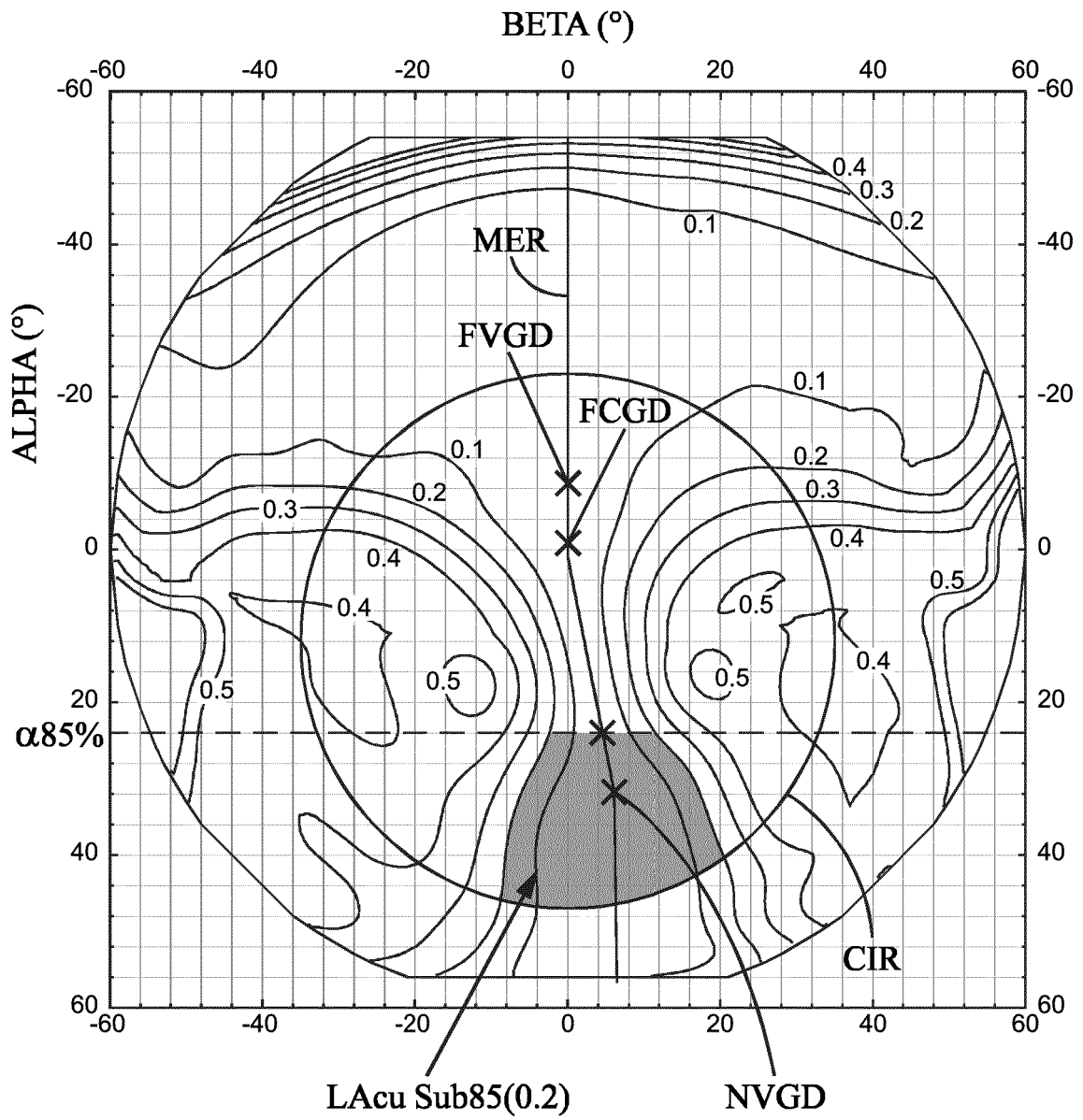
FIG. 5
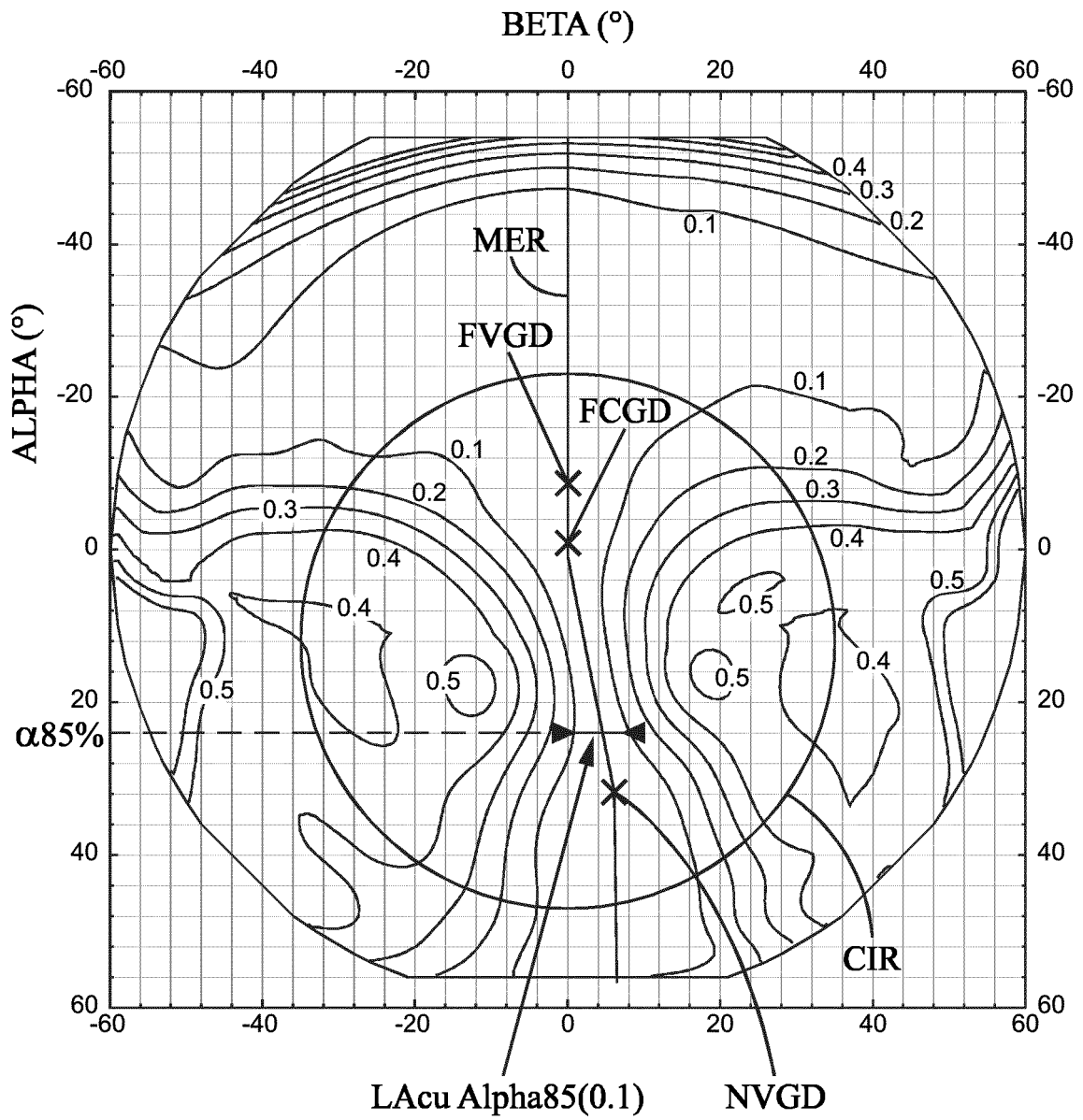
FIG. 6

FIG. 7

FIG. 8

FIG. 9

LAcu Domain(0.1)
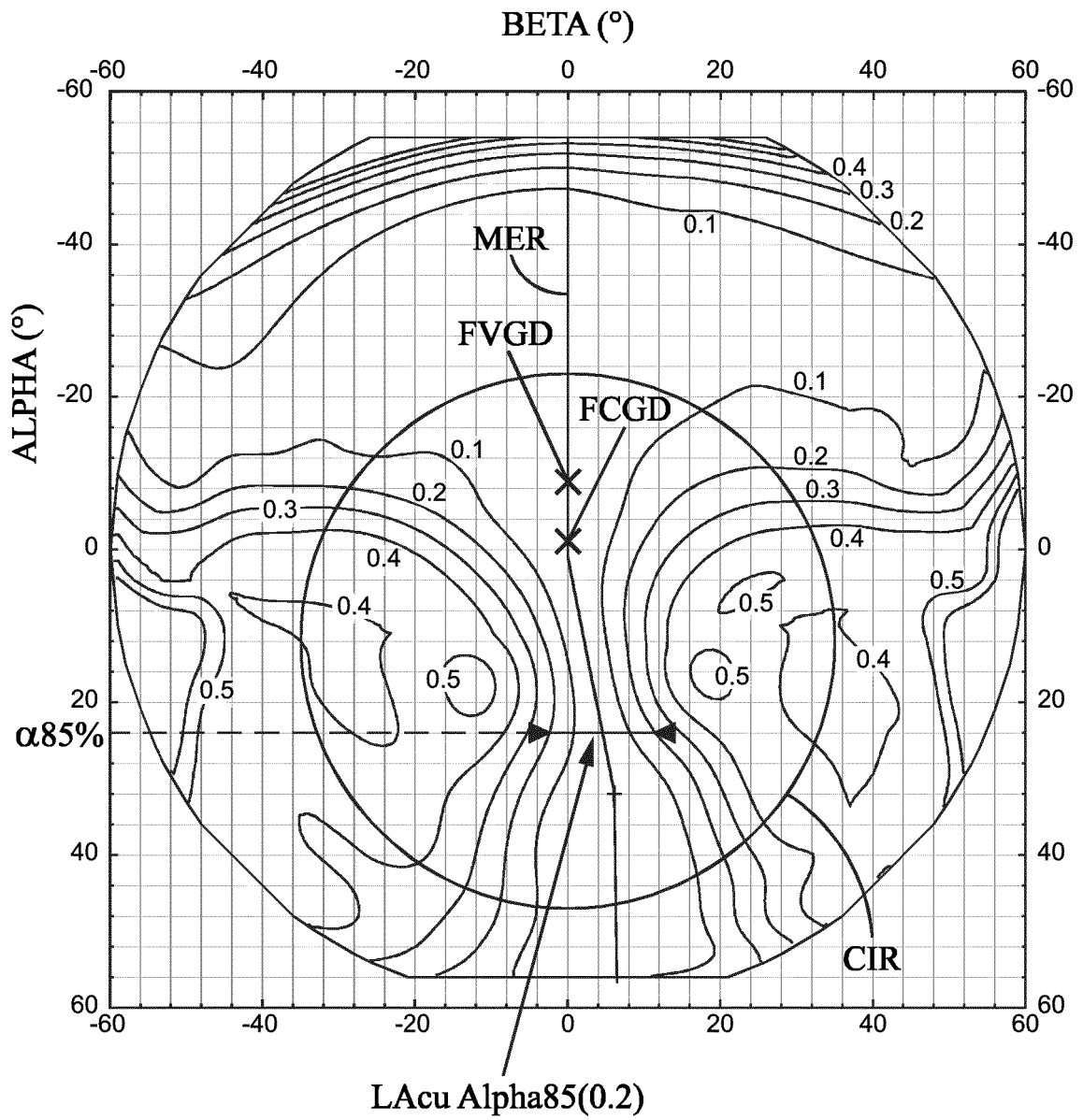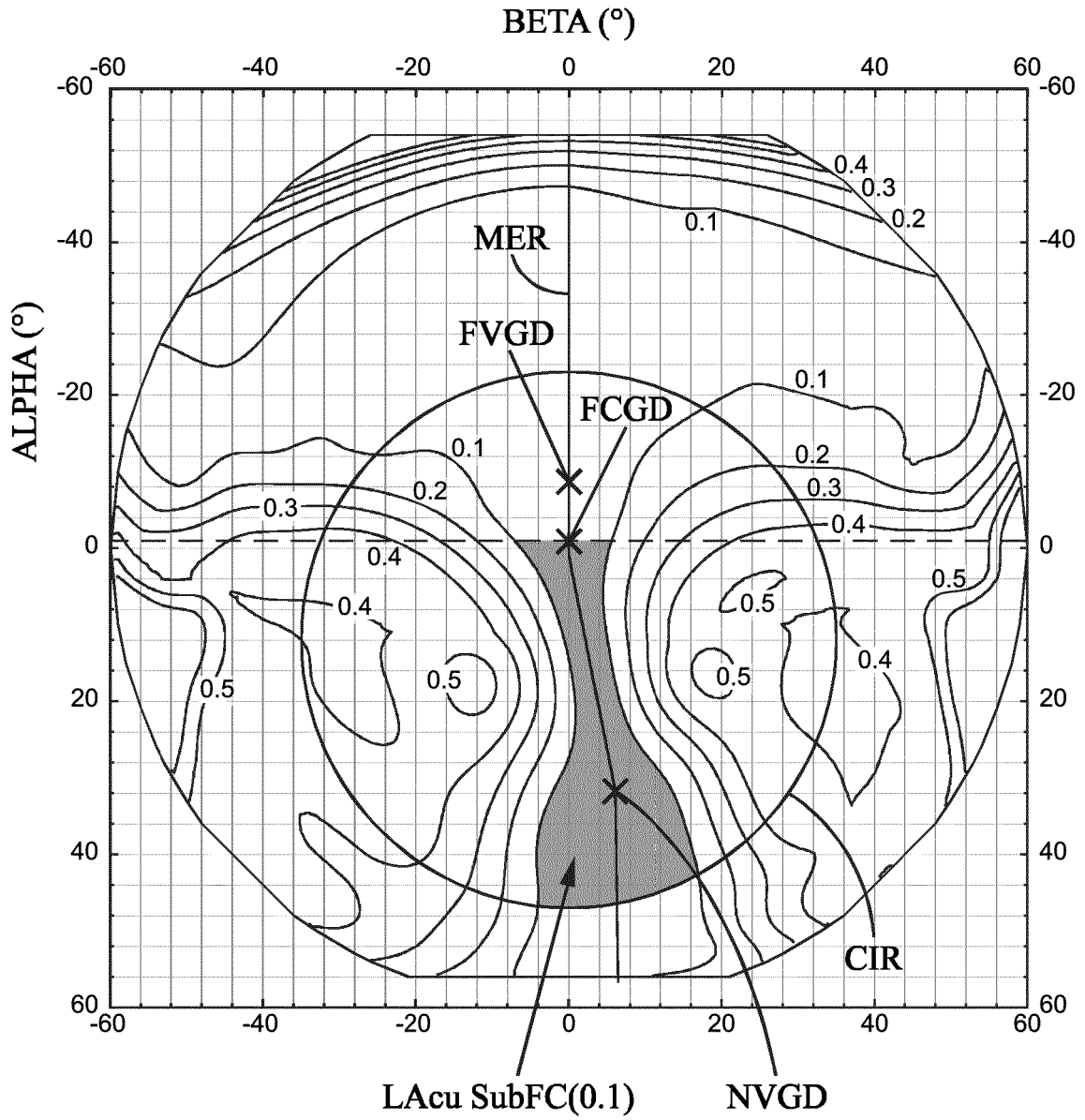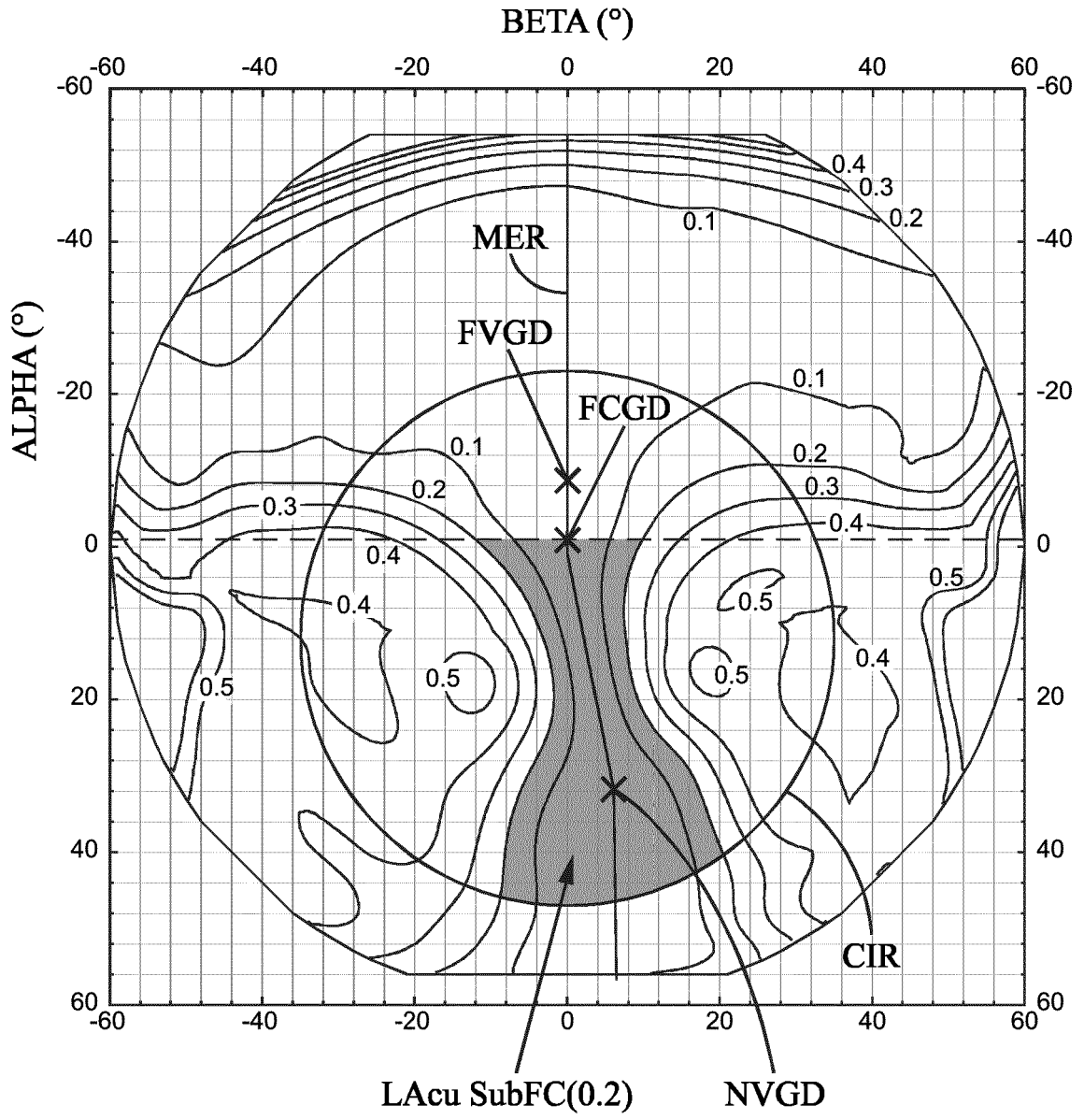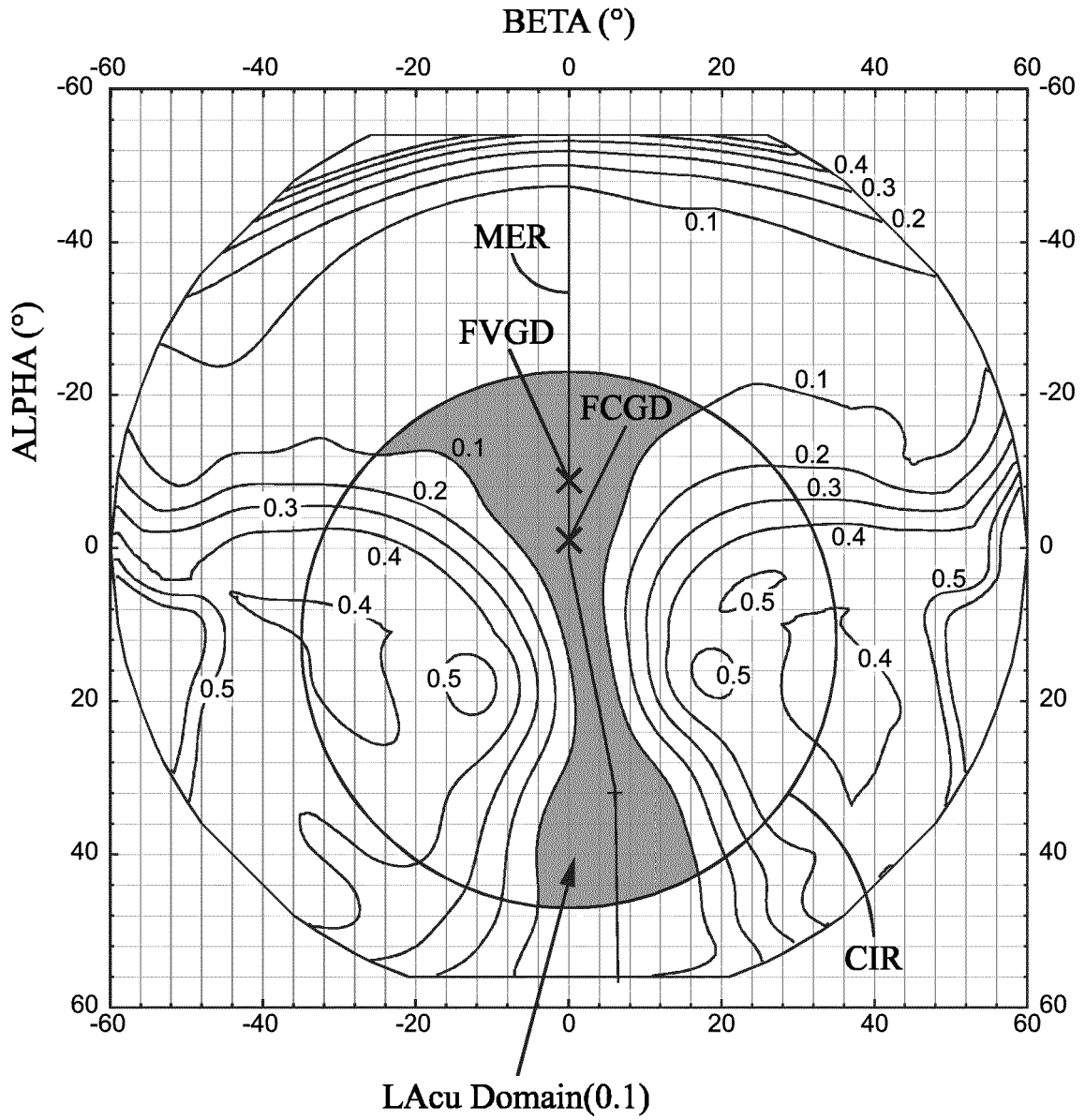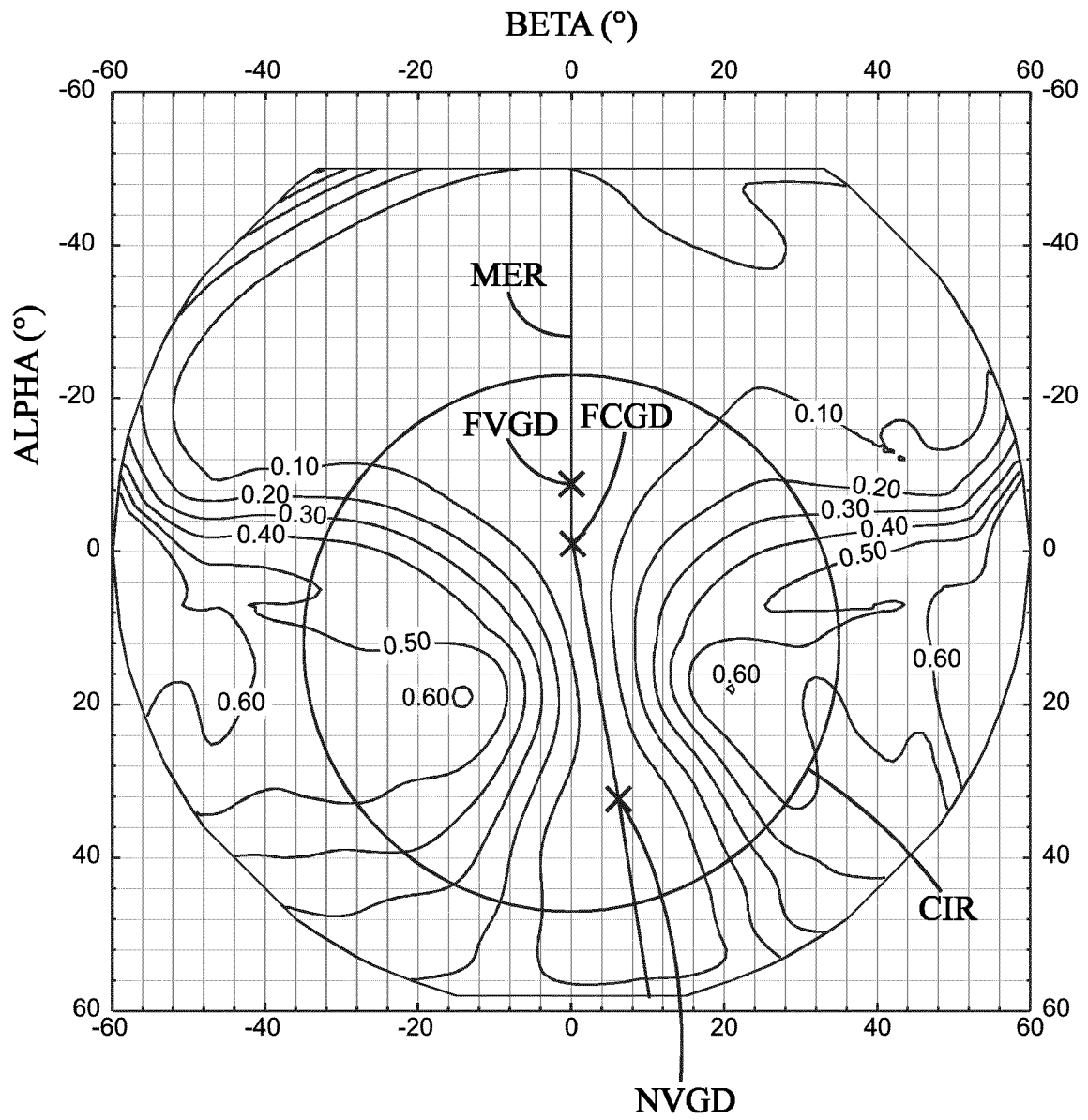
FIG. 10
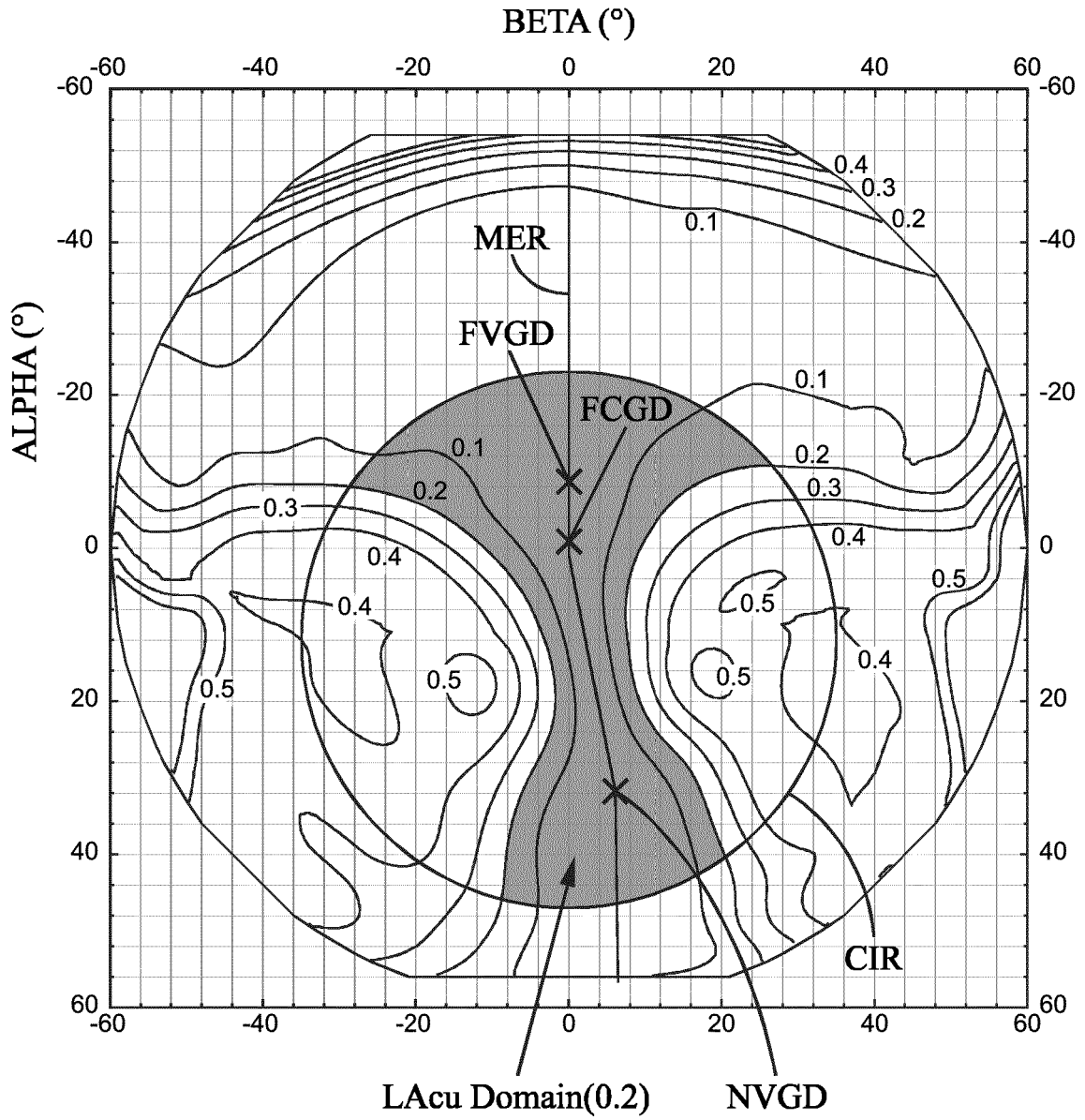
FIG. 11
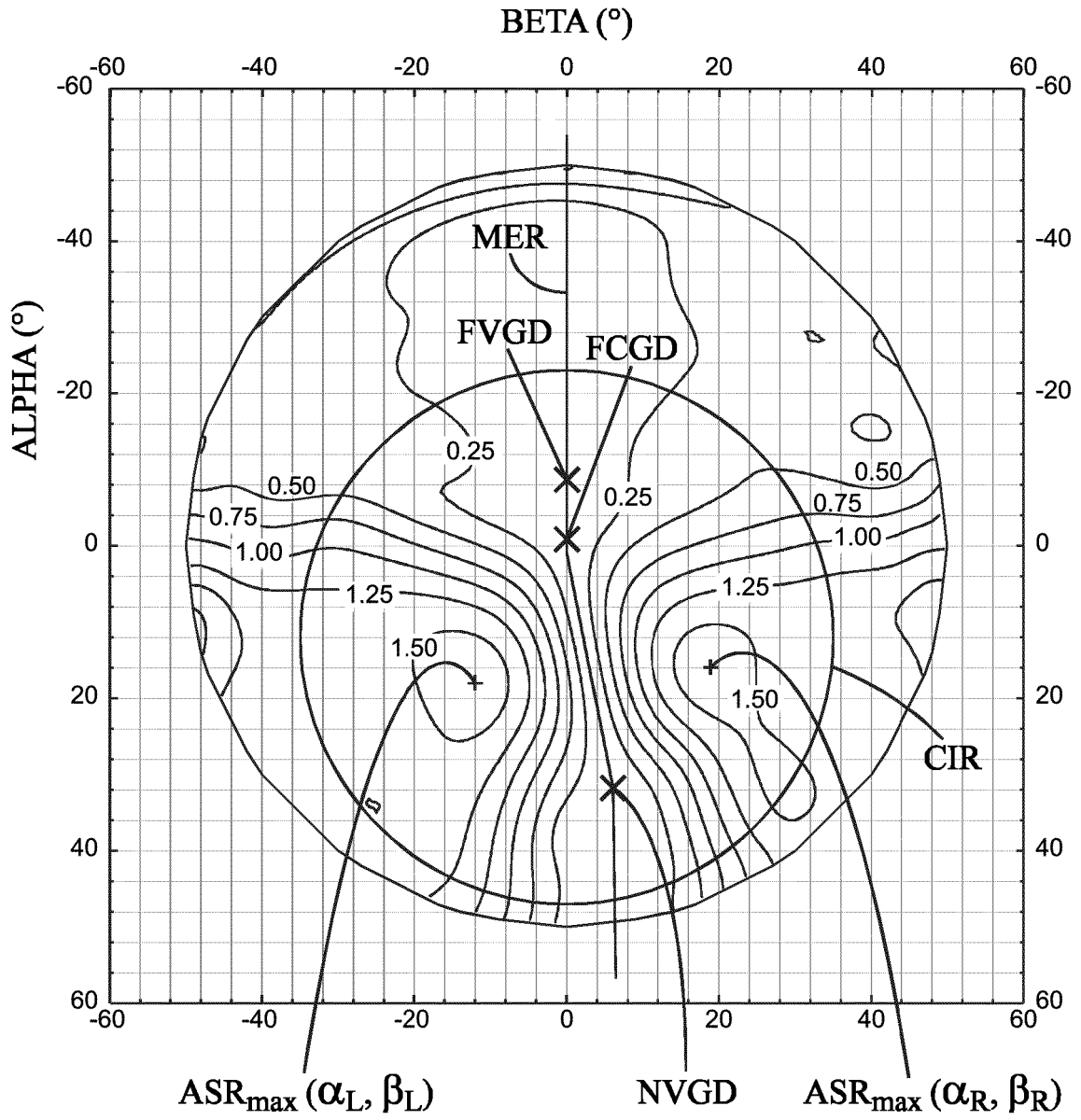
FIG. 12

