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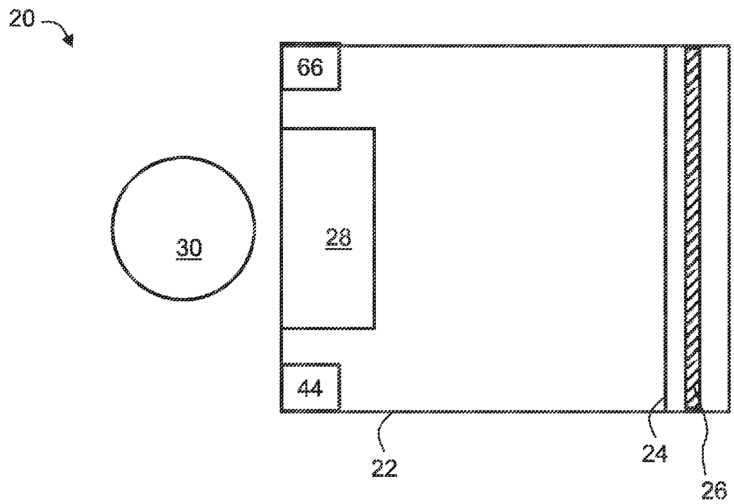

FIG. 2

(57) **Abstract**: An optical magnification is disclosed. The system comprises: a structure having a frame configured to removably secure a display device thereto; and a pair of spaced apart ocular systems, mounted on the structure in front of the frame for providing a view of the display device once mounted on the frame; wherein each of the ocular systems has an aspheric optical surface and provides a prismatic refraction.

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NEAR-EYE DISPLAY SYSTEM

RELATED APPLICATION

This application claims the benefit of priority of U.S. Provisional Patent Application Nos. 62/024,171, filed July 14, 2014, and 62/137,623, filed March 24, 2015, the contents of which are incorporated herein by reference in their entirety.

FIELD AND BACKGROUND OF THE INVENTION

The present invention, in some embodiments thereof, relates to personal display system and, more particularly, but not exclusively, to a near-eye display system.

Three dimensional (3D) images are increasingly used to display vivid images in movies, electronic games and in other applications. For example 3D movies are displayed in theatres and are viewed by persons equipped with special 3D glasses. Additionally, 3D movies and electronic games may be displayed on specially equipped televisions or computer displays for viewing by persons equipped with special 3D glasses.

The basic approach to displaying 3D images is to display two slightly offset images separately to the left and right eye. The two principal strategies have been used to accomplish this are: (1) for the viewer to wear a special 3D eyepiece that filters each offset image to a different eye; and (2) to split the light source directionally into each of the viewer's eyes, thus eliminating the need for special glasses.

One increasingly common approach to projecting stereoscopic image pairs is a head mounted display system that mounts to a person's head and that displays a virtual image on an attached eyepiece. Head mounted displays are often used in simulators or for games, though they can also be used to view media such as movies or digital photos.

SUMMARY OF THE INVENTION

According to an aspect of some embodiments of the present invention there is provided an optical magnification system. The system comprises: a structure having a frame configured to removably secure a display device thereto; and a pair of spaced apart ocular systems, mounted on the structure in front of the frame for providing a view of the display device once mounted on the frame; wherein each of the ocular systems has an aspheric optical surface and provides a prismatic refraction.

According to some embodiments of the invention the aspheric optical surface and the optically opposite surface are spaced apart from each other at a nasal portion of a periphery of the lens by a cut through a thickness thereof.

According to some embodiments of the invention the system comprises: a pair of controllable light shutters respectively positioned between the ocular systems and the frame; and a controller having a circuit configured for receiving synchronization signal from the display device and activating and deactivating the light shutters in an alternating manner, responsively to the synchronization signal.

According to some embodiments of the invention the system comprises an ocular manipulation assembly configured for displacing and rotating each of the ocular systems.

According to some embodiments of the invention the each of the ocular systems comprises a lens having the aspheric surface and at least one prismatic element positioned in front of the lens and being separated from the lens.

According to some embodiments of the invention the ocular manipulation assembly is configured to rotate also the prismatic element, and wherein the rotation is reciprocally from a first state at which each ocular system focus all light rays from the display device, to a second state at which the prismatic elements block a left light beam from a left part of the display device from arriving at a lens of a right ocular system of the pair, and a right light beam from a right part of the display device from arriving at a lens of a left ocular system of the pair.

According to some embodiments of the invention ocular manipulation assembly is configured to vary a distance between the ocular systems and the frame, wherein the distance is larger at the first state of the ocular systems than at the second state of the ocular systems.

According to some embodiments of the invention the ocular manipulation assembly is controllable mechanically.

According to some embodiments of the invention the ocular manipulation assembly is controllable electronically.

According to some embodiments of the invention the frame and the ocular systems are arranged such that light beams from the display device directly arrive to at least one of the ocular systems.

According to some embodiments of the invention the system comprises at least one pair of reflective optical elements configured for redirecting light beams from the display device respectively onto the pair of ocular systems.

According to some embodiments of the invention the frame is mounted on the structure such that when the structure is head mounted in an upright position, the frame is tilted with respect to a vertical direction.

According to some embodiments of the invention the frame is mounted on the structure such that when the structure is head mounted in an upright position, the frame is generally vertical.

According to some embodiments of the invention the structure comprises a variable length support element for supporting the frame at an adjustable optical distance from the pair of ocular systems, and wherein the ocular systems are configured to adjust a focal distance thereof responsively to a variation of the optical distance.

According to some embodiments of the invention the structure comprises a variable length support element for supporting the frame at an adjustable optical distance from the pair of ocular systems, and wherein, responsively to a variation of the optical distance, the ocular systems adjust a focal distance thereof, and wherein the ocular manipulation assembly actuates the displacement and the rotation.

According to an aspect of some embodiments of the present invention there is provided a method of an image, the method comprises securing a display device to the system, placing the structure near the eyes, and viewing the display device through the ocular systems.

According to an aspect of some embodiments of the present invention there is provided a method of viewing an image displayed on a display device, the method comprises: securing the display device to a structure having a frame configured to secure the display device thereto; mounting the structure on a head; and viewing the image through a pair of spaced apart ocular systems mounted on the structure in front of the frame, wherein each of the ocular systems has an aspheric optical surface and provides a prismatic refraction.

According to some embodiments of the invention the image is a three-dimensional video image having an alternating sequence of images for left and right views, and the method comprises receiving synchronization data from the display device and, responsively to the synchronization signal, activating and deactivating a pair of controllable light shutters respectively positioned between the ocular systems and the frame, in an alternating manner corresponding to the alternating sequence.

According to some embodiments of the invention the system comprises displacing and rotating each of the ocular systems.

According to some embodiments of the invention the displacement and the rotation is reciprocally from a first state at which central optical paths of the ocular systems converge, to a second state at which the central optical paths are generally parallel to each other.

According to some embodiments of the invention the each of the ocular systems comprises a lens having the aspheric surface and at least one prismatic element positioned in front of the lens and being separated from the lens.

According to some embodiments of the invention the method comprises reciprocally rotating also the prismatic element from a first state at which each ocular system focus all light rays from the display device, to a second state at which the prismatic elements block a left light beam from a left part of the display device from arriving at a lens of a right ocular system of the pair, and a right light beam from a right part of the display device from arriving at a lens of a left ocular system of the pair.

According to some embodiments of the invention the method comprises varying a distance between the ocular systems and the frame, wherein the distance is larger at the first state of the ocular systems than at the second state of the ocular systems.

According to some embodiments of the invention the structure comprises a variable length support element for supporting the frame, and the method comprises adjusting an optical distance from the pair of ocular systems to the frame, and also adjusting a focal distance thereof responsively to a variation of the optical distance.

According to an aspect of some embodiments of the present invention there is provided a display system comprises: a structure having a frame configured to removably secure thereto a left display device and a right display device in a tilted relationship therebetween; and a left ocular system and right ocular system, mounted on the structure in front of the frame such that central optical paths of the ocular systems diverge towards the frame to respectively provide enlarged views of the left and the right display devices; wherein each of the ocular systems has an aspheric optical surface and provides a prismatic refraction.

According to some embodiments of the invention the aspheric optical surface and the optically opposite surface are spaced apart from each other at a temporal portion of a periphery of the lens by a cut through a thickness thereof.

According to some embodiments of the invention the system wherein each of the ocular systems is a lens having prismatic shape.

According to some embodiments of the invention a second optical surface of the lens, optically opposite to the aspheric optical surface, is generally planar or spherical.

According to some embodiments of the invention a second optical surface of the lens, optically opposite to the aspheric optical surface, is also aspheric.

According to some embodiments of the invention the system according to any wherein each of the ocular systems comprises a lens having the aspheric surface and at least one prismatic element positioned between the lens and the frame or behind of the lens.

According to some embodiments of the invention the system according to any wherein each of the ocular systems is diffractive.

According to some embodiments of the invention the system comprises a controller having a circuit for controlling the display devices to display different portions of an image having a left periphery, a binocular overlap and a right periphery, wherein the left display device displays the left periphery and the binocular overlap, and the right display device displays the binocular overlap and the right periphery.

According to some embodiments of the invention the controller comprises a user interface and wherein circuit is configured for shifting a location of the binocular overlap over at least one of the display devices, responsively to a user input received by the user interface.

According to some embodiments of the invention the system comprises a separator device mounted on the structure along a symmetry line between the left and the right display devices to block light beams from the left display device from arriving at the right ocular system, and light beams from the right display device from arriving at the left ocular system.

According to some embodiments of the invention the separator device comprises a back-to-back pair of auxiliary display devices, and wherein light beams from a left auxiliary display device of the pair arrive at the left ocular system, and light beams from a right auxiliary display device of the pair arrive at the right ocular system.

According to some embodiments of the invention the circuit is configured to control the left auxiliary display device to display the right periphery, and the right auxiliary display device to display the left periphery.

According to some embodiments of the invention the system comprises: a pair of controllable light shutters respectively positioned between the ocular systems and the frame; and a controller having a circuit configured for receiving synchronization signal from the display device and activating and deactivating the light shutters in an alternating manner, responsively to the synchronization signal.

According to some embodiments of the invention the structure comprises a variable length support element for supporting the frame at an adjustable optical distance from the pair of ocular systems, and wherein the ocular systems are configured to adjust a focal distance thereof responsively to a variation of the optical distance.

According to some embodiments of the invention at least one of the each of the ocular systems comprises a vision correction lens.

According to some embodiments of the invention each of the each of the ocular systems comprises a vision correction lens, and wherein a refractive power of a vision correction lens of a first lens system of the pair differ from a refractive power of a vision correction lens of a second lens system of the pair.

According to an aspect of some embodiments of the present invention there is provided a method of viewing an image, the method comprises securing a left display device and a right display device to the system, placing the structure near the eyes, and viewing the display devices through the ocular systems.

According to an aspect of some embodiments of the present invention there is provided a method of viewing an image displayed on a left display device and a right display device, the image having a left periphery, a binocular overlap and a right periphery, the method comprises: securing the display devices to a structure having a frame configured to receive the display devices in a tilted relationship therebetween; mounting the structure on a head; and viewing the left periphery through a left ocular system, the right periphery through a right ocular system, and the binocular overlap through at least one of the left and the right ocular systems; wherein central optical paths of the ocular systems diverge towards the display devices, and wherein each of the ocular systems has an aspheric optical surface and provides a prismatic refraction.

According to some embodiments of the invention the method comprises shifting a location of the binocular overlap over at least one of the display devices to correct for diplopya.

According to some embodiments of the invention the viewing comprises viewing the left periphery and the binocular overlap through the left ocular system, and the binocular overlap and the right periphery through the right ocular system.

According to some embodiments of the invention the system comprises viewing a left auxiliary display device displaying the right periphery, and a right auxiliary display device displaying the left periphery, wherein the auxiliary display devices are arranged in a back-to-back arrangement along a symmetry line between the left and the right display devices.

According to some embodiments of the invention the binocular overlap is displayed on the left and the right display devices in an alternating manner and, wherein the viewing comprises alternating between viewing the left display device when the binocular overlap is displayed on the left display device, and viewing the right display device when the binocular overlap is displayed on the right display device.

According to an aspect of some embodiments of the present invention there is provided a display system for displaying a stereoscopic image having a stereoscopic left periphery, a stereoscopic binocular overlap and a stereoscopic right periphery, the system comprises: a structure having a frame configured to removably secure a display device thereto; a plurality of auxiliary display devices each mounted on the structure at an angle to a plane engaged by the frame, the auxiliary display devices including at least a left auxiliary display device and a right auxiliary display device; a left ocular system and right ocular system, mounted on the structure in front of the frame and the auxiliary display devices, wherein a field-of-view of the left ocular system includes the left auxiliary display device, and field-of-view of the right ocular system includes the right auxiliary display device; and a controller having a circuit configured to display (i) a left-eye image of the stereoscopic left periphery on the left auxiliary display device, (ii) a left-eye image and a right-eye image of the stereoscopic binocular overlap on the display device in a side-by-side configuration, and (iii) a right-eye image of the stereoscopic right periphery on the right auxiliary display device.

According to some embodiments of the invention the system wherein the plurality of auxiliary display devices comprises a central-left auxiliary display device and a central-right auxiliary display device, and wherein the circuit is configured to display (iv) a right-eye image of the stereoscopic left periphery on the central-right auxiliary display device, and (v) a left-eye image of the stereoscopic right periphery on the central-left auxiliary display device.

According to an aspect of some embodiments of the present invention there is provided a method of viewing a stereoscopic image, the method comprises securing a display device to the system, mounting the structure on a head, and viewing the display device and the auxiliary display devices through the ocular systems.

According to an aspect of some embodiments of the present invention there is provided a method varying an aspect ratio of an image, the method comprises; identifying on the image a first region and at least one additional region; processing the image to resize the at least one additional region along at least one dimension, while maintaining an aspect ratio of the first region substantially unchanged, thereby varying the an aspect ratio of the image; and transmitting the image to a display system.

According to some embodiments of the invention the method wherein the processing comprises varying an aspect ratio of the at least one additional region.

According to some embodiments of the invention the method wherein the processing comprises resizing the second region while preserving an aspect ratio thereof.

According to some embodiments of the invention the identifying the at least one additional region comprises identifying a second region and a third region.

According to some embodiments of the invention the first region is a central region of the image, and the at least one additional region is a peripheral region of the image.

According to an aspect of some embodiments of the present invention there is provided a display system for augmented reality, the system comprises: a structure having a frame configured to removably secure a display device thereto, such that when the structure is mounted on a head, the frame is above the eyes; and an optics assembly mounted on the structure and being partially reflective and partially transmissive for simultaneously providing a view of an image displayed on the display device and a view of an environment outside the structure.

According to some embodiments of the invention the system wherein the optics assembly is configured to converge light beams arriving from the display device but not light beams arriving from the environment.

According to some embodiments of the invention the structure comprises a variable length support element for supporting the frame at an adjustable optical distance from the optics assembly, thereby to effect focal distance adjustment for the light beams arriving from the display device.

According to some embodiments of the invention the frame is mounted on the structure such that when the structure is head mounted in an upright position, the frame is tilted with respect to a vertical direction.

According to some embodiments of the invention the frame is mounted on the structure such that when the structure is head mounted in an upright position, the frame is generally vertical.

According to some embodiments of the invention the optics assembly comprises a reflecting element for light beams arriving from the environment onto a back side of the display device.

According to an aspect of some embodiments of the present invention there is provided an augmented reality method, comprises mounting a display device on the system, placing the structure near the eyes, and viewing the display device and the environment using the optics assembly.

Unless otherwise defined, all technical and/or scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention pertains. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of embodiments of the invention, exemplary methods and/or materials are described below. In case of conflict, the patent specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and are not intended to be necessarily limiting.

Implementation of the method and/or system of embodiments of the invention can involve performing or completing selected tasks manually, automatically, or a combination thereof. Moreover, according to actual instrumentation and equipment of embodiments of the method and/or system of the invention, several selected tasks could be implemented by hardware, by software or by firmware or by a combination thereof using an operating system.

For example, hardware for performing selected tasks according to embodiments of the invention could be implemented as a chip or a circuit. As software, selected tasks according to embodiments of the invention could be implemented as a plurality of software instructions being executed by a computer using any suitable operating system. In an exemplary embodiment of the invention, one or more tasks according to exemplary embodiments of method and/or system as described herein are performed by a data processor, such as a computing platform for executing a plurality of instructions. Optionally, the data processor includes a volatile memory for storing instructions and/or data and/or a non-volatile storage, for example, a magnetic hard-disk and/or removable media, for storing instructions and/or data. Optionally, a network connection is provided as well. A display and/or a user input device such as a keyboard or mouse are optionally provided as well.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Some embodiments of the invention are herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of embodiments of the invention. In this regard, the description taken with the drawings makes apparent to those skilled in the art how embodiments of the invention may be practiced.

In the drawings:

FIG. 1 is a schematic illustration of a side-by-side, near eye 3D display;

FIG. 2 is a schematic illustration showing a side view of an optical magnification system, according to some embodiments of the present invention;

FIG. 3A is a schematic illustration of a top view of the optical magnification system, according to some embodiments of the present invention;

FIGs. 3B and 3C are schematic illustrations showing exemplary implementations of ocular systems, according to some embodiments of the present invention;

FIGs. 4A-D are schematic illustrations of embodiments in which each ocular system comprises a plurality of optical elements;

FIG. 5 is a schematic illustration of the system in embodiments of the invention in which the ocular systems comprise a vision correction lens;

FIGs. 6A and 6B are schematic illustration of in embodiments of the invention in which an image is separated into an alternating field sequence;

FIGs. 7A-D are schematic illustrations of the system in embodiments of the invention in which an image is displayed in a side-by-side configuration;

FIGs. 8A-D are schematic illustrations of the system in embodiments of the invention in which each of the ocular systems comprises a lens having the aspheric surface and a prismatic element positioned in front of the lens and being separated from the lens;

FIG. 9 is a schematic illustration of the system in embodiments of the invention in which the system comprises add-on positive lenses;

FIGs. 10A-E are schematic illustrations of the system in embodiments of the invention in which reflective optical elements redirect light beams from the display device onto the ocular systems;

FIGs. 11A-C are schematic illustrations of the system in embodiments of the invention in which the system comprises a variable length support element for supporting a frame at an adjustable optical distance from the ocular systems;

FIG. 12 is a schematic illustration of a display system, according to some embodiments of the present invention;

FIGs. 13A and 13B are schematic illustrations of an image (FIG. 13A) and the different portions of the image on two display devices (FIG. 13B), according to some embodiments of the present invention;

FIG. 14 is a schematic illustration of a configuration in which the system provides a 24:9 view using two 16:9 display devices, according to some embodiments of the present invention;

FIGs. 15A and 15B are schematic illustrations of the system in embodiments of the invention in which the systems corrects for muscular imbalance or eccentric fixation by the eyes;

FIG. 16 illustrates the system in embodiments of the invention in which the system comprises a separator device;

FIGs. 17A and 17B are schematic illustrations of the system in embodiments of the invention in which the system comprises controllable light shutters;

FIG. 18 is a schematic illustration of a display system which comprises side auxiliary display devices, according to some embodiments of the present invention;

FIG. 19 is a schematic illustration of a display system in embodiments in which the system comprises four auxiliary display devices, according to some embodiments of the present invention;

FIG. 20 is a schematic illustration of a representative implementation in which a 21:9 aspect ratio 3D image is provided using a 16:9 display, according to some embodiments of the present invention;

FIG. 21A-C are schematic illustrations of a display system useful for augmented reality, according to some embodiments of the present invention;

FIGs. 22A-D are schematic illustrations of a method suitable for varying an aspect ratio of an image, according to some embodiments of the present invention;

FIG. 23A is a schematic illustration of a graph showing nonlinear or piecewise linear aspect ratio transformation, according to some embodiments of the present invention;

FIG. 23B is a schematic illustration of representative implementation example in which an aspect ratio of an input image is transformed from 16:9 to a combination of 2:9, 4:9 and 2:9 forming an output aspect ratio of 8:9;

FIG. 24 is a schematic illustration describing design considerations, according to some embodiments of the present invention; and

FIG. 25 is a schematic illustration of an electronic circuitry layout that can be used by a controller, according to some embodiments of the present invention.

DESCRIPTION OF SPECIFIC EMBODIMENTS OF THE INVENTION

The present invention, in some embodiments thereof, relates to personal display system and, more particularly, but not exclusively, to a near-eye display system.

For purposes of better understanding some embodiments of the present invention, reference is first made to the construction and operation of a side-by-side, near eye 3D display as illustrated in FIG. 1. The display divides the screen to left and right parts such that each eye receives half screen correspondingly.

A portable or mobile electronics device, referred to hereinbelow as a mobile device, such as a smartphone, is capable of generating and displaying a stereoscopic or 3D movie or image that when projected onto an eyepiece appears to a viewer to have depth. This approach offers a low cost, mobile, solution to viewing 3D images since mobile electronics devices such as smartphones are widespread and relatively inexpensive. Therefore, it would be desirable to able to attach a mobile device to a head mounted display that properly displays 3D images or movies on an attached eyepiece.

It was found by the present inventor that regular Operating System (OS) and 2D content cannot be viewed using the system shown in FIG. 1. In order to operate such a system to view 2D content a special software layer above the OS is required. Alternatively, the operator is required to remove the smartphone from the display system and view the content not through the display system. Therefore, the operation of such display systems is uncomfortable and is limited to side-by-side contents.

Some embodiments of the present invention successfully provide a system that provide a field-of-view of at least 100° or at least 120° or at least 140° or at least 160°, and optionally also allows switching from full screen view into a side-by-side 3D view. As a representative example, which is not intended to be limiting, the system of the present embodiments can provide a field-of-view that is equivalent to an unaided view of a 50" display from a distance of about half a meter. In full screen view, the system of the present embodiments optionally and preferably allows regular usage of the mobile electronics device while mounted on the system.

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not necessarily limited in its application to the details of construction and the arrangement of the components and/or methods set forth in the following description and/or illustrated in the drawings and/or the Examples. The invention is capable of other embodiments or of being practiced or carried out in various ways.

FIG. 2 is a schematic illustration showing a side view of an optical magnification system **20**, according to some embodiments of the present invention. System **20** comprises a structure **22** which optionally and preferably has a frame **24** configured to removably secure a display device **26** thereto. Structure **22** is preferably portable. In some embodiments of the present invention structure **22** is head-mountable, some embodiments of the present invention structure **22** is wearable, and in some embodiments of the present invention structure **22** is hand-held. Structure **22** can also be on mechanical adjustable arm or other type of support.

As used herein "removably secure" describes a configuration in which an object (*e.g.*, a display device) can be attached and detached from a structure (*e.g.*, a frame), in a manner such that when the object is attached any displacement of the object relative to the structure is substantially prevented (e.g., with a tolerance of less than 1 mm).

In various exemplary embodiments of the invention system **20** comprises a pair of spaced apart ocular systems **28**, mounted on structure **22** in front of frame **24** for providing a view of display device **26** once mounted on frame **24**. In various exemplary embodiments of the invention the central optical paths of systems **28** (not shown in the side view of FIG. 2, see, *e.g.*, FIG. 7A) converge away from system **28** towards frame **24**.

The collection of all light rays originating from the center of a binocular overlap region of the display device, once mounted on frame **24**, and propagating toward a particular ocular system is referred to as a central light beam. In system **20**, the binocular overlap region is optionally and preferably at the center of the display device, once mounted on frame **24**.

As used herein "central optical path" of a particular ocular system refers to a path along which a light ray that is central with respect to the central light beam propagates.

It was found by the present Inventor that convergence of the central optical paths allows each of ocular systems **28** to provide a view of the entire screen of display device **26** while maintaining a relatively short distance between ocular systems **28** and device **26**. System **20** optionally and preferably also comprises a controller **44**, which typically includes a dedicated circuit configured to communicate with device **26** as further detailed hereinbelow.

