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(54) **A NOVEL NEAR EYE DISPLAY OPTICAL SYSTEM**

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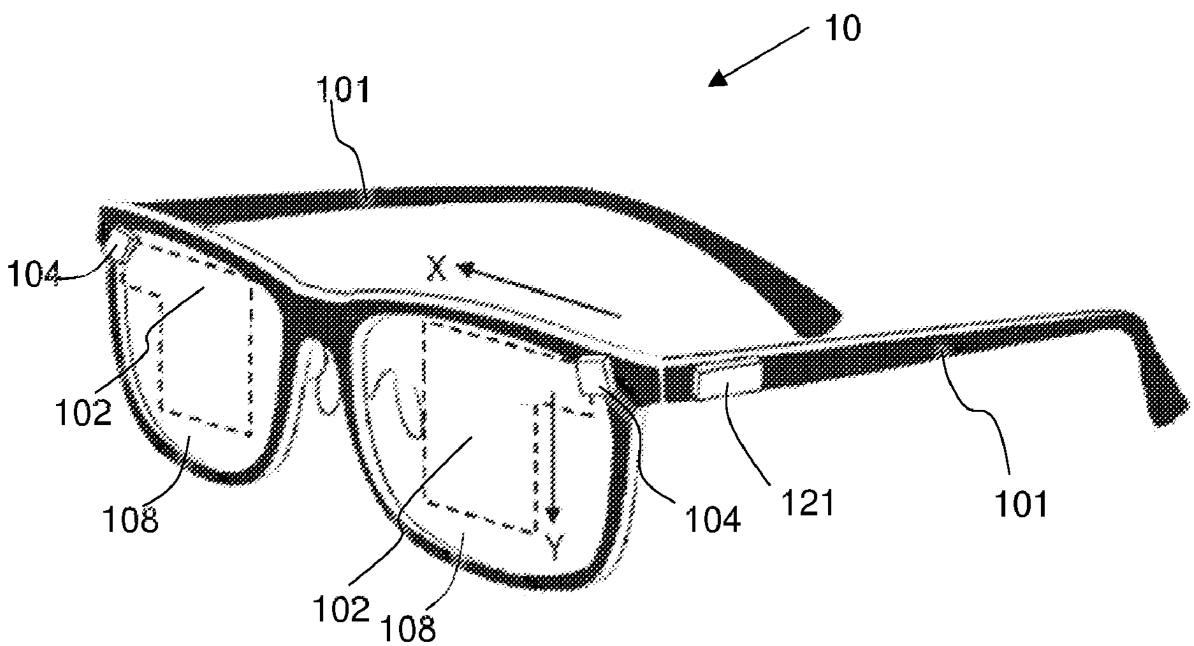
(57) **ABSTRACT**

A near eye display optical system may include a lens extending along an arrangement axis and having (a) an input plane and (b) first and second major surfaces generally extending along the arrangement axis, the lens may be configured to receive collimated light to an image via the input plane, the lens comprising a set of partially reflective internal surfaces disposed along the arrangement axis at angles relative to the arrangement axis, a first partially reflective internal surface from the set having partial reflectance such that at least some of the collimated light is reflected out of the lens by the first partially reflective internal surface without previously having reflected off the first or second major surfaces.



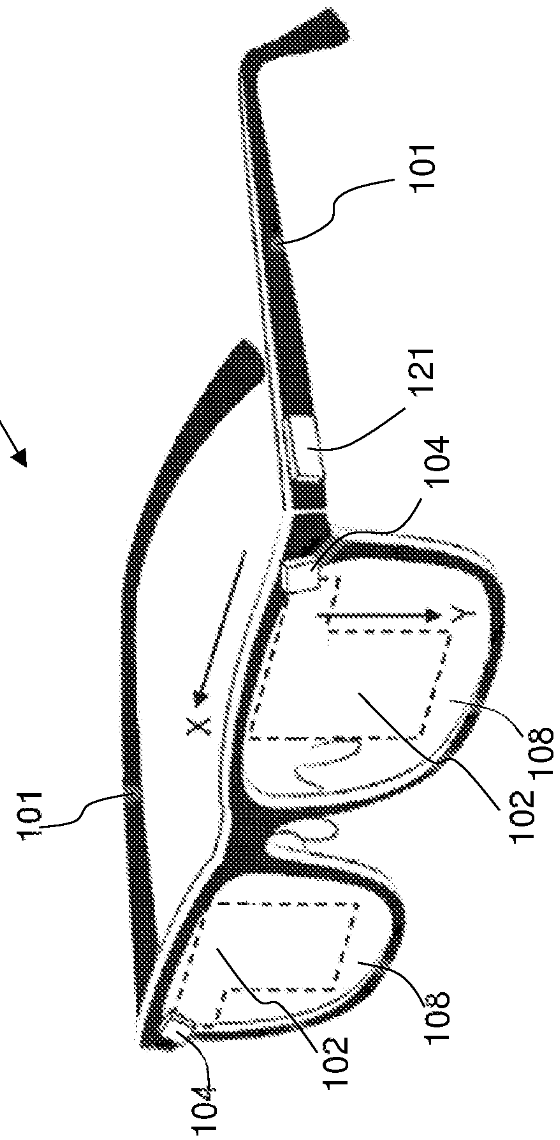


FIG. 1A

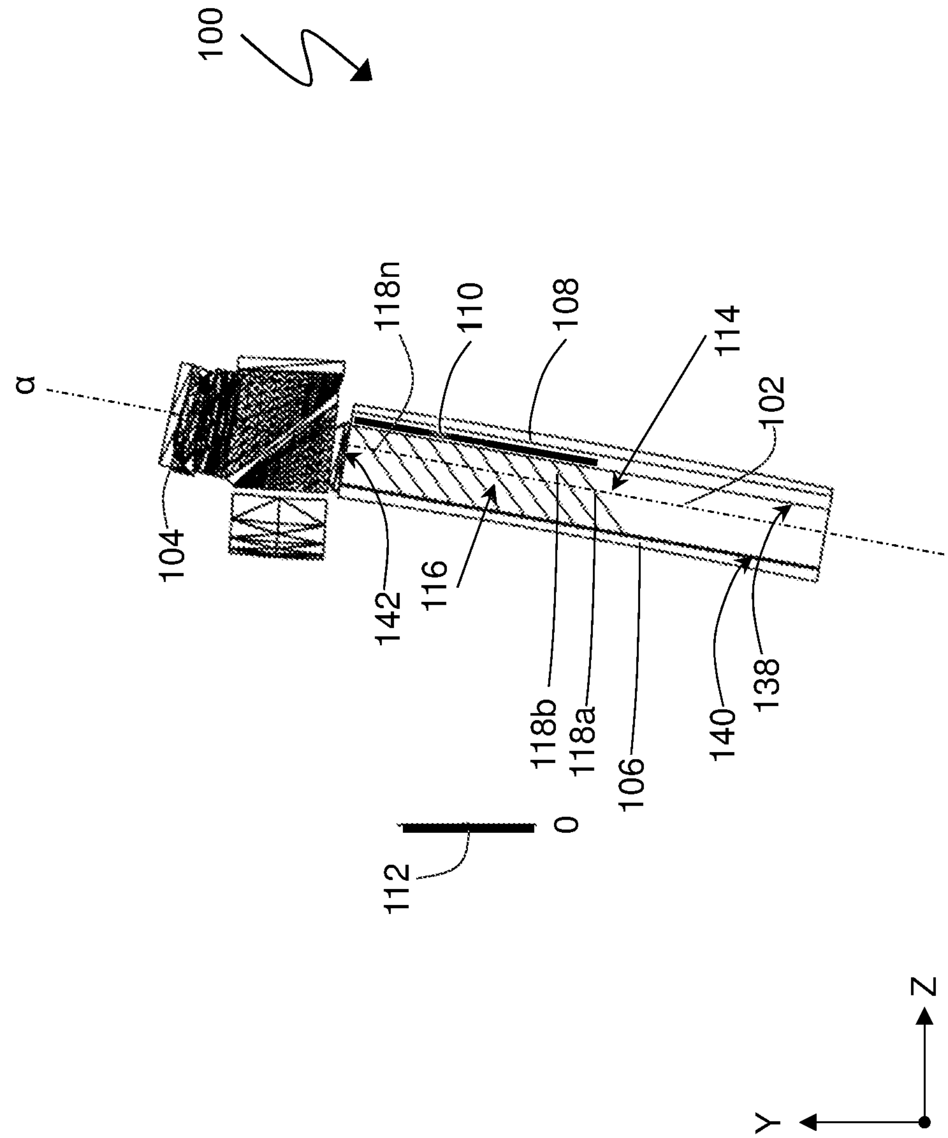

100
α
118n
110
108
114
102
104
142
116
118b
118a
106
140
138
0
112
Z
Y

Fig. 1B

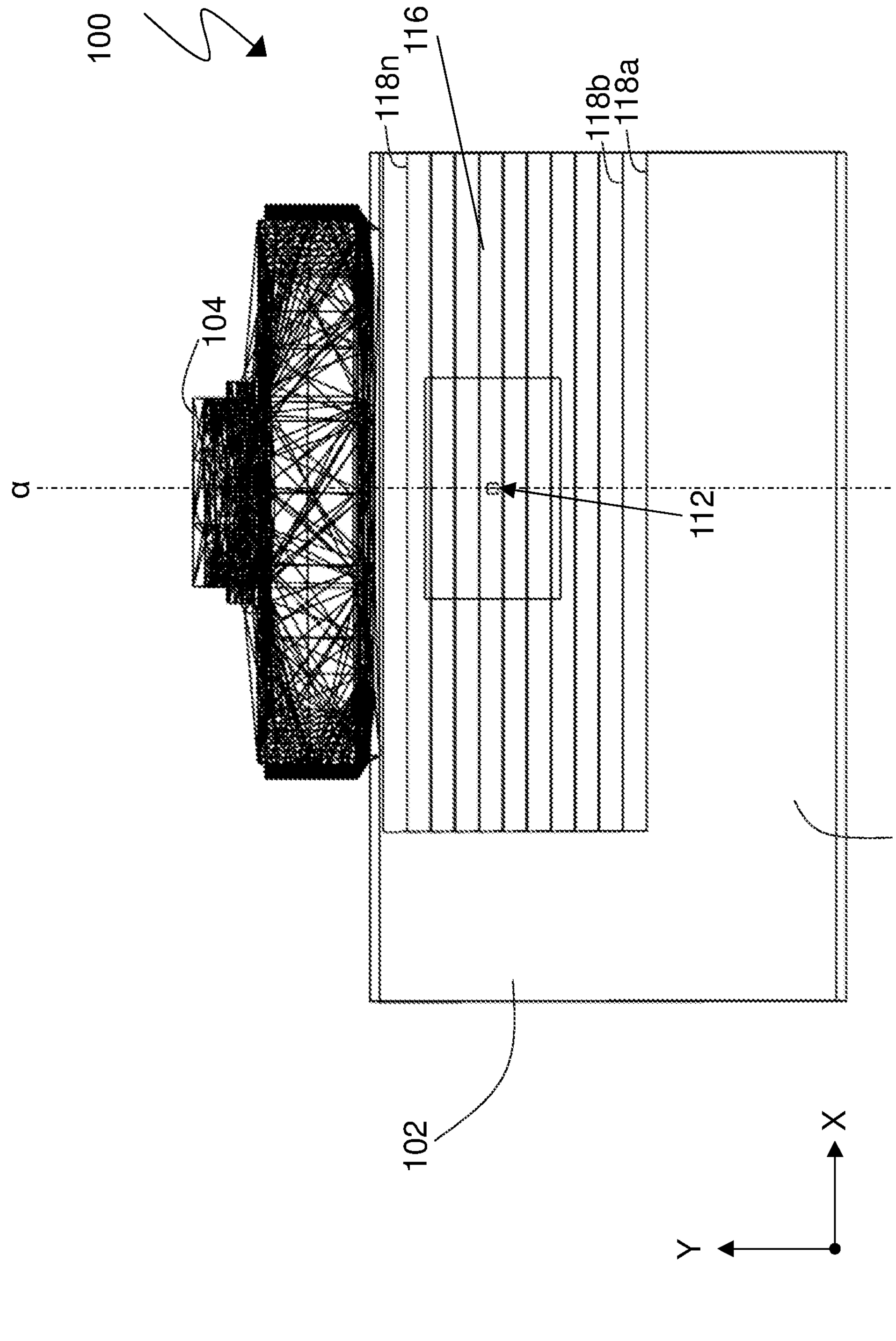


Fig. 1C

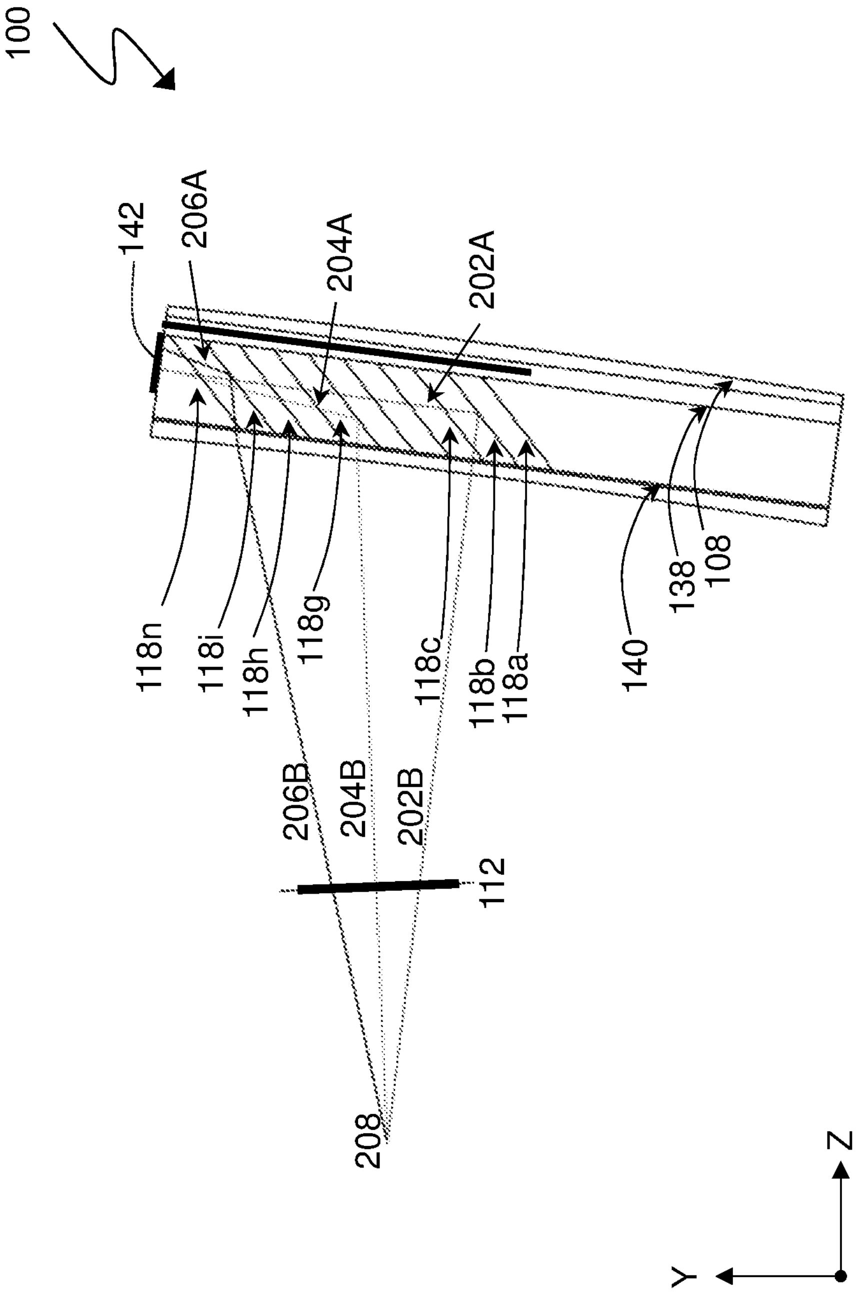

100
142
206A
204A
202A
118n
118i
118h
118g
118c
118b
118a
140
138
108
206B
204B
202B
112
208
Z
Y

Fig. 2A

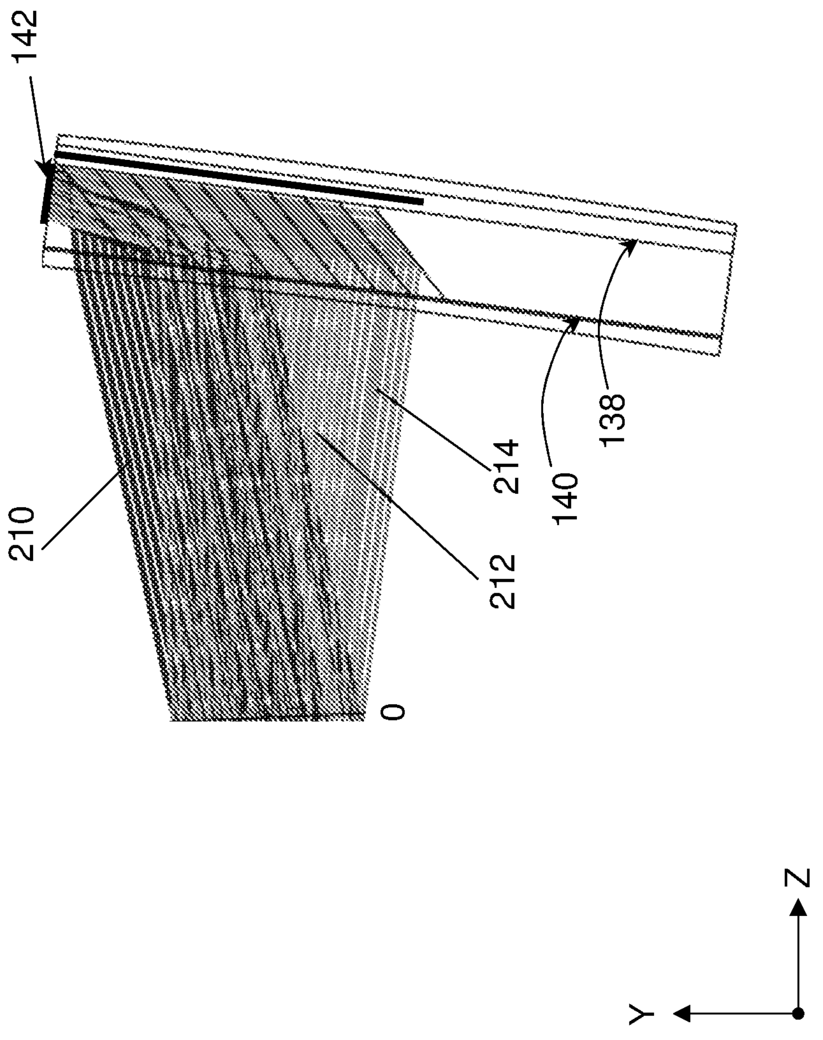


Fig. 2B

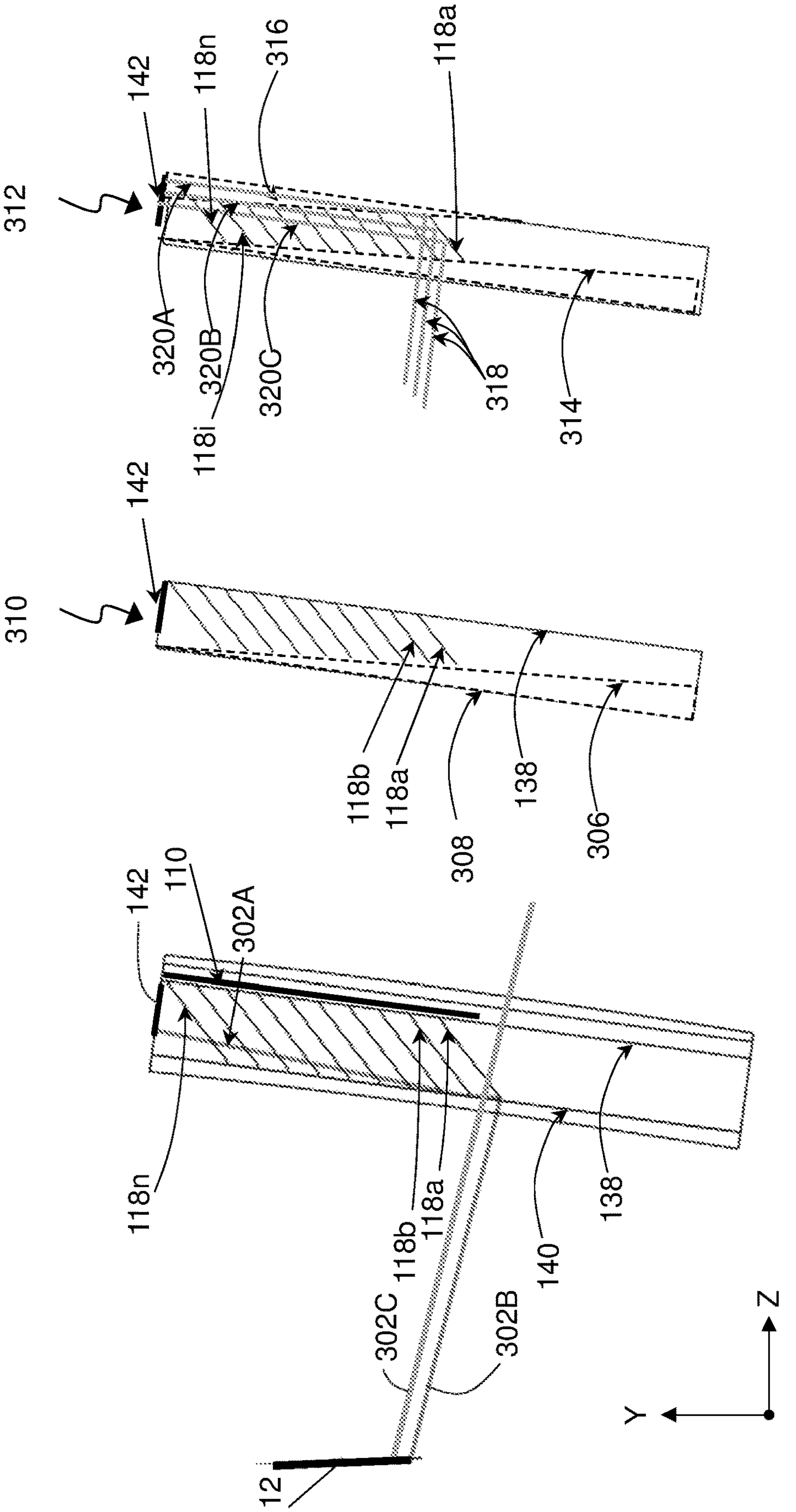


Fig. 3A

Fig. 3B

Fig. 3C

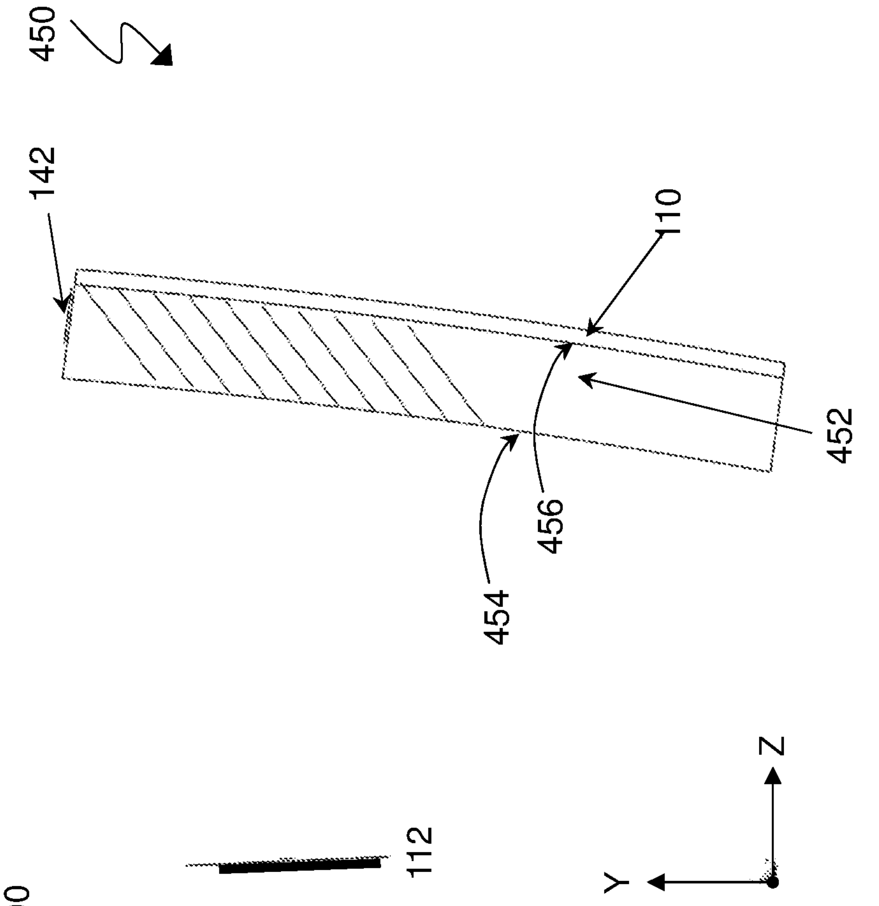


Fig. 4B

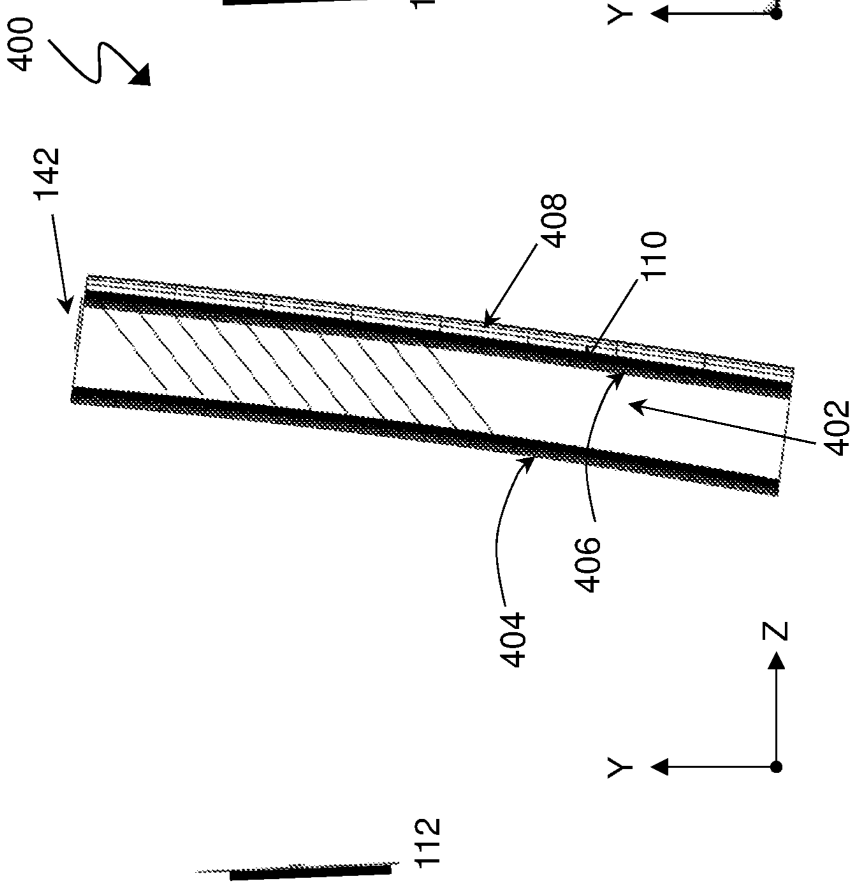


Fig. 4A

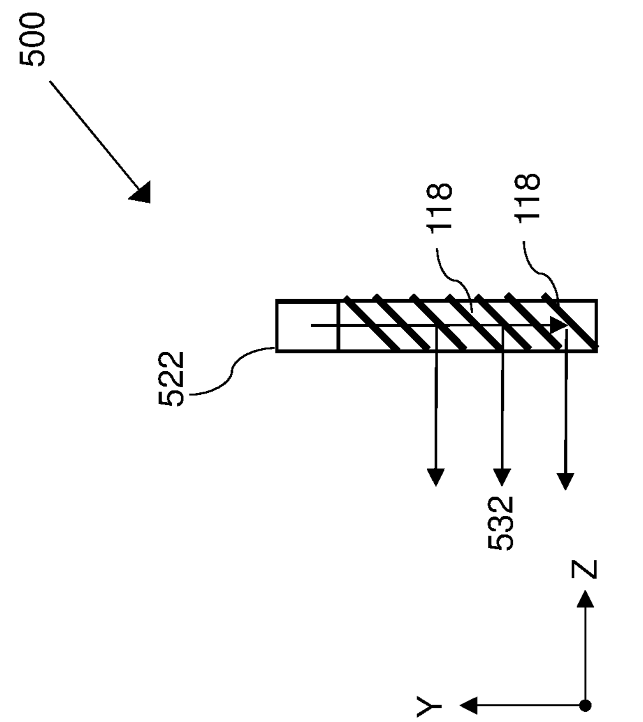


Fig. 5B

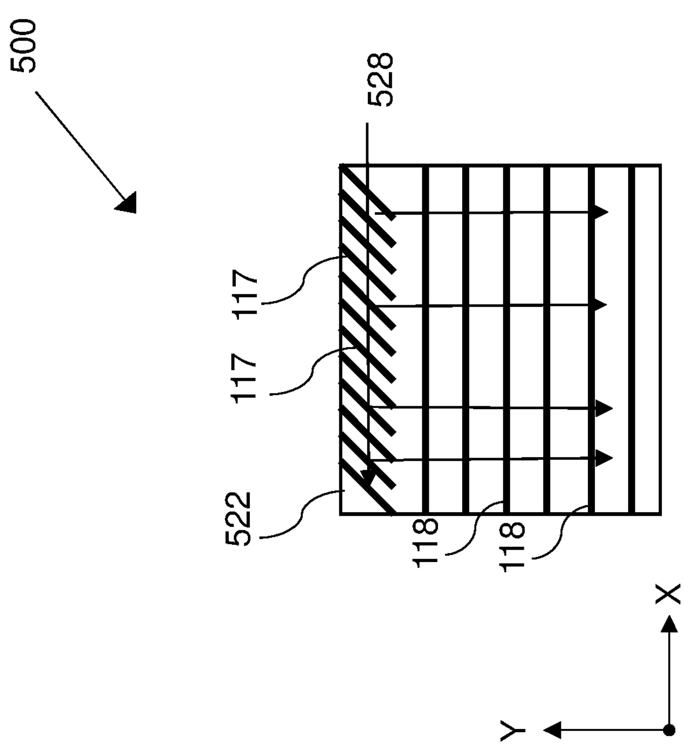


Fig. 5A

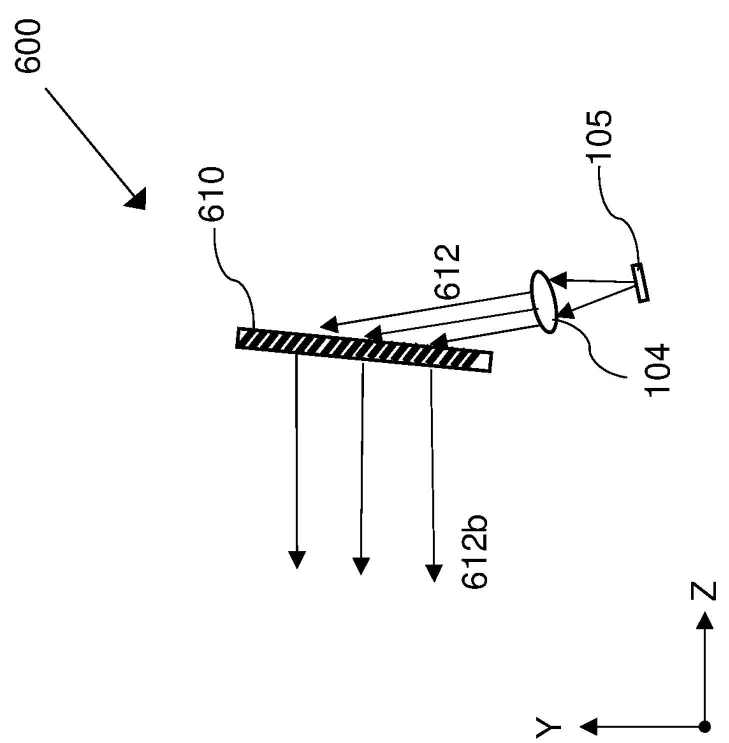


Fig. 6A

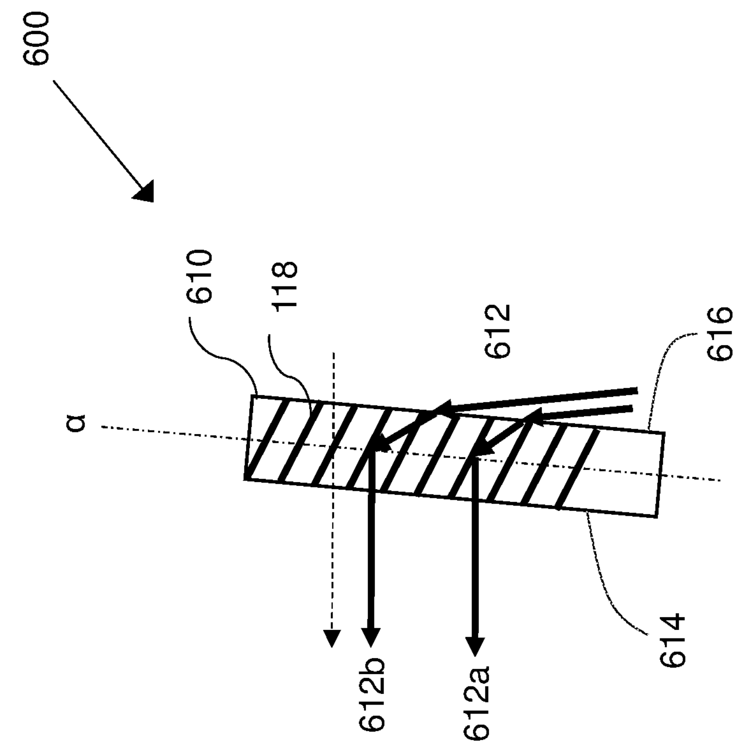


Fig. 6B

A NOVEL NEAR EYE DISPLAY OPTICAL SYSTEM

FIELD OF THE INVENTION

[0001] The present disclosure relates to the field of near eye display optical systems such as head-mounted displays. More specifically, the present disclosure relates to potentially waveguide-less near eye display optical systems.

BACKGROUND OF THE INVENTION

[0002] Consumer demands for improved human-computer interfaces have led to an increased interest in high-quality image head-mounted displays (HMDs) or near-eye displays, commonly known as smart glasses. These devices can provide virtual reality (VR) or augmented reality (AR) experiences, enhancing the way users interact with digital content and their surrounding environment.

[0003] Consumers are seeking better image quality, immersive experiences, and greater comfort when using HMDs. They expect displays with high resolution, vibrant colors, and minimal distortion to create a realistic and enjoyable viewing experience. Additionally, comfort is a crucial factor since users often wear these devices for extended periods. Consumers desire lightweight, sleek designs that are less obtrusive and more convenient to wear in various scenarios. Smaller devices also offer improved portability, making them easier to carry and use in different environments. As such, there is a growing demand for higher performing yet smaller and more compact HMDs.

[0004] A critical element in traditional near-eye display systems is the waveguide. It is a device that guides light from a system image projector to the user's eyes. Waveguides rely on total internal reflection along the major surfaces within the device to propagate light. Achieving optimal waveguide performance requires precise design and manufacturing to prevent imperfections that could degrade the user's visual experience. This process of designing and producing waveguides is both time-consuming and costly, which hampers the availability and adoption of near-eye display systems. Additionally, there are inherent limitations in miniaturizing waveguides, which in turn restricts the miniaturization of head-mounted displays (HMDs).

SUMMARY OF THE INVENTION

[0005] The current disclosure presents an enhanced optical system for near-eye displays that is straightforward and convenient to build, with minimal demands placed on one of its primary components, the lens. This innovative optical system for near-eye displays has the capability to deliver performance that is comparable or even superior to traditional systems, all without the necessity of incorporating a waveguide as part of the setup.

[0006] The present disclosure introduces a novel optical system for near eye displays, which utilizes a series of parallel partial reflecting surfaces. This approach bears similarities to the Light-Guide Optical Element (LOE) described in U.S. Pat. No. 7,643,214 and U.S. Pat. No. 7,724,442. The LOE incorporates a lens that acts as a light-transmitting substrate with two parallel major surfaces. Light is guided between these surfaces, aided by an optical element that achieves total internal reflection or dielectric coatings to trap the light. Additionally, the LOE incorporates multiple partially reflecting surfaces that are non-parallel to the major surfaces, facilitating the coupling of light to the user's eye.

[0007] In contrast, the new optical system for near eye displays in the present disclosure employs a set of parallel partial reflecting surfaces but does not rely on waveguiding through internal reflection of the major surfaces. As a result, the near eye display optical system introduced here is significantly simpler to construct compared to the aforementioned LOE. It also imposes fewer strict requirements on the major surfaces of the lens.

[0008] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate various example systems, methods, and so on, that illustrate various example embodiments of aspects of the invention. It will be appreciated that the illustrated element boundaries (e.g., boxes, groups of boxes, or other shapes) in the figures represent one example of the boundaries. One of ordinary skill in the art will appreciate that one element may be designed as multiple elements or that multiple elements may be designed as one element. An element shown as an internal component of another element may be implemented as an external component and vice versa. Furthermore, elements may not be drawn to scale.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1**A illustrates an exemplary implementation of a near-eye display device.

[0010] FIGS. **1**B and **1**C are schematic illustrations of a one eye portion of a near eye display optical system.

[0011] FIGS. **2**A and **2**B illustrate the optical path of light for the optical system of FIGS. **1**A and **1**B.

[0012] FIG. **3**A illustrates a case of undesired reflections (ghost image) created inside the disclosed lens.

[0013] FIG. **3**B illustrates an improved system that improves the ghost effects.

[0014] FIG. **3**C illustrates a further embodiment which improves the manufacturability and the brightness of the system.

[0015] FIG. **4**A illustrates an optional near eye display optical system with a main lens having a spherically curved inner major surface.

[0016] FIG. **4**B illustrates an alternative compact near eye display system where the main lens is cylindrically curved at the inner major surface and the outer major surface.

[0017] FIGS. **5**A and **5**B illustrate front and side views of a two dimensional expansion optical system.

[0018] FIGS. **6**A and **6**B illustrate schematic and magnified views of an optical system that deflects light from an external source to the EMB with no propagation along the lens itself.

DETAILED DESCRIPTION

[0019] Certain embodiments of the present invention provide a light projecting system and an optical system for achieving optical aperture expansion for the purpose of, for example, head-mounted displays (HMDs) or near-eye displays, commonly known as smart glasses, which may be virtual reality or augmented reality displays. Consumer demands for better and more comfortable human computer interfaces have stimulated demand for better image quality and for smaller devices.

[0020] FIG. **1**A illustrates an exemplary implementation of a near-eye display device **10**. The near-eye display device

10 is disclosed here merely as an example and the inventive techniques disclosed herein are not limited to such devices.

[0021] In the illustrated embodiment of FIG. 1A, the near-eye display **10** employs compact image projectors or projection units **104** optically coupled so as to inject an image into optical elements **102**. Optical aperture expansion of light from the projection unit **104** may be achieved within optical elements **102** by one or more arrangements for progressively redirecting the image illumination employing a set of partially reflecting surfaces (interchangeably referred to as "facets") that are parallel to each other and inclined obliquely to the direction of propagation of the image light, with each successive facet deflecting a proportion of the image light into a deflected direction. Partially reflecting facets may also work as a coupling-out arrangement that progressively couples out a proportion of the image illumination towards the eye of an observer located within a region defined as the eye-motion box (EMB).

[0022] The overall device **10** is preferably supported relative to the head of a user with each projection unit **104** and optical elements **102** serving a corresponding eye of the user. In one particularly preferred option as illustrated here, a support arrangement is implemented as a face-mounted set of lenses (e.g., Rx lenses, sunglasses, etc., referred colloquially herein as "eye glasses") with lenses **108** to which the projection unit **104** and optical element **102** are optically connected and a frame with sides **101** for supporting the device relative to ears of the user. Other forms of support arrangement may also be used, including but not limited to, head bands, visors or devices suspended from helmets.

[0023] The near-eye display **10** may include various additional components, typically including a controller **121** for actuating the projection unit **104**, typically employing electrical power from a small onboard battery (not shown) or some other suitable power source. Controller **121** may include all necessary electronic components such as at least one processor or processing circuitry to drive the image projector **104**.

[0024] FIGS. **1**B and **1**C are schematic illustrations of a one eye portion of a near eye display optical system **100**. The system **100** is similar to the system **10** of FIG. **1**A, a main exception being that, in the near eye display optical system **100**, the projection unit **104** is disposed above the optical element **102** (henceforth also referred to as the lens **102**) instead of to the side of the optical element **102** as shown in FIG. **1**A. FIG. **1**B is a side view (along YZ plane) and FIG. **1**C is a front view (along the XY plane) of the near eye display optical system **100**.

[0025] Lens **102** is positioned in front of the user's eye motion box (EMB) **112** to direct projected light from the projection unit **104** towards the EMB **112**. The projection unit **104** may be positioned either above or below lens **102**, as illustrated. Unlike a waveguide, lens **102** guides the light from the projection unit **104** to the EMB **112** without relying on total internal reflection off the major surfaces of the optical element.

[0026] Lens **102** may have two regions: a first region **114** that does not guide or reflect light and a second region **116** with multiple partially reflective internal surfaces **118**, forming a Folded Beam Splitter (FBS) to expand the image apertures. Projection unit **104** projects light (micro display images) onto the second region **116** of lens **102**, which reflects the light towards the center of the EMB **112** through the set of internal surfaces **118**. The projected light is collimated or nearly collimated along an arrangement axis α of lens **102**. The arrangement axis α is defined herein as an axis along which the internal surfaces **118** are disposed or arranged.

[0027] System **100** may also include two external lenses (first external lens **106** and second external lens **108**) and a shutter **110**. The first external lens **106** and second external lens **108**, along with the shutter **110**, may be attached to the main lens **102**. They may help change the plane of focus for both the projected light and the landscape light. The inner surface of the first external lens **106** alters the focus planes of the projected and landscape images, while the inner surface of the second external lens **108** changes the focus of the landscape image. The shutter **110**, positioned between the main lens **102** and the second external lens **108**, may control the brightness of the landscape image. To ensure a smooth appearance, a gradually spatially varying coating may be applied to lens **102** between the first region **114** and the second region **116**.

[0028] The optical shutter **110** may incorporate a polarizer that allows only P-polarized light from the landscape to pass through the lens **102** and the partially reflective surfaces **118** towards the user's eye. Coatings on the partial reflective surfaces **118** may have low reflectivity for P polarization and higher reflectivity for S polarization. The first external lens **106** may be directly attached to the main lens **102** at its major surface **140**. The optical shutter **110**, which can be divided into multiple independently controllable pixels, is designed to control the brightness of the landscape image using techniques like polarizers and a controllable liquid crystal cell (LCC). The shuttering may cover the entire lens **102** or be limited to overlapping the second region **116** only, affecting the brightness of the fields overlapping the projected Field of View (FOV) as shown in FIG. **1**B.

[0029] FIGS. **2**A and **2**B illustrate the optical path of light for system **100**.

[0030] FIG. **2**A illustrates the ray path of **3** different rays. Seen in FIG. **2**A is lens **102** of FIGS. **1**B-**1**C. Projection unit **104** is not shown, however, the coupling surface **142** between the lens **102** and projection unit **104** is illustrated. Seen in the figure are three rays, first ray **202**, second ray **204**, and third ray **206** coupled to lens **102** and reflected towards the fixating center **208** of the user. The fixating center **208** of the user is positioned at a pre-defined distance from the human eye, for example, about 11 mm behind the human eye **112**.

[0031] In the illustration, first ray **202**A propagates through multiple surfaces **118** until reaching surface **118***b* from which it is reflected, e.g., ray **202**B reflecting towards the user's eye. As seen in the figure, ray **202**A has the longest path to propagate through before it is reflected, e.g., ray **202**B, towards the fixating center **208** of the user. The second ray **204**A propagates through **4** surfaces **118** before reaching and being reflected, e.g., ray **204**B reflecting by surface **118***g* towards the fixating center **208** of the user. The closest ray, third ray **206**A, propagates through a single surface only, through surface **118***n*, before being reflected, e.g., ray **206**B reflecting by surface **118***i* towards the fixating center **208** of the user.

[0032] In order to have the same intensity in all reflecting rays **202**B, **204**B and **206**B, the reflectance increases as the surface is positioned further away relative to the projection unit **104**. For instance, surface **118***n* has lower reflectance than surfaces **118***a* and **118***b*.

[0033] In accordance with some embodiments of the present invention, the spacings between the reflective surfaces **118** vary; the spaces are set in such a way to induce an even intensity distribution of all fields at EMB **112**.

[0034] FIG. **2**B illustrates the beam path of **3** different beams. Seen in the figure are **3** beams, first beam **210**, second beam **212** and third beam **214** containing the three rays, rays **202**A&B, **204**A&B and **206**A&B shown in FIG. **2**A. Each one of first beam **210**, second beam **212** and third beam **214** is almost continuous and has no or very few areas where no rays fill the aperture of a certain beam-field. Also shown in the figure is coupling surface **142** between lens **102** and the projection unit **104**.

[0035] In accordance with some embodiments of the present invention, the angle of coupling surface **142** relative to the lens **102** is set so as to decrease chromatic aberrations and other keystone effects caused by propagating through a high refractive index material where the coupling in angle and the coupling out angle are not equal (wedge effect). If the surfaces of the FBS lens **102** are set at angle θ relative to the normal to the major surfaces of lens **102**, then surface **142** should be rotated relative to the major surface. For instance, if θ=**45**°, then surface **142** may be rotated by 90° with respect to the major surface of lens **102**.

[0036] In accordance with some embodiments of the present invention, in order to make the lens as compact as possible, the most extreme ray may propagate inside the lens **102** relatively parallel to the lens **102** major surfaces (about 90° to the normal to the major surfaces) so as to decrease the lens width. All other fields may propagate at larger angles, greater than 90°.

[0037] In accordance with some embodiments of the present invention, in order to minimize the width of surface **142**, it should be positioned as close as possible to the external surface **138** as can be seen in FIG. **2**B.

[0038] In accordance with some embodiments of the present invention, light projected from the projection unit **104** to the lens **102** may be reflected from both the major surfaces, from surface **140** of external lens **106** and from surface **138** of external lens **108**. However, in a specific case where the light propagates at angles of 90° and higher, light injected via surface **142** may not hit the external surface **138** of external lens **108**.

[0039] Undesired reflections (ghost images) may be created via surface **140**. Therefore, to eliminate undesired reflections, the adhesive used in between lens **102** and external lens **106** may have the same RI (refractive index), and coating should not be used on surface **140** of external lens **106**. In the case that such a requirement cannot be met, undesired reflections (seen in FIG. **3**A) may occur.

[0040] FIG. **3**A illustrates a case of undesired reflections (ghost image) created inside the disclosed lens. As seen in the figure, ray **302**A is reflected at surface **140** as an undesired reflection, ray **302**B. It should be noted that the undesired reflection comes from a direction outside the FOV of ray **302**C, and light from the landscape may reach EMB **112** from this direction without propagating via shutter **110**. Hence, the relative brightness of ray **302**B relative to ray **302**C, may be much lower than that of light within the FOV of the image.

[0041] FIG. **3**B illustrates an improved system that improves the ghost effects. Seen in the figure is lens **310** having an active area (i.e., an area incorporating partially reflecting surfaces) that is slanted relative to the lens structure. The active area of the surfaces **118** positioned further away from the input plane, e.g., surface **142**, for instance, surfaces **118***a* and **118***b*, is closer to the surface **138**, while the active area of surfaces that are closer to the input plane, surface **142**, for instance, surfaces **118***i* and **118***n*, is closer to the surface **308**. Hence, the coated active area of the surfaces could be slanted relative to the main lens structure as shown in FIG. **3**B.

[0042] Thus, only light that is very far away from the FOV fields may be reflected to the EMB **112**. This may be achieved by selectively coating different areas of the different plates when making lens **102** or by adhering two parts together with surface **306** in between (however, the light hitting surface **306**, will have lower angle of incidence (AOI) relative to surface **308** so the demand on matching the RI will be lower). FIG. **3**B shows such an exemplary structure whereas the correcting external lenses **106** and **108** and the optical shutter **110** are not shown.

[0043] Furthermore, for the same reason of the shift of the active area of the surfaces, the surfaces may also shift their edge along the Y axis, at the side closer to the coupling in surface (+Y), they will be closer to the user's eye (−Z) and as they are positioned away from the coupling in surface (−Y), the surfaces are positioned towards the landscape side of the glasses (+Z). Thus, the structure of lens **312** shown in FIG. **3**C may be used as well.

[0044] FIG. **3**C illustrates a further embodiment which improves the manufacturability and the brightness of the system. Seen in the figure is lens **312** with surfaces having their edges shifted along the Y axis, at the side closer to the +Z side. Such structure is advantageous for the following reasons:

- **[0045]** it is relatively easy to manufacture a structure having an array with parallel edges **314** and **316**.
- **[0046]** system efficiency is improved where surface **118***n* does not reflect the light of beam **318** away from EMB **112**. However, the rays of beam **318** reaching surface **118***a* have different intensities since the number of surfaces beam **318** propagates through till reaching surface **118***a* varies along the Z axis position of the ray hitting surface **118***a*.

[0047] This should be considered when designing coating reflectivity and the spacing in between surfaces **118**. For instance, ray **320**C may have lower intensity than ray **320**A since unlike ray **320**A, ray **320**C propagates through surface **118**.

[0048] In addition, special care should be taken at the edges of surfaces **118** along plane **316** in order not to scatter light and harm the images by scattering and diffraction effects, for instance, ray **320***b* may be scattered by the edge effects of surface **134**.

[0049] By the nature of the surfaces array of the FBS lens **102**, the light hitting the array and being expanded should be collimated along the axis of expansion (the vertical, Y direction in the figure).

[0050] In accordance with some embodiments of the present invention, the plane of focus may be changed by additional lens(es) positioned in between the user's eye and the FBS (for instance, lens **106** in FIG. **1**B).

[0051] In accordance with some embodiments of the present invention, additional lens(es) may be used to correct the focus of the landscape image.

[0052] In accordance with some embodiments of the present invention, if spherical lenses are to be used, it may not be possible to use an optical shutter(s) since it may not be possible to adhere the shutter to the spherical surface of the lens. Therefore, shutter **110** may be situated in between lens **108** and the FBS lens **102** as shown in FIGS. **1**B, **2**A and **3**A.

[0053] FIG. **4**A illustrates an optional near eye display (NED) optical system **400** with a main lens **402** having a spherically curved inner major surface. Seen in the figure, inner major surface **404** may have optical power, while outer major surface **406** may not have optical power. Therefore, shutter **110** may be adhered to the outer major surface **406** of lens **402** and an additional external lens **408** may be adhered to the shutter **110**.

[0054] FIG. **4**B illustrates an alternative compact near eye display (NED) system **450** where the main lens **452** is cylindrically curved at the inner major surface **454** and the outer major surface **456**. As seen in the figure, both major surfaces of lens **452**, inner major surface **454** and outer major surface **456** have optical power. The shutter **110** may be adhered to the non-flat major surface **456**.

[0055] However, in case of a shutter **110** that cannot adhere to a spherical surface, but can only adhere to a cylindrically curved surface, both surfaces **454** and **456** should have only a cylindrical radius of curvature.

[0056] In accordance with some embodiments of the present invention, both major inner surface **454** and major outer surface **456** may have (along the array of the FBS lens **452**) vertical cylindrical power in such a way the power of the two surfaces is set in a way that they (almost) cancel one another, and thus, do not change the landscape image focus, however, the focus of the vertical focus of the image may be changed.

[0057] In accordance with some embodiments of the present invention, the light projected via projection unit **104** on lens **452** may have different planes of focus between the two axes, such that after propagating via curved surface **454**, the image may have symmetrical focus, at the desired distance.

[0058] FIGS. **5**A and **5**B illustrate a 2D expansion system **500** where the FBS lens **522** is composed of two parts: where surfaces **118** expand the image vertically and where surfaces **117** expand the light along the horizontal direction. For simplicity reasons the projection unit is not shown in the figure. As seen, ray **528** is injected first to the upper part and expanded along the horizontal direction by the surfaces **117** and then expanded along the vertical direction by the surfaces **118**. The same system is shown from the side view in FIG. **5**B. The rays after 2D expansion exiting the FBS lens **522** are denoted **532**. For simplicity reasons only a single direction of propagation of light is shown in the figure.

[0059] FIGS. **6**A and **6**B illustrate an optical system using an FBS lens **610** to deflect light from outside the lens **610** from an external source to the EMB with no propagation along the lens **610** itself. Projection unit **104** and its micro display **105** project rays **612** of collimated light at acute angles relative to the arrangement axis α. The light **612** enters the lens **610** through the major surface **616**. In one embodiment, the collimated light enters the major surface **616** at angles between 5° and 45° relative to the arrangement axis α. A thin film or coating with specific optical properties may be applied to the major surface **616** such that the incoming light can be directed to enter the lens **610** at shallow angles.

[0060] Some of the light **612** entering the lens **610** through the first major surface **616** may be immediately deflected off an FBS surface **118** towards the EMB as ray **612***a*. Some of the light **612** entering the lens **610** through the first major surface **616** may be transmitted through one or more FBS surfaces **118** and then reflected off another surface **118** towards the EMB as ray **612***b*. Notice that in the embodiment of FIGS. **6**A and **6**B there is no light propagation along lens **610** (along the arrangement axis α) itself by total internal reflection off the first and second major surfaces **614** and **616**.

DEFINITIONS

[0061] The following includes definitions of selected terms employed herein. The definitions include various examples or forms of components that fall within the scope of a term and that may be used for implementation. The examples are not intended to be limiting. Both singular and plural forms of terms may be within the definitions.

[0062] An "operable connection," or a connection by which entities are "operably connected," is one in which signals, physical communications, or logical communications may be sent or received. Typically, an operable connection includes a physical interface, an electrical interface, or a data interface, but it is to be noted that an operable connection may include differing combinations of these or other types of connections sufficient to allow operable control. For example, two entities can be operably connected by being able to communicate signals to each other directly or through one or more intermediate entities like a processor, operating system, a logic, software, or other entity. Logical or physical communication channels can be used to create an operable connection.

[0063] To the extent that the term "includes" or "including" is employed in the detailed description or the claims, it is intended to be inclusive in a manner similar to the term "comprising" as that term is interpreted when employed as a transitional word in a claim. Furthermore, to the extent that the term "or" is employed in the detailed description or claims (e.g., A or B) it is intended to mean "A or B or both." When the applicants intend to indicate "only A or B but not both" then the term "only A or B but not both" will be employed. Thus, use of the term "or" herein is the inclusive, and not the exclusive use. See, Bryan A. Garner, A Dictionary of Modern Legal Usage **624** (2d. Ed. 1995).

[0064] While example systems, methods, and so on, have been illustrated by describing examples, and while the examples have been described in considerable detail, it is not the intention of the applicants to restrict or in any way limit scope to such detail. It is, of course, not possible to describe every conceivable combination of components or methodologies for purposes of describing the systems, methods, and so on, described herein. Additional advantages and modifications will readily appear to those skilled in the art. Therefore, the invention is not limited to the specific details, the representative apparatus, and illustrative examples shown and described. Thus, this application is intended to embrace alterations, modifications, and variations that fall within the scope of the appended claims. Furthermore, the preceding description is not meant to limit the scope of the invention. Rather, the scope of the invention is to be determined by the appended claims and their equivalents.

What is claimed is:

1. A near eye display optical system, comprising:

a lens extending along an arrangement axis and having (a) an input plane and (b) first and second major surfaces generally extending along the arrangement axis, the lens configured to receive light corresponding to an image collimated along the arrangement axis via the input plane; and

the lens comprising a set of partially reflective internal surfaces disposed along the arrangement axis at angles relative to the arrangement axis, a first partially reflective internal surface from the set disposed closest to the input plane having lower reflectance than a second partially reflective internal surface farthest from the input plane such that at least some of the light reaches the second partially reflective internal surface after being transmitted by the first partially reflective internal surface and without previously having reflected off the first or second major surfaces.

2. The near eye display optical system of claim **1**, wherein the second partially reflective internal surface reflects the at least some the light out of the lens at a 90 degree angle towards an eye motion box of a user of the near eye display.

3. The near eye display optical system of claim **1**, comprising a projection unit configured to project the light corresponding to the image collimated along the arrangement axis onto the lens via the input plane.

4. The near eye display optical system of claim **1**, comprising:

a first external lens adjacent the first major surface and having optical power; and

a second external lens adjacent the second major surface and having optical power complementary to the optical power of the first external lens such that landscape light transmitted through the first external lens and acted upon by the optical power of the first major surface is subsequently transmitted through the second external lens acted upon by the optical power of the second major surface to appear to a user similar to the landscape light as first received by the first external lens.

5. The near eye display optical system of claim **4**, wherein

at least one of the first and second external lenses is nonplanar, or

the first and second external lenses are not parallel to each other.

6. The near eye display optical system of claim **4**, comprising:

an optical shutter disposed between (a) one of the first and second external lenses and (b) a corresponding one of the first and second major surfaces to overlap at least some of the partially reflective surfaces along an optical axis of the near eye display, the optical shutter incorporating a polarizer oriented such that only P polarized light is transmitted from the landscape light through the lens and the partially reflective surfaces towards and eye of the user, wherein the partially reflective surfaces coatings are polarization dependent with lower P polarization reflectivity and higher S polarization reflectivity.

7. The near eye display optical system of claim **1**, comprising:

an external lens adjacent the second major surface and having optical power configured to reflect light towards a fixating center of a user of the near eye display, the fixating center of the user positioned at a pre-defined distance from the user's eye.

8. The near eye display optical system of claim **7**, wherein the external lens has a curved surface, wherein the image has different planes of focus between two axes such that, after propagating via the curved surface, the image has symmetrical focus, at the pre-defined distance.

9. The near eye display optical system of claim **1**, wherein the first partially reflective internal surface and the second partially reflective internal surface are configured to reflect light towards a fixating center of a user of the near eye display, the fixating center of the user positioned at a pre-defined distance from the user's eye.

10. The near eye display optical system of claim **1**, wherein at least one of the first and second major surfaces is nonplanar or the first and second major surfaces are not parallel.

11. The near eye display optical system of claim **1**, wherein the set of partially reflective internal surfaces is configured to reflect the light out of the lens towards an eye motion box of a user of the near eye display, wherein spacings between partially reflective surfaces in the set vary, the spacings being set such as to induce an even intensity distribution of all light fields at the eye motion box.

12. The near eye display optical system of claim **1**, wherein a partially reflecting area of the second partially reflecting internal surface is closer to the first major surface while a partially reflecting area of the first partially reflecting internal surface is closer to the second major surface such that the respective partially reflecting areas of the first and second partially reflecting surfaces are slanted relative to the arrangement axis.

13. A near eye display comprising multiple lenses according to claim **1**, a first lens of the multiple lenses configured to expand the light in a first direction and a second lens of the multiple lenses configured to, thereafter, expand the light in a second direction perpendicular to the first direction.

14. A near eye display optical system, comprising:

a lens extending along an arrangement axis and having (a) an input plane and (b) first and second major surfaces generally extending along the arrangement axis,

the lens configured to receive collimated light corresponding to an image, the collimated light entering the lens through the input plane; and

the lens comprising a set of partially reflective internal surfaces disposed along the arrangement axis at angles relative to the arrangement axis, a first partially reflective internal surface from the set having partial reflectance such that at least some of the collimated light is reflected out of the lens by the first partially reflective internal surface without previously having reflected off the first or second major surfaces.

15. The near eye display optical system of claim **14**, wherein the input plane corresponds to the first major surface or the second major surface.

16. The near eye display optical system of claim **14**, wherein the collimated light enters the lens through the first major surface or the second major surface at acute angles relative to the arrangement axis.

17. The near eye display optical system of claim **14**, wherein at least some of the collimated light reaches and is reflected out of the lens by a second partially reflective internal surface from the set after being transmitted by the first partially reflective internal surface.

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