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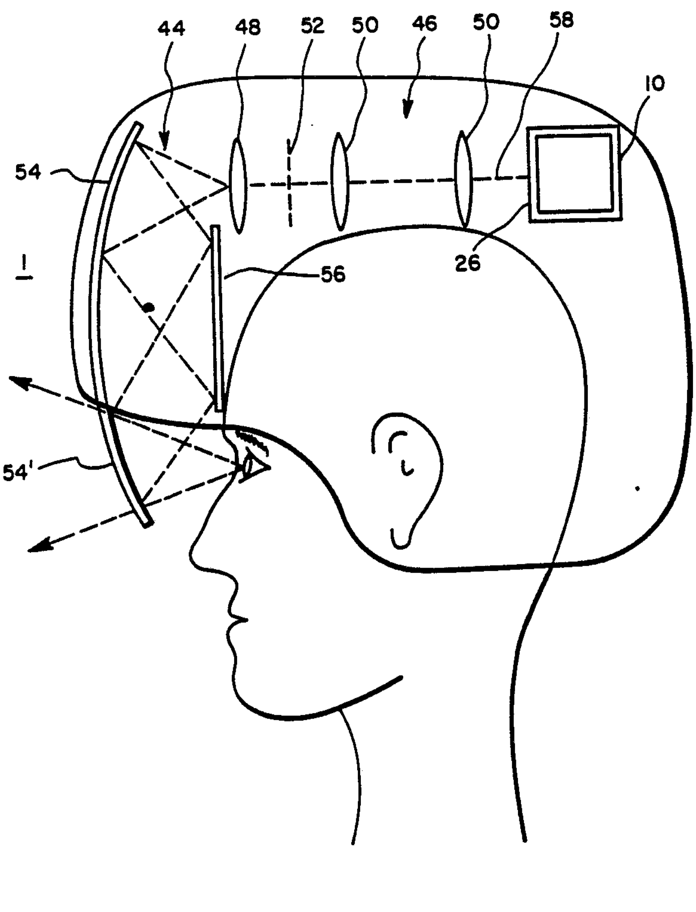
(57) Abstract

A helmet-mountable display device includes a pair of dichroic prism assemblies, each having a projection face and three side faces. A liquid crystal light valve (LCLV) device is mounted on each side face and a fluorescent light source is mounted in alignment with each LCLV to respectively project a red, green and blue light beam through the corresponding LCLV and into each dichroic prism. Each dichroic prism assembly synthesizes the separate beams of colored light and projects a resultant beam through the projection face. Each resultant beam is transferred by relay lenses to a pair of projection lenses; the projection lenses respectively project each light beam onto a spherical reflector which, in combination with a plane reflector, projects an undistorted, full-color, three-dimensional virtual image at infinity into the eyes of a helmet wearer.



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HELMET MOUNTED DISPLAY

Background of the Invention

This application is a continuation-in-part of application Serial No. 07/407,178, filed September 14, 1989, now abandoned.

The present invention relates to helmet mounted displays and, more particularly to a thin-film-transistor/ liquid crystal device (TFT-LCD) projection system which can be mounted in (or on) headgear, such as a helmet or the like.

Head-up displays (HUDs) have found wide application in military aircraft and other vehicles. The HUD is typically mounted for superpositioning of information on a forward-looking view and permits the pilot to monitor aircraft systems, navigational systems and like information without removing his vision from the scene looking out the front of the cockpit. The HUD reduces pilot work load and eye strain because the pilot does not have to continually refocus his eyes between the scene outside the cockpit and monitoring instrumentation inside the cockpit. However, the pilot loses HUD information whenever he directs his vision to a portion of the canopy not immediately toward the front of the vehicle.

Helmet-mounted displays (HMDs) are one next generation device which overcomes many of the disadvantages of HUDs. HMDs permit viewing of the display no matter what direction the pilot is looking; the pilot doesn't have to be looking out the front of the canopy to view the information normally displayed by an HUD. Many different types of information can be shown to the pilot/wearer by the HMD, such as aircraft and navigational systems information, radar displays, forward-looking infrared (FLIR) camera view, low-light-level camera view and the like. Computer software can be developed to sequentially display the items or to display them according to the desires or needs of the pilot. A cross hair corresponding to the pilot's line of sight may also be generated by computer on the display which will allow the pilot to aim his weapon systems merely by looking at the intended target.