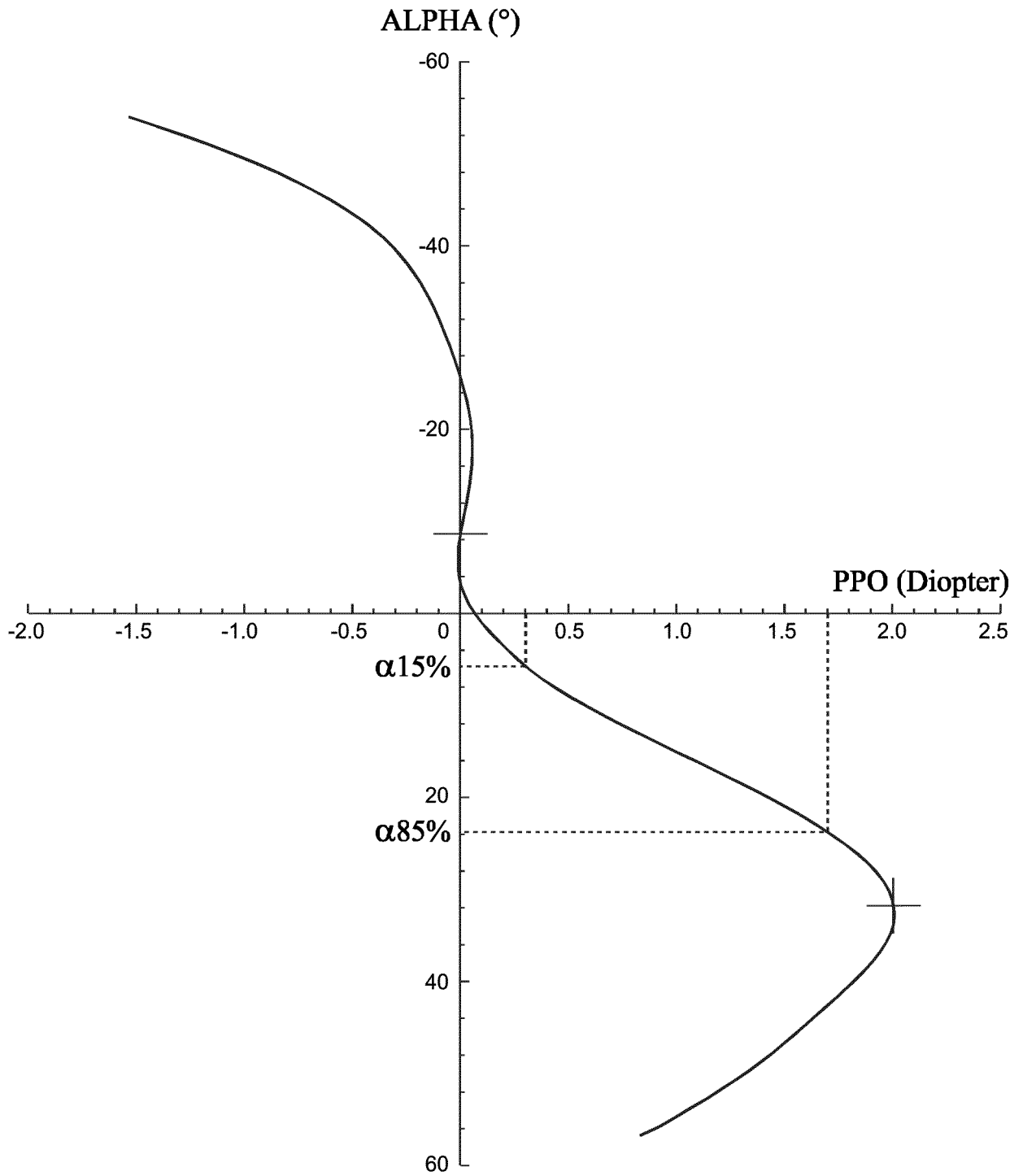FIG. 13

FIG. 14

FIG. 15

BETA (°)
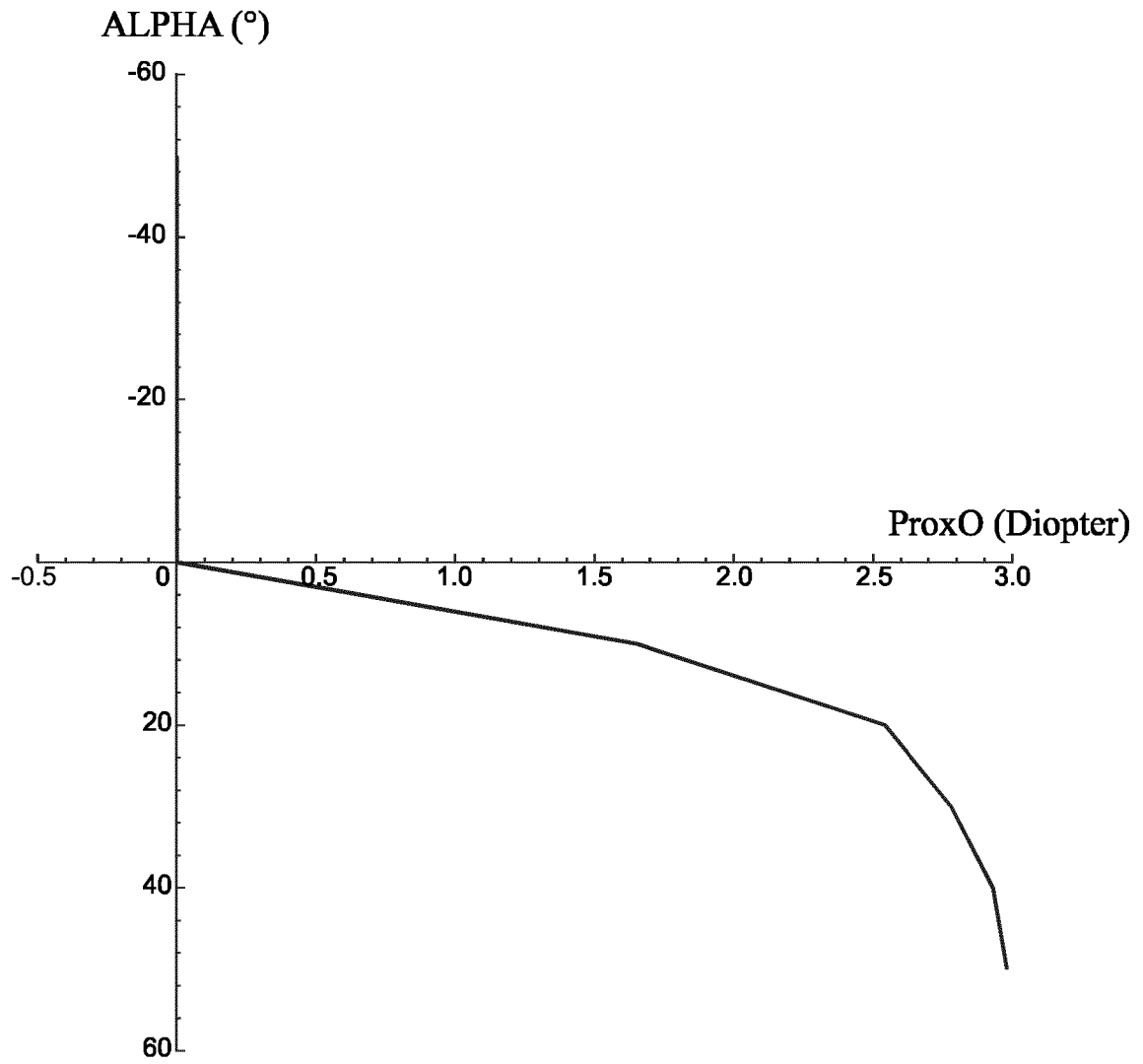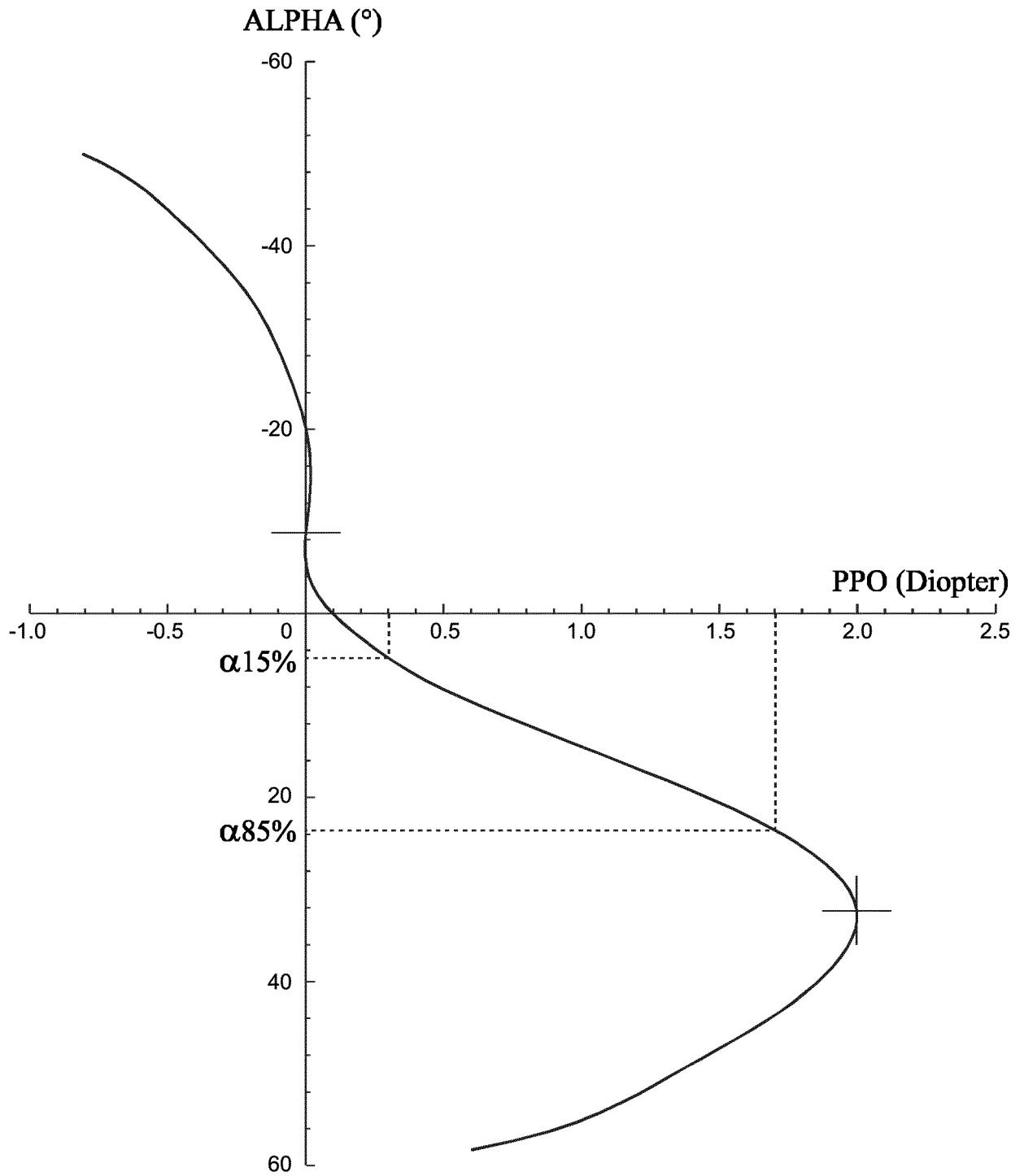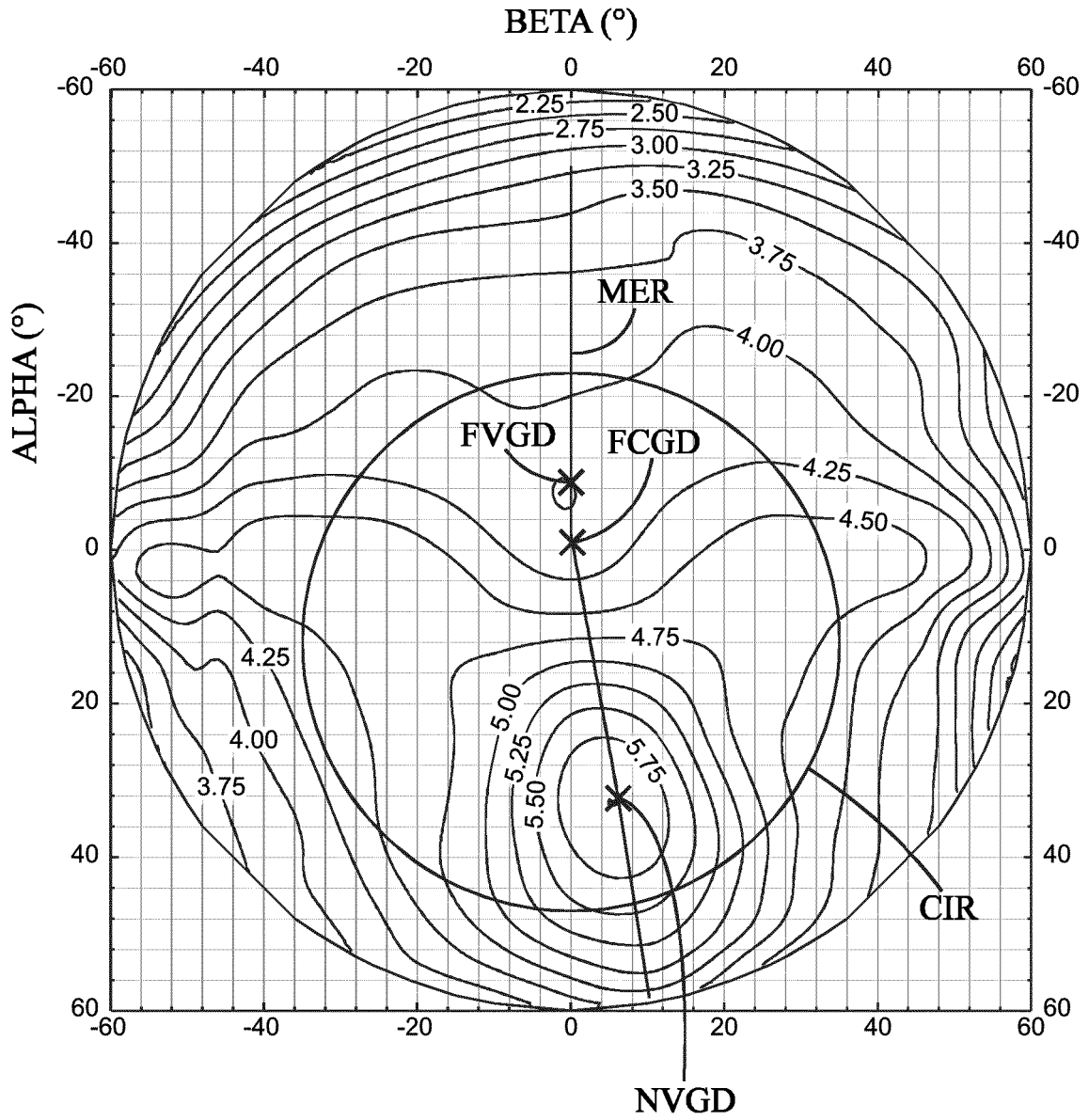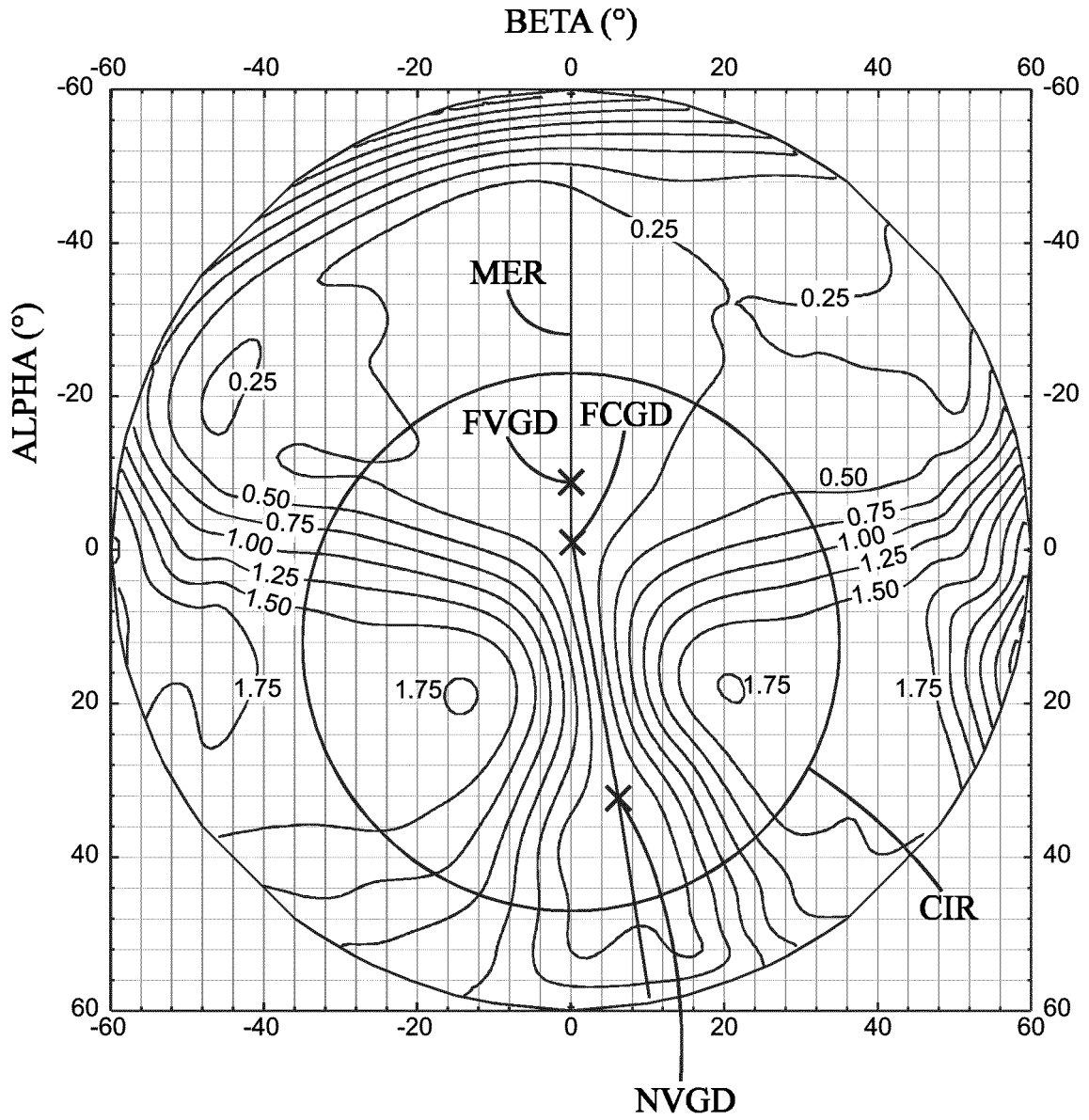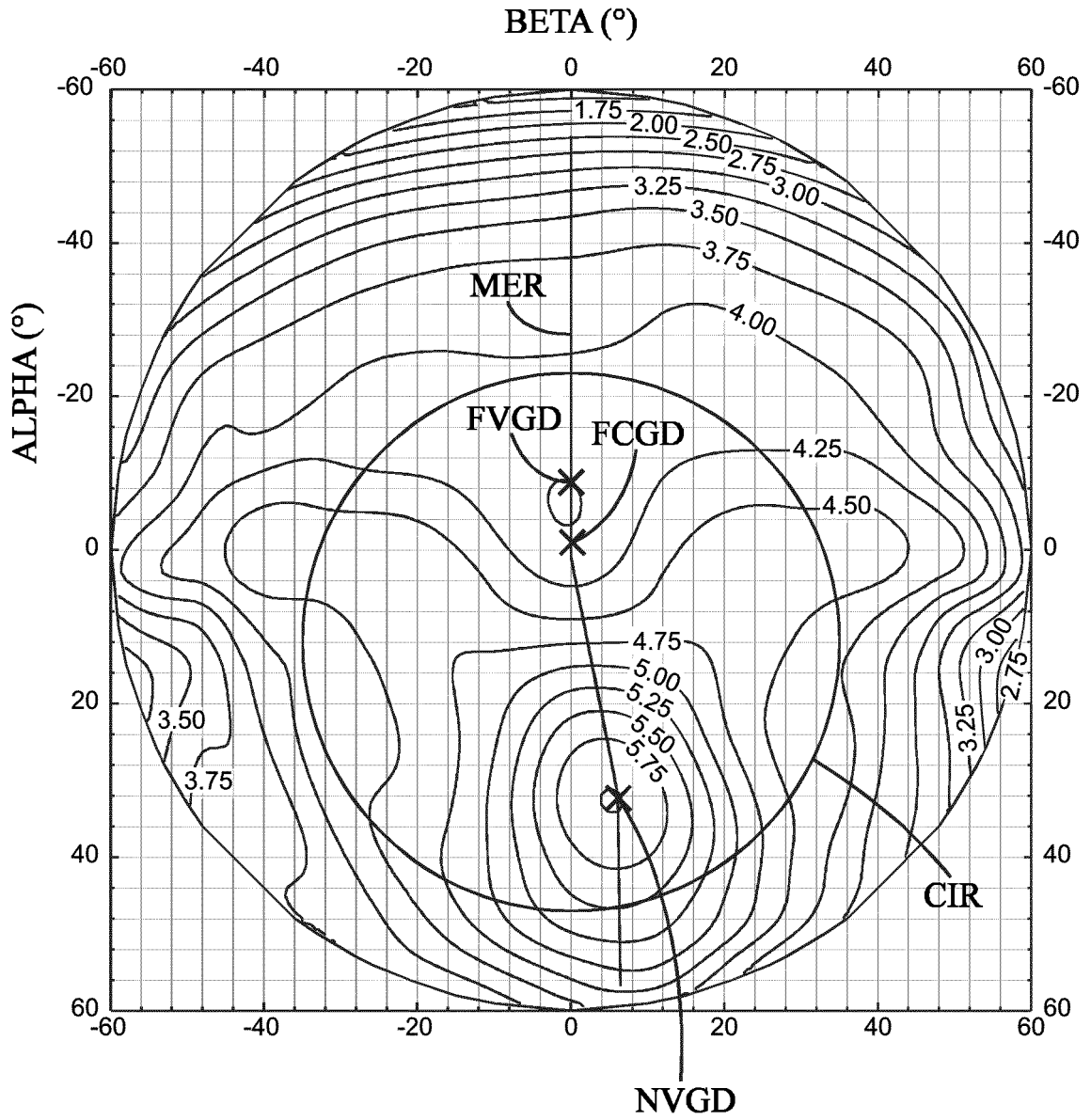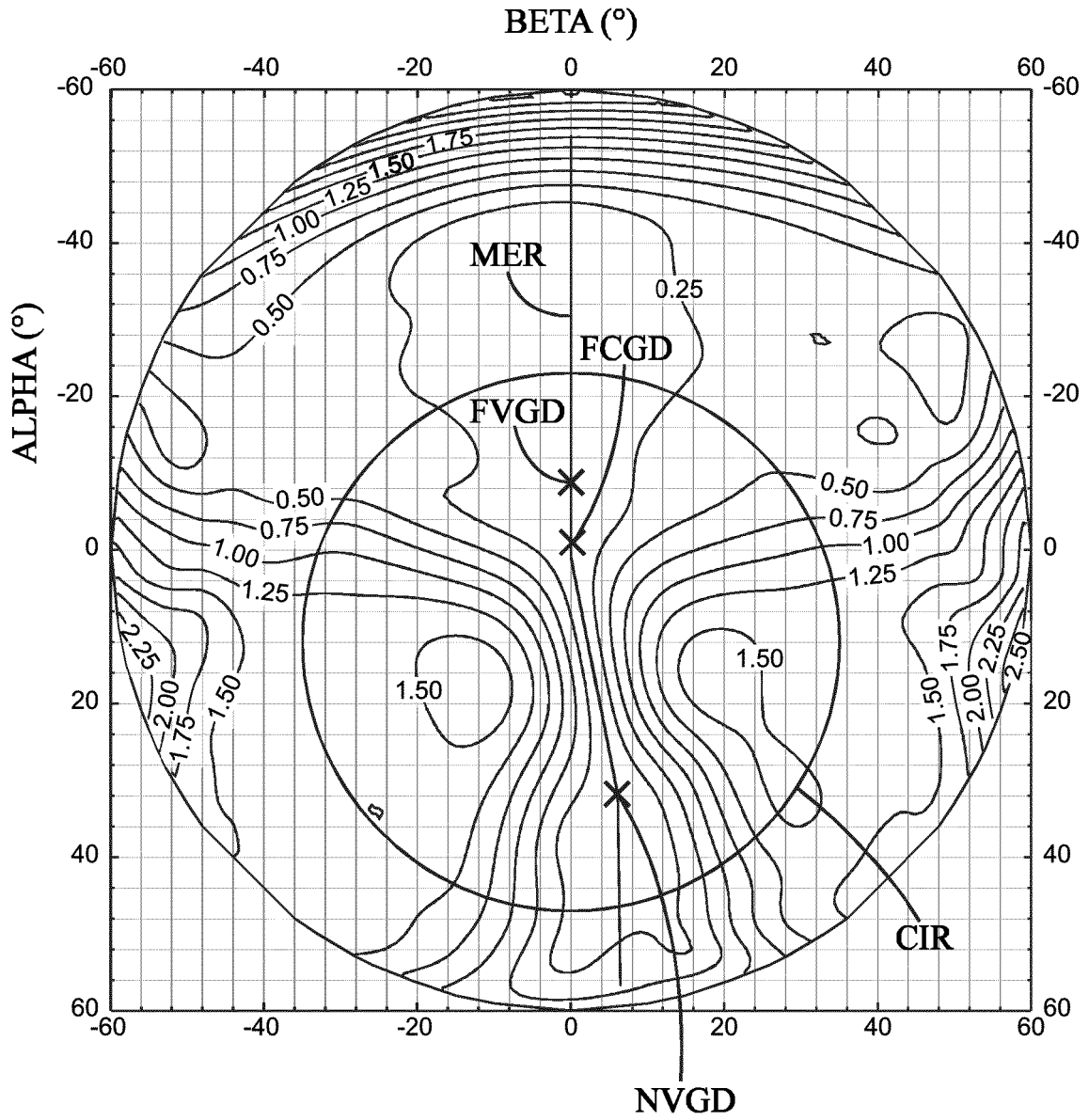

FIG. 16

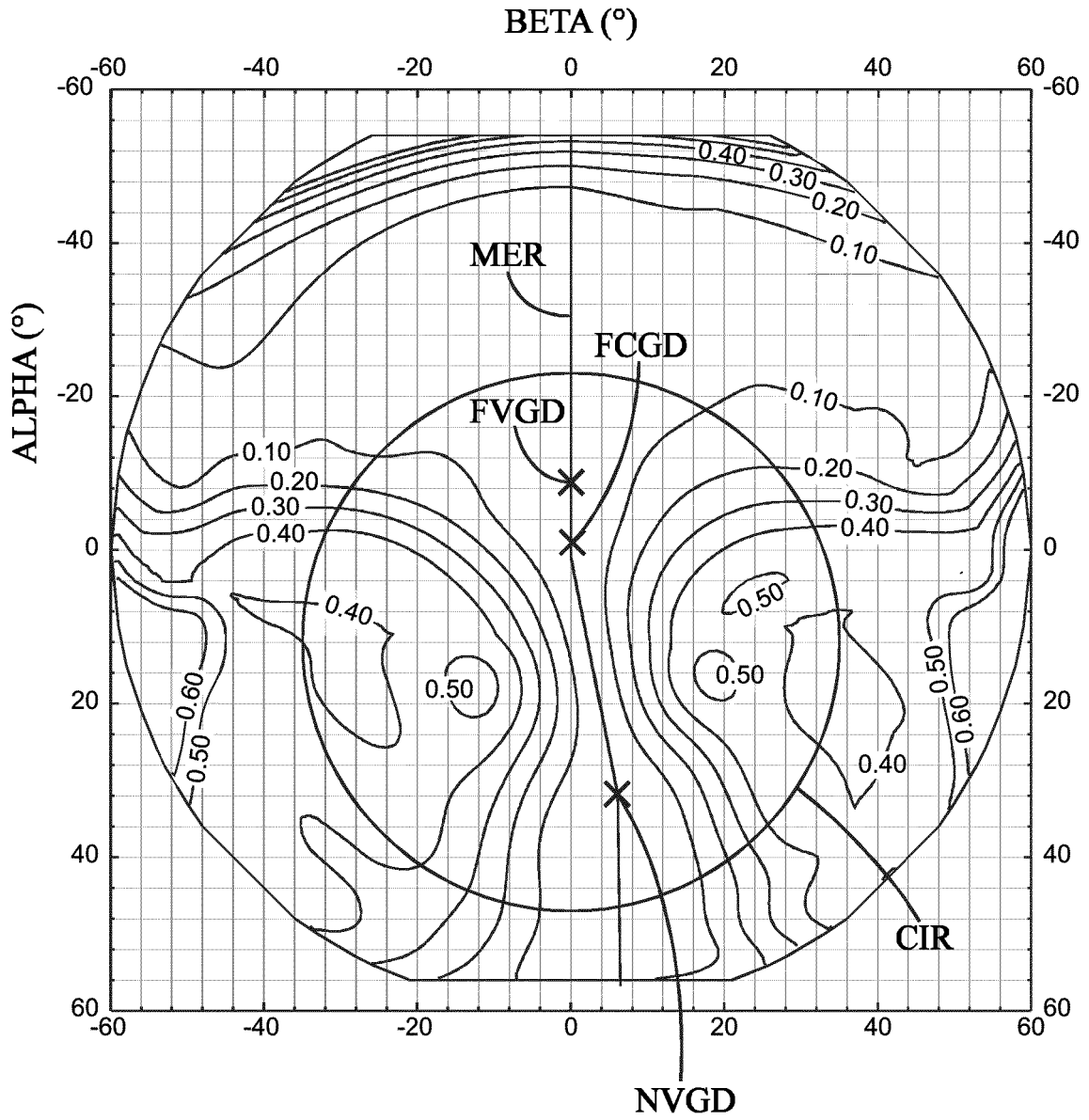FIG. 17

FIG. 18

FIG. 19

FIG. 20

FIG. 21

REFERENCES CITED IN THE DESCRIPTION

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