In an exemplified use of system **20**, the operator secures a display device **26**, such as, but not limited to, a cellular phone, a smartphone, a portable media player, a portable gaming device, a portable digital assistant device, a portable navigation device and the like, to frame **24**, places structure **22** such that ocular systems **28** are in front of the of user's eyes **30** which receive the views provided by ocular systems **28**. The view of display FIG. 2 illustrates a side view of system **20** and therefore illustrates ocular systems **28** as a single device. A more detailed description of the principles and operations of ocular systems **28** is described below.

FIG. 3A illustrate a top view of system **20**, according to some embodiments of the present invention. Shown are a left-eye ocular system **28L** and right-eye ocular system **28R** once placed in front of a left eye **30L** and right eye **30R**. For a display device having a width *W* of about 120 mm, the distance *d* between ocular systems **28** and device **26** is preferably from about 60 mm to about 80 mm, *e.g.*, about 70 mm. The minimal emulated distance *D* between ocular systems **28** and the image **26'** of device **26** is preferably from about 200 mm to about 300 mm, *e.g.*, about 250 mm. System **20** is optionally and preferably designed for an average inter-pupillary distance (IPD) of about 64 mm, and for a minimal IPD of about 50 mm. In FIG. 3A, d1FS denotes the spacing between ocular systems **28L** and **28R** for smaller IPD. Thus, in some embodiments of the present invention systems **28L** and **28R** are movable so as to adjust for different IPD. An assembly suitable for manipulating systems **28** that is described below can also be utilized, *mutatis mutandis*, to adjust for different IPD.

In various exemplary embodiments of the invention each of ocular systems **28L** and **28R** has an aspheric optical surface and provides a prismatic refraction. In some embodiments of the present invention at least one of lenses **28** comprise a single positive lens with prismatic addition (LwP), and in some embodiments of the present invention at least one of lenses **28** comprises a combination of LwP with a prism. Also contemplated are embodiments in which one or more of ocular systems **28** employs a progressive addition lens, *e.g.*, for compensating for distance difference between the ocular systems **28** and different regions over display device **26**.

In the illustration of FIG. 3A, each of ocular systems **28L** and **28R** is a lens having prismatic shape.

Exemplary implementations for ocular systems **28L** and **28R** are illustrated in FIGs. 3B and 3C. FIG. 3B shows a lens that has an aspheric surface **32** and a planar surface **34** which is optically opposite to aspheric surface **32**. These embodiments are particularly useful when it is desired to make lenses **28** using injection molding. FIG. 3C shows a lens in which aspheric surface **32** is semi-finished, wherein the surface **36** that is optically opposite to aspheric surface **32** is also aspheric. These embodiments are particularly useful for free-form customization per refraction condition using optical semi-finished blank.

FIGs. 4A-D are schematic illustrations of embodiments in which each ocular systems **28** comprises a plurality of optical elements. For clarity of presentation, only ocular system **28L** is illustrated. FIG. 4A illustrates an embodiment in which at least one of the ocular systems comprises a plurality of optical elements denoted as Lens/Prism-1 through Lens/Prism-i. Each of the elements can have a different combination of Refraction Index (RI) and Abbe number (NAbbe). Alternatively, at least one of the ocular systems can employ gradient-index (GRIN) optics. The advantage of these embodiments are that the variable optical properties of the ocular system can reduce or minimize chromatic aberrations. Several configurations of the present embodiments are illustrated in FIGs. 4B-4D, where FIG. 4B illustrates an embodiment in which the ocular system comprises a lens having aspheric surface and at least one prismatic element positioned between behind the lens (between the lens and the eye), FIG. 4C illustrates an embodiment in which the ocular system comprises a lens having aspheric surface and at least one prismatic element positioned in front of the lens (between the lens and the frame), and FIG. 4D illustrates an embodiment in which the ocular system employs diffractive optics (*e.g.*, a stack including a Fresnel prism and a Fresnel lens).

In any of the above embodiments, for any of ocular systems **28L** and **28R** the aspheric surface of the lens and the optically opposite surface of the lens are preferably spaced apart from each other at a nasal portion of a periphery of the lens by a cut **38** (see FIGs. 3A-C) through a thickness thereof. Specifically, while the two surfaces of the les (*e.g.*, surfaces **32** and **34** in FIG. 3B, or surfaces **32** and **36** in FIG. 3C) are connected generally continuously **40**, for example, at the temporal side of the lens, they are discontinued by cut **38** at the nasal side. The advantage of these embodiments is that it reduces weight and also provides space for the nose of the wearer. The cut is optionally and preferably parallel to marginal rays so as to reduce optical field losses.

The present embodiments also contemplate configuration in which one or more of ocular systems **28** comprise a vision correction lens. These embodiments are illustrated in FIG. 5. In the illustrated embodiments, which is not to be considered as limiting, each of ocular systems **28L** and **28R** comprises a vision correction lens **42L** and **42R**, respectively, wherein a refractive power of vision correction lens **42L** of system **28L** differs from a refractive power of vision correction lens **42R** of system **28R**. Embodiments in which only one of the systems **28L** and **28R** comprise a vision correction, and embodiments in which both systems **28L** and **28R** comprise vision correction lenses with the same refractive power are also contemplated.

In various exemplary embodiments of the invention system **20** is used for viewing a 3D image, optionally and preferably a stereoscopic image. This can be done in more than one way.

In some embodiments, illustrated in FIGs. 6A and 6B, the stereoscopic 3D image is separated into an alternating field sequence, where the stereoscopic 3D image includes a left-eye image **48L** and a right-eye image **48R** fields in a single frame. Preferably, the frame occupies the entire area of device **26**. The alternating field sequence of the left-eye and right-eye images is displayed on display device **26**. Controller **44** receives a synchronization signal from display device **26** and actively controls viewing for left and right eyes based on the synchronization signal. This can be done, for example, by means of a pair of controllable light shutters **46L** and **26R** respectively positioned between ocular systems **28L** and **28R** and display device **26**. Referring more specifically to FIGs. 6A and 6B, when shutter **46L** is open and shutter **46R** is closed (FIG. 6A), only left eye **30L** receives a view of display device **26**. At these times, display device **26** displays frames of the left-eye image. Conversely, when shutter **46R** is open and shutter **46L** is closed (FIG. 6B), only right eye **30R** receives a view of display device **26**. At these times, display device **26** displays frames of the right-eye image.

The left-eye image and right-eye image are preferably alternating at a rate that is at least twice the rate of a two-dimensional video image (for example, twice a rate of 60

Hz), so that each eye receives a frame sequence at a rate of a two-dimensional video image, thus providing an illusion of a stereoscopic view, as if the left-eye image and the right-eye image are viewed simultaneously for each frame. The generated stereoscopic view is shown at **48**.

In some embodiments, a side-by-side configuration is employed, wherein the left-eye image **48L** and right-eye image **48R** are displayed simultaneously on display device **26**, but are spatially separated from each other. A left part of the screen of device **26** (typically the left half) displays image **48L** and a right part of the screen device **26** (typically the right half) displays image **48R**, as illustrated in FIG. 7A. A separator device **50**, such as, but not limited to, an opaque wall is optionally mounted on structure **22** (not shown in FIG. 7A, see FIG. 2) along a symmetry line **52** between the left and right parts of display device **26**, so as to block light beams from the left part from arriving at right ocular system **28R**, and light beams from the right part from arriving at left ocular system **28L**.

A side-by-side configuration is preferably achieved arranging said ocular systems **28** such that their central optical paths **54L** and **54R** are generally parallel (*e.g.*, with a deviation from parallelism of less than 5° or less than 4° or less than 3° or less than 2° or less than 1°) to each other. This arrangement differs from the arrangement in which the central optical paths converge such that each ocular system provides a view of the entire screen of device **26**. Thus, in various exemplary embodiments of the invention each of ocular systems **28** is spatially manipulated so as to switch from a full screen view to a side-by-side view. The process is illustrated in FIGs. 7B-D, for left ocular system **28L**. One of ordinary skills in the art, provided with the details described herein would know how to adjust the process for ocular system **28R**.

FIG. 7B illustrates a first state of ocular system **28L** which is suitable for a full screen view, wherein the central optical paths **54L** and **54R** converge, as further detailed hereinabove, and FIG. 7D illustrates a second state of ocular system **28L** which is suitable for a side-by-side view, wherein the central optical paths **54L** and **54R** are parallel to each other, as further detailed hereinabove. The spatial manipulation between the states is illustrated in FIG. 7C, showing the spatial relation between the first state (solid line) and the second state (dashed line). As illustrated, the spatial manipulation includes a combination of displacement **56** and a rotation **58**, wherein for transition from the first state (full screen view) to the second state (side-by-side view) the displacement and rotation is towards the temporal side, and for the opposite transition the displacement and rotation is towards the nasal side.

The spatial manipulation is preferably effected by an ocular manipulation assembly **64** that displaces and rotates each of ocular systems **28L** and **28R**. Ocular manipulation assembly **64** can include a set of pins **64a** and corresponding guide slots **64b**, wherein the manipulation from one state to the other is by establishing relative sliding motion of pins **64a** within guide slots **64b**. FIGs. 7B-C show a configuration in which pins **64a** are movable and slots **64b** are static. Alternatively, pins **64a** can be made static and slots **64b** movable. In any event, the movable part of assembly **64** is preferably attached to or formed on the body of the lenses **28**, and the static part of assembly **64** is preferably attached to or formed on structure **22**. Assembly **64** can be actuated mechanically or electronically, as desired, for example, by a user interface **66** mounted on structure **22** (see FIG. 2). For mechanical actuation, user interface **66** can include a knob or handle, for electronic actuation, user interface **66** can include a touch screen or a set of buttons connected to a motor (not shown) that establishes the displacement and rotation.

FIGs. 8A-D illustrates another embodiment suitable for a side-by-side view, wherein each of ocular systems **28** comprises a lens having the aspheric surface and a prismatic element positioned in front of the lens and being separated from the lens. The lenses of systems **28L** and **28R** are shown at **60L** and **60R**, respectively, and the prismatic elements of systems **28L** and **28R** are shown at **62L** and **62R**, respectively. The advantage of these embodiments for switching between a full screen view and a side-by-side view is that the prismatic elements can serve for providing a view of the entire screen of device **26** in the full screen view, and as a separator device in the side-by-side view, as will now be explained.

FIG. 8A illustrates system **20** in a full screen view configuration. Prismatic elements **62L** and **62R** are in front of lenses **60L** and **60R** such that light beams from the entire screen area of device **26** are refracted by elements **60L** and **60R** onto lenses **60L** and **60R** which in turn refract the light beams into eyes **30L** and **60R**. FIG. 8B illustrates system **20** in a side-by-side view configuration, suitable for viewing a stereoscopic image as further detailed hereinabove. In this configuration, lenses **60L** and **60R** are displaced toward the temporal side and toward frame **24** (not shown) holding display device **60**, and are also rotated to the state at which their central optical paths are parallel to each other as further detailed hereinabove. Prismatic elements **62L** and **62R** are also displaced and rotated to assume a position generally along the symmetry line **52** between the left and right parts of display device **26**, so as block a left light beam from the left part of display device from arriving at lens **60R**, and a right light beam from the right part of display device from arriving at lens **60L**.

In the present embodiments, ocular manipulation assembly **64** displaces lenses **60L** and **60R** toward the temporal side and toward frame **24**, rotates lenses **60L** and **60R**, and also rotates prismatic elements **62L** and **62R**, preferably about a fixed axis **68** as is illustrated in FIGs. 8C and 8D. FIGs. 8C and 8D only show assembly **64** in relation to ocular system **28L**. One of ordinary skills in the art, provided with the details described herein would know how to configure assembly **64** for ocular system **28R**. Assembly **64** comprises pins **64a** and guide slots **64b** as further detailed hereinabove, and also includes a slidably rotatable linking member **64c** linking lenses **60** with prismatic elements **62**, for example, via support pins **64d** formed or attached to the lenses and prismatic elements.

FIG. 8C illustrates the state of ocular system **28L** in a full screen view configuration. The arrows MV2, MV3, MV4 and MV5 show the direction of motion of the respective pins in the transition from the first state (full screen view) to the second state (side-by-side view), and VS1 denotes a guide slot within member **64c** guiding the motion MV3. FIG. 8D illustrates the second state of ocular system **28L** (solid line), following the transition from the first state (dashed line). For clarity of presentation, the arrows MV2, MV3, MV4 and MV5 are not shown in FIG. 8D.

The amount of displacement of lenses **60** between the first and the second states is preferably about 10 mm, the amount of rotation of lenses **60** is preferably from about 10° to about 20°, *e.*g., about 15°, and the amount of rotation of prismatic elements **62** is preferably from about 90° to about 120°, *e.g.*, about 105°.

FIG. 9 is a schematic illustration of system **20** in embodiments in which system **20** comprises add-on positive lenses **70L** and **70R**, and optionally also a central shutter **72** covering at least the apex **74** formed by elements **62L** and **62R** once in the second state. It was found by the present Inventors that this improves the ability to view stereoscopic images. The add-on positive lenses **70L** and **70R** extend the field-of-view and the central shutter blocking undesired reflections from prismatic elements back onto display **16**. Additionally or alternatively, the back surfaces of the prismatic elements can be coated by and anti-reflection coatings. Both lenses **70L** and **70R** and central shutter **72** can be made removable or foldable such that in full screen view they are not employed.

In the above embodiments, frame **24** and ocular systems **28** are arranged such that light beams from display device **26** directly arrive to at least one of ocular systems **28**. However, this need not necessarily be the case since in some embodiments, it may be desired to have one or more pairs of reflective optical elements for redirecting light beams from display device **26** respectively onto the pair of ocular systems **28**. These embodiments are illustrated in FIGs. 10A-E.

FIGs. 10A and 10B illustrates a side view of system **20** in an embodiment in which frame **24** is mounted on structure **22** such that when structure **22** is mounted on a head **78** in an upright position, frame **24** is tilted with respect to a vertical direction. The vertical direction is shown at **74**, and the tilt angle is denoted θ. For clarity of presentation head **78**, structure **22** and frame **24** are not illustrated in FIG. 10B. Typical values for θ are from about 40° to about 90°, more preferably from about 60° to about 85°. Light beams from display device **26** are directed generally downwards, and reflected by a pair of reflectors **76** positioned in front of eyes **30**, in the direction of ocular systems **28**. Since there is a single reflection, a flipped image is received. Thus, in various exemplary embodiments of the invention display device **26** performs image processing to provide a mirror image such that once the image arrives at ocular system **28** its direction is resorted.

FIGs. 10C-E illustrate a side view of system **20** in an embodiment that is similar to the embodiment shown in FIGs. 10A-B except that device **26** is mounted on frame generally vertically. In these embodiments, there is a plurality of pairs of reflectors **74** for redirecting the light downwards and then into ocular systems **28**.

The configurations shown in FIGs. 10A-B is preferred from the standpoint of structural simplicity, and the configuration shown in FIGs. 10C-E is preferred from the standpoint of image processing simplicity. Reflectors **74** can be flat (FIGs. 10A and

10C), or they can be concaved (FIGs. 10B and 10E), for adding a positive diopter. Also contemplated are combinations of flat and concaved reflectors (FIG. 10D).

In some embodiments of the present invention structure **22** comprises a variable length support element **80** for supporting frame **24** at an adjustable optical distance from ocular systems **28**. These embodiments are illustrated in FIGs. 11A-C. Element **80** can be, for example, an accordion spring, as illustrated in FIGs. 11A-C or a telescopic element (not shown). Also shown in FIGs. 11A-C is flexible structure **82** designed and constructed to be applied to the face, for allowing comfort wearing of system **20** and optionally and preferably also to block environmental light to bypass system **20** and enter eye **30**. Preferably, ocular systems **28** are configured to adjust **84** their focal distance responsively to a variation of the optical distance between systems **28** and frame **24**. In some embodiments of the present invention ocular manipulation assembly **84** (not shown in FIGs. 11A-C) actuates the aforementioned displacement and rotation responsively to the variation of the optical distance that can be implemented using any known technique, such as, but not limited to, rack and pinion mechanism as illustrated in FIGs. 11A-C, or any other motion regulation mechanism.

There are several advantages for employing a variable length support element. One advantage is that it can be utilized for effecting different distances in different view configuration. Preferably, element **80** provides larger distance between ocular systems **28** and frame **24** for full screen view configuration, than for side-by-side view configuration. This is because the area of display device that is viewable to each ocular systems **28** is larger in full screen view than in side-by-side view. Another advantage is that element **80** can be used for folding system **20**, for example, for storage, carrying in a pocket of the like.

In FIGs. 11A-C, FIG. 11A illustrates an unfolded configuration which is suitable for full- screen view. At this configuration, the distance d_{FS} between systems **28** and frame **24** can be about 60 mm. FIG. 11B illustrates a partially folded configuration suitable for side-by-side view, wherein the distance between the display device **26** and ocular systems **28** is reduced. At this configuration, the distance d_{SBS} between systems **28** and frame **24** can be about 40 mm. FIG. 11C illustrates a completely folded configuration for storage. An additional compactification can be achieved by folding structure, as illustrated in FIG. 11. The thickness of system **20** in the folded configuration can thus be reduced to approximately equal the thickness of systems **28**, with addition of several millimeters. Typically, system **20** can be folded to a thickness of about 20 mm.

FIG. 12 is a schematic illustration of a display system **120**, according to some embodiments of the present invention. Display system **120** comprises a head-mountable structure **22** having frame **24** configured to removably secure thereto a left display device **26L** and a right display device **26R** in a tilted relationship therebetween. Display devices **26L** and **26R** can be of any type described above with respect to device **26**. System **120** optionally and preferably further comprises left ocular system **28L** and right ocular system **28R**, that respectively provide enlarged views of left and right display devices **26L** and **26R**. System **120** can further comprise a controller **44** and user interface **66** as further detailed hereinabove.

The construction of ocular systems **28** in system **120** can be similar to their construction in system **20**, except that in system **120** the central optical paths **54L** and **54R** of ocular systems **28L** and **28R** diverge towards frame **24**.

System **120** can be used for viewing an image that is complementary displayed on display devices **26L** and **26R**.

The terms "complementary," as used herein in conjunction to images, refer to a combination of two images so as to provide the information required for substantially reconstructing the scene captured by both images.

The human visual system is known to possess a physiological mechanism capable of inferring a complete image based on several portions thereof, provided sufficient information reaches the retinas. This physiological mechanism operates on monochromatic as well as chromatic information received from the rod cells and cone cells of the retinas. Thus, in a cumulative nature, two views, reaching each individual eye, can form a combined field-of-view perceived by the user, which combined field-of-view is wider than the individual field-of-view provided to each eye. Thus, according to some embodiments of the present invention controller **44** controls display devices **26L** to display different portions of the same image. By the aforementioned physiological mechanism a user viewing devices **26L** and **26R** through systems **28L** and **28R** can perceive the entire image even though none of devices **26L** and **26R** displays the entire image.

The situation can be better understood with reference to FIGs. 13A-B, which illustrates an image **122** (FIG. 13A) and the different portions of the image on each of devices **26L** and **26R** (FIG. 13B). Image **122** is defined in FIG. 13A as having three mutually exclusive portions that together form the entire image **122**, namely the portions do not overlap and do not have gaps therebetween. The portions are referred to as a left periphery **122L**, a binocular overlap **122B** and a right periphery **122R**. The center of binocular overlap **122B** is shown at **122C**. According to some embodiments of the present invention left display device **26L** displays left periphery **122L** and binocular overlap **12B**, and right display device **26R** displays binocular overlap **122B** and right periphery **122R**.

In the representative illustration of FIG. 13B, which is not to be considered as limiting, system **120** provides a 21:9 view using two 16:9 display devices. The binocular overlap **122B** that is displayed by both display devices forms 11/21 of the width of the image and each of the right and left periphery forms 5/21 of the image. FIG. 14 illustrates a configuration in which system **120** provides a 24:9 view using two 16:9 display devices. The binocular overlap that is displayed by both display devices forms 2/3 of the width of the image and each of the right and left periphery forms 1/3 of the image. Other ratios are also contemplated. The relative proportions of the binocular overlap and the peripherals are optionally and preferably determined based on the prismatic power of systems **28L** and **28R**.

Some embodiments also provide a solution to the problems of muscular imbalance or eccentric fixation by the eyes. In these embodiments, the user operates user interface **66** for signaling controller **44** to shift a location of the binocular overlap over one or more of display devices **26L** and **26R**. FIG. 15A illustrates an embodiment in which systems **120** adapts for a condition in which there is an eccentric fixation by the right eye. The right eye gaze is straight, but its fixation point is shifted by a certain amount (*e.g.*, 10°) from the fovea. In these embodiments, the central point **122C** of binocular overlap **122B** is shifted toward the left end of the right display, thereby reducing or preventing diplopia. FIG. 15B illustrates an embodiment in which systems **120** adapts for a condition in which there is a muscular imbalance by right eye. The right eye gaze is shifted leftwards due to strabismic condition, but a central fixation is preserved. In these embodiments, the central point **122C** of binocular overlap **122B** is shifted toward the right end of the right display so as to allow the right eye to be in rest condition without diplopia.

FIG. 16 illustrates system **120** in embodiments in which system **120** comprises a separator device **50** mounted on structure **22** (not shown in FIG. 16, see FIG. 12) along a symmetry line **52** between the left **26L** and right **26R** display devices, so as to block light beams from the left display device from arriving at right ocular system **28R**, and light beams from the right display device from arriving at left ocular system **28L**. It was found by the present Inventor that the viewing experience is enhanced by providing separator **50** as a back-to-back pair of auxiliary display devices **124L** and **124R**. Light beams from auxiliary display device **124L** arrive at ocular system **28L** and light beams from auxiliary display device **124R** arrive at ocular system **28R**. Optionally, the pixel density of auxiliary display devices **124** is less than the pixel density of devices **26** since peripheral vision is less important for image recognition and is mostly for situation awareness. In various exemplary embodiments of the invention controller **44** controls left auxiliary display device **124L** to display right periphery **122R**, and right auxiliary display device **124R** to display left periphery **122L**. The advantage of using auxiliary display device **124** is that they provide immersive view with reduced or substantially without discontinuity.

FIGs. 17A and 17B illustrate system **120** in embodiments of the invention in which system **120** comprises a pair of controllable light shutters **46L** and **46R** respectively positioned between ocular systems **28L** and **28R** and devices **26L** and **26R**. These embodiments are also useful for providing immersive view with reduced or substantially without discontinuity, and are therefore preferably employed as a substitute to auxiliary display devices **124**.

Controller **44** receives synchronization signals from display devices and activates and deactivates light shutters **46** in an alternating manner, responsively to the synchronization signals. Referring more specifically to FIGs. 17A and 17B, when shutter **46L** is open and shutter **46R** is closed (FIG. 17A), left display device **26L** displays the left periphery **122L** and binocular overlap **122B**, and right display device **26R** displays, at its left portion that is within the field-of-view of left ocular system **28L**, the right periphery **122R**. Conversely, when shutter **46R** is open and shutter **46L** is closed (FIG. 17B), right display device **26R** displays the binocular overlap **122B** and right periphery **122R**, and left display device **26L** displays, at its left portion that is within the field-of-view of right ocular system **28R**, the left periphery **122L**.

The rate of alternation between the closing and opening of shutters is preferably at a rate that is twice the rate of a two-dimensional video image (for example, twice a rate of 60Hz), so that each eye receives a frame sequence at a rate of a two-dimensional video image, thus providing an illusion as if the two displays are viewed simultaneously.

FIG. 18 is a schematic illustration of a display system **180** which comprises side auxiliary display devices, according to some embodiments of the present invention. System **180** comprises structure **22** having frame **24** configured to removably secure display device **26**. System **180** further comprising a plurality of auxiliary display devices mounted on structure **22** at an angle to a plane engaged by frame **24**. In the illustration shown in FIG. 18, which is not to be considered as limiting, system **18** comprises a left auxiliary display device **182L** and a right auxiliary display device **182R**. Optionally, the pixel density of auxiliary display devices **182** is less than the pixel density of devices **26**.

System **180** further comprises a left ocular system **184L** and right ocular system **184L**, which are mounted on structure **22** in front of frame **24** and auxiliary display devices **182L** and **182R**. Left **184L** and right **184R** ocular systems can have similar optical properties as systems **28L** and **28R** above, but this is not necessary. In various exemplary embodiments of the invention ocular systems **184** do not include an aspheric surface, and in various exemplary embodiments of the invention ocular systems **184** are not prismatic. In any event systems **28L** and **28R** are designed and constructed such that the field-of-view of left ocular system **184L** includes at least left auxiliary display device **182**, and the field-of-view of right ocular system **184R** includes at least right auxiliary display device **182R**. Preferably, the field-of-view of each of ocular systems **184** also includes half of the area of display **26** (or half of the area of frame **24**), so as to allow side-by-side view of stereoscopic images.

System **180** further comprises controller **44** and user interface **66**. System **180** is particularly useful for displaying a stereoscopic image in a side-by-side configuration. The stereoscopic image can include a stereoscopic left periphery **200**, a stereoscopic binocular overlap **202** and a stereoscopic right periphery **204**. Each of these portions **200**, **202** and **204** of the stereoscopic image is also stereoscopic, and therefore includes a left-eye and a right-eye image versions corresponding to different viewpoints from which the respective image version. These left-eye and right-eye image versions are labeled by the letters L and R. Thus, stereoscopic left periphery **200**, has a left-eye image version denoted **200L** and a right-eye image version denoted **200R**, and so on.

Controller **44** preferably controls display **26** to display on its left part the left-eye image **202L** of the stereoscopic binocular overlap **202** and on its right part the right-eye image **202R** of the stereoscopic binocular overlap **202**. Optionally, controller **44** also displays on the left part of controls display **26** the left-eye image **204L** of the stereoscopic right periphery, to the right of image **202L**, and on the right part of controls display **26** the right-eye image **200R** of the stereoscopic left periphery **200**, to the left of image **202R**.

Controller **44** also controls display **182L** to display the left-eye image **200L** of the stereoscopic left periphery **200**, and display **182R** to display the right-eye image **204R** of the stereoscopic right periphery **204**.

FIG. 19 is a schematic illustration of display system **180** in embodiments in which system **180** comprises four auxiliary display devices, according to some embodiments of the present invention. In the illustrated embodiment, system **180** comprises, in addition to auxiliary display devices **182L** and **182R**, a central-left auxiliary display device **186L** and a central-right auxiliary display device **186R**. Devices **286L** and **286R** are mounted on structure **22** along a symmetry line **52** between the left and right halves of display device **26**, preferably to block light beams from the left part of display device **26** from arriving at right ocular system **184R**, and light beams from the right part of display device **26** from arriving at left ocular system **184L**. When central-left **186L** and central-right **186R** auxiliary display devices are employed they can be utilized to display the peripheral portion of the stereoscopic image. Specifically, controller **44** can control display **186L** to display image **204L** and display **186R** to display image **200R**. In these embodiments, images **204L** and **200R** are preferably not displayed by device **26**, thereby allowing each of images **202L** and **202R** to occupy a larger portion of device **26** (*e.g.*, image **202L** can occupy the left half of display **26**, and image **202R** can occupy the right half of display **26**).

System **180** can be used for providing a wide screen illusion of stereoscopic images. FIG. 20 illustrates a representative implementation of system **180** for providing a 21:9 aspect ratio 3D image using a 16:9 display. Other aspect ratios are also contemplated.

FIG. 21A-C are schematic illustrations of a display system **210** useful for augmented reality, according to some embodiments of the present invention. System **210** can employ any of the features and techniques described above with respect to systems **20**, **120** and **180**. In various exemplary embodiments of the invention system **210** comprises structure **22** having frame **24** configured to removably secure display device **26** thereto, such that when structure **22** is mounted on head **78**, frame **24** is above the eyes. Device **26** optionally and preferably has a back camera **26'**. In some embodiments of the present invention system **210** comprises device **26**.

System **210** further comprises an optics assembly **212** mounted on structure **22** and being partially reflective and partially transmissive for simultaneously providing a view of an image displayed on display device **26** and a view **216** of an environment **218** outside structure **22**. For clarity of presentation, the image displayed on device **26** is not illustrated. A light beam constituting the displayed image is represented by arrow **214**.

Optionally and preferably, system **210** provides a side-by-side view which is particularly useful for augmented reality implementation. In these embodiments, system **210** may comprise separator device **50**, which can be embodied according to any of the teachings described above (opaque wall, prismatic elements, auxiliary display devices) mounted on structure **22** along a symmetry line (not shown) between the left and right parts of display device **26**, so as to block light beams from the left part of display device **26** from arriving at the right eye, and light beams from the right part of display device **26** from arriving at the left eye.

FIG. 21A illustrates a side view of system **210** in an embodiment in which frame **24** is mounted on structure **22** such that when structure **22** is mounted on head **78** in an upright position, frame **24** is tilted at tilt angle θ with respect to vertical direction **74**, as further detailed hereinabove. Light beams from display device **26** are directed generally downwards, and reflected by optics **212** in the direction of eyes **30**. Since there is a single reflection, a flipped image is received. Thus, in various exemplary embodiments of the invention display device **26** performs image processing to provide a mirror image such that once the image arrives at ocular system **28** its direction is resorted.

FIGs. 21B and 21C illustrate a side view of system **210** in an embodiment that is similar to the embodiment shown in FIG. 21A except that device **26** is mounted on the frame generally vertically (head **78**, structure **22** and frame **24** not shown, for clarity of presentation). In these embodiments, optics **212** includes a plurality of pairs of reflectors for redirecting the light downwards and then into eyes **30**.

The configurations shown in FIG. 21A is preferred from the standpoint of structural simplicity, and the configuration shown in FIGs. 21B-C is preferred from the standpoint of image processing simplicity.

In various exemplary embodiments of the invention optics assembly **212** converges light beams **214** arriving from display device **26** but not light beams **216** arriving from environment **218**. This can be achieved in more than one way.

In some embodiments, a partially reflective (and partially transmissive) concave mirror **220** (see FIG. 21A). Light beam **214** is reflected by the concave side of mirror **220** and is therefore converged following the reflection. Light beam **216** first arrives at the convex side of mirror **220** and is divergent while passing through the body of mirror **220** but is then converged by the concave surface at the other side. Thus, according to some embodiments of the present invention the concave and convex surfaces of mirror **220** have the same radius of curvature so that the convergence by the concave surface cancels the divergence by the convex surface.

In some embodiments, a combination of a reflective mirror **222** and a partially reflective (and partially transmissive) flat surface **224** is employed (see FIG. 21B). Light beam **214** is reflected by the concave side of mirror **222** to form a converged beam **214’** propagating towards surface **224**. Light beam **214’** is then reflected by flat surface **224** which is neutral with respect to convergence or divergence. Light beam **216** passes through flat surface **224** and is not converged or diverged due to the neutrality of surface **224**.

Also contemplates, are embodiments in which beam **214** is converged twice, as illustrated in FIG. 21C. In these embodiments, optics **212** comprises reflective concave mirror **222** and partially reflective (and partially transmissive) concave mirror **220**, wherein light beam is first reflected from mirror **222** and then from mirror **220**, and light beam **216** passes through mirror **220**.

In various exemplary embodiments of the invention structure **22** comprises a variable length support element **80** (shown in FIG. 21A) for supporting frame at an adjustable optical distance *d* (shown in FIGs. 21B and 21C) from optics assembly **212**, thereby to effect focal distance adjustment for light beams **214** arriving from display device **26**.

In various exemplary embodiments of optics assembly **212** comprises a reflecting element **226** for redirecting light beam **216** arriving from environment **218** onto the back side of display device **26**. Preferably, element **226** is constituted to reflect the beam onto the back camera **26'** of device **26**. A particular advantage of the present embodiments is that it allows camera **26'** to capture a scene from the forward direction with respect to head **78**. Since structure **22** is head mounted, the forward direction dynamically varies with the motion of the head so that camera **26'** substantially captures images of objects in the gaze direction of the user. The data processor of display device **26** can identifies objects in the scene and can add virtual objects to be displayed in an overlaid manner with the objects captured from the scene.

Reference is now made to FIGs. 22A-D which are schematic illustrations of a method suitable for varying an aspect ratio of an image, according to some embodiments of the present invention. The method can be use for processing an image before being viewed by any of the systems described herein.

The method can be embodied in many forms. For example, it can be embodied in on a tangible medium such as a computer for performing the method operations. It can be embodied on a computer readable medium, comprising computer readable instructions for carrying out the method operations. It can also be embodied in an electronic device having digital computer capabilities arranged to run the computer program on the tangible medium or execute the instruction on a computer readable medium. A representative example of such an electronic device is data processor of a mobile device, such as, but not limited to, a smartphone or a tablet device.

Computer programs implementing the method according to some embodiments of this invention can commonly be distributed to users on a distribution medium such as, but not limited to flash memory devices, flash drives, or, in some embodiments, drives accessible by means of network communication, over the internet (*e.g.*, within a cloud environment), or over a cellular network. From the distribution medium, the computer programs can be copied to a hard disk or a similar intermediate storage medium. The computer programs can be run by loading the computer instructions either from their distribution medium or their intermediate storage medium into the execution memory of the computer, configuring the computer to act in accordance with the method of this invention. Computer programs implementing the method according to some embodiments of this invention can also be executed by one or more data processors that belong to a cloud computing environment. All these operations are well-known to those skilled in the art of computer systems. Data used and/or provided by the method of the present embodiments can be transmitted by means of network communication, over the internet, over a cellular network or over any type of network, suitable for data transmission.

It is to be understood that, unless otherwise defined, the operations described hereinbelow can be executed either contemporaneously or sequentially in many combinations or orders of execution. Specifically, the ordering of the flowchart diagrams is not to be considered as limiting. For example, two or more operations, appearing in the following description or in the flowchart diagrams in a particular order, can be executed in a different order (*e.g.*, a reverse order) or substantially contemporaneously. Additionally, several operations described below are optional and may not be executed.

The method can be utilized for two-dimensional as well as for stereoscopic images. The method is particularly useful for solving the problem of cropping of wide images when displayed on a screen having a different aspect ratio than the original image. For example, when a display device receives an input image having an aspect ratio that is compatible with the size of the device's screen, and it is desired to display the image on a sub-area of the screen with a different aspect ratio (*e.g.*, in a side-by-side view configuration), it is required to either crop the image or to resize it to a size that is smaller than the desired sub-area.

In a search for a solution to this problem, the present Inventor realized that certain regions over the image that are of less interest to the average viewer can be resized relative to other regions that are of greater interest to the average user.

Referring to FIGs. 22A-D, FIG. 22A illustrates the input image. In the exemplified illustration, a stereoscopic image, having left-eye viewable features **230** and right-eye viewable features **232**, but the method can also be employed for two-dimensional images, depth images, or any other type of image. A two or more regions are identified on the image. In the illustrated example, three regions are identified, a central region **234**, a left peripheral region **236** and a right peripheral region **238**, but any number of regions can be identified.

The image is then processed to vary the aspect ratio of regions **236** and **238** while maintaining the aspect ratio and optionally also the size of region **234** substantially unchanged. The aspect ratio is varied by stretching or squeezing the region along at least one direction of the image such that the height to width ratio before processing differs from the height to width ratio after processing. This operation is illustrated in FIGs. 22B and 22C for the left-eye image and the right-eye image, respectively. This effects a variation of the aspect ratio of the image. The method then transmits the processed image as an output image to a computer readable medium or displays the image on a screen of a display device, as illustrated in FIG. 22D. In some embodiments of the present invention the resizing of regions **236** and **238** is while preserving their aspect ratio, and in some embodiments of the present invention the resizing of regions **236** and **238** effects a change in the aspect ratio. Preferably the processing is executed such that the relative aspect ratio of at least one two regions in the image changes.

The method of the present embodiments thus utilize an aspect ratio variation that is nonlinear or piecewise linear as a function of the image's coordinate, as illustrated in the graph of the output image as a function of the input image shown FIG. 23A. In FIG. 23A zi is a horizontal coordinate along the input image, normalized to unity, and zo is a horizontal coordinate along the output image, normalized to unity. Line **240** corresponds to a case in which the aspect ratios of the input and output images is the same. Line **242** corresponds to a typical 50% cropping operation (25% from each side), and the three lines shown generally at **244** correspond to a nonlinear or piecewise linear variation of the aspect ratio according to some embodiments of the present invention.

A representative implementation example of the method of the present embodiments for varying an aspect ratio of an input image is illustrated in FIG. 23B. In the illustrated example, the input image has an aspect ratio of 16:9 and the output image has an aspect ratio of 8:9. The identified regions on the input image are an input left peripheral region ziL having an aspect ratio of 6:9, a central region ziC having an aspect ratio of 4:9, and a right peripheral region ziR having an aspect ratio of 6:9. The regions ziL and ziR are processed to provide output left peripheral regions zoL and zoR, respectively, each having an aspect ratio of 2:9. The central region is unmodified so that the output central region zoC is the same as region ziC.

As used herein the term “about” refers to ± 10 %.

The word "exemplary" is used herein to mean "serving as an example, instance or illustration." Any embodiment described as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments and/or to exclude the incorporation of features from other embodiments.

The word "optionally" is used herein to mean "is provided in some embodiments and not provided in other embodiments." Any particular embodiment of the invention may include a plurality of "optional" features unless such features conflict.

The terms "comprises", "comprising", "includes", "including", “having” and their conjugates mean "including but not limited to".

The term “consisting of” means “including and limited to”.

The term "consisting essentially of" means that the composition, method or structure may include additional ingredients, steps and/or parts, but only if the additional ingredients, steps and/or parts do not materially alter the basic and novel characteristics of the claimed composition, method or structure.

As used herein, the singular form "a", "an" and "the" include plural references unless the context clearly dictates otherwise. For example, the term "a compound" or "at least one compound" may include a plurality of compounds, including mixtures thereof.

Throughout this application, various embodiments of this invention may be presented in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the invention. Accordingly, the description of a range should be considered to have specifically disclosed all the possible subranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed subranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

Whenever a numerical range is indicated herein, it is meant to include any cited numeral (fractional or integral) within the indicated range. The phrases “ranging/ranges between” a first indicate number and a second indicate number and “ranging/ranges from” a first indicate number “to” a second indicate number are used herein interchangeably and are meant to include the first and second indicated numbers and all the fractional and integral numerals therebetween.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination or as suitable in any other described embodiment of the invention. Certain features described in the context of various embodiments are not to be considered essential features of those embodiments, unless the embodiment is inoperative without those elements.

Various embodiments and aspects of the present invention as delineated hereinabove and as claimed in the claims section below find experimental support in the following examples.

EXAMPLES

Reference is now made to the following examples, which together with the above descriptions illustrate some embodiments of the invention in a non limiting fashion.

Optical Design Considerations

FIG. 24 is a schematic illustration describing some design consideration with respect to the systems described above.

It is desired to employ oculars that shift the optical center of the display to the left to allow easy gaze (ideally, but not necessarily straight) for the left eye, and the optical center of the display to the right to allow easy gaze (ideally, but not necessarily straight) for the right eye.

Preferably, but not necessarily, the systems are configured to allow viewing of at least 4” screens (*e.g.*, 4-6") having standard aspect ratio of 16:9, with maximal angular field of view by lens power. It is preferred to provide easy convergence for the eyes, at least for the center points. Representative example is a 1.5° convergence, for IPD of 63 mm, equal to a 26.5 cm non-aided eye distance. It is recognized that convergence chromatic aberrations may evolves due to prismatic shift in horizontal direction. In order to reduce horizontal chromatic aberrations, the ocular systems are preferably designed such that a smear for originally white pixel (combined from RGB sub-pixels) along the horizontal dimension of the screen smear is extended over a single neighboring pixel or less.

The left and right peripheral points are of the present embodiments within the field-of-view and approximately equidistant from the central point.

The aspheric surface can be designed, *e.g.*, by zernike polynomials to allow focusing to all points despite the different distances. Preferably, a 6 mm pupil diameter is used in the calculation of the surface such that the light rays cover the entire active surface area of the lens that provides focusing of the different points on the retina. Following the calculation, the pupil can be changed to about 3 mm diameter, which is typical pupil size under relevant illumination level, in order to make visual performance analysis.

The systems of the present embodiments are preferably designed for IPD distance of about 62mm. The lens extreme nasal point is preferably about 3mm from the center to allow IPD adjustment within the range of 56 mm to 62mm.

Electronic Design Considerations

FIG. 25 illustrates an electronic circuitry layout that can be used by the controller **44** in any of systems described above. Optionally and preferably, the circuitry is employed by system **180** for enabling immersive view using single central display device through preferred MIPI-DSI interface. The Left and Right auxiliary displays are preferably connected through MIPI-DSI interface as well.

The circuitry can decode a stream of video frames, such as blue-ray 3D images, or cinematic 21:9 3D or 24:9 3D content as well as stream coming from SD Card, Smartphone, Disk-on-Key or and Media Player. The decoded stream passes through a Media Stream Transformation Engine that transcodes the stream to the Central and Auxiliary displays, as described above with reference to FIGs. 13-20. For a wider content, for example, a 360° content, acceleration sensors, preferably connected through I2C or SPI interfaces, track the head or body motion (preferably rotation), via a position calculation engine, and the portion of content corresponding to angle of view is selected from the decoded stream and/or content corresponding to viewed angel is retrieved from the media for decoding and transcoding.

In addition the system can have an Eyes tracking camera, preferably connected through an MIPI-CSI with a near infrared (NIR) illumination, that is preferably operated via General-purpose input/output (GPIO), for various applications while the electronic system can have Pupils position calculation engine. The system can optionally also interface Front left and right cameras with auto-focus mechanisms, which are preferably connected through MIPI-CSI interfaces for either video capturing, augmented reality or 3D info extraction from the scene. The system can also interconnect with keyboard/mouse through USB or GPIOS and embedded computer, preferably via a Peripheral Component Interconnect Express (PCIE) interface.

The system may also be equipped with Audio CODEC to receive voice commands or record sounds and for generation of sounds. The system is preferably connected through an I2S interface to the system electronics.

Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.

All publications, patents and patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present invention. To the extent that section headings are used, they should not be construed as necessarily limiting.

WHAT IS CLAIMED IS:

1. An optical magnification system comprising:

a structure having a frame configured to removably secure a display device thereto; and

a pair of spaced apart ocular systems, mounted on said structure in front of said frame for providing a view of said display device once mounted on said frame;

wherein each of said ocular systems has an aspheric optical surface and provides a prismatic refraction.

2. The system of claim 1, wherein each of said ocular systems is a lens having prismatic shape.

3. The system according to any of claims 1 and 2, wherein a second optical surface of said lens, optically opposite to said aspheric optical surface, is generally planar or spherical.

4. The system according to any of claims 1 and 2, wherein a second optical surface of said lens, optically opposite to said aspheric optical surface, is also aspheric.

5. The system according to claim 3, wherein said aspheric optical surface and said optically opposite surface are spaced apart from each other at a nasal portion of a periphery of said lens by a cut through a thickness thereof.

6. The system according to claim 4, wherein said aspheric optical surface and said optically opposite surface are spaced apart from each other at a nasal portion of a periphery of said lens by a cut through a thickness thereof.

7. The system according to claim 1, wherein each of said ocular systems comprises a lens having said aspheric surface and at least one prismatic element positioned between said lens and said frame or behind of said lens.

8. The system according to any of claims 2-5, wherein each of said ocular systems comprises a lens having said aspheric surface and at least one prismatic element positioned between said lens and said frame or behind of said lens.

9. The system according to claim 1, wherein each of said ocular systems is diffractive.

10. The system according to any of claims 2-5, wherein each of said ocular systems is diffractive.

11. The system according to claim 1, wherein at least one of said each of said ocular systems comprises a vision correction lens.

12. The system according to any of claims 2-8, wherein at least one of said each of said ocular systems comprises a vision correction lens.

13. The system according to claim 1, wherein each of said each of said ocular systems comprises a vision correction lens, and wherein a refractive power of a vision correction lens of a first lens system of said pair differ from a refractive power of a vision correction lens of a second lens system of said pair.

14. The system according to any of claims 2-8, wherein each of said each of said ocular systems comprises a vision correction lens, and wherein a refractive power of a vision correction lens of a first lens system of said pair differ from a refractive power of a vision correction lens of a second lens system of said pair.

15. The system according to claim 1, further comprising:

a pair of controllable light shutters respectively positioned between said ocular systems and said frame; and

a controller having a circuit configured for receiving synchronization signal from said display device and activating and deactivating said light shutters in an alternating manner, responsively to said synchronization signal.

16. The system according to any of claims 2-14, further comprising:

a pair of controllable light shutters respectively positioned between said ocular systems and said frame; and

a controller having a circuit configured for receiving synchronization signal from said display device and activating and deactivating said light shutters in an alternating manner, responsively to said synchronization signal.

17. The system according to claim 1, further comprising an ocular manipulation assembly configured for displacing and rotating each of said ocular systems.

18. The system according to any of claims 2-16, further comprising an ocular manipulation assembly configured for displacing and rotating each of said ocular systems.

19. The system according to claim 17, wherein said displacement and said rotation is reciprocally from a first state of said ocular systems at which central optical paths of said ocular systems converge, to a second state of said ocular systems at which said central optical paths are generally parallel to each other.

20. The system according to claim 18, wherein said displacement and said rotation is reciprocally from a first state of said ocular systems at which central optical paths of said ocular systems converge, to a second state of said ocular systems at which said central optical paths are generally parallel to each other.

21. The system according to any of claims 18 and 20, wherein each of said ocular systems comprises a lens having said aspheric surface and at least one prismatic element positioned in front of said lens and being separated from said lens.

22. The system according to any of claims 17 and 19, wherein each of said ocular systems comprises a lens having said aspheric surface and at least one prismatic element positioned in front of said lens and being separated from said lens.

23. The system according to claim 21, wherein said ocular manipulation assembly is configured to rotate also said prismatic elements, and wherein said rotation is reciprocally from a first state of said ocular systems at which each ocular system focus all light rays from said display device, to a second state of said ocular systems of said ocular systems at which said prismatic elements block a left light beam from a left part of said display device from arriving at a lens of a right ocular system of said pair, and a right light beam from a right part of said display device from arriving at a lens of a left ocular system of said pair.

24. The system according to claim 22, wherein said ocular manipulation assembly is configured to rotate also said prismatic elements, and wherein said rotation is reciprocally from a first state of said ocular systems at which each ocular system focus all light rays from said display device, to a second state of said ocular systems of said ocular systems at which said prismatic elements block a left light beam from a left part of said display device from arriving at a lens of a right ocular system of said pair, and a right light beam from a right part of said display device from arriving at a lens of a left ocular system of said pair.

25. The system according to claim 23, wherein said ocular manipulation assembly is configured to vary a distance between said ocular systems and said frame, wherein said distance is larger at said first state of said ocular systems than at said second state of said ocular systems.

26. The system according to claim 24, wherein said ocular manipulation assembly is configured to vary a distance between said ocular systems and said frame, wherein said distance is larger at said first state of said ocular systems than at said second state of said ocular systems.

27. The system according to claim 18, wherein said ocular manipulation assembly is controllable mechanically.

28. The system according to any of claims 17-25, wherein said ocular manipulation assembly is controllable mechanically.

29. The system according to claim 18, wherein said ocular manipulation assembly is controllable electronically.

30. The system according to any of claims 17-25, wherein said ocular manipulation assembly is controllable electronically.

31. The system according to claim 1, wherein said frame and said ocular systems are arranged such that light beams from said display device directly arrive to at least one of said ocular systems.

32. The system according to any of claims 2-30, wherein said frame and said ocular systems are arranged such that light beams from said display device directly arrive to at least one of said ocular systems.

33. The system according to claim 1, further comprising at least one pair of reflective optical elements configured for redirecting light beams from said display device respectively onto said pair of ocular systems.

34. The system according to any of claims 2-30, further comprising at least one pair of reflective optical elements configured for redirecting light beams from said display device respectively onto said pair of ocular systems.

35. The system according to claim 34, wherein said frame is mounted on said structure such that when said structure is head mounted in an upright position, said frame is tilted with respect to a vertical direction.

36. The system according to claim 33, wherein said frame is mounted on said structure such that when said structure is head mounted in an upright position, said frame is tilted with respect to a vertical direction.

37. The system according to claim 34, wherein said frame is mounted on said structure such that when said structure is head mounted in an upright position, said frame is generally vertical.

38. The system according to claim 33, wherein said frame is mounted on said structure such that when said structure is head mounted in an upright position, said frame is generally vertical.

39. The system according to claim 1, wherein said structure comprises a variable length support element for supporting said frame at an adjustable optical distance from said pair of ocular systems, and wherein said ocular systems are configured to adjust a focal distance thereof responsively to a variation of said optical distance.

40. The system according to any of claims 2-37, wherein said structure comprises a variable length support element for supporting said frame at an adjustable optical distance from said pair of ocular systems, and wherein said ocular systems are configured to adjust a focal distance thereof responsively to a variation of said optical distance.

41. The system according to claim 18, wherein said structure comprises a variable length support element for supporting said frame at an adjustable optical distance from said pair of ocular systems, and wherein, responsively to a variation of said optical distance, said ocular systems adjust a focal distance thereof, and wherein said ocular manipulation assembly actuates said displacement and said rotation.

42. The system according to any of claims 17-30, wherein said structure comprises a variable length support element for supporting said frame at an adjustable optical distance from said pair of ocular systems, and wherein, responsively to a variation of said optical distance, said ocular systems adjust a focal distance thereof, and wherein said ocular manipulation assembly actuates said displacement and said rotation.

43. A method of an image, the method comprising securing a display device to the system according to any of claims 1-42, placing said structure near the eyes, and viewing said display device through said ocular systems.

44. A method of viewing an image displayed on a display device, the method comprising:

securing the display device to a structure having a frame configured to secure the display device thereto;

mounting said structure on a head; and

viewing the image through a pair of spaced apart ocular systems mounted on said structure in front of said frame, wherein each of said ocular systems has an aspheric optical surface and provides a prismatic refraction.

45. The method according to claim 44, wherein said image is a three-dimensional video image having an alternating sequence of images for left and right views, and the method comprises receiving synchronization data from said display device and, responsively to said synchronization signal, activating and deactivating a pair of controllable light shutters respectively positioned between said ocular systems and said frame, in an alternating manner corresponding to said alternating sequence.

46. The method according to any of claims 44-45, further comprising displacing and rotating each of said ocular systems.

47. The method according to claim 46, wherein said displacement and said rotation is reciprocally from a first state of said ocular systems at which central optical paths of said ocular systems converge, to a second state of said ocular systems at which said central optical paths are generally parallel to each other.

48. The method according to any of claims 46 and 47, wherein each of said ocular systems comprises a lens having said aspheric surface and at least one prismatic element positioned in front of said lens and being separated from said lens.

49. The method according to claim 48, further comprising reciprocally rotating also said prismatic element from a first state of said ocular systems at which each ocular system focus all light rays from said display device, to a second state of said ocular systems at which said prismatic elements block a left light beam from a left part of said display device from arriving at a lens of a right ocular system of said pair, and a right light beam from a right part of said display device from arriving at a lens of a left ocular system of said pair.

50. The method according to claim 49, further comprising varying a distance between said ocular systems and said frame, wherein said distance is larger at said first state of said ocular systems than at said second state of said ocular systems.

51. The method according to any of claims 44-49, wherein said structure comprises a variable length support element for supporting said frame, and the method comprises adjusting an optical distance from said pair of ocular systems to said frame, and also adjusting a focal distance thereof responsively to a variation of said optical distance.

52. A display system comprising:

a structure having a frame configured to removably secure thereto a left display device and a right display device in a tilted relationship therebetween; and

a left ocular system and right ocular system, mounted on said structure in front of said frame such that central optical paths of said ocular systems diverge towards said frame to respectively provide enlarged views of said left and said right display devices;

wherein each of said ocular systems has an aspheric optical surface and provides a prismatic refraction.

53. The system of claim 52, wherein each of said ocular systems is a lens having prismatic shape.

54. The system according to any of claims 52 and 53, wherein a second optical surface of said lens, optically opposite to said aspheric optical surface, is generally planar or spherical.

55. The system according to any of claims 52 and 53, wherein a second optical surface of said lens, optically opposite to said aspheric optical surface, is also aspheric.

56. The system according to claim 54, wherein said aspheric optical surface and said optically opposite surface are spaced apart from each other at a temporal portion of a periphery of said lens by a cut through a thickness thereof.

57. The system according to claim 55, wherein said aspheric optical surface and said optically opposite surface are spaced apart from each other at a temporal portion of a periphery of said lens by a cut through a thickness thereof.

58. The system according to claim 52, wherein each of said ocular systems comprises a lens having said aspheric surface and at least one prismatic element positioned between said lens and said frame or behind of said lens.

59. The system according to any of claims 53-56, wherein each of said ocular systems comprises a lens having said aspheric surface and at least one prismatic element positioned between said lens and said frame or behind of said lens.

60. The system according to claim 52, wherein each of said ocular systems is diffractive.

61. The system according to any of claims 53-56, wherein each of said ocular systems is diffractive.

62. The system according to claim 52, further comprising a controller having a circuit for controlling said display devices to display different portions of an image

having a left periphery, a binocular overlap and a right periphery, wherein said left display device displays said left periphery and said binocular overlap, and said right display device displays said binocular overlap and said right periphery.

63. The system according to any of claims 53-59, further comprising a controller having a circuit for controlling said display devices to display different portions of an image having a left periphery, a binocular overlap and a right periphery, wherein said left display device displays said left periphery and said binocular overlap, and said right display device displays said binocular overlap and said right periphery.

64. The system according to claim 62, wherein said controller comprises a user interface and wherein circuit is configured for shifting a location of said binocular overlap over at least one of said display devices, responsively to a user input received by said user interface.

65. The system according to claim 63, wherein said controller comprises a user interface and wherein circuit is configured for shifting a location of said binocular overlap over at least one of said display devices, responsively to a user input received by said user interface.

66. The system according to any of claims 62 and 63, further comprising a separator device mounted on said structure along a symmetry line between said left and said right display devices to block light beams from said left display device from arriving at said right ocular system, and light beams from said right display device from arriving at said left ocular system.

67. The system according to any of claims 63 and 65, further comprising a separator device mounted on said structure along a symmetry line between said left and said right display devices to block light beams from said left display device from arriving at said right ocular system, and light beams from said right display device from arriving at said left ocular system.

68. The system according to claim 66, wherein said separator device comprises a back-to-back pair of auxiliary display devices, and wherein light beams from a left auxiliary display device of said pair arrive at said left ocular system, and light beams from a right auxiliary display device of said pair arrive at said right ocular system.

69. The system according to claim 67, wherein said separator device comprises a back-to-back pair of auxiliary display devices, and wherein light beams from a left auxiliary display device of said pair arrive at said left ocular system, and light beams from a right auxiliary display device of said pair arrive at said right ocular system.

70. The system according to claim 68, wherein said circuit is configured to control said left auxiliary display device to display said right periphery, and said right auxiliary display device to display said left periphery.

71. The system according to claim 69, wherein said circuit is configured to control said left auxiliary display device to display said right periphery, and said right auxiliary display device to display said left periphery.

72. The system according to claim 52, further comprising:

a pair of controllable light shutters respectively positioned between said ocular systems and said frame; and

a controller having a circuit configured for receiving synchronization signal from said display device and activating and deactivating said light shutters in an alternating manner, responsively to said synchronization signal.

73. The system according to any of claims 53-65, further comprising:

a pair of controllable light shutters respectively positioned between said ocular systems and said frame; and a controller having a circuit configured for receiving synchronization signal from said display device and activating and deactivating said light shutters in an alternating manner, responsively to said synchronization signal.

74. The system according to claim 52, wherein said structure comprises a variable length support element for supporting said frame at an adjustable optical distance from said pair of ocular systems, and wherein said ocular systems are configured to adjust a focal distance thereof responsively to a variation of said optical distance.

75. The system according to any of claims 53-73, wherein said structure comprises a variable length support element for supporting said frame at an adjustable optical distance from said pair of ocular systems, and wherein said ocular systems are configured to adjust a focal distance thereof responsively to a variation of said optical distance.

76. The system according to claim 52, wherein at least one of said each of said ocular systems comprises a vision correction lens.

77. The system according to any of claims 53-75, wherein at least one of said each of said ocular systems comprises a vision correction lens.

78. The system according to claim 76, wherein each of said each of said ocular systems comprises a vision correction lens, and wherein a refractive power of a vision correction lens of a first lens system of said pair differ from a refractive power of a vision correction lens of a second lens system of said pair.

79. The system according to claim 77, wherein each of said each of said ocular systems comprises a vision correction lens, and wherein a refractive power of a vision correction lens of a first lens system of said pair differ from a refractive power of a vision correction lens of a second lens system of said pair.

80. A method of viewing an image, the method comprising securing a left display device and a right display device to the system according to any of claims 52-78, placing said structure near the eyes, and viewing said display devices through said ocular systems.

81. A method of viewing an image displayed on a left display device and a right display device, the image having a left periphery, a binocular overlap and a right periphery, the method comprising:

securing the display devices to a structure having a frame configured to receive the display devices in a tilted relationship therebetween;

mounting said structure on a head; and

viewing the left periphery through a left ocular system, the right periphery through a right ocular system, and the binocular overlap through at least one of said left and said right ocular systems;

wherein central optical paths of said ocular systems diverge towards said display devices, and wherein each of said ocular systems has an aspheric optical surface and provides a prismatic refraction.

82. The method according to claim 81, further comprising shifting a location of said binocular overlap over at least one of said display devices to correct for diploia.

83. The method according to any of claims 81 and 82, wherein said viewing comprises viewing the left periphery and the binocular overlap through said left ocular system, and the binocular overlap and the right periphery through said right ocular system.

84. The method according to any of claims 81-83, further comprising viewing a left auxiliary display device displaying said right periphery, and a right auxiliary display device displaying said left periphery, wherein said auxiliary display devices are arranged in a back-to-back arrangement along a symmetry line between said left and said right display devices.

85. The method according to any of claims 81-82, wherein said binocular overlap is displayed on said left and said right display devices in an alternating manner and, wherein said viewing comprises alternating between viewing said left display device when said binocular overlap is displayed on said left display device, and viewing said right display device when said binocular overlap is displayed on said right display device.

86. A display system for displaying a stereoscopic image having a stereoscopic left periphery, a stereoscopic binocular overlap and a stereoscopic right periphery, the system comprising:

a structure having a frame configured to removably secure a display device thereto;

a plurality of auxiliary display devices each mounted on said structure at an angle to a plane engaged by said frame, said auxiliary display devices including at least a left auxiliary display device and a right auxiliary display device;

a left ocular system and right ocular system, mounted on said structure in front of said frame and said auxiliary display devices, wherein a field-of-view of said left ocular system includes said left auxiliary display device, and field-of-view of said right ocular system includes said right auxiliary display device; and

a controller having a circuit configured to display (i) a left-eye image of said stereoscopic left periphery on said left auxiliary display device, (ii) a left-eye image and a right-eye image of said stereoscopic binocular overlap on said display device in a side-by-side configuration, and (iii) a right-eye image of said stereoscopic right periphery on said right auxiliary display device.

87. The system of claim 86, wherein said plurality of auxiliary display devices comprises a central-left auxiliary display device and a central-right auxiliary display device, and wherein said circuit is configured to display (iv) a right-eye image of said stereoscopic left periphery on said central-right auxiliary display device, and (v) a left-eye image of said stereoscopic right periphery on said central-left auxiliary display device.

88. A method of viewing a stereoscopic image, the method comprising securing a display device to the system according to any of claims 86 and 87, mounting said structure on a head, and viewing said display device and said auxiliary display devices through said ocular systems.

89. A method varying an aspect ratio of an image, the method comprising;

identifying on said image a first region and at least one additional region;

processing said image to resize said at least one additional region along at least one dimension, while maintaining an aspect ratio of said first region substantially unchanged, thereby varying the an aspect ratio of said image; and

transmitting said image to a display system.

90. The method of claim 89, wherein said processing comprises varying an aspect ratio of said at least one additional region.

91. The method of claim 89, wherein said processing comprises resizing said second region while preserving an aspect ratio thereof.

92. The method according to any of claims 89-91, wherein said identifying said at least one additional region comprises identifying a second region and a third region.

93. The method according to any of claims 89-92, wherein said first region is a central region of said image, and said at least one additional region is a peripheral region of said image.

94. A display system for augmented reality, the system comprising:

a structure having a frame configured to removably secure a display device thereto, such that when said structure is mounted on a head, said frame is above the eyes; and an optics assembly mounted on said structure and being partially reflective and partially transmissive for simultaneously providing a view of an image displayed on said display device and a view of an environment outside said structure.

95. The system of claim 94, wherein said optics assembly is configured to converge light beams arriving from said display device but not light beams arriving from said environment.

96. The system according to any of claims 94 and 95, wherein said structure comprises a variable length support element for supporting said frame at an adjustable optical distance from said optics assembly, thereby to effect focal distance adjustment for said light beams arriving from said display device.

97. The system according to claim 94, wherein said frame is mounted on said structure such that when said structure is head mounted in an upright position, said frame is tilted with respect to a vertical direction.

98. The system according to any of claims 95-96, wherein said frame is mounted on said structure such that when said structure is head mounted in an upright position, said frame is tilted with respect to a vertical direction.

99. The system according to claim 94, wherein said frame is mounted on said structure such that when said structure is head mounted in an upright position, said frame is generally vertical.

100. The system according to any of claims 95-96, wherein said frame is mounted on said structure such that when said structure is head mounted in an upright position, said frame is generally vertical.

101. The system according to claim 94, wherein said optics assembly comprises a reflecting element for light beams arriving from said environment onto a back side of said display device.

102. The system according to any of claims 95-100, wherein said optics assembly comprises a reflecting element for light beams arriving from said environment onto a back side of said display device.

103. An augmented reality method, comprising mounting a display device on the system according to any claim 86-102, placing said structure near the eyes, and viewing said display device and said environment using said optics assembly.

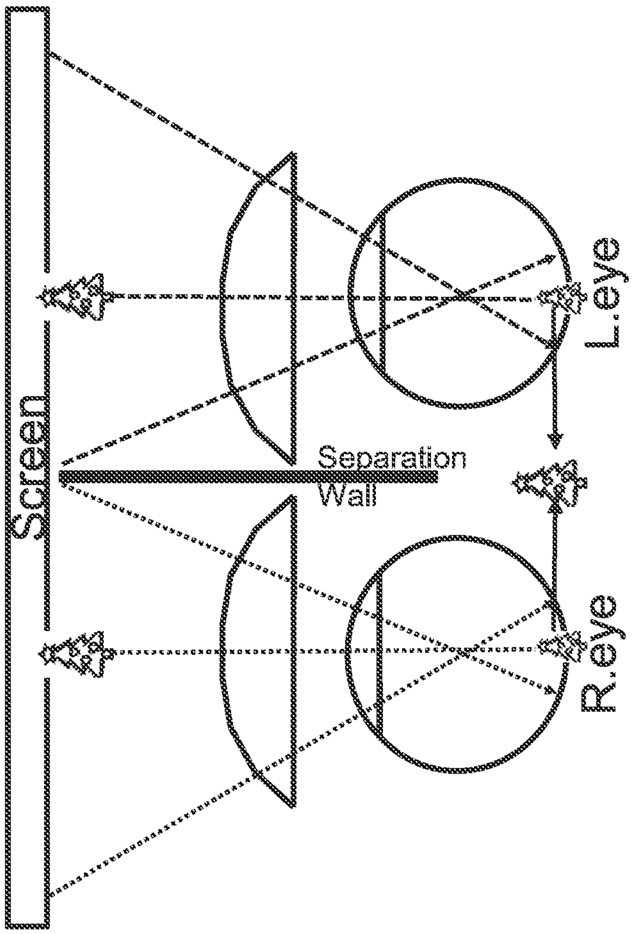


FIG. 1

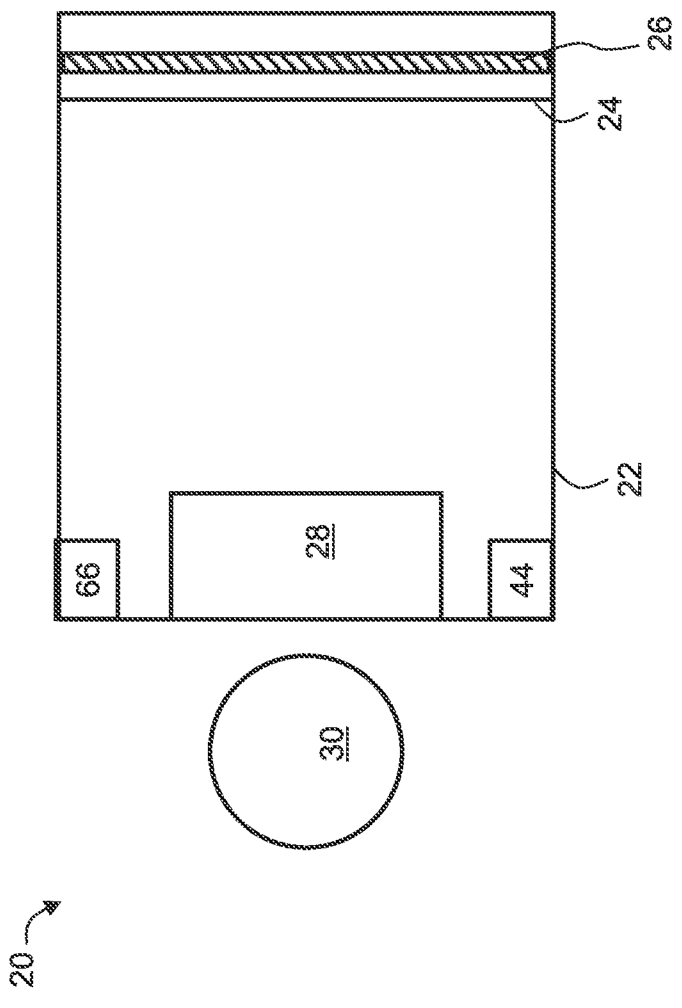


FIG. 2

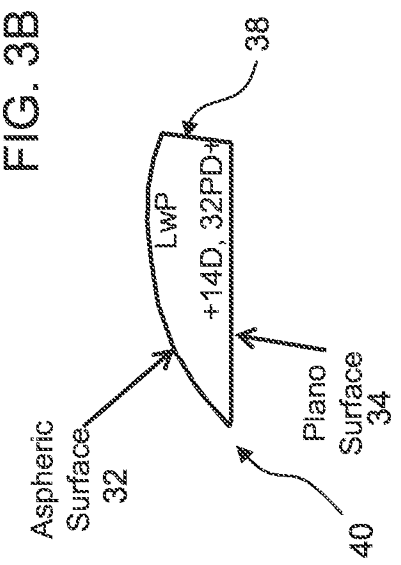


FIG. 3B
Aspheric Surface 32
LwP
+14D, 32PD+
38
Plano Surface 34
40

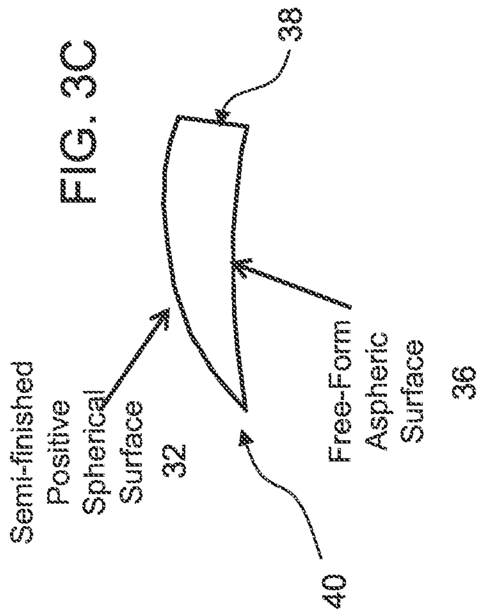


FIG. 3C
38
Semi-finished Positive Spherical Surface 32
Free-Form Aspheric Surface 36
40

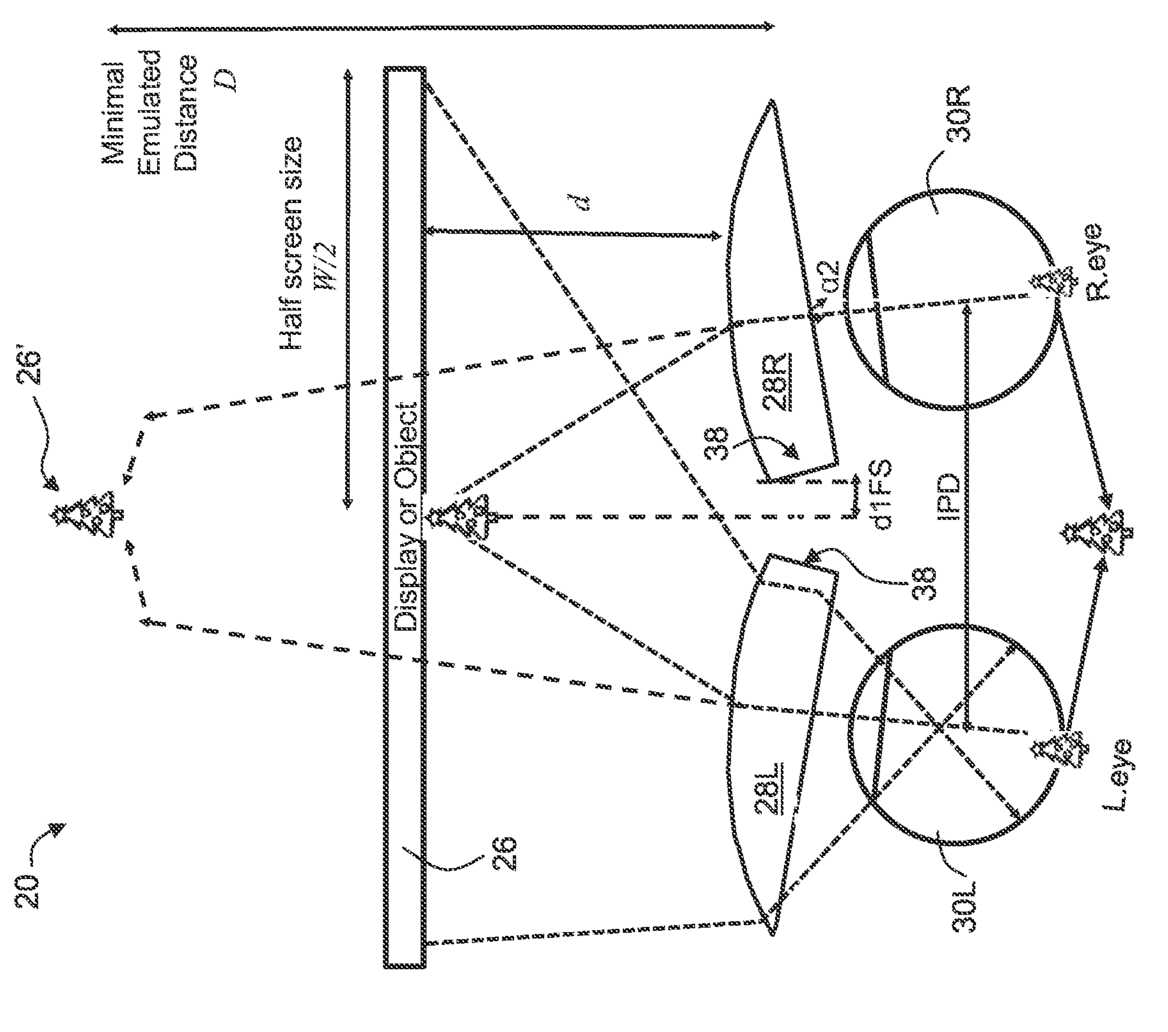

20
26'
Minimal Emulated Distance D
Half screen size W/2
Display or Object
26
d
d2
d1FS
28R
28L
38
38
IPD
30R
30L
R.eye
L.eye