Prior art HMDs, which are small and light enough to be worn by pilots flying aircraft, have used miniature cathode ray tubes (CRTs), typically one mounted on each side of the helmet for proper balance and to provide three-dimensional imaging. Each CRT is optically coupled with a series of mirrors and lenses to project the virtual image of each CRT in front of the eyes of the pilot and superposed on a view of the real world. A problem with CRTs is that high resolution and color are not possible with CRTs small enough to be practically mounted on a helmet. Since a miniature CRT picture is typically sequentially generated from a single electron beam, a CRT having a 25 mm. diameter screen with acceptable resolution would require a tube about 110 mm. long. Additionally, miniature CRTs typically have a small angle-of-view and the arrangement of the optics to project the images into the pilot's eyes may partially obscure the real world view of the pilot.

One other prior art HMD system uses a single CRT mounted behind the pilot's head and a coherent optical fiber bundle to project the image forward for viewing by the pilot. Another prior art full-color system uses a projection TV-type device, such as a General Electric Company Talaria™ light valve projector, as the image source. Because of its bulk, the light valve projector cannot be helmet mounted, but is optically coupled to the helmet by a long fiber-optics bundle. The fiber-optics bundle may severely limit the freedom of motion of the pilot and hinder safe evacuation from the aircraft in an emergency; therefore, systems of this type are not very desirable for flying purposes.

The added weight of the HMD, the balance of the weight and the safe evacuation of a pilot wearing an HMD are major concerns with regard to the use of HMDs in high-performance aircraft. The weight and balance of the HMD can be particularly strenuous and fatiguing to a fighter pilot subjected to high G-forces during high-speed maneuvering. If a pilot has to eject, any cables, fiber-optic or other types, leading to the HMD must be reliably severed to prevent injury to the pilot.

It is accordingly a primary object of the present invention to provide a novel HMD which is not subject to the foregoing disadvantages.

It is a further object of the present invention to provide a high-resolution, full-color, three-dimensional virtual image at infinity and superpositioned on the real world view in front of the HMD wearer's eyes.

It is another object of the present invention to provide a light weight, balanced HMD.

These and other objects of the invention, together with the features and advantages thereof, will become apparent from the following detailed specification when read with the accompanying drawings in which like reference numerals refer to like elements.

Summary of the Invention

In accordance with the present invention, a helmet mounted display (HMD) device includes a pair of dichroic prism assemblies, each mounted on the helmet and each having a projection face and side faces. Three thin-film-transistor liquid crystal light valves (TFT-LCLV) are each mounted on a different side face of each dichroic prism assembly and one of red, green and blue light source means are respectively mounted in alignment with a different corresponding TFT-LCLV, for projecting an associated red, green or blue light beam through the corresponding TFT-LCLV and into each respective dichroic prism assembly. The pixels of each TFT-LCLV act as one of multiple shutters to control the quantity of light entering each side of the dichroic prism assemblies; each dichroic prism assembly synthesizes the separate beams of colored light to form a separate full-color image which is projected through the projection face of each prism assembly. Relay lenses, similar to those in a periscope, transfer each image forward from the dichroic prisms and form images focused at infinity near a front portion of the helmet. A pair of projection lenses respectively project each image forward onto a spherical reflector mounted in the front of the helmet. A plane reflector is mounted in the helmet behind the spherical reflector; the spherical reflector reflects the images back and downwardly onto the plane reflector and the plane reflector reflects the images downwardly and back to the spherical reflector. The projection lenses, spherical reflector and plane reflector are each positioned to project an undistorted image into each eye of a wearer on the second reflection from the spherical reflector to cause the wearer to see a full-color, three-dimensional image focused at infinity.

The projected image may be superimposed on a view of the real world by providing a spherical reflector which has a partially reflecting lower portion alignable with the wearer's eyes so as to allow a clear field of vision through the lower portion.

Depending upon the polarization of the TFT-LCLVs and the dichroic prism assemblies, a polarization filter may be mounted between each light source means and its corresponding TFT-LCLV to provide a dark output when a pixel (picture element) or cell of the TFT-LCLV is in an off state.

In an alternate embodiment, each dichroic prism may be replaced by a TFT-LCLV and the different-colored light source means may be replaced by monochromatic light source means; the monochromatic light source means may be respectively mounted in alignment with each TFT-LCLV for projecting an associated monochromatic light beam through each corresponding TFT-LCLV to cause the wearer to see a black and white, three-dimensional image focused at infinity.

Brief Description of the Drawings

Figure 1A is a side elevation view of a helmet mounted display device in accordance with the present invention.

Figure 1B is a top view of the helmet mounted display device of Figure 1A.

Figure 1C is a front elevation view of the helmet mounted display device of Figures 1A and 1B.

Figure 2 is a cross-sectional top view of a dichroic prism assembly.

Detailed Description of the Preferred Embodiments

In accordance with the present invention, a helmet-mounted display 1 has a pair of dichroic prism assemblies 10 mounted side by side in a rear portion of a helmet 11 (Figures 1A, 1B and 1C). A top cross-sectional view of a dichroic prism assembly 10 is shown in Figure 2. Each of the juxtaposed dichroic prism assemblies 10 is formed by joining four isosceles-right triangle prisms 12a, 12b, 12c and 12d together at their equal-length sides 14 and 16 to form a substantially cubically-shaped prism. A first dichroic interface layer 18, which reflects red light, is positioned between equal-length sides 14 and extends diagonally in one direction through dichroic prism assembly 10. A second dichroic interface layer 20, which reflects blue light, is positioned between equal-length sides 16 and extends diagonally through dichroic prism assembly 10 in a direction substantially perpendicular to first dichroic layer 18.

A first thin-film-transistor/liquid crystal light valve (TFT-LCLV) 22a is mounted on a prism assembly back face 24, opposite to an outlet or projection face 26 of prism assembly 10; other TFT-LCLVs 22b and 22c are each respectively mounted on opposite side faces 28 and 30 of prism assembly 10. A green light source 32 is mounted in alignment with TFT-LCLV 22a; a red light source 34 or a blue light source 36 is respectively mounted in alignment with an associated one of TFT-LCLV 22b or 22c. Light sources 32, 34 and 36 are preferably fluorescent lamps with appropriate colored phosphors and with total power requirements of under 15 watts so as to maintain power dissipation within the helmet (which is preferably vented to provide convection cooling) at a low enough level to avoid causing discomfort to the wearer. Although each of sources 32, 34 and 36 is represented as a single fluorescent lamp, each source would preferably comprise three 1.5 watt fluorescent lamps. Red light source 34 or blue light source 36 are located so that light from each will be respectively incident upon red-light-reflecting layer 18 or blue-light-reflecting layer 20. Light from green light source 32 will be transmitted through dichroic layers 18 and 20. The combination of dichroic prism assembly 10 and one of TFT-LCLVs 22a, 22b or 22c will cause the polarization of a light beam passing through them to rotate; a polarization filter 38a, 38b or 38c is respectively mounted between an associated light source 32, 34 or 36 and an associated one of TFT-LCLVs 22a, 22b or 22c, to counter-rotate the light beam to cause the light output through a pixel of one of the TFT-LCLVs to be dark when the pixel cell is in an off state. The dichroic prism assembly, TFT-LCLVs and light sources may be suitably mounted in a housing 40.

In operation, the pixels of TFT-LCLVs 22a, 22b and 22c will act as multiple shutters to control the presence and intensity of red, green or blue light beams entering each side of dichroic prism assembly 10. Dichroic prism assembly 10 then synthesizes each separate beam of colored light to form a full-color image which is outwardly projected from the projection, or outlet, face 26 of prism assembly 10.

Referring again to Figures 1A, 1B and 1C, the pair of TFT-LCLV-containing prism assemblies 10 are located at the back of the helmet to balance the weight of a collimator-combiner means 44 mounted in a front portion of the helmet; means 44 will be described in more detail hereinafter. A synthesized light beam projected from the outlet face 26 of each dichroic prism provides a pair of full-color images. Each of a pair telecentric projection means 46, for preventing divergence of the synthesized light beams, is mounted in an optical path between each aichroic prism assembly outlet 26 and an associated one of a pair of projection lenses 48, each mounted proximate to the front portion of the helmet. Each telecentric projection means 46 typically includes a pair of relay lenses 50 which co-act to form an image at a position 52 (shown by a broken line in Figure 1A and 1B) between the associated projection lenses 48 and the relay lens 50 nearest thereto.

Collimator-combiner means 44 includes the pair of projection lenses 48, a spherical reflector 54 mounted in the front of helmet 11, and a plane reflector 56 mounted in helmet 11 at a location proximate to the helmet wearer's forehead (Figure 1A). Lenses 48 and reflectors 54 and 56 are positioned relative to the helmet wearer's eyes so as to project an image into each eye of the wearer to cause the wearer to see an undistorted, three-dimensional, full-color image at infinity. This occurs because lenses 48 project the images on an upper portion of spherical reflector 54 for reflection of the images laterally and downwardly to plane reflector 56. The reflected light beams form a distorted real image approximately at plane reflector 56. Because of the angle of incidence of the reflected light beams from spherical reflector 54, plane reflector 56 will reflect the light beams laterally and downwardly back to a lower portion 54' of spherical reflector 54 (Figure 1A); this spherical reflector portion 54' will then reflect and collimate the light beam and project an undistorted image on this second bounce from spherical reflector 54 into each eye of the wearer. If a view of the real world is desired with the projected image superposed thereon, the lower portion 54' (Figures 1A and 1C) of spherical reflector 54 will then be a partially reflecting surface. It should be noted that a single set of reflector optics is used to form an independent image for each eye, thus offering a very simple system without any obscuring structure in front of the wearer's eyes. Also, since spherical reflector 54 is substantially dome-shaped, the reflected images will cross when reflected by spherical reflector 54 and plane reflector 56, as shown in Figure 1B. Thus, the image produced by the dichroic prism assembly on the left side of the helmet will be projected into the wearer's right eye and the right side dichroic prism assembly image will be projected into the left eye. Each of dichroic prisms 10, associated relay lenses 50 and associated projection lenses 48 may all be positioned to provide optical paths 58 (shown by broken lines in Figure 1B) which may each be adjusted to a selected angle α relative to the normal of plane reflector 56 to insure the proper angles of reflection from the spherical and plane reflectors for optimum viewing of the images by the wearer.

