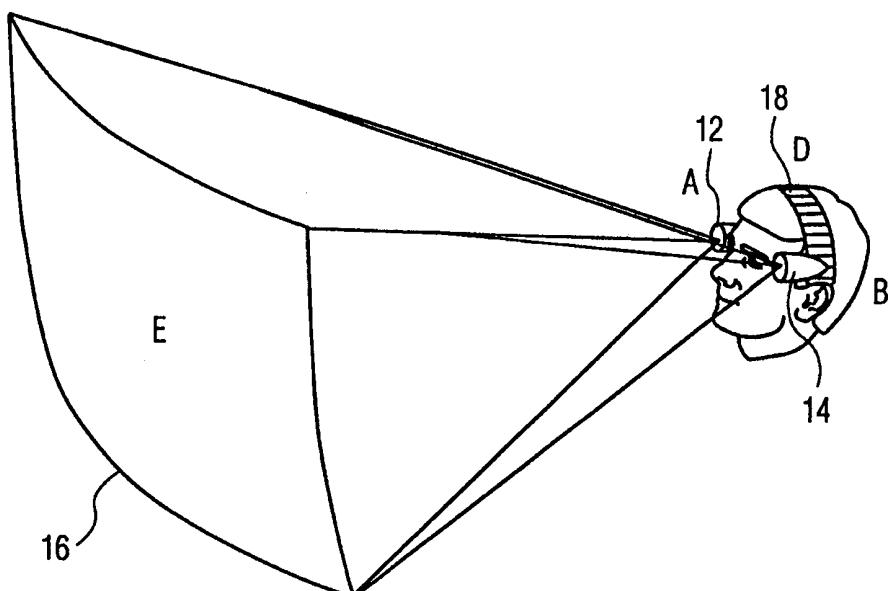




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(54) Title: HEAD-MOUNTED PROJECTION DISPLAY SYSTEM



(57) Abstract

A head-mounted projection display system is characterized by a pair of head-mounted low-power image projectors mounted adjacent the eyes of the viewer, and aimed to project in a direction along the line of sight of the viewer toward a high-gain, retro-reflective screen (16). Stereoscopic viewing is enabled by projecting separate images to the right and left projectors. The retro-reflectivity of the screen (16) ensures that the right and left images will be returned to the right and left eye, respectively.

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Head-mounted projection display system.

This invention relates to a head-mounted projection display system, and more particularly relates to such a display system in which the display is stereoscopic.

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A variety of head-mounted displays are in use or have been proposed. Usually they involve a CRT or a spatial light modulator coupled to a source of light to create the display image. In the simplest versions, the images are viewed directly by the eye, assisted by suitable optics. See, for example, Japanