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(71) Applicant: THE ARIZONA BOARD OF REGENTS
ON BEHALF OF THE UNIVERSITY OF ARIZONA
[US/US]; Tech Transfer Arizona, 220 W. Sixth Street, 4th
Floor, Tucson, AZ 85701 (US).

(72) Inventor: TAKASHIMA, Yuzuru; 22442 McClellan Rd.,
Cupertino, CA 95014 (US).

(74) Agents: RIESEN, Michael, J. et al.; Ballard Spahr LLP,
999 Peachtree Street, Suite 1000, Atlanta, GA 30309 (US).

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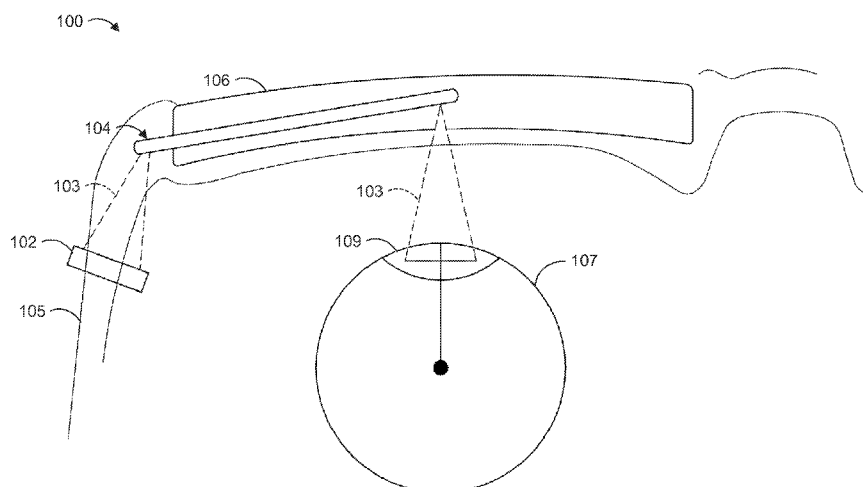
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(57) Abstract: An optical system and methods are disclosed. In an aspect, an optical system can comprise a display device configured to emit an image information and an image guide optically coupled to the display device, wherein the image guide is configured to receive the image information and transmit the image information along a longitudinal axis of the image guide, and wherein the image guide has a thickness along a lateral axis between about 0.3 mm and about 1 mm. The optical system can further comprise a beam combiner disposed in the image guide, the beam combiner configured to transmit at least a portion of the received image information to exit the image guide.

GLASS IMPLEMENTED DISPLAY

CROSS REFERENCE TO RELATED PATENT APPLICATION

[0001] This application claims priority to U.S. Patent Application No. 61/796,403 filed November 9, 2012, herein incorporated by reference in its entirety.

BACKGROUND

[0002] A wearable display device, such as eyewear, can be configured to superimpose image information over see-through images. The image information can represent images of communications such as emails and text alerts. Users can access such image information via a wireless network using the wearable display device. Furthermore, with an aid of location mechanisms such as a global positioning system (GPS), location specific information can also be displayed to the user. However, such image superposition capability is not fully implemented in devices for consumer applications. For example, certain wearable devices include a display panel that obscures a part of the field of view of the user. As a further example, helmet mounted devices can be bulky, complicated, and costly. Thus, such technologies cannot be adopted for low cost and light weight implementations for consumer applications. These and other shortcomings are addressed by the present disclosure.

SUMMARY

[0003] It is to be understood that both the following general description and the following detailed description are exemplary and explanatory only and are not restrictive. Methods and apparatus for transmitting image information are disclosed.

[0004] In an aspect, systems can comprise a display device configured to emit image information and an image guide optically coupled to the display device, wherein the image guide is configured to receive the image information and transmit the image information along a longitudinal axis of the image guide, and wherein the image guide has a thickness along a lateral axis between about .3mm and about 1mm. The system can further comprise a beam combiner disposed in the image guide, the beam combiner configured to transmit at least a portion of the received image information to exit the image guide.

- [0005] In an aspect, methods can comprise receiving image information by an image guide, wherein the image guide has a thickness along a lateral axis between about .3mm and about 1mm and transmitting the image information along a longitudinal axis of the image guide via total internal reflection. The methods can further comprise transmitting the image information to exit the image guide.
- [0006] Additional advantages will be set forth in part in the description which follows or may be learned by practice. The advantages will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0007] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments and together with the description, serve to explain the principles of the methods and compositions:
- Figure 1 illustrates a schematic diagram of an exemplary optical system;
- Figure 2 illustrates a schematic diagram representing a top view of an exemplary optical system;
- Figure 3 illustrates a schematic diagram representing a side view of an exemplary optical system;
- Figure 4 illustrates a schematic diagram representing a side view of an exemplary optical system including example light rays;
- Figure 5 illustrates a schematic diagram representing a perspective view of an exemplary optical system including example light rays;
- Figure 6 illustrates a schematic diagram representing a perspective view of an exemplary optical system including example light rays;
- Figure 7 illustrates pre-distortion of an input image and a final image through the optical system;
- Figure 8 illustrates a schematic diagram representing a top view of an exemplary optical system;
- Figure 9 illustrates a flow diagram of an exemplary method; and
- Figure 10 illustrates schematic diagrams of an exemplary optical system.

DETAILED DESCRIPTION

- [0008] Before the present methods and systems are disclosed and described, it is to be understood that the methods and systems are not limited to specific methods, specific components, or to particular compositions. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting.
- [0009] As used in the specification and the appended claims, the singular forms “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise. Ranges may be expressed herein as from “about” one particular value, and/or to “about” another particular value. When such a range is expressed, another embodiment includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent “about,” it will be understood that the particular value forms another embodiment. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint.
- [0010] “Optional” or “optionally” means that the subsequently described event or circumstance may or may not occur, and that the description includes instances where said event or circumstance occurs and instances where it does not. “On the order of” can mean approximately, a fraction thereof, or a multiple thereof.
- [0011] Throughout the description and claims of this specification, the word “comprise” and variations of the word, such as “comprising” and “comprises,” means “including but not limited to,” and is not intended to exclude, for example, other additives, components, integers or steps. “Exemplary” means “an example of” and is not intended to convey an indication of a preferred or ideal embodiment. “Such as” is not used in a restrictive sense, but for explanatory purposes.
- [0012] Ranges can be expressed herein as from “about” one particular value, and/or to “about” another particular value. When such a range is expressed, another aspect includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent “about,” it will be understood that the particular value forms another aspect. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint. It is also understood

that there are a number of values disclosed herein, and that each value is also herein disclosed as “about” that particular value in addition to the value itself. For example, if the value “10” is disclosed, then “about 10” is also disclosed. It is also understood that each unit between two particular units are also disclosed. For example, if 10 and 15 are disclosed, then 11, 12, 13, and 14 are also disclosed. All ranges disclosed herein are inclusive and combinable (e.g., ranges of “up to 25%, or, more specifically 5% to 20%” is inclusive of the endpoints and all intermediate values of the ranges of “5% to 25%,” etc.).

[0013] The terms “first,” “second,” “first part,” “second part,” and the like, where used herein, do not denote any order, quantity, or importance, and are used to distinguish one element from another, unless specifically stated otherwise.

[0014] As used herein, the terms “optional” or “optionally” means that the subsequently described event or circumstance can or cannot occur, and that the description includes instances where said event or circumstance occurs and instances where it does not.

[0015] Disclosed are components that can be used to perform the disclosed methods and systems. These and other components are disclosed herein, and it is understood that when combinations, subsets, interactions, groups, etc. of these components are disclosed that while specific reference of each various individual and collective combinations and permutations of these may not be explicitly disclosed, each is specifically contemplated and described herein, for all methods and systems. This applies to all aspects of this application including, but not limited to, steps in disclosed methods. Thus, if there are a variety of additional steps that can be performed it is understood that each of these additional steps can be performed with any specific embodiment or combination of embodiments of the disclosed methods.

[0016] The present methods and systems may be understood more readily by reference to the following detailed description of preferred embodiments and the Examples included therein and to the Figures and their previous and following description.

[0017] In an aspect, the methods and systems of the present disclosure provide a compact display device comprising an image guide such as plane parallel plate (PPP) image guiding optics. As an example, the image guide can be a thin (less than about 0.5mm) rectangular glass plate. As a further example, the image guide can be transparent. The image guide can be disposed inside a lens of eye wear, such as corrective glasses, eye protection glasses, and/or sun glasses. As such, images

displayed on passive or active light emitting devices such as digital micro mirror devices (DMD) and liquid crystal displays (LCD) can be transmitted to a user (e.g., observer) by total internal reflections via the image guide. Accordingly, the users can observe see-through images passing through the image guide and obstruction of a field of view of the user is minimized. As an example, a pass through or see-through image can be from a source other than the display device. As another example, the see-through image can be transmitted from a second display or objects disposed outside eye wear. In an aspect, the plane parallel plate has no optical power, as a result the implemented plane parallel plate inside the glassware does not affect the power of the eye wear.

[0018] In an aspect, **FIGS. 1-3** show schematic diagrams of an exemplary optical system **100**. The optical system **100** can comprise a display device **102** and an image guide **104**. As shown, the display device **102** and the image guide **104** can be disposed in at least a portion of a wearable device **105**, such as eyewear having one or more lenses **106** such as corrective lenses, for example. In an aspect, material used for the image guide **104** can have a higher index of refraction compared to the index of refraction for the corrective lenses **106**. As an example, Sapphire glass, and optical glasses such as LAK, LAF, BASF SF and LASF series from Schott glass, and equivalents are usable for the image guide **104**. The image guide **104** can be implemented into conventional eye wear such as prescription glasses, sun-glasses as well as helmets, protection goggles, ski goggles, clip-on glasses, and the like.

[0019] In an aspect, the display device **102** can be or comprise a flat display device (FDD), digital micro mirror device (DMD), and/or a liquid crystal display (LCD). Other devices for presenting images can be used such as a flat or curved organic light emitting diode (OLED) arrays, spatial phase light modulators, spatial polarization modulators, and grating based light modulators. In operation, the display device **102** can present image information such as emitted light rays **103** representing one or more images. In an aspect, image information provided by the display device **102** can be transmitted via the image guide **104** to present a virtual image. As an example, the virtual image can be formed at an accommodation distance or further (e.g., about 250mm or further) measured from the eye **107** (e.g., pupil **109**) of the user.

[0020] In a further aspect, one or more optical elements **108** (**FIG. 2**) can be disposed between the display device **102** and the image guide **104** to direct the image

information into the image guide **104**. As an example, the display device **102** can be located close to the front focal point of the one or more optical elements **108** so that light rays from a point at the display device **102** are collimated or quasi-collimated inside the image guide **104** by optical element **108**

[0021] In an aspect, one or more of the optical elements **108** can be a positive lens used in a magnifying configuration so that a virtual and magnified image is formed toward a reflective portion **110** of the image guide **104**. As another example, the reflective portion **110** can comprise a half mirror. Alternatively, one or more of the optical elements **108** can be situated at a polished edge of the image guide **104**. As a further example, one or more separate optical elements can be used to provide the function of the reflective portion **110** of the image guide **104**. In another aspect, the image information of the display device **102** can be transmitted to the eye **107** of the user by total internal reflection(s).

[0022] In an aspect, the image information can be coupled to the eye **107** of the user via a beam combiner **112** (FIGS. 2-3). As an example, the beam combiner **112** can be disposed in the image guide **104**. As another example, the beam combiner **112** can be at least partially encompassed by the image guide **104**. As another example, the beam combiner **112** can be or comprise a half mirror. As a further example, a coated mirror, dichroic mirror, planer hologram, curved hologram, volume hologram, and/or segmented mirror, are usable as the beam combiner **112**.

[0023] In an aspect, the beam combiner **112** can have a horizontal projected width **114** that is smaller than a diameter of an eye pupil **109** of a user of the optical system **100**. Eye pupils can vary in diameter (e.g., from about 3mm to about 9mm), for example, based on an age of the user, an environment of the user, or other factors. As such, favorable results have been achieved when the beam combiner **112** has a horizontal projected width **114** of less than the diameter of the eye pupil. For example, favorable results have been achieved when the beam combiner **112** has a horizontal projected width **114** of about 3mm, about 2.9mm, about 2.8mm, about 2.7mm, about 2.6mm, about 2.5mm, about 2.4mm, or about 2.3mm. In an aspect, a horizontal projected width of 0.1mm to about 3mm can minimize degradation of the transmitted image information **103** due to any diffraction effect. Other projected widths can be used and can depend on the pupil diameter of the user. In an aspect, the extent of the beam combiner **112** in a vertical direction can be on the order of tens of millimeters. Due to the small extent of the beam combiner in the horizontal

direction, obstruction of a field of view **116** of the user by the beam combiner **112** is minimized. As an example, since the eye of the user accommodates see-through objects, but not the beam combiner **112**, the image of the beam combiner **112** on the user's retina is substantially defocused.

- [0024] In an aspect, the image guide **104** can be a transparent plane parallel plate, consequently, cross talk between see-through images (e.g., passing through the plane of the image guide **104**) and the transmitted image information from the display device **102** is minimized. In another aspect, when the image guide **104** is disposed in a corrective lens (e.g., lens **106** (**FIG. 1**)), the correcting power of the lens is not altered by the image guide **104**, since the image guide **104** has no additional optical power. As an example, see-through images passing through the corrective lenses can be altered by the corrective lens, but will not interfere with image information transmitted via the image guide **104**.
- [0025] **FIG. 4** shows a side view of the image guide **104a** with a lens **400** to form a virtual image at infinity. **FIG. 5** shows a perspective view of the system depicted in **FIG. 4**. As depicted in **FIGS. 4-5**, light rays are directed along a longitudinal axis (Z-axis) of the image guide **104a**. As shown in the example of **FIGS. 4-5**, no total internal reflections (TIR) (or substantially none) are involved for the vertical field of view (along the lateral X-axis of **FIG. 5**), whereas TIR occurs during the image transfer (transmission of image information) for the horizontal field of view (along the vertical Y-axis of **FIG. 5**).
- [0026] **FIG. 6** illustrates an optical system that has been modified from the configuration in **FIGS. 4-5**. In **FIG. 6**, an image **600** of the object **602** (or FDD) is formed at infinity by a first lens **604** (e.g., having a focal length (f) of about 100mm). In an aspect, image information is transferred through image guide **104b**. As an example, the image guide **104b** is shown having dimensions of 20x25x1mm. The intermediate image at infinity is then focused by a second lens **606** (having $f=100$ mm) on the image plane **608**. The second lens **606** and final image **600** operates as an eye and retinal image, respectively.
- [0027] As illustrated in **FIG. 7**, due to the multiple reflections in the image guide and truncation of the beam at the output of the image guide, a single object image forms two symmetrical output images with respect to the vertical Y-axis. In addition, each of the symmetrical output images complementally has dark regions. To address the dark regions, input image information can be pre-distorted such that an image

represented by the input image information has symmetry with respect to at least one axis. As an example, **FIG. 7** illustrates such pre-distortion of the input image information and a resultant final image through the optical system **100** (**FIG. 2**). As shown in **FIG. 7**, the input image information can be pre-distorted to result in mirrored images about at least one axis. When the pre-distorted input image information is transmitted through the optical system **100** (**FIG. 2**), the dark regions of the output image are minimized and/or eliminated. In an aspect, one of the resultant output images can be eliminated by adjusting a tilt angle of the beam combiner **112**. In another aspect, the tilt angle of the beam combiner **112** can be pre-configured to eliminate one of the resultant output images (or any portion of image information exiting the image guide) from a field of view of the user. In a further aspect, a placement (e.g., tilt, distance from pupil, etc.) of the image guide **104** can be configured to minimize or eliminate unwanted image information (e.g., one of the resultant output images or any unwanted portions of image information exiting the image guide) from a field of view of the user.

[0028] As shown in **FIG. 8**, an image guide **104c** can comprise two or more optical layers **800a**, **800b**, **800c**. In an aspect, each of the layers **800a**, **800b**, **800c** can be configured to provide total internal reflection along a longitudinal axis of the respective layer **800a**, **800b**, **800c**. In another aspect, each of the layers **800a**, **800b**, **800c** can operate as a separate image guide to extend a FOV. As an example, each of the layers **800a**, **800b**, **800c** can comprise a beam combiner **112a**, **112b**, **112c** to direct image information to exit the respective layer **800a**, **800b**, **800c** (e.g., toward an eye of a user).

[0029] **FIG. 9** illustrates an exemplary method. In step **902**, image information can be received by an image guide. In an aspect, image information can comprise emitted light rays representing one or more images. In another aspect, the received image information is distorted to have image symmetry about an axis. In yet another aspect, the image guide has a thickness along a lateral axis between about .3mm and about 1mm. As an example, the image guide can be or comprise a transparent plane plate.

[0030] In step **904**, the image information can be transmitted along a longitudinal axis of the image guide via total internal reflection. In step **906**, the image information can be transmitted to exit the image guide. In an aspect, the image information can exit the image guide and can be coupled to an eye of a user via a beam combiner. As an

example, the beam combiner can be disposed in the image guide. As another example, the beam combiner can be at least partially encompassed by the image guide. As another example, the beam combiner can be or comprise a half mirror. As a further example, a coated mirror, dichroic mirror, planer hologram, curved hologram, volume hologram, and/or segmented mirror, are usable as the beam combiner **112**.

[0031] The systems and methods described herein provide a full field of view, wherein outside (pass through) images are preserved. An image system can be integrated with wearable devices such as correction glasses. As such, the user observes both displayed and see-through images without being disturbed by the display device located within the FOV. As an example, see-through images can comprise image information transmitted from a source outside the image system through a plane of an image guide. As another example, the source of see-through images can be an object or a second display device.

[0032] The following examples are put forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how the compounds, compositions, articles, devices and/or methods claimed herein are made and evaluated, and are intended to be purely exemplary and are not intended to limit the scope of the methods and systems. Efforts have been made to ensure accuracy with respect to numbers (e.g., amounts, temperature, etc.), but some errors and deviations should be accounted for.

[0033] **FIG. 10** illustrates an optical system comprising an image guide **104d**. In an aspect, the image guide **104d** is shown having the following dimensions:

Thickness (T) = about 1mm;

Height (H) = about 10mm;

Width (W) = about 20mm; and

distance (d) = about 10mm, wherein d is measured between an exit plane of the image guide **104d** and an eye pupil.

[0034] In certain circumstances, the values for T, W, H, and d can have certain ranges, such as:

T is between about 0.3mm and about 1.0mm;

W is between about 1mm and about 40mm;

H is between about 1mm and about 40mm; and

d is less than about 11mm.

- [0035] Other dimensions can be used to maintain a favorable FOV of a user. As an example, d can be greater than 11mm, while a favorable FOV is maintained by implementing a multilayer image guide such as illustrated in **FIG. 8**.
- [0036] While the methods and systems have been described in connection with preferred embodiments and specific examples, it is not intended that the scope be limited to the particular embodiments set forth, as the embodiments herein are intended in all respects to be illustrative rather than restrictive.
- [0037] Unless otherwise expressly stated, it is in no way intended that any method set forth herein be construed as requiring that its steps be performed in a specific order. Accordingly, where a method claim does not actually recite an order to be followed by its steps or it is not otherwise specifically stated in the claims or descriptions that the steps are to be limited to a specific order, it is no way intended that an order be inferred, in any respect. This holds for any possible non-express basis for interpretation, including: matters of logic with respect to arrangement of steps or operational flow; plain meaning derived from grammatical organization or punctuation; the number or type of embodiments described in the specification.
- [0038] It will be apparent to those skilled in the art that various modifications and variations can be made without departing from the scope or spirit. Other embodiments will be apparent to those skilled in the art from consideration of the specification and practice disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit being indicated by the following claims.

CLAIMS

What is claimed is:

1. A system comprising:
a display device configured to emit image information;
an image guide optically coupled to the display device, wherein the image guide is configured to receive the image information and transmit the image information along a longitudinal axis of the image guide, and wherein the image guide has a thickness along a lateral axis between about .3mm and about 1mm; and
a beam combiner disposed in the image guide, the beam combiner configured to transmit at least a portion of the received image information to exit the image guide.
2. The system of claim 1, wherein the display device is a flat display device.
3. The system of claim 1, wherein the display device is one of a micro mirror device and a liquid crystal device.
4. The system of claim 1, wherein the image guide is a transparent plane plate.
5. The system of claim 1, wherein the image guide minimizes optical cross-talk between the image guide and a see-through image by limiting an extent of the beam combiner along the longitudinal axis.
6. The system of claim 5, wherein the extent of the beam combiner along the longitudinal axis is based upon an estimated diameter of a pupil of a user of the system.
7. The system of claim 1, wherein the image guide is further configured to transmit the image information via total internal reflection.
8. The system of claim 1, wherein a length of the image guide along the longitudinal axis is between about 1mm and about 40mm.
9. The system of claim 1, wherein a height of the image guide along a vertical axis is between about 1mm and about 40mm.
10. The system of claim 1, wherein the image guide comprises two or more adjacent layers.
11. The system of claim 1, wherein the beam combiner comprises a half mirror or a holographic beam combiner.
12. The system of claim 1, further comprising an optical element encompassing at least a portion of the image guide.

13. The system of claim 12, wherein the optical element has an optical power that is non-zero.
14. The system of claim 12, wherein the optical element is a lens of corrective eyewear.
15. The system of claim 1, wherein the image guide is configured to be disposed less than about 11mm from a pupil of an eyeball of a user.
16. The system of claim 1, wherein the beam combiner is configured relative to the image guide to eliminate unwanted image information from a field of view of a user.
17. A method comprising:
receiving image information by an image guide, wherein the image guide has
a thickness along a lateral axis between about .3mm and about 1mm;
transmitting the image information along a longitudinal axis of the image
guide via total internal reflection; and
transmitting the image information to exit the image guide.
18. The method of claim 17, wherein the image guide is a transparent plane plate.
19. The method of claim 17, wherein the image guide comprises two or more adjacent layers.
20. The method of claim 17, wherein the image information exiting the image guide represents mirrored images about at least one axis.

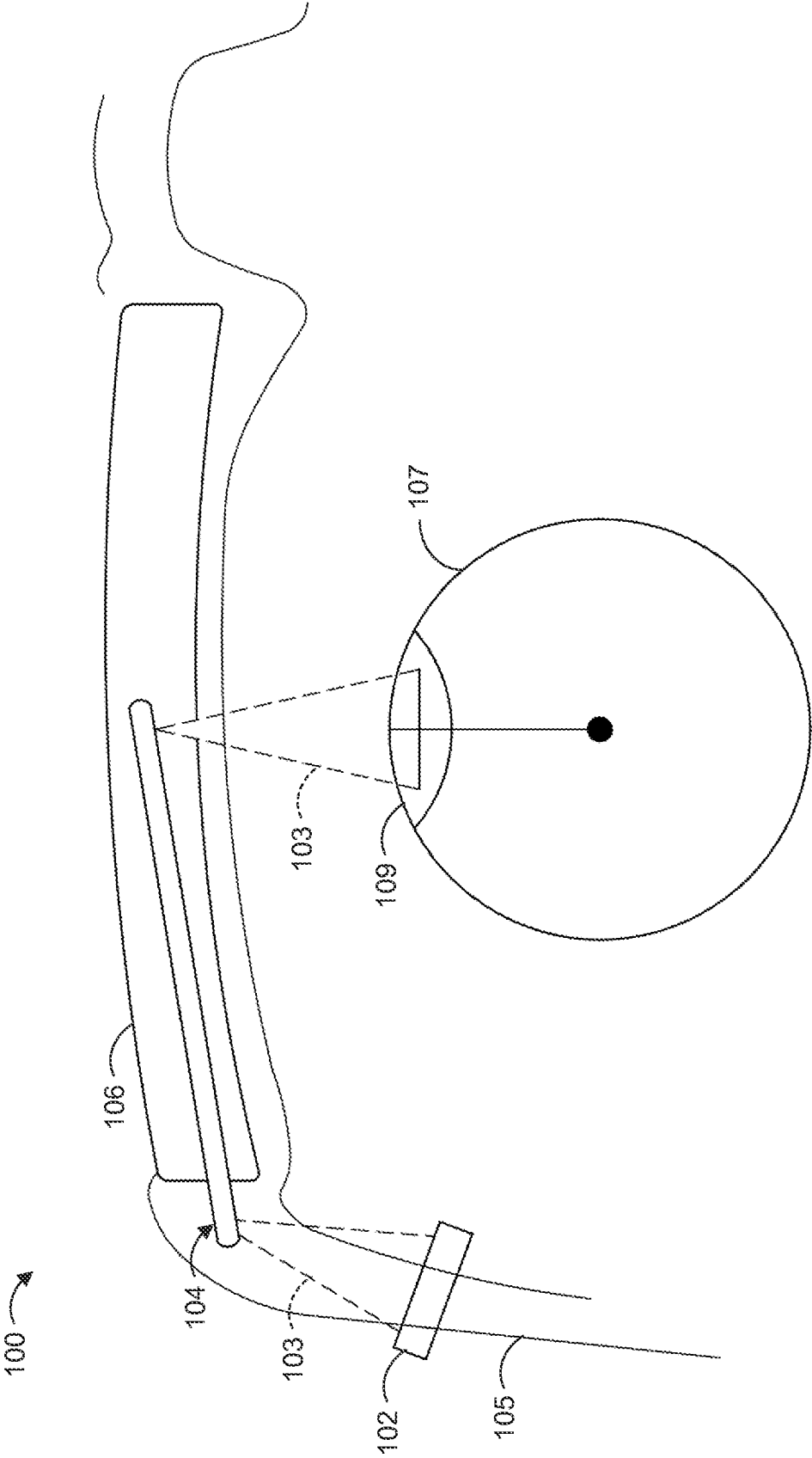
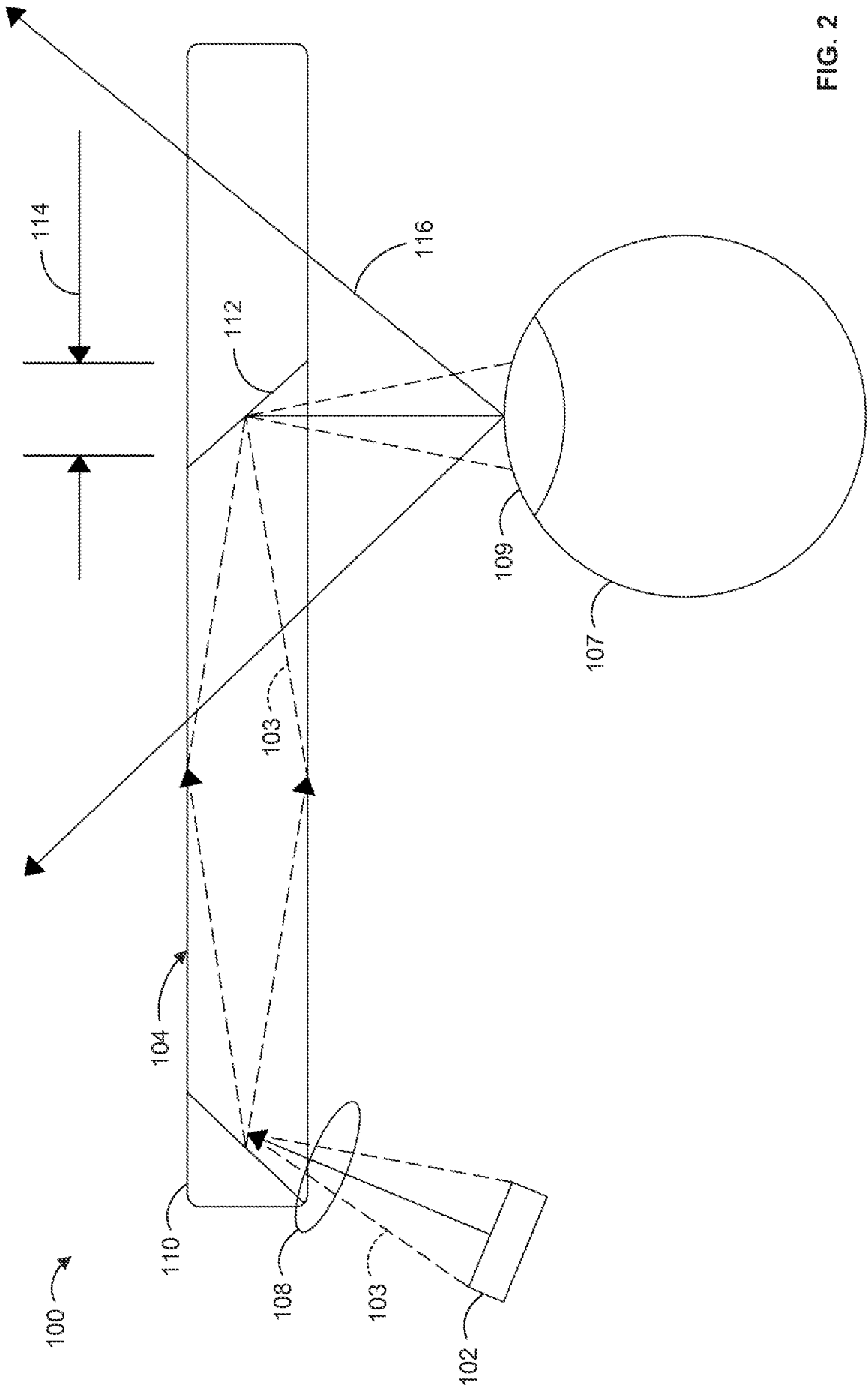


FIG. 1



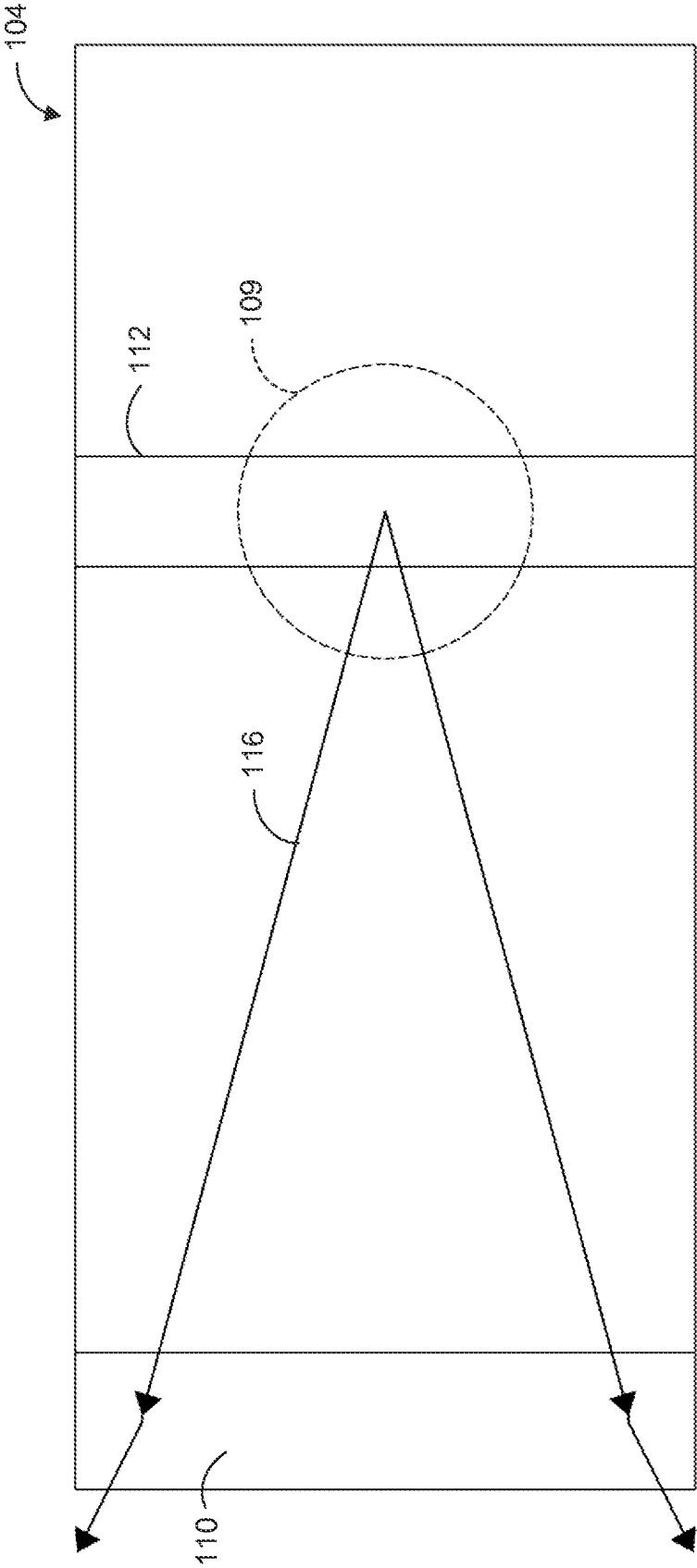


FIG. 3

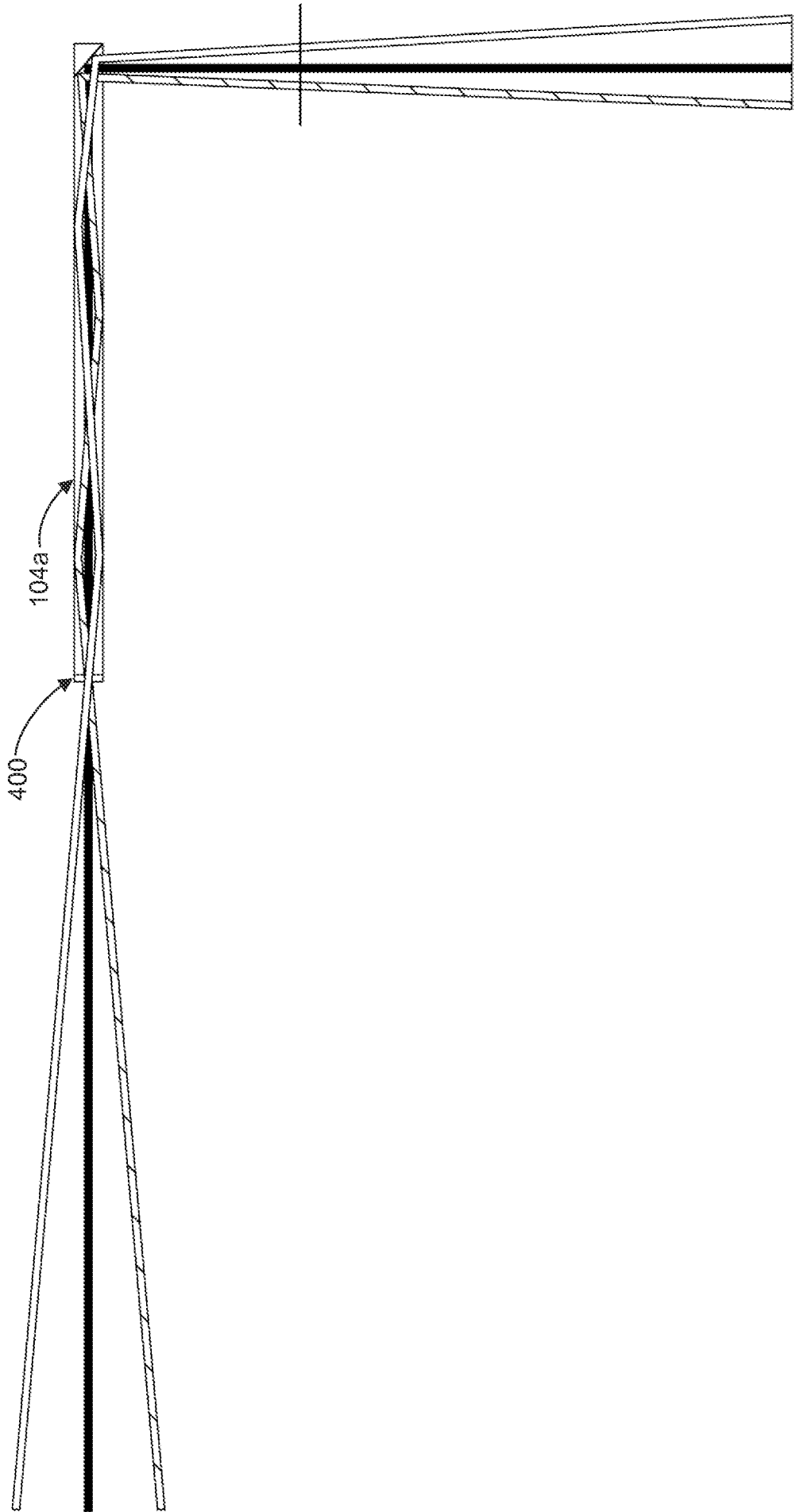


FIG. 4

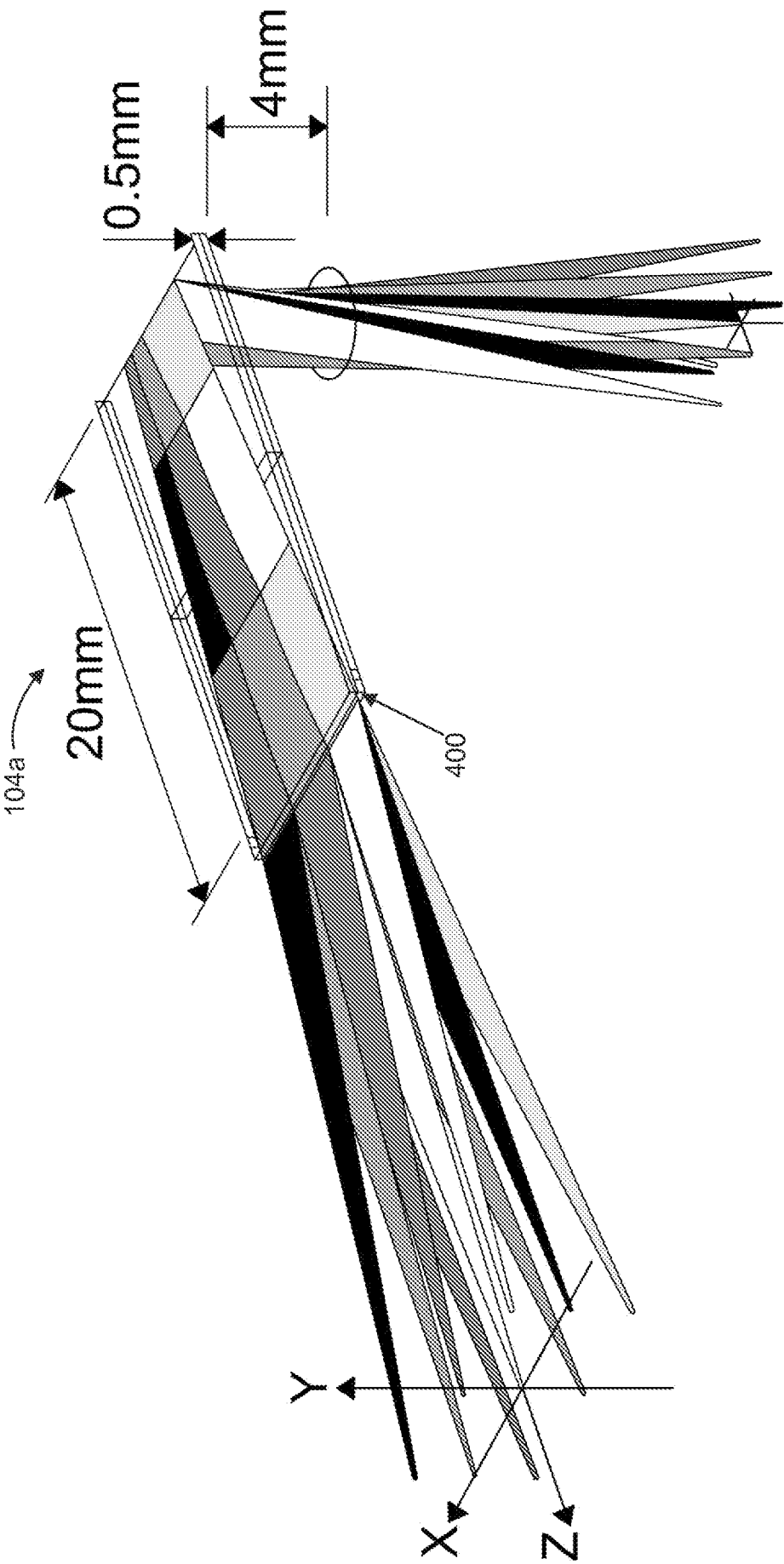


FIG. 5

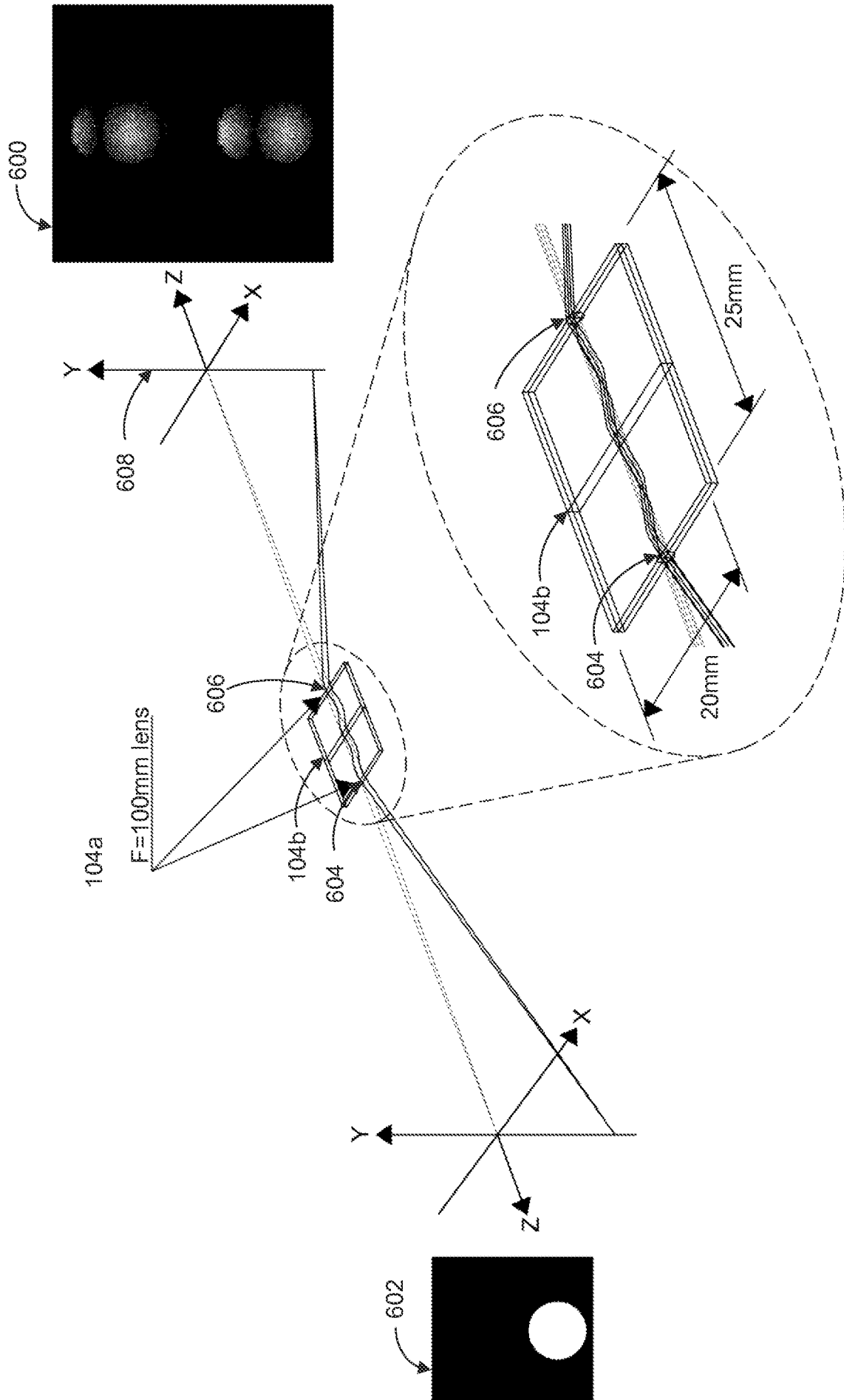
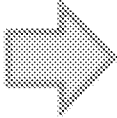


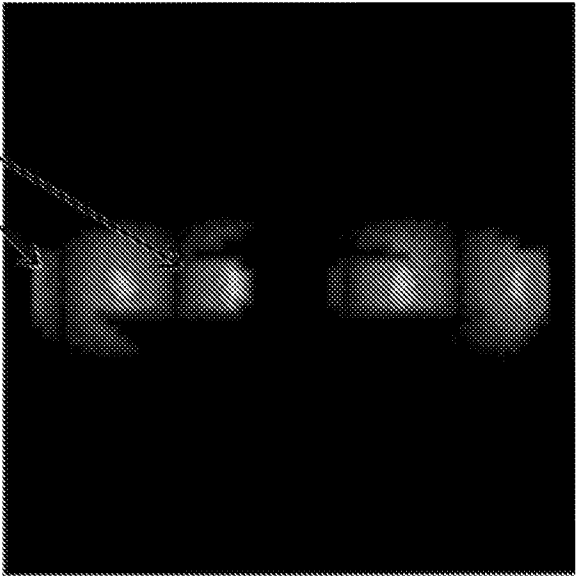
FIG. 6



Object



Black stripes



Image



+

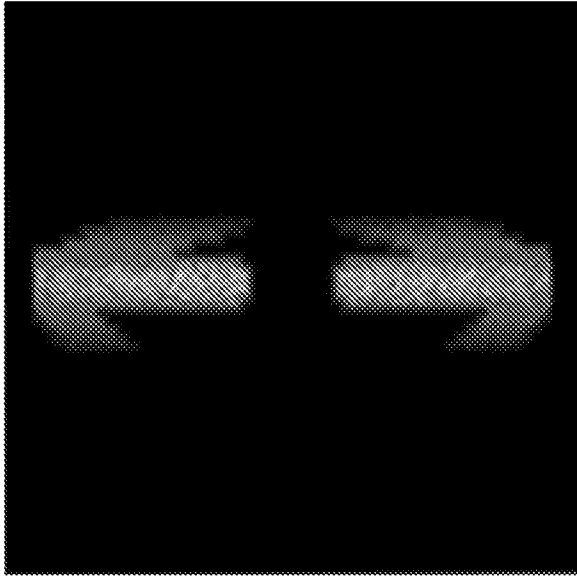
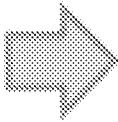
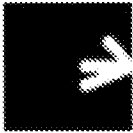


FIG. 7

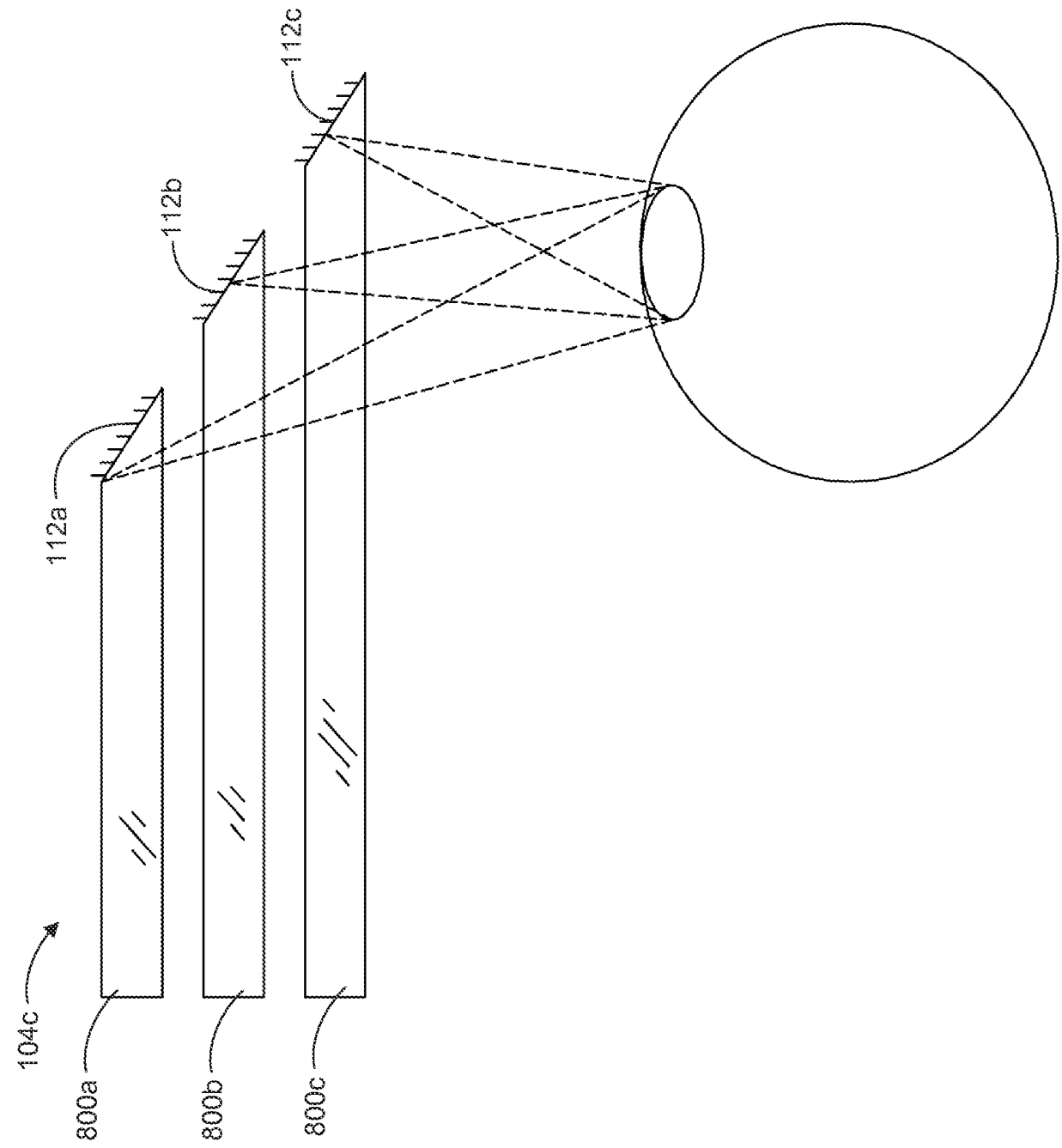
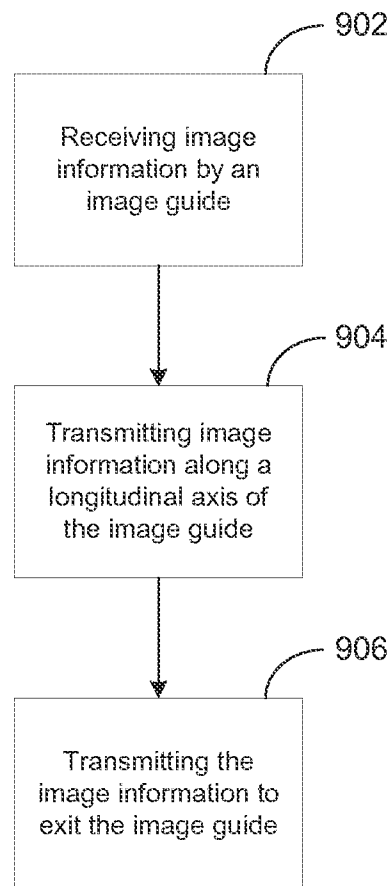


FIG. 8

**FIG. 9**

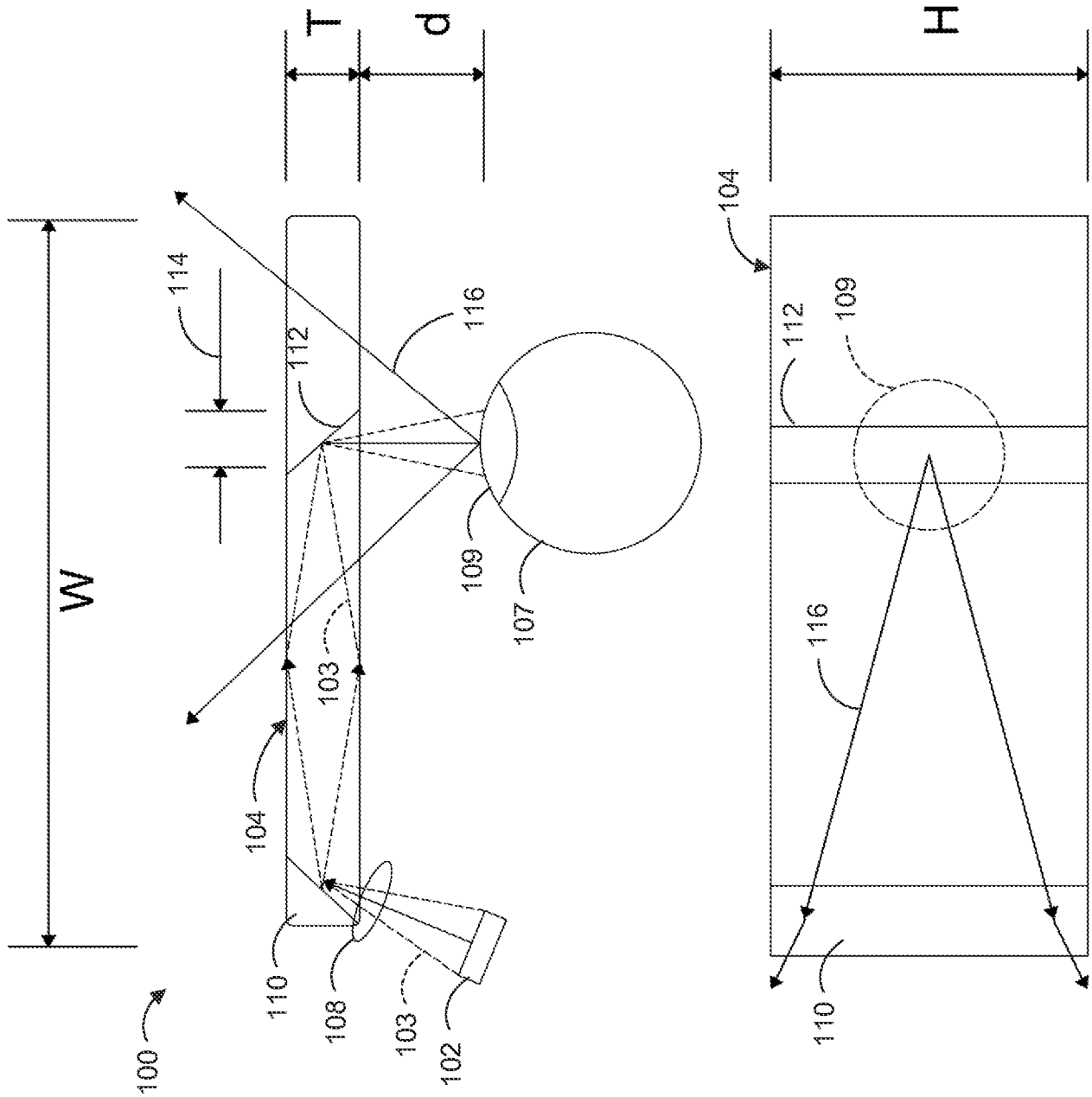


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2013/069205

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G02B 27/01 (2014.01)

USPC - 359/630

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - G02B 27/01, 10, 14; G02C 1/00 (2014.01)

USPC - 345/8; 351/158; 359/630, 633

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - G02B 27/01, 0101, 0103, 017, 0172, 0938, 0944, 095, 0955, 0977, 10, 14, 144; G02C 1/00 (2013.01)

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

PatBase, Google Patents, Google

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6,023,372 A (SPITZER et al) 08 February 2000 (08.02.2000) entire document	1-20
Y	US 2012/0002294 A1 (DOBSCHAL et al) 05 January 2012 (05.01.2012) entire document	1-20
A	US 5,585,871 A (LINDEN) 17 December 1996 (17.12.1996) entire document	1-20
A	US 7,631,968 B1 (DOBSON et al) 15 December 2009 (15.12.2009) entire document	1-20
A	US US 6,573,952 A1 (YAMAZAKI et al) 03 June 2003 (03.06.2003) entire document	1-20
A	US 2005/0225868 A1 (NELSON et al) 13 October 2005 (13.10.2005) entire document	1-20

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

13 March 2014

Date of mailing of the international search report

04 APR 2014

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P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer:

Blaine R. Copenheaver

PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774