The brightness of light sources 32, 34 and 36 may be about 7000 foot-lamberts. Loss of brightness through TFT-LCLVs 22a, 22b and 22c, and dichroic prism 10 will be about 90 percent of the light sources. Transmission loss through the remaining optics may be about 20 percent if a view of the real world is not combined with the image. With this embodiment, the viewer/wearer would see an image having a brightness of about 560 foot-lamberts. The transmission loss when the images are combined with a view of the real world will be about 60 percent which will provide an image having a brightness of about 280 foot-lamberts to the viewer/wearer.

The resolution of the image projected to the viewer/wearer will be a function of the number of pixels in each TFT-LCLV. A matrix array of about 300 X 300 to 500 X 500 pixels should provide adequate resolution in most applications. The helmet-mounted display of the present invention is expected to increase the weight of the helmet by less than about 2 lb.. Dichroic prism assemblies 10 and associated lenses will weigh about 0.8 lb., and the spherical reflector and plane reflector, if manufactured from a plastic material, will each weigh about 0.3 lb. The mounting components for the dichroic prism and optics will weigh about 0.5 lb. The constituent parts of the present invention will be uniformly distributed as much as practicable when mounted in the helmet to keep wearer fatigue at a minimum. The weight of components of other systems, such as audio components and the like, which may be mounted on a helmet, may also be considered with respect to balancing the helmet to further reduce wearer fatigue.

Those skilled in the art will recognize that a single image could be projected into either one or both eyes of a wearer by use of a single dichroic prism assembly and set of optical components similar to those described above, if a three-dimensional display is not desired. Likewise, monochromatic light sources could be used if a color display is not desired or two different-colored light sources could be used and the dichroic prism could be configured accordingly (triangular-shaped) if a full-color display is not desired.

It will be readily understood by those skilled in the art that the present invention is not limited to the specific embodiments described and illustrated herein. Different embodiments and adaptations besides those shown herein and described, as well as many variations, modifications and equivalent arrangements, will now be apparent or will be reasonably suggested by the foregoing specification and drawings, without departing from the substance or scope of the invention. While the present invention has been described herein in detail in relation to its preferred embodiments, it is to be understood that this disclosure is only illustrative and exemplary of the present invention and is made merely for purposes of providing a full and enabling disclosure of the invention. Accordingly, it is intended that the invention be limited only by the spirit and scope of the claims appended hereto.

What is claimed is:

1. A display device mountable in a helmet, comprising:

light source means for projecting at least one light beam, said light source means comprising at least one fluorescent lamp, said at least one light beam having a multiplicity of light segments;

means for controlling the quantity of light in each source means light segment;

telecentric projection means for collimating and focusing the at least one light beam, to form an image; and

collimator-combiner means for projecting an undistorted virtual image from said telecentric projection means into at least one eye of a wearer.

2. The device of claim 1, wherein said light source means projects a plurality of different-colored light beams.

3. The device of claim 2, further comprising a dichroic prism assembly, in an optical path between said light source means and said telecentric projection means, having a plurality of side faces each receiving a different light beam, and a projection face from which emerges a light beam synthesized from all received beams.

4. The device of claim 1, wherein said light source means projects a monochromatic light beam.

5. The device of claim 1, wherein said light controlling means comprises a plurality of matrix-addressed liquid crystal light valves.

6. The device of claim 5, further comprising polarization means, mounted between said light source means and each of said liquid crystal light valves, for selecting the polarization of light to be transmitted.

7. The device of claim 1, wherein said telecentric projecting means comprises a pair of relay lenses.

8. The device of claim 1, wherein said collimator-combiner means comprises:

a spherical reflector;

lens means for projecting the image from said telecentric projection means onto said spherical reflector;

a plane reflector receiving from said spherical reflector a reflected image and causing the received image to be reflected back to said spherical reflector as a distorted image; and

said spherical reflector further reflecting the distorted image to appear as an undistorted image in said at least one eye.