FIG. 3A

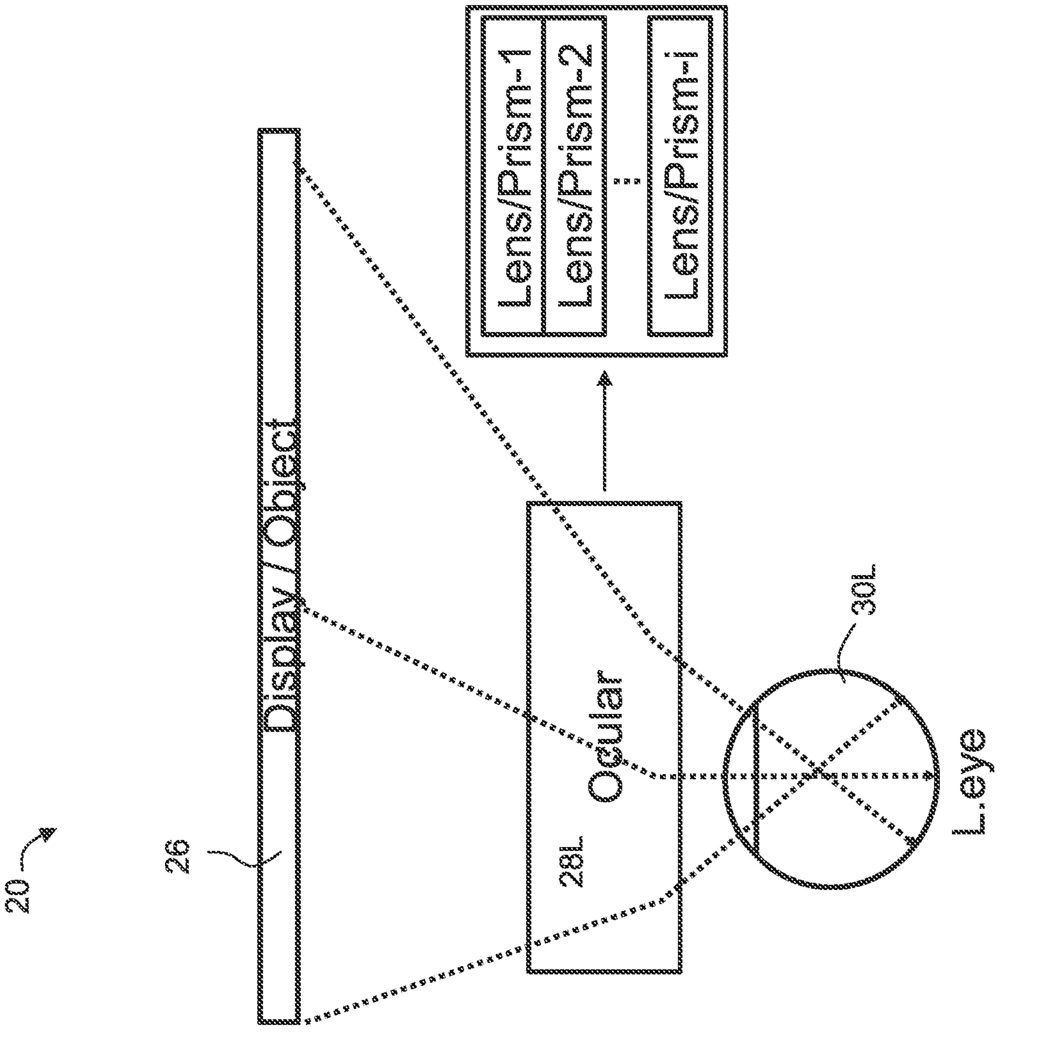


FIG. 4A

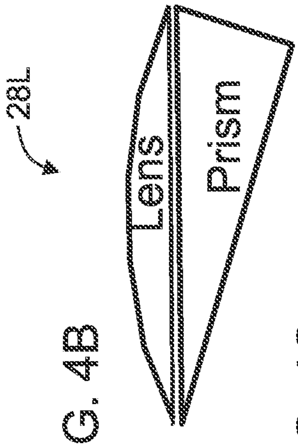


FIG. 4B

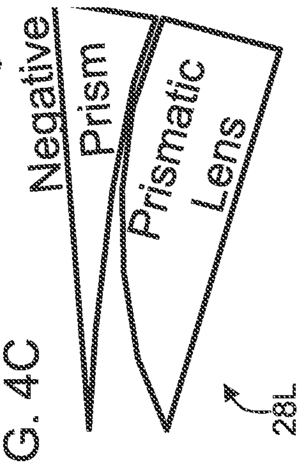


FIG. 4C

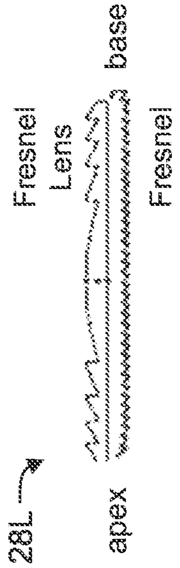


FIG. 4D

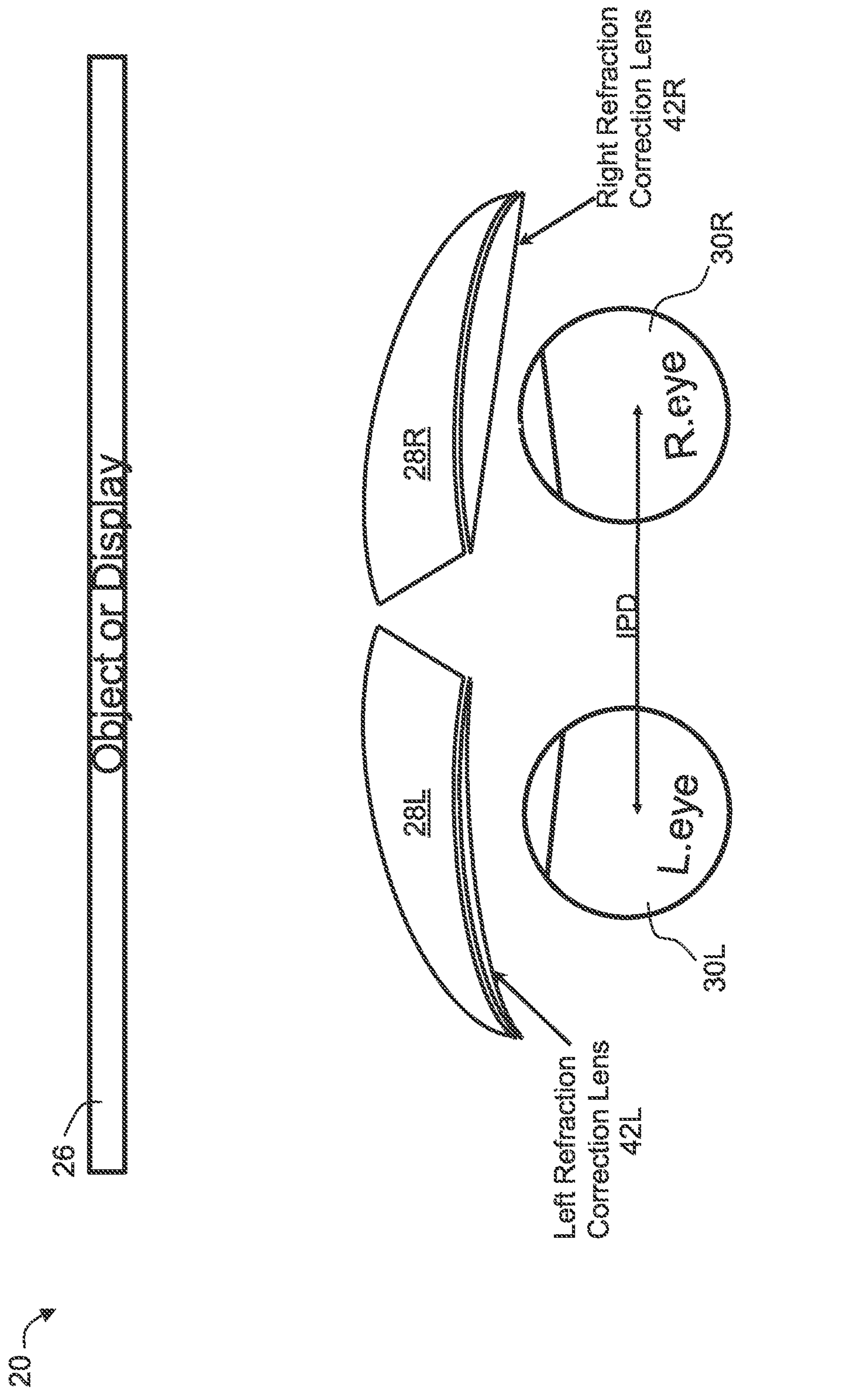
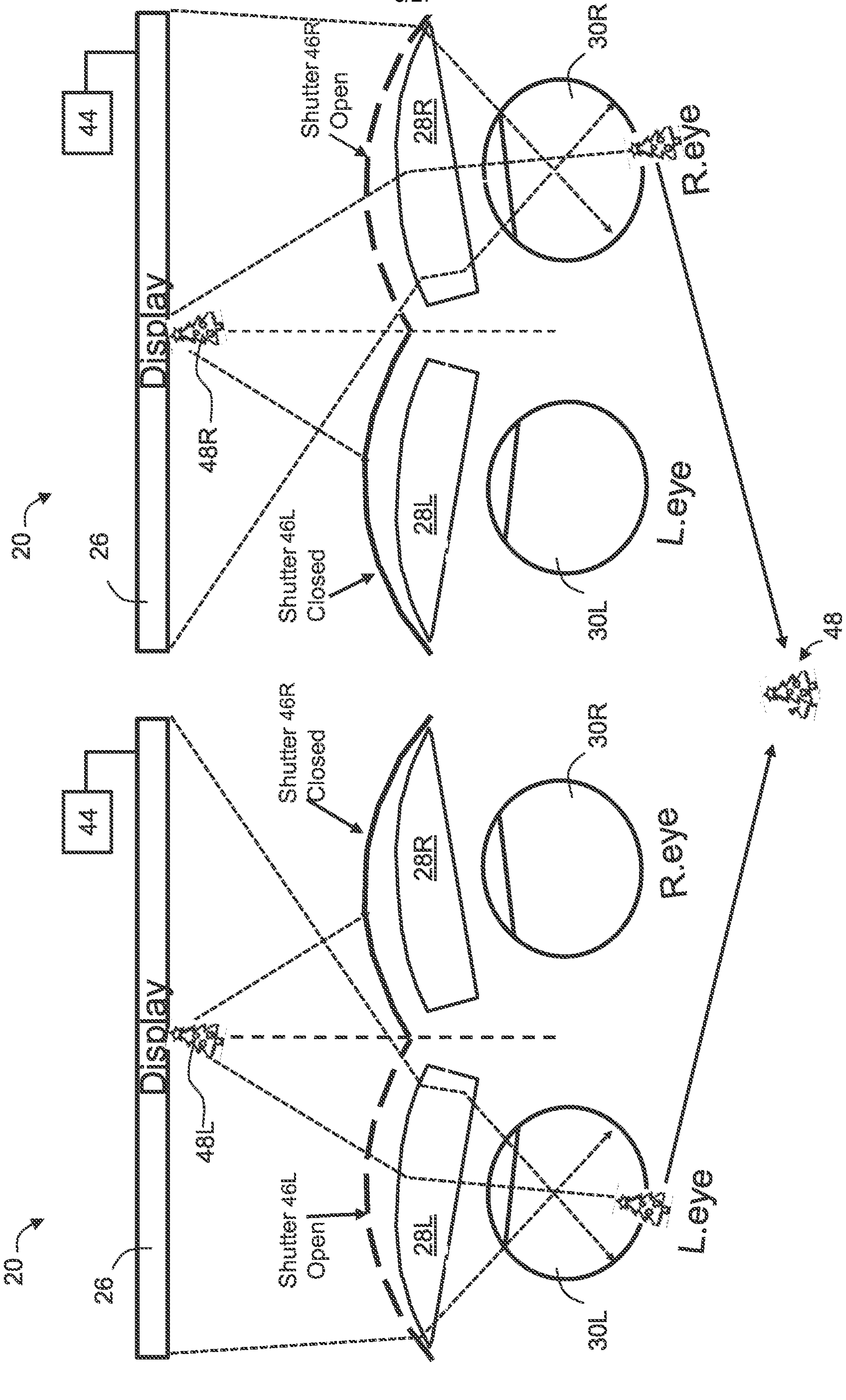

Object or Display
26
28R
28L
Right Refraction
Correction Lens
42R
Left Refraction
Correction Lens
42L
30R
30L
R.eye
L.eye
IPD
20

FIG. 5



20
26
Display
44
48R
48L
Shutter 46R Open
Shutter 46R Closed
Shutter 46L Closed
Shutter 46L Open
28R
28L
30R
30L
R.eye
L.eye
48

FIG. 6B

FIG. 6A

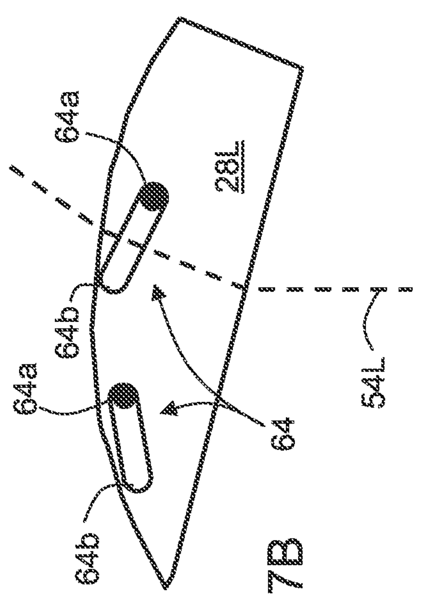


FIG. 7B

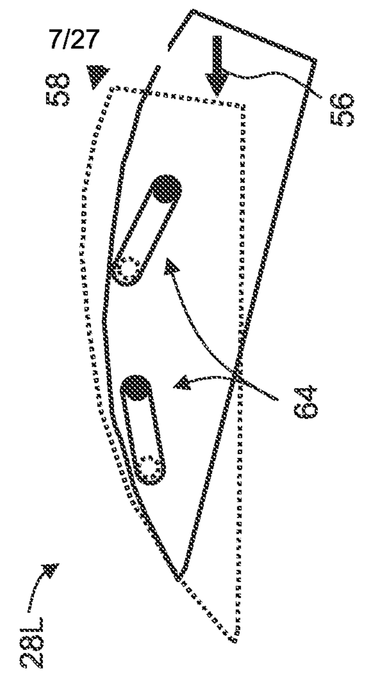


FIG. 7C

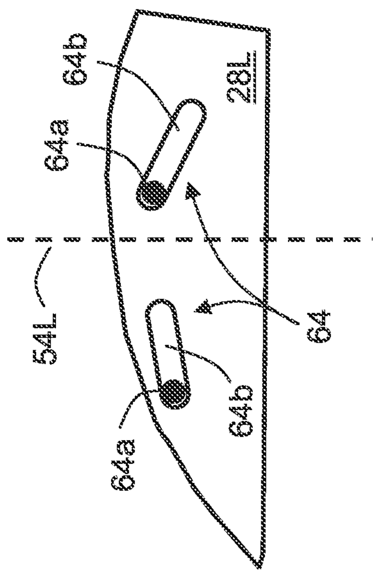


FIG. 7D

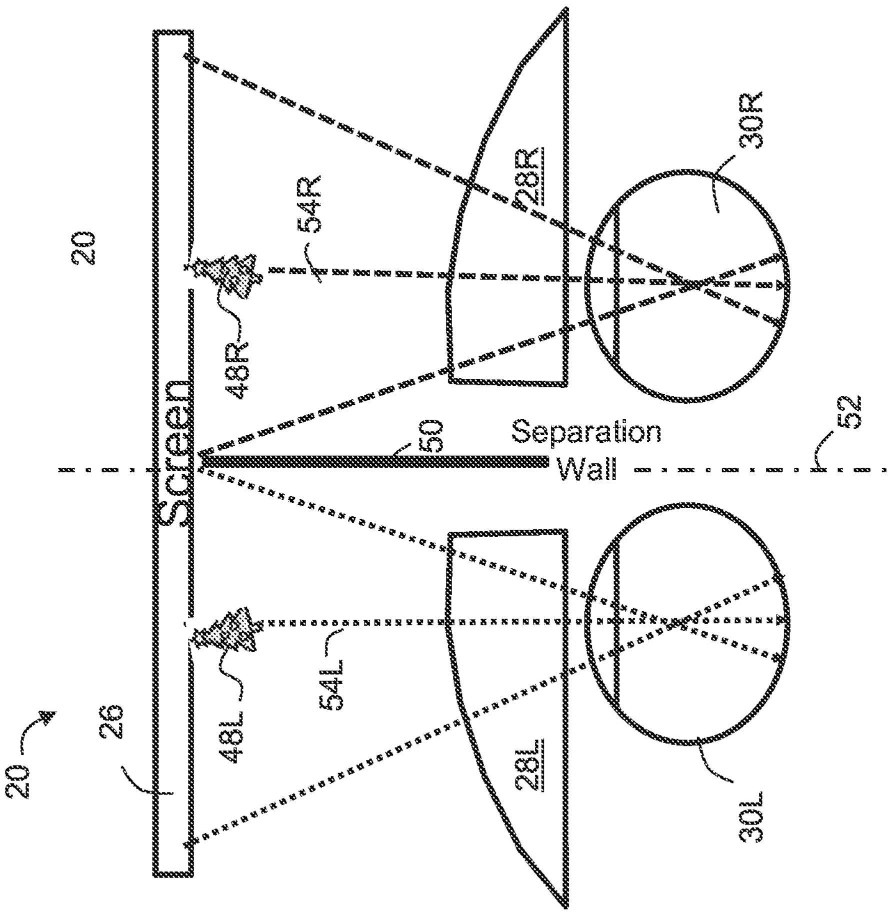


FIG. 7A

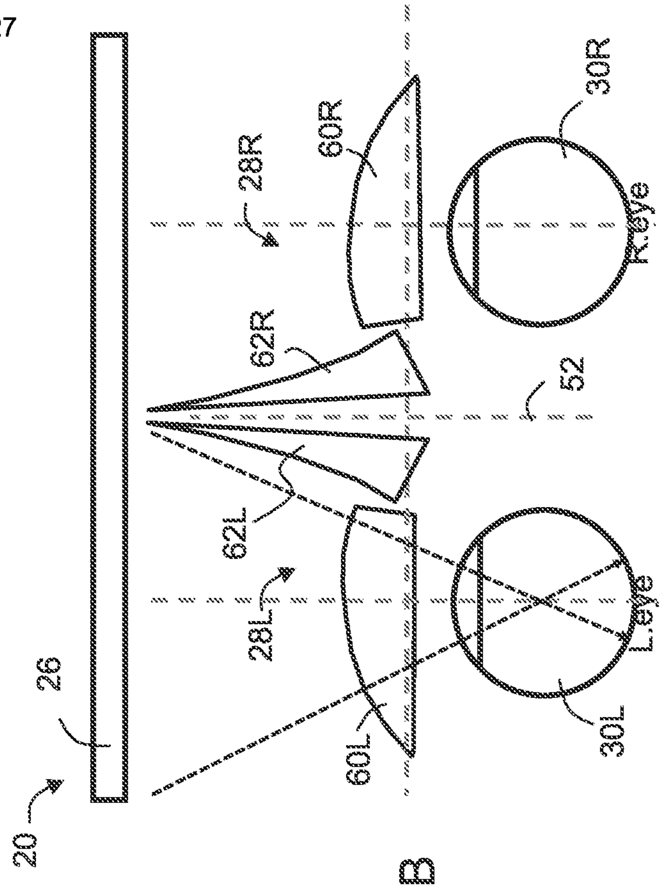

20
26
28R
28L
60R
62R
62L
60L
52
30R
30L
R.eye
L.eye

FIG. 8B

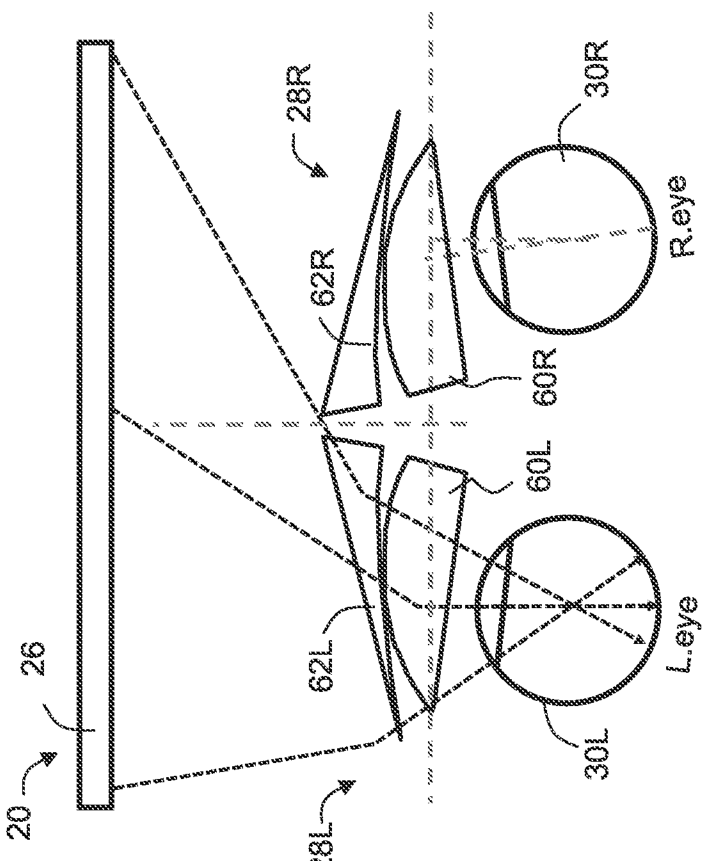

20
26
28R
28L
62R
62L
60R
60L
30R
30L
R.eye
L.eye

FIG. 8A

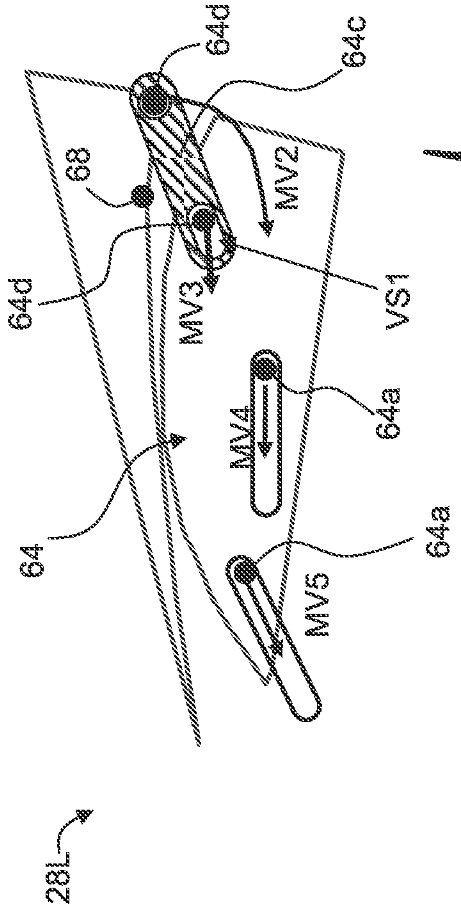

64d
64c
68
MV2
64d
MV3
VS1
64a
MV4
64
64a
MV5
28L

FIG. 8C

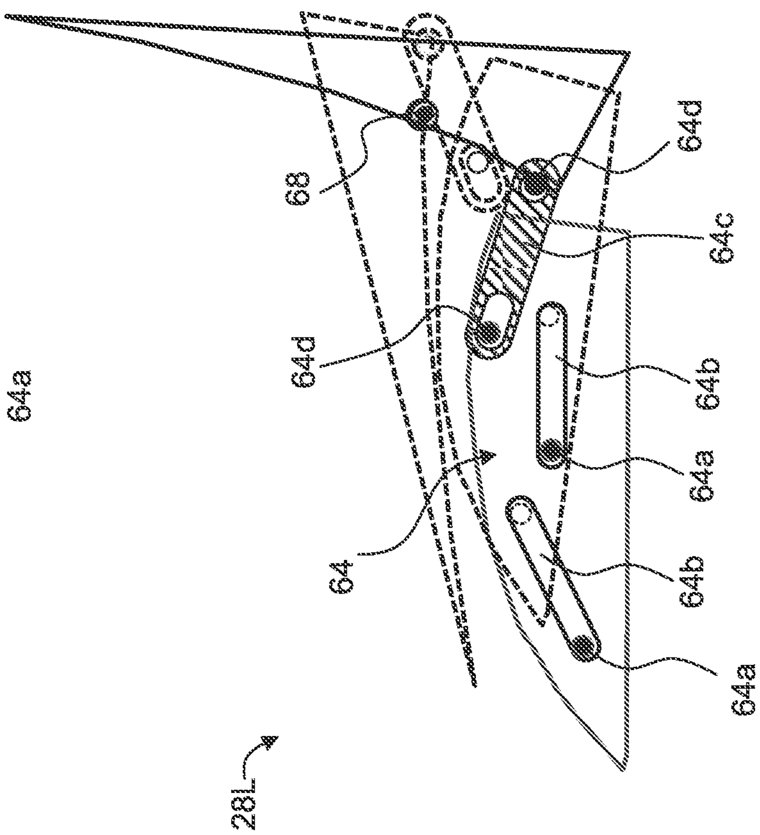

68
64d
64c
64d
64b
64a
64
64b
64a
28L

FIG. 8D

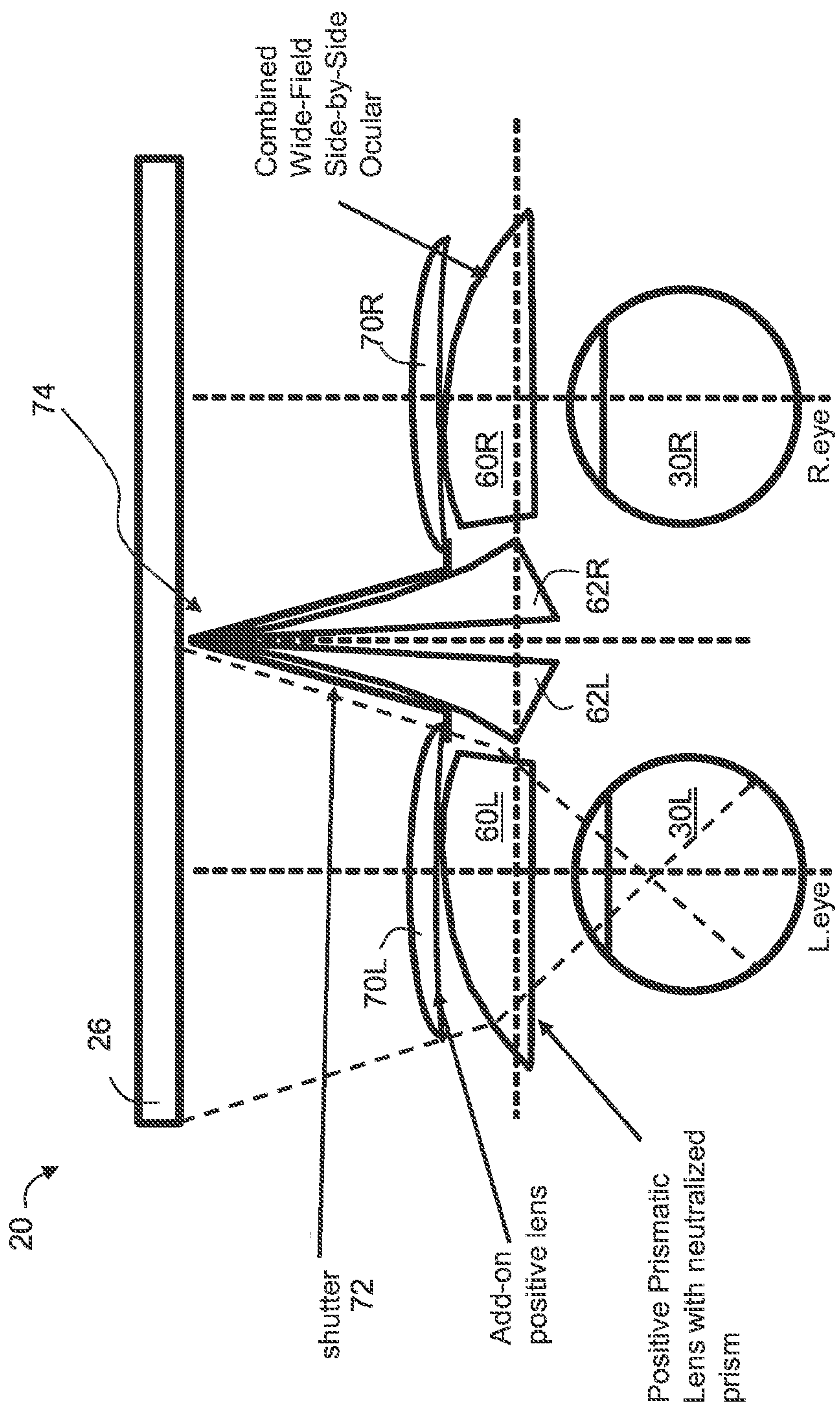

Combined Wide-Field Side-by-Side Ocular
74
70R
60R
30R
R.eye
62R
62L
60L
30L
L.eye
70L
26
20
shutter 72
Add-on positive lens
Positive Prismatic Lens with neutralized prism

FIG. 9

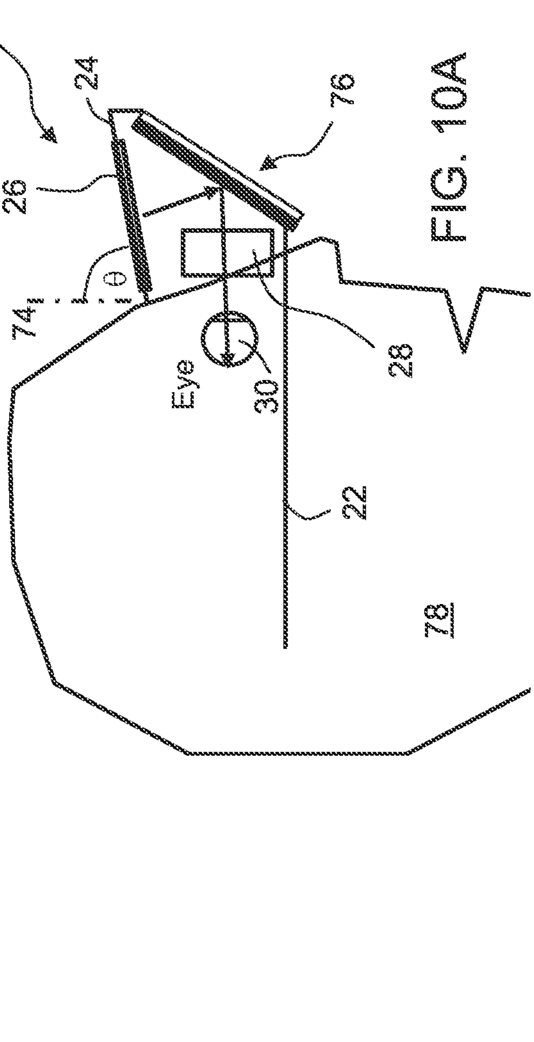


FIG. 10A

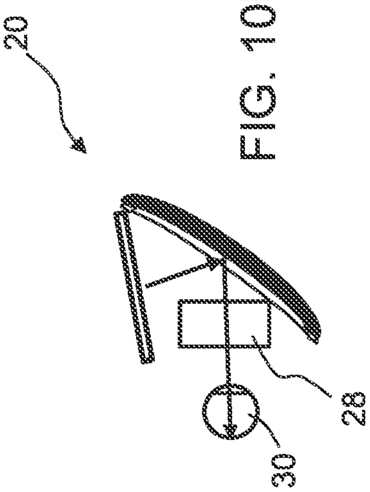


FIG. 10B

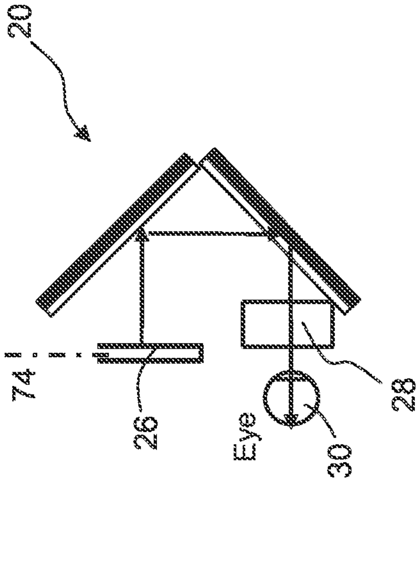


FIG. 10C

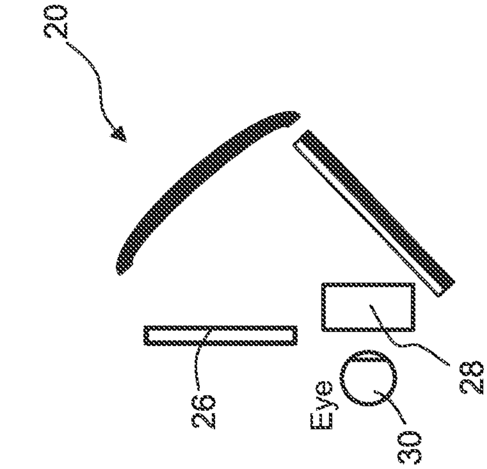


FIG. 10D

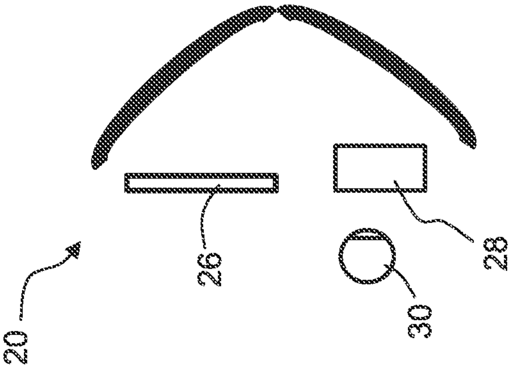


FIG. 10E

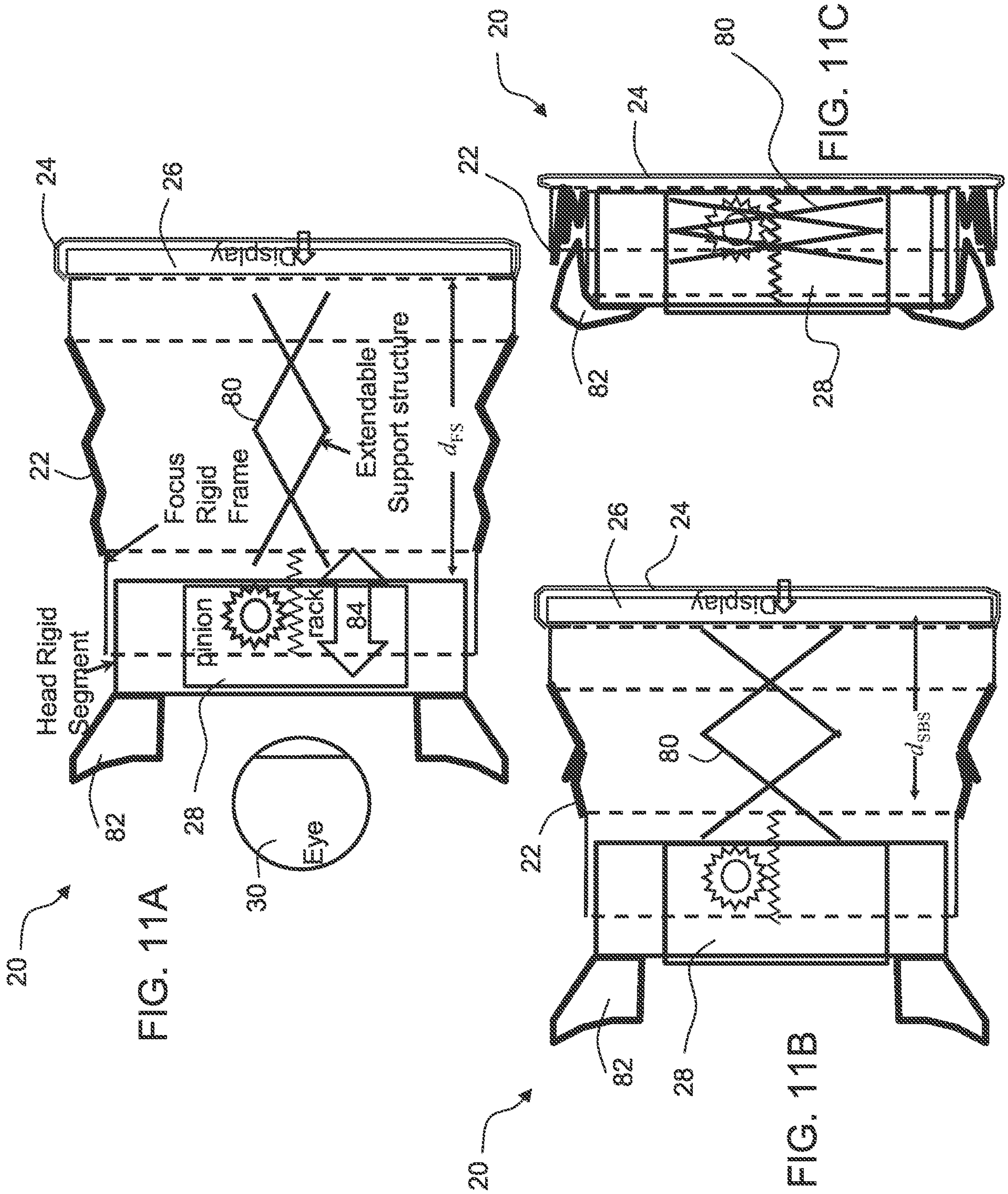


FIG. 11A

FIG. 11B

FIG. 11C

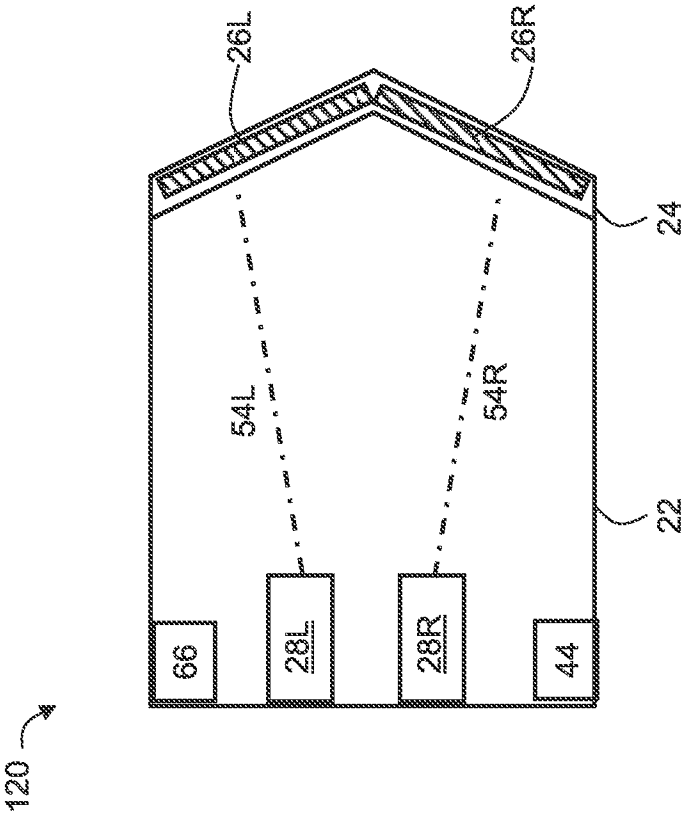


FIG. 12

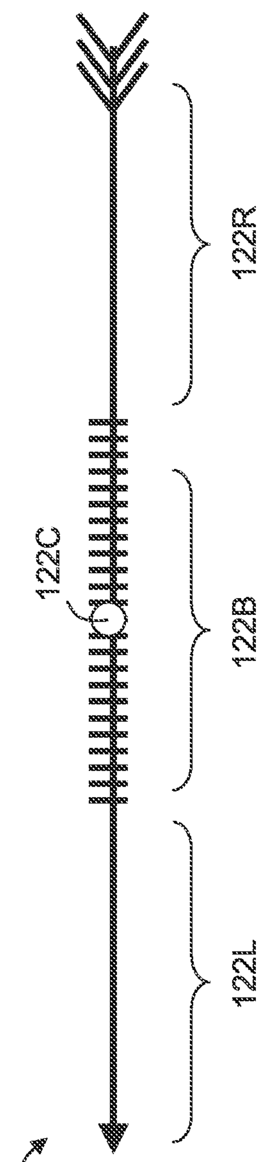


FIG. 13A

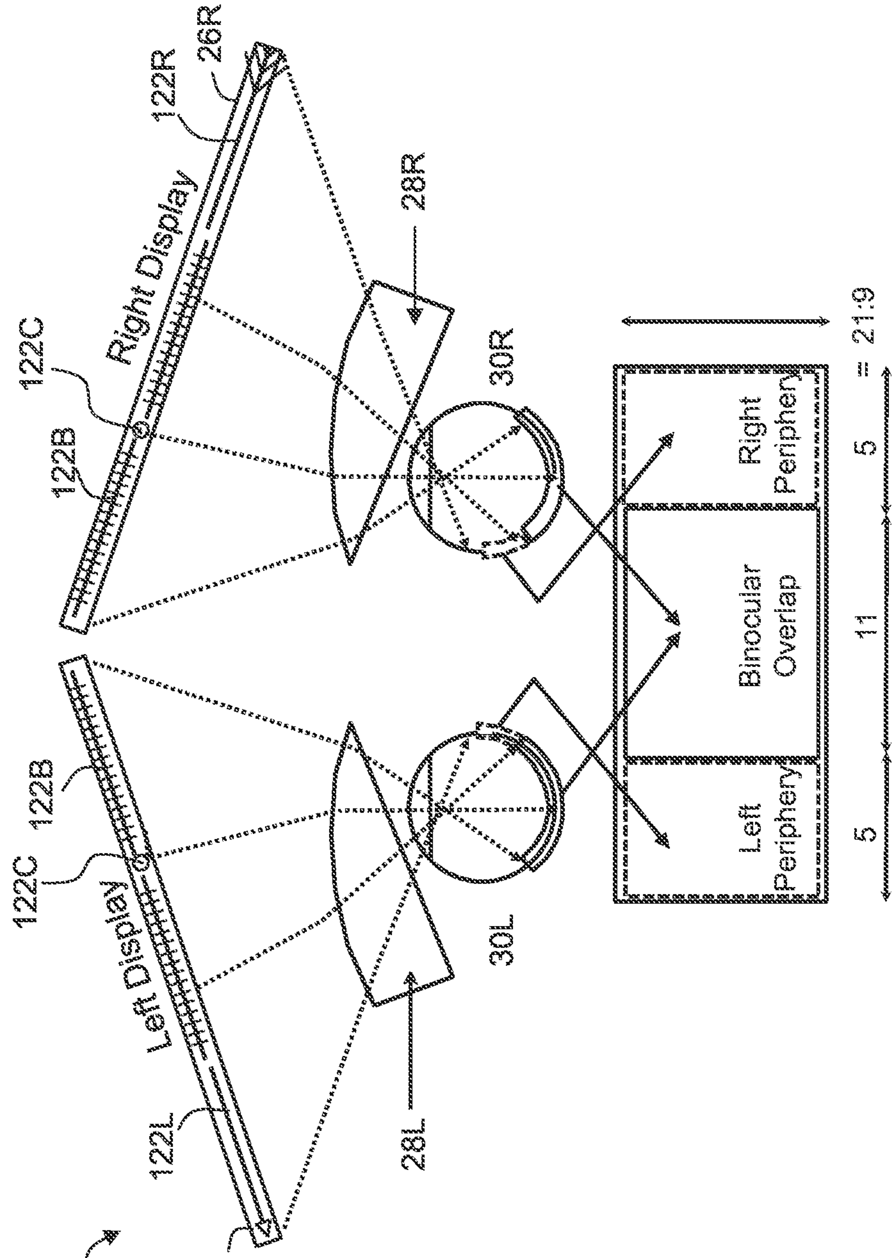


FIG. 13B

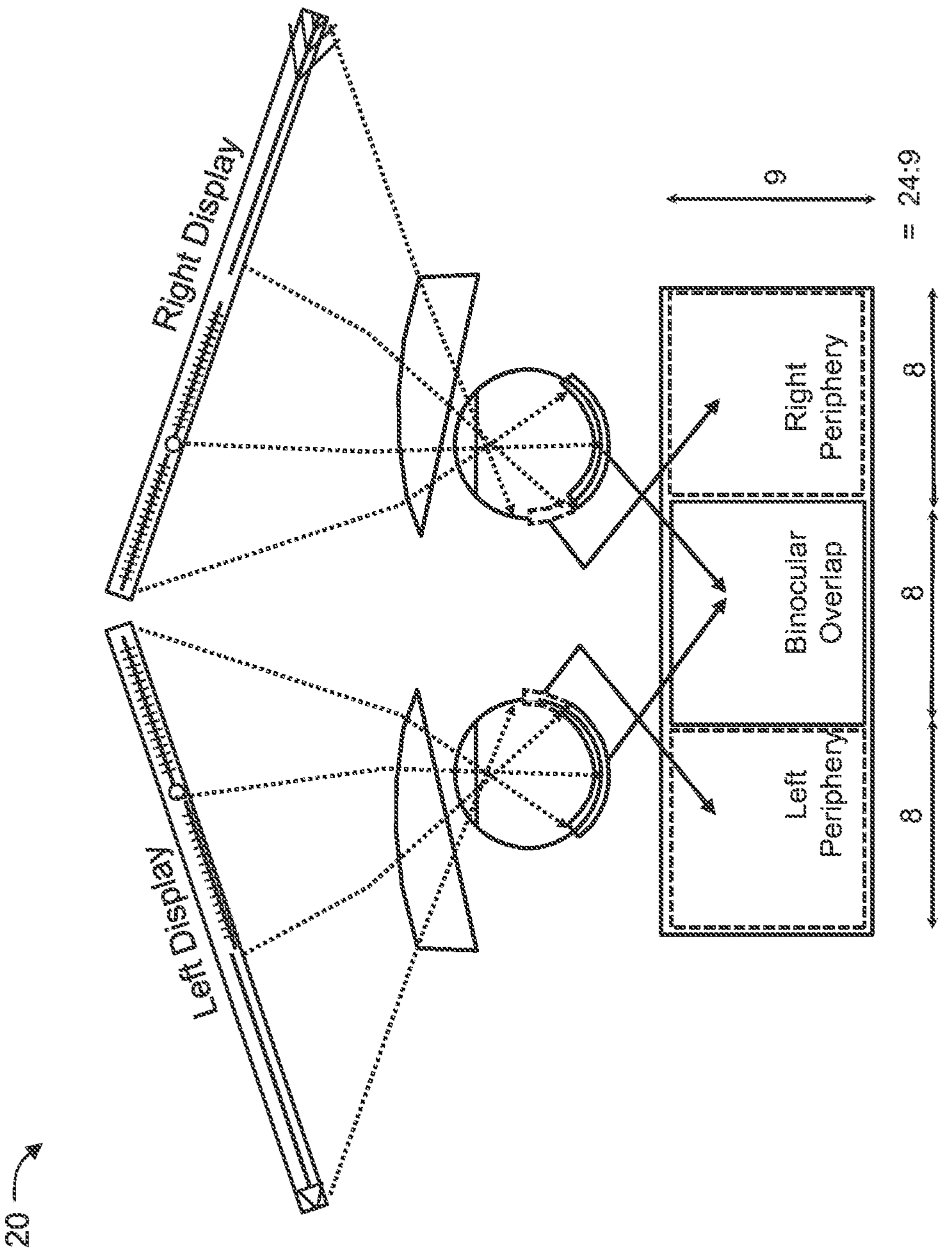

120
Right Display
Left Display
Right Periphery
Binocular Overlap
Left Periphery
8
8
8
9
= 24:9

FIG. 14

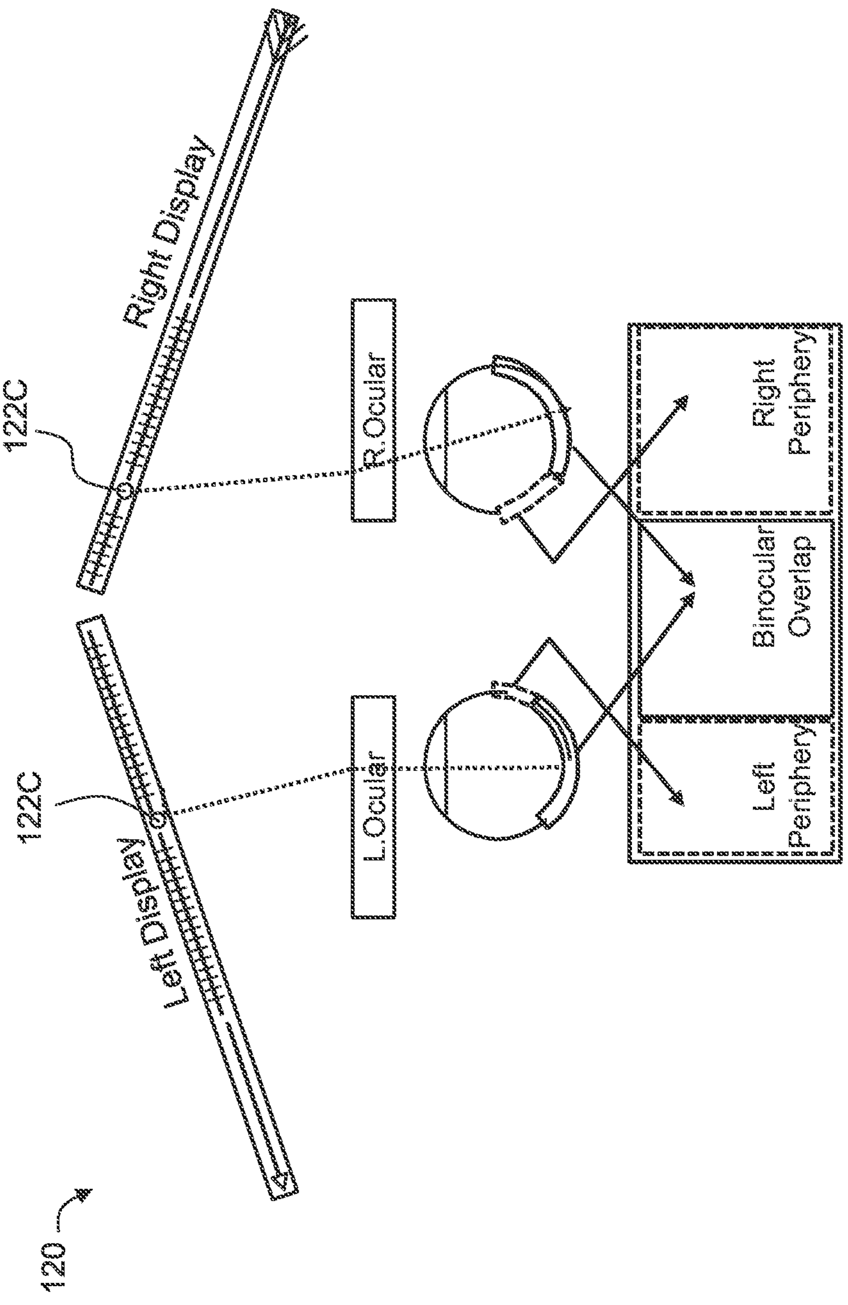

120
122C
Left Display
122C
Right Display
L.Ocular
R.Ocular
Left Periphery
Binocular Overlap
Right Periphery

FIG. 15A

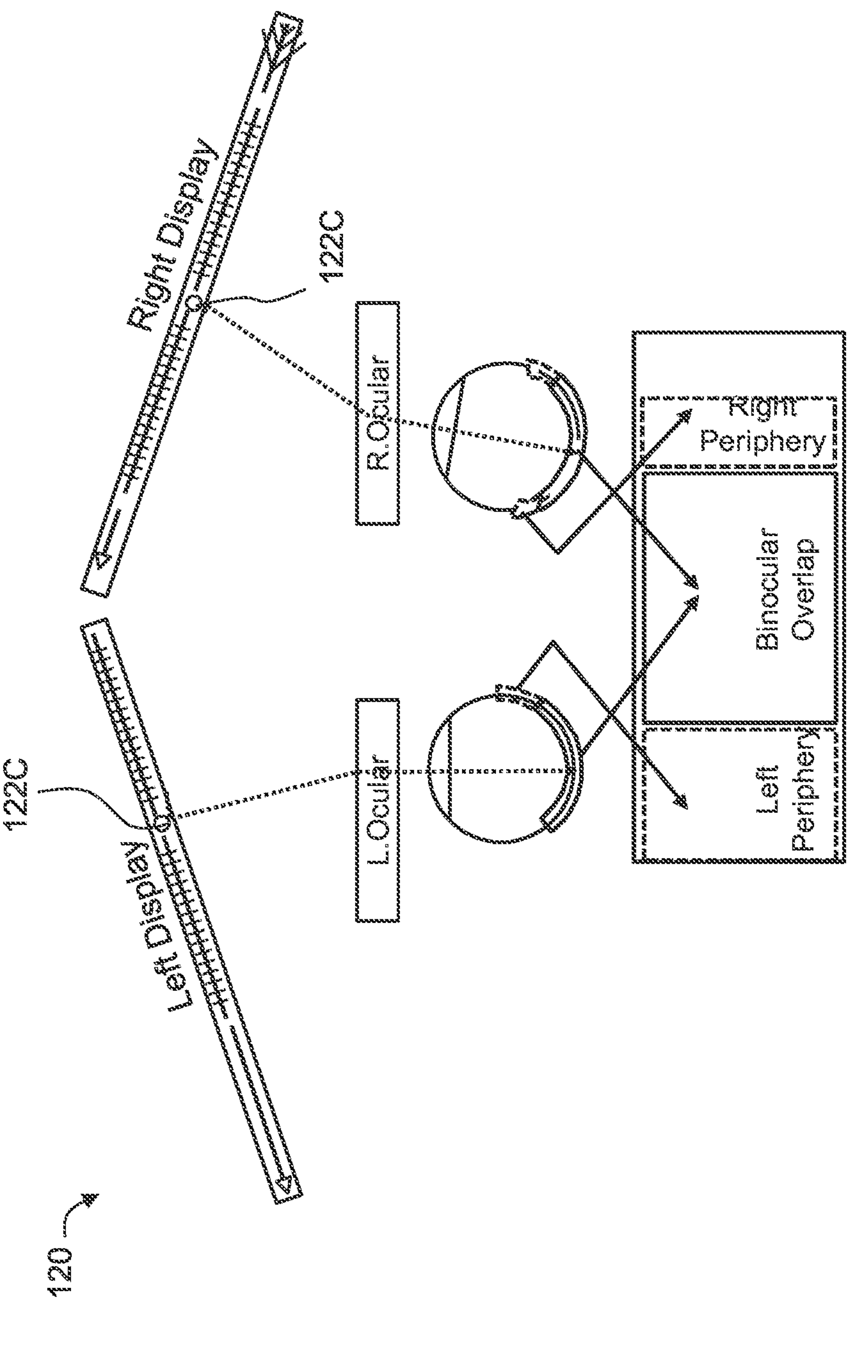

Right Display
122C
R.Ocular
Right
Periphery
Binocular
Overlap
Left
Periphery
L.Ocular
122C
Left Display
120

FIG. 15B

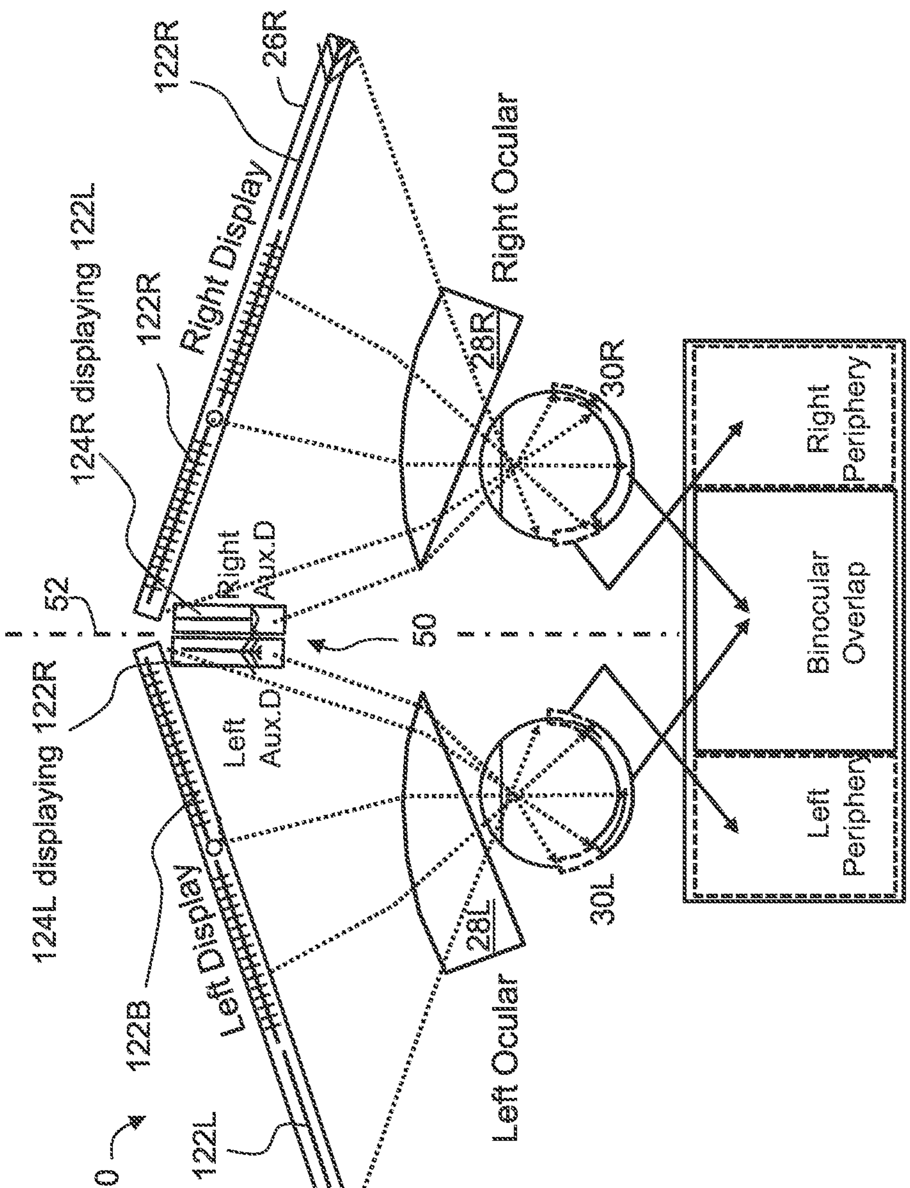

120
122L
26L
122B
Left Display
124L displaying 122R
Left Aux.D
Right Aux.D
124R displaying 122L
122R
Right Display
122R
26R
52
50
28L
28R
Left Ocular
Right Ocular
30L
30R
Left Periphery
Binocular Overlap
Right Periphery

FIG. 16

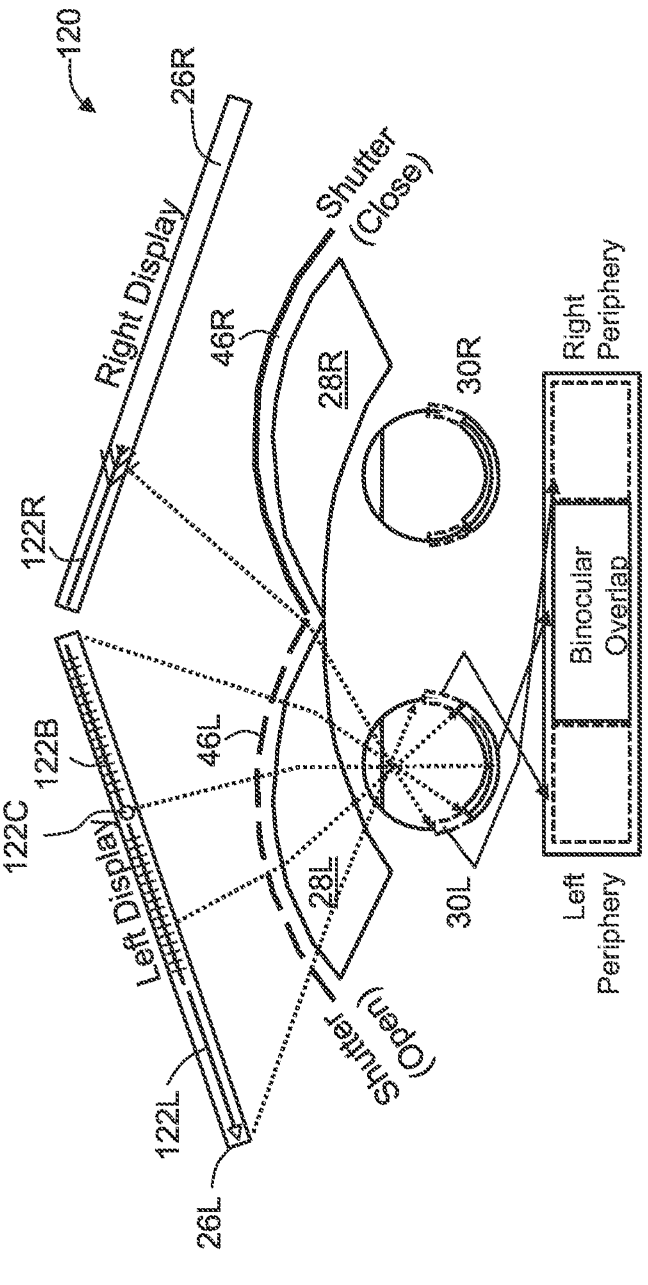


FIG. 17A

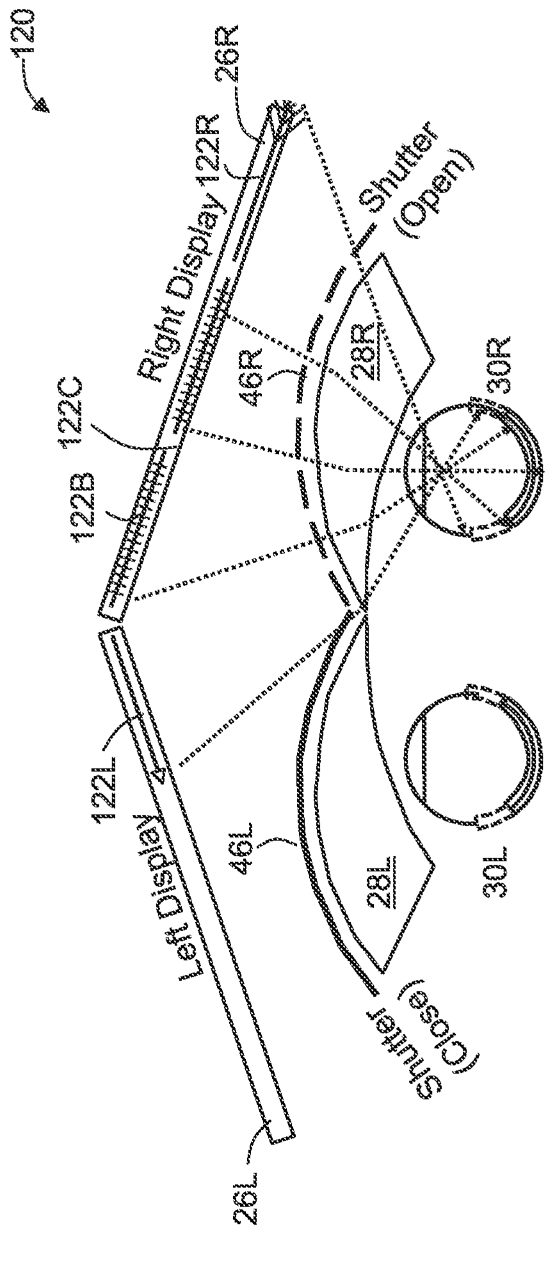


FIG. 17B

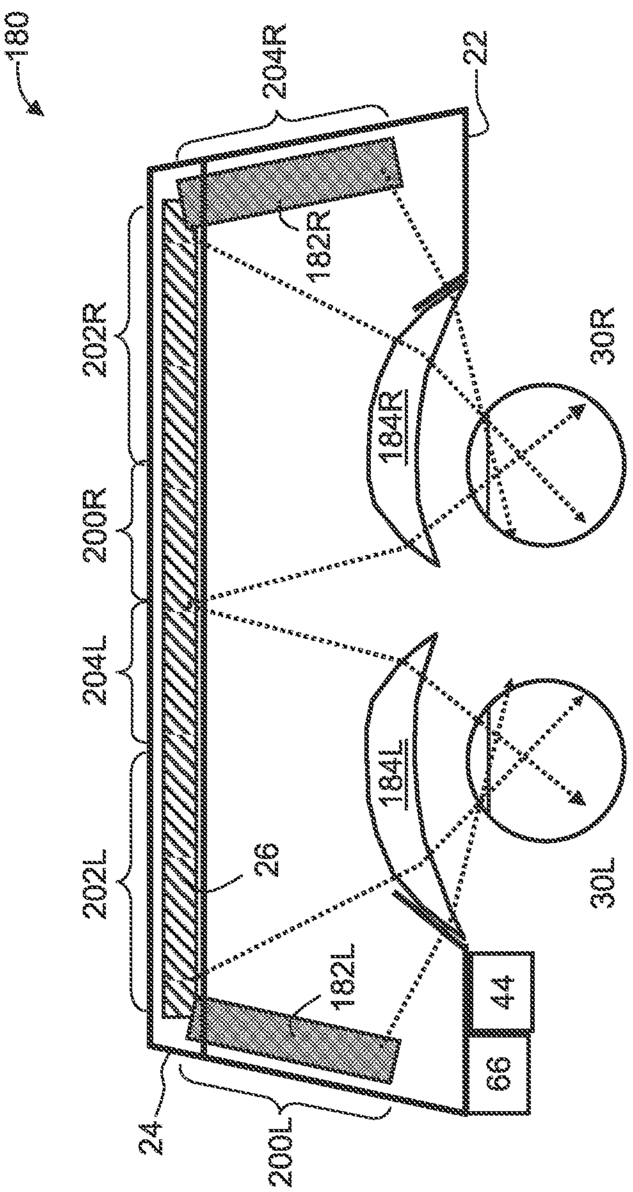

180
204R
22
182R
202R
184R
30R
200R
204L
184L
202L
26
30L
182L
44
66
24
200L

FIG. 18

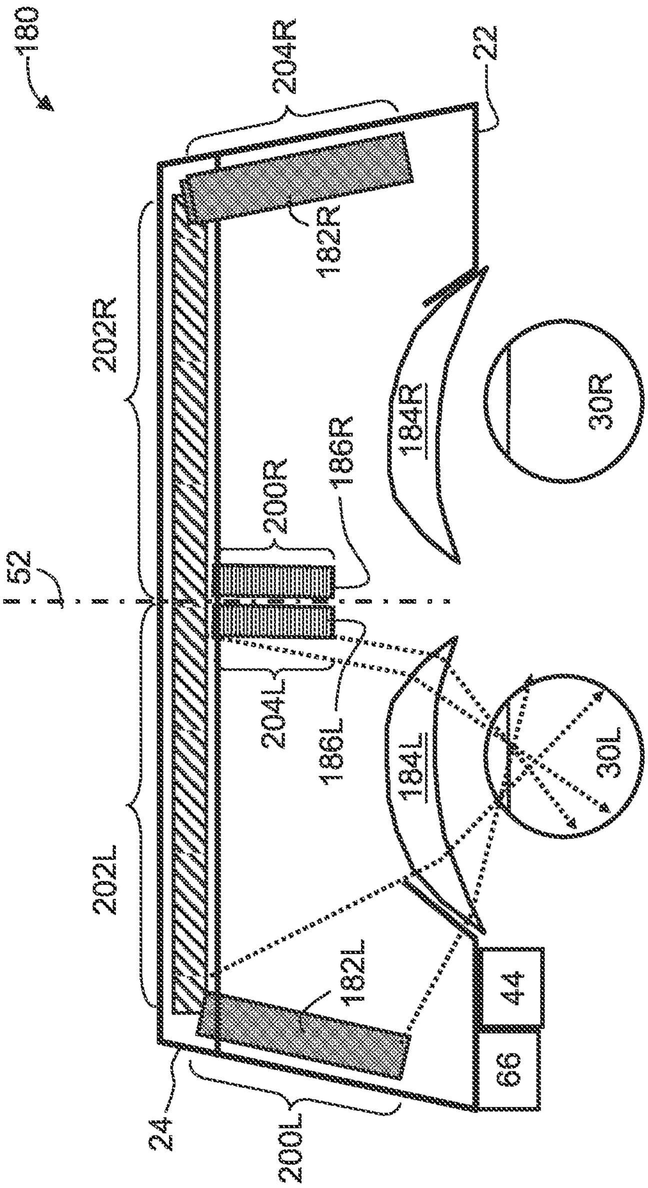

180
204R
22
182R
202R
184R
30R
186R
200R
52
204L
186L
184L
30L
202L
182L
44
66
24
200L

FIG. 19

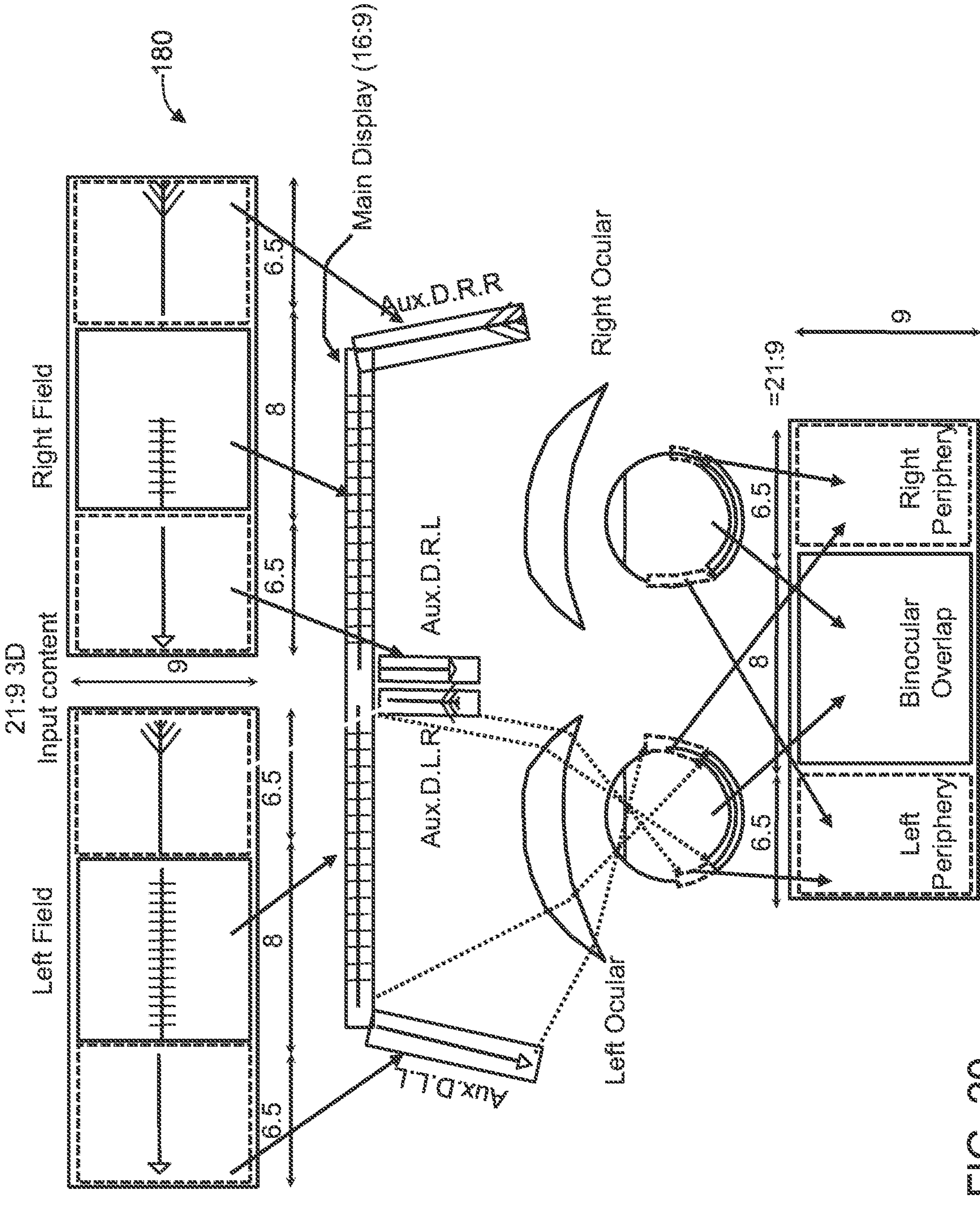

180
Main Display (16:9)
Right Field
Left Field
21:9 3D
Input content
9
6.5
8
6.5
6.5
8
6.5
Aux.D.R.R
Aux.D.R.L
Aux.D.L.R
Aux.D.L.L
Right Ocular
Left Ocular
≈21:9
9
6.5
8
6.5
Right Periphery
Binocular Overlap
Left Periphery

FIG. 20

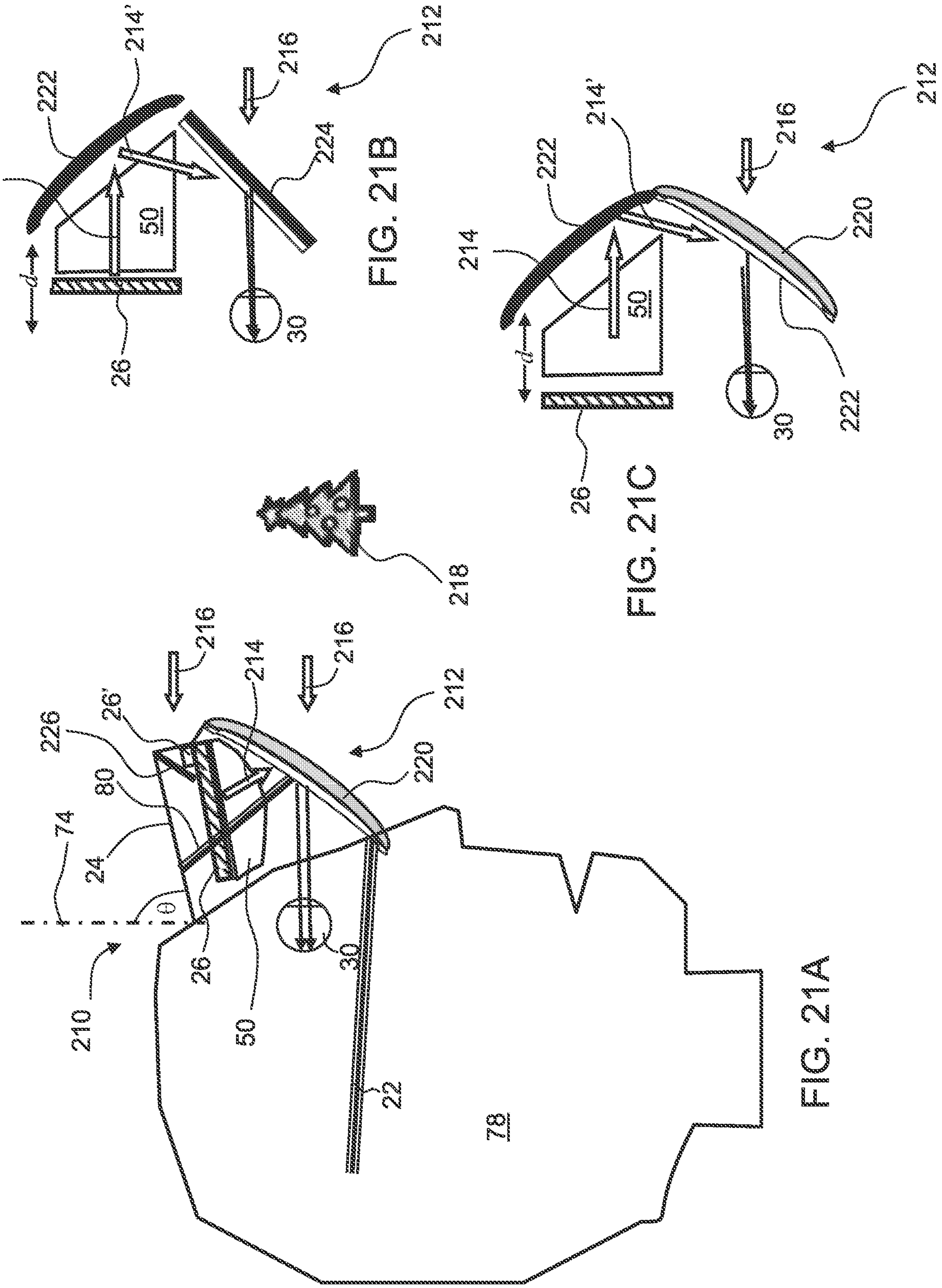


FIG. 21B

FIG. 21C

FIG. 21A

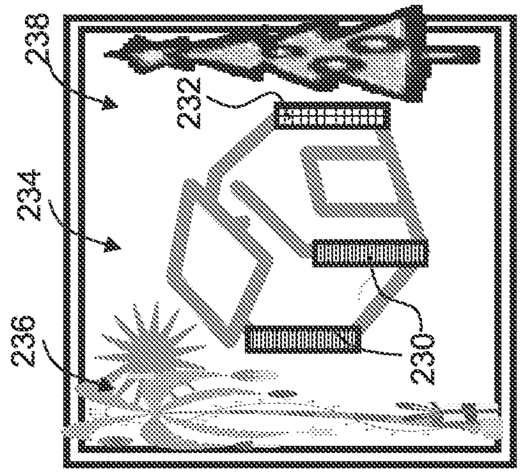


FIG. 22D

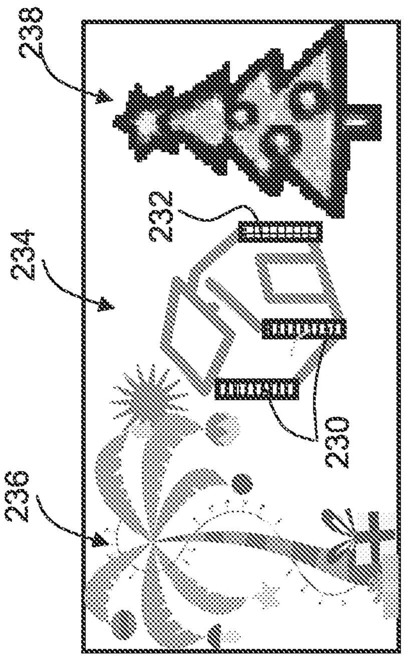


FIG. 22A

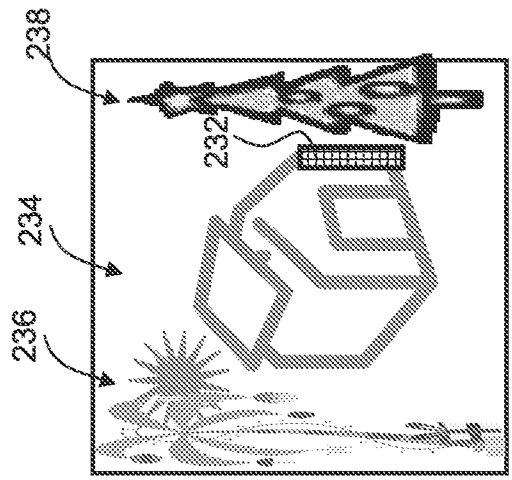


FIG. 22C

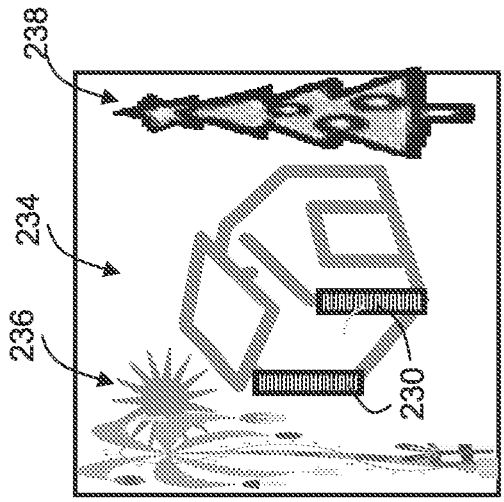


FIG. 22B

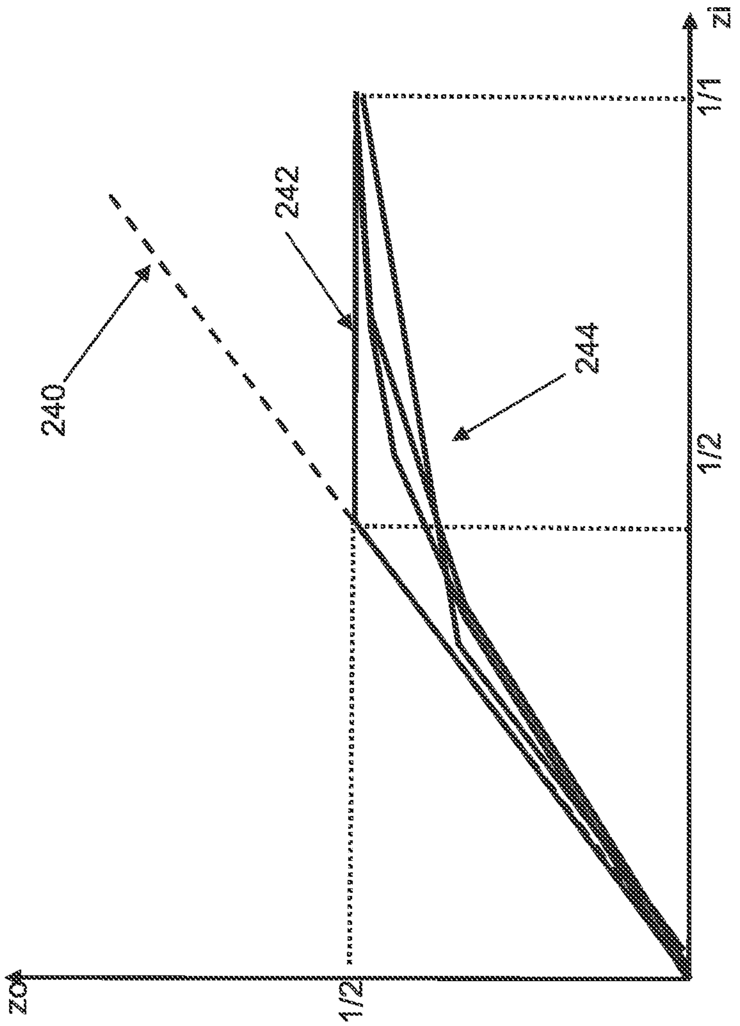
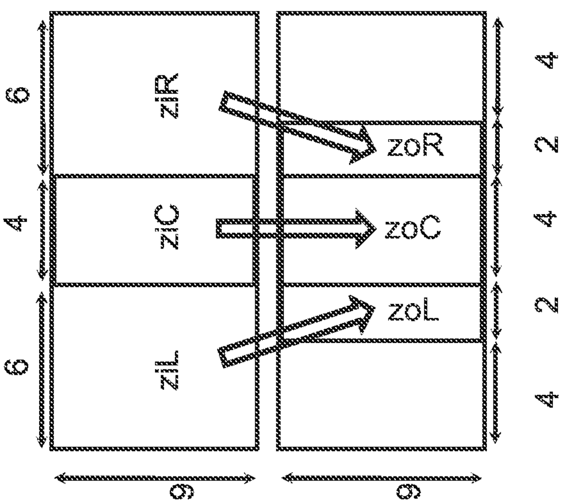


FIG. 23A

FIG. 23B



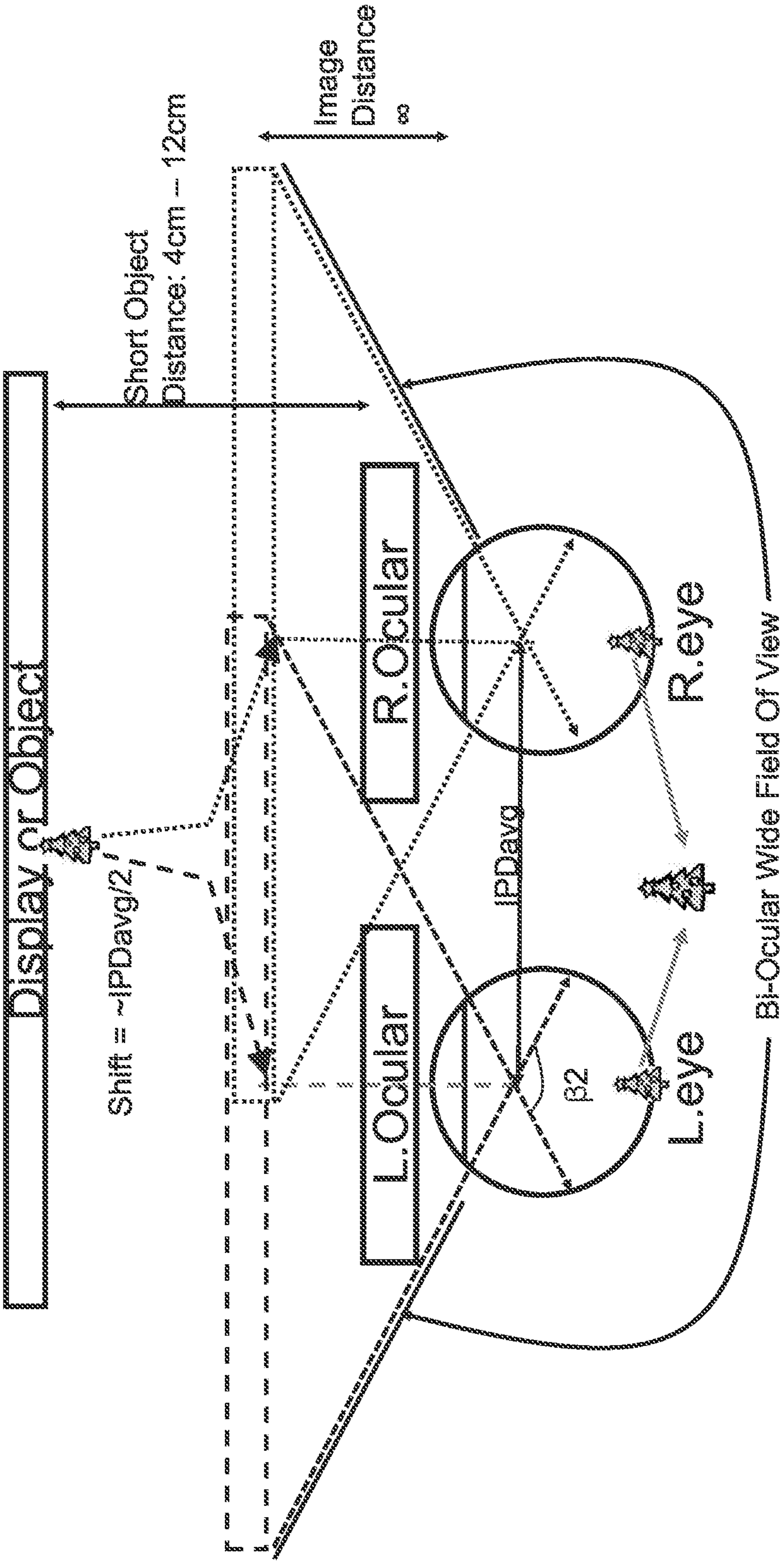


Image
Distance
∞
Short Object
Distance: 4cm -- 12cm
Display or Object
Shift = ~IPDavg/2
R.Ocular
L.Ocular
IPDavg
β2
R.eye
L.eye
Bi-Ocular Wide Field Of View

FIG. 24

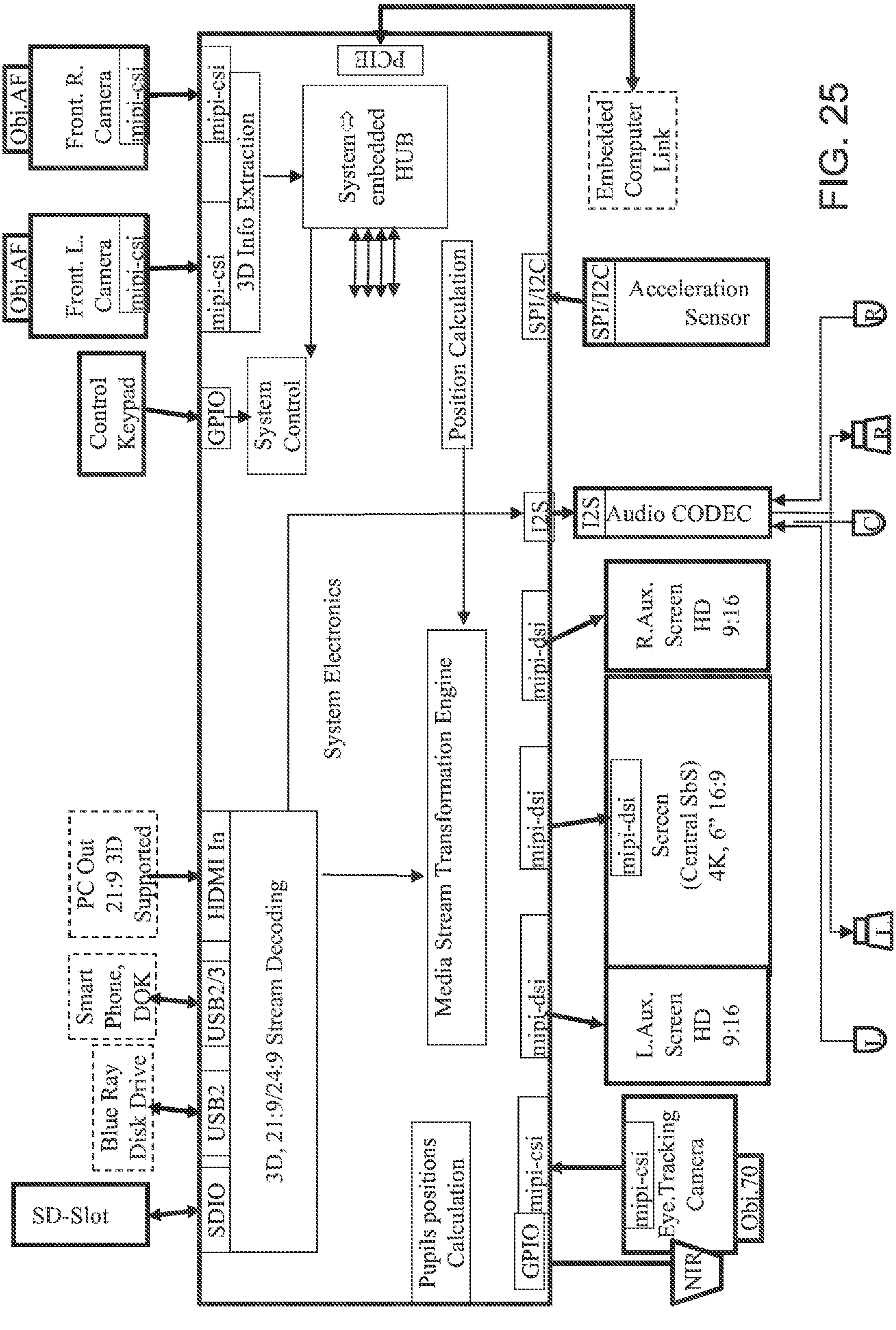

Obj.AF
Front. R. Camera
mipi-csi
Obj.AF
Front. L. Camera
mipi-csi
Control Keypad
SD-Slot
Blue Ray Disk Drive
Smart Phone, DOK
PC Out 21:9 3D Supported
mipi-csi
mipi-csi
3D Info Extraction
PCIE
System⇔ embedded HUB
GPIO
System Control
Position Calculation
SPI/I2C
Embedded Computer Link
SPI/I2C
Acceleration Sensor
I2S
I2S
Audio CODEC
R
R
C
L
L
System Electronics
Media Stream Transformation Engine
SDIO
USB2
USB2/3
HDMI In
3D, 21:9/24:9 Stream Decoding
Pupils positions Calculation
GPIO
mipi-csi
mipi-dsi
mipi-dsi
mipi-dsi
R.Aux. Screen HD 9:16
mipi-dsi
Screen (Central SbS) 4K, 6" 16:9
L.Aux. Screen HD 9:16
mipi-csi
Eye Tracking Camera
Obj.70
NIR

FIG. 25

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL2015/050730

A. CLASSIFICATION OF SUBJECT MATTER
IPC (2015.01) G02B 27/00

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 (2015.01) G02B 27/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Databases consulted: Esp@cenet, FamPat database

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 101419007 B1 GOGGLE-TECH, INC 11 Jul 2014 (2014/07/11) The whole document	1-103
A	US 2012050144 A1 MORLOCK CLAYTON RICHARD 01 Mar 2002 (2002/03/01) The whole document	1-103

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"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	Date of mailing of the international search report
05 Nov 2015	10 Nov 2015
Name and mailing address of the ISA: Israel Patent Office Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel Facsimile No. 972-2-5651616	Authorized officer BITTON Oren Telephone No. 972-2-5657812

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See extra sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet):

* This International Searching Authority found multiple inventions in this international application, as follows:

Invention/s 1	An optical magnification system comprising: a structure having a frame configured to removably secure a display device thereto; and a pair of spaced apart ocular systems, mounted on said structure in front of said frame for providing a view of said display device once mounted on said frame; wherein each of said ocular systems has an aspheric optical surface and provides a prismatic refraction.	Claim/s 1-85
Invention/s 2	A display system for displaying a stereoscopic image having a stereoscopic left periphery, a stereoscopic binocular overlap and a stereoscopic right periphery, the system comprising: a structure having a frame configured to removably secure a display device thereto; a plurality of auxiliary display devices each mounted on said structure at an angle to a plane engaged by said frame, said auxiliary display devices including at least a left auxiliary display device and a right auxiliary display device; a left ocular system and right ocular system, mounted on said structure in front of said frame and said auxiliary display devices, wherein a field-of-view of said left ocular system includes said left auxiliary display device, and field-of-view of said right ocular system includes said right auxiliary display device; and a controller having a circuit configured to display (i) a left-eye image of said stereoscopic left periphery on said left auxiliary display device, (ii) a left-eye image and a right-eye image of said stereoscopic binocular overlap on said display device in a sideby-side configuration, and (iii) a right-eye image of said stereoscopic right periphery on said right auxiliary display device.	Claim/s 86-88
Invention/s 3	A method varying an aspect ratio of an image, the method comprising; identifying on said image a first region and at least one additional region; processing said image to resize said at least one additional region along at least one dimension, while maintaining an aspect ratio of said first region substantially unchanged, thereby varying the an aspect ratio of said image; and transmitting said image to a display system.	Claim/s 89-93
Invention/s 4	A display system for augmented reality, the system comprising: a structure having a frame configured to removably secure a display device thereto, such that when said structure is mounted on a head, said frame is above the eyes; and an optics assembly mounted on said structure and being partially reflective and partially transmissive for simultaneously providing a view of an image displayed on said	Claim/s 94-103

display device and a view of an environment
outside said structure.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IL2015/050730

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
KR 101419007 B1	11 Jul 2014	KR 101419007 B1	11 Jul 2014
US 2012050144 A1	01 Mar 2002	US 2012050144 A1	01 Mar 2012