9. The device of claim 8, wherein said spherical reflector comprises a partially-reflecting portion alignable with the wearer's eyes to permit viewing of the real world through said portion even while the undistorted image is superposed on the real world view.

10. A display device mountable in a helmet, comprising:

first and second light source means, each comprising at least one fluorescent lamp for projecting at least one light beam, each of said at least one light beam having a multiplicity of light segments;

means for controlling the quantity of light in each source means light segment;

a pair of telecentric projection means for independently collimating and focusing each light beam to form one of a pair of images; and

collimator-combiner means for projecting, from each telecentric projection means, an undistorted image into an associated eye of a wearer to cause the wearer to see a three-dimensional virtual image.

11. The device of claim 10, wherein said first and second light source means each project a monochromatic light beam.

12. The device of claim 10, wherein said first and second light source means each project a plurality of different-colored light beams.

13. The device of claim 12, further comprising a pair of dichroic prism assemblies, each respectively in an optical path between one of said light source means and one of said telecentric projection means, and each having a plurality of side faces, each side face receiving a different light beam, and each assembly having a projection face from which emerges a light beam synthesized from all beams received by the assembly.

14. The device of claim 13, wherein said dichroic prism assemblies, said pair of telecentric projection means and said collimator-combiner means are each mounted at locations within the helmet to provide a weight-balanced helmet.

15. The device of claim 13, wherein each of said light source means comprises:

a green light source mounted adjacent to a dichroic prism back face which is opposite to said projection face;

a red light source mounted adjacent to one dichroic prism side face between said back face and said projection face; and

a blue light source mounted adjacent to another dichroic prism side face opposite to said one side face.

16. The device of claim 15, wherein each of said dichroic prism assemblies comprises four isosceles right triangular-shaped prisms attached together at their equal sides to form a cubically-shaped prism with each hypotenuse of the triangular-shaped prisms corresponding to a face of said cubically-shaped dichroic prism.

17. The device of claim 16, wherein each of said dichroic prism assemblies further comprises:

first dichroic interface means for reflecting red light, extending diagonally through said dichroic prism between a first vertex, formed by said one side face and said back face, and a second vertex, formed by said another side face and said projection face; and

second dichroic interface means for reflecting blue light, extending diagonally through said dichroic prism between a third vertex, formed by said another side face and said back face, and a fourth vertex, formed by said one side face and said projection face.

18. The device of claim 10, wherein said light controlling means comprises a plurality of matrix-addressed liquid crystal light valves.

19. The device of claim 18, further comprising polarization means, mounted between each of said light source means and each of said liquid crystal light valves, for selecting the polarization of light to be transmitted.

20. The device of claim 10, wherein each telecentric projecting means comprises a pair of relay lenses.

21. The device of claim 10, wherein said collimator-combiner means comprises:

a spherical reflector;

a pair of lens means, one for projecting each of the pair of images onto said spherical reflector;

a plane reflector receiving from said spherical reflector a pair of reflected images and causing each received image to be reflected back to said spherical reflector as a distorted image; and

said spherical reflector further reflecting each distorted image to appear as an undistorted virtual image in an associated eye of the wearer.

22. The device of claim 21, wherein an optical path is provided between each of said first and second light source means and an associated one of said pair of projecting lens means, each of said optical paths being at a selected angle relative to the normal of said plane reflector to provide said virtual image.

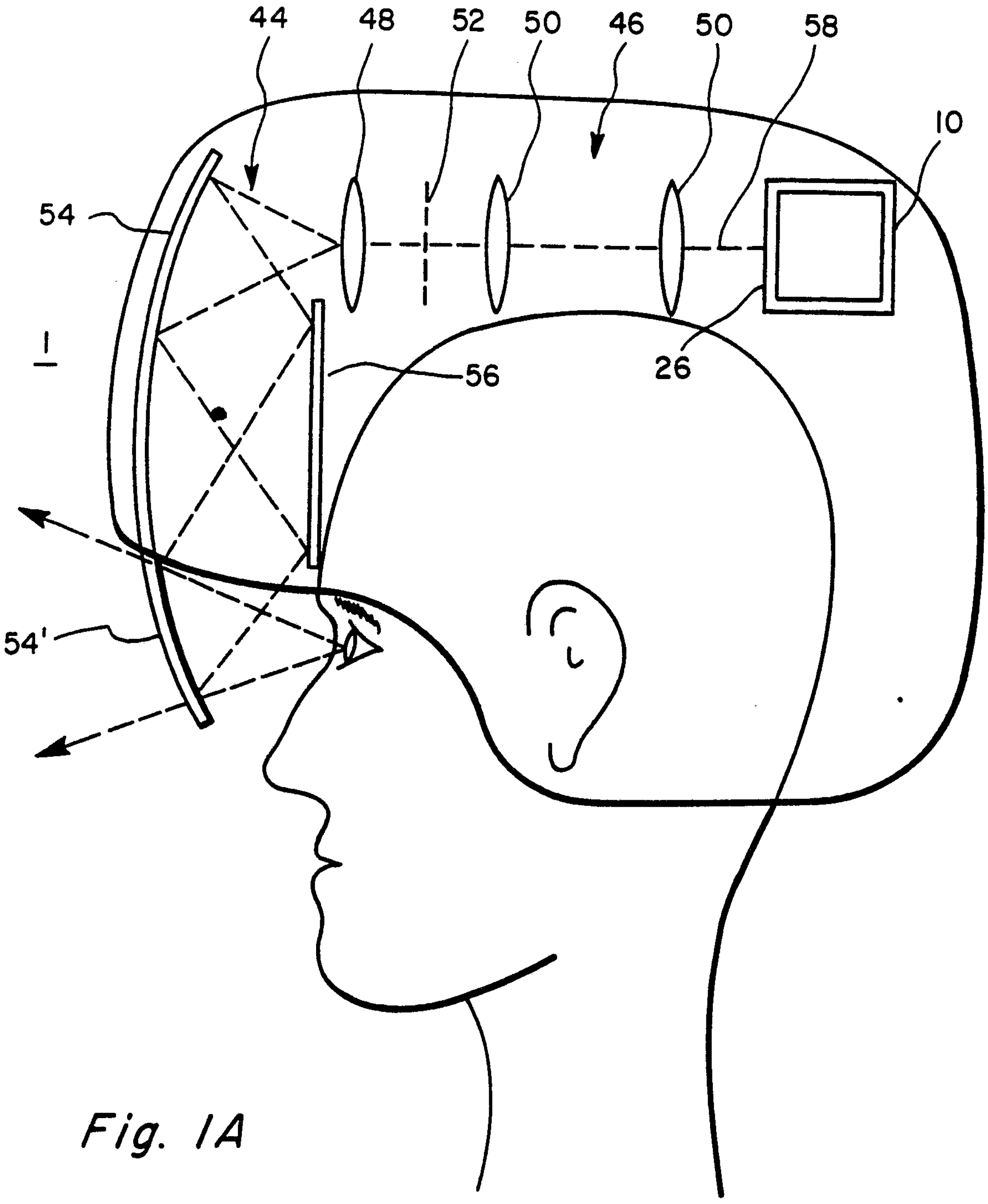

Fig. 1A

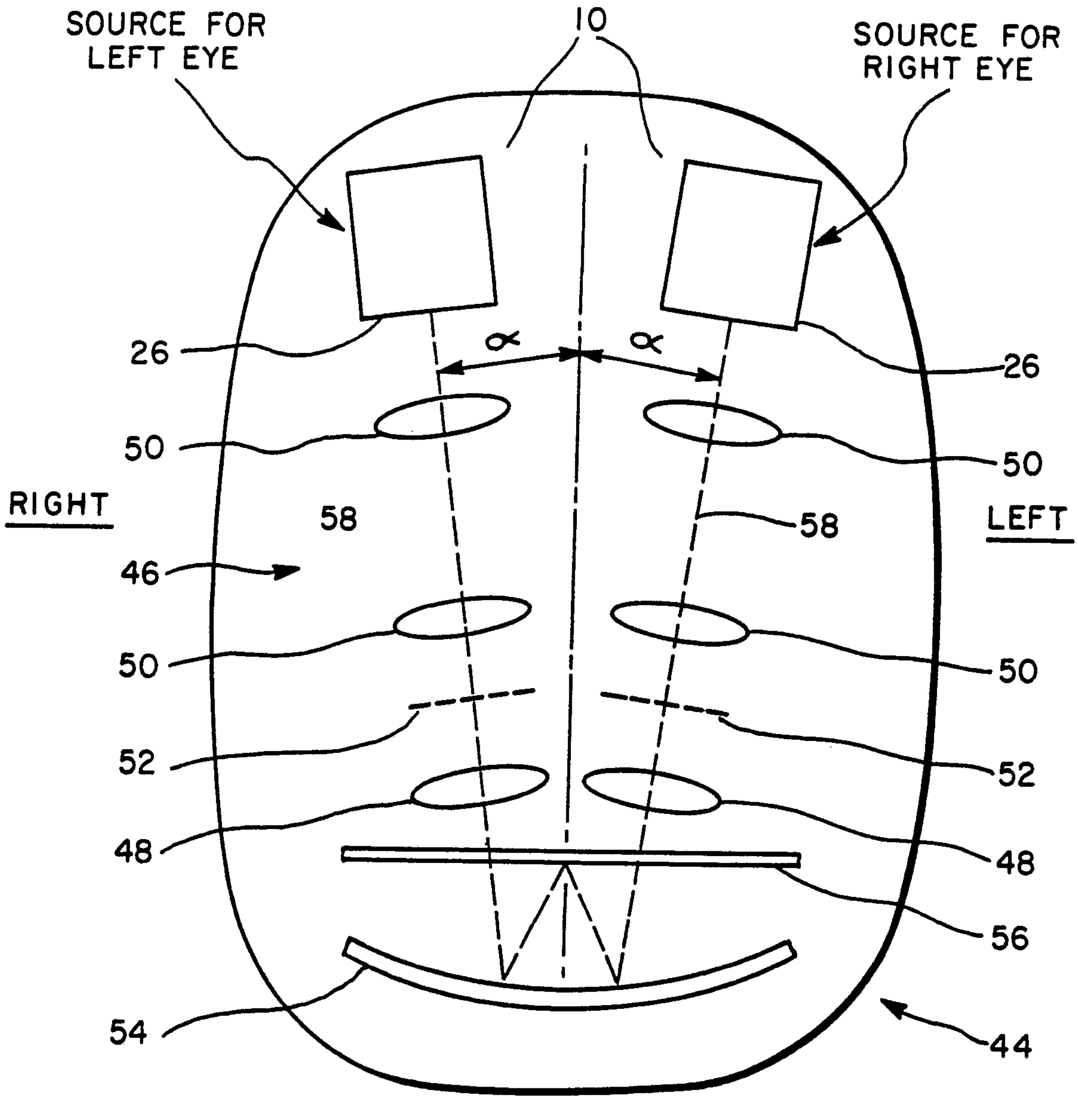
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Fig. 1B

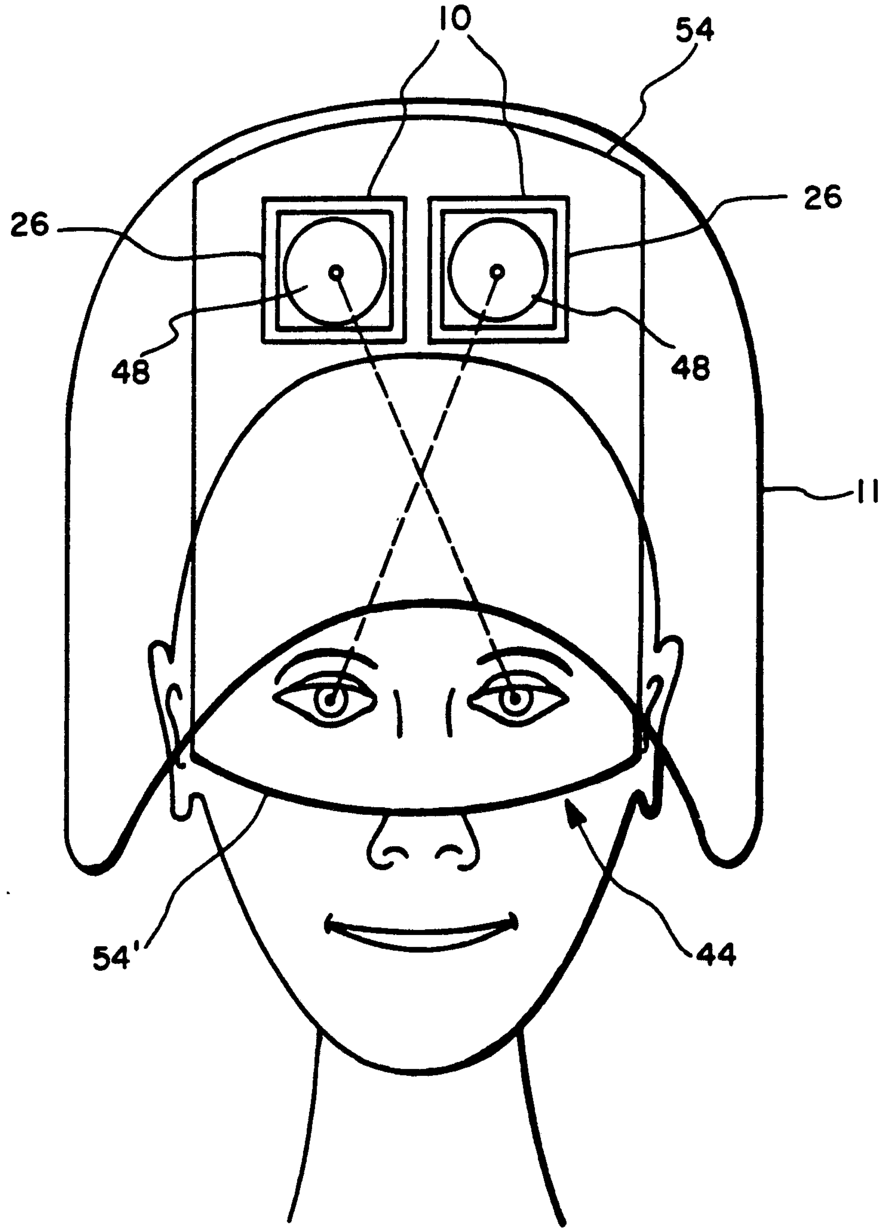
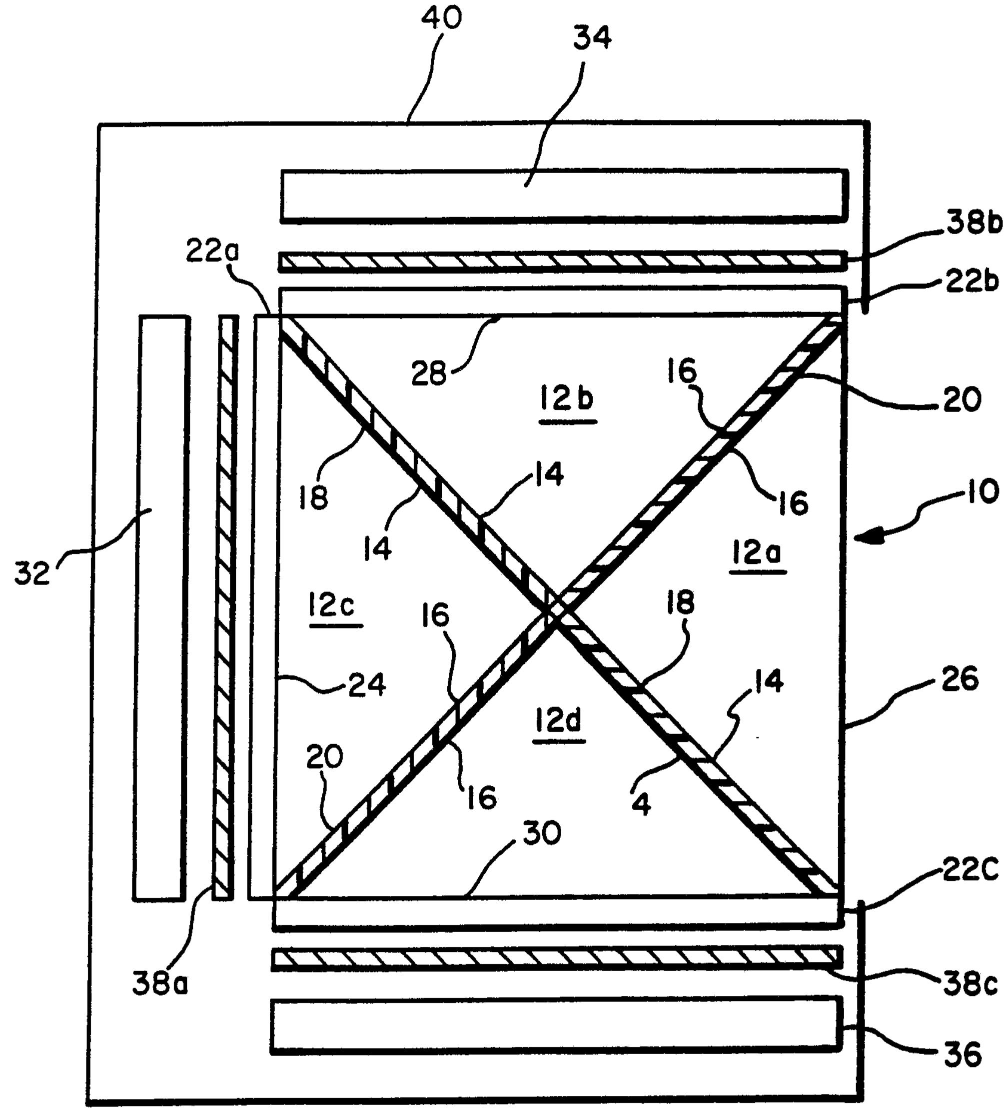


Fig. 1C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22C
38a
38c
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Fig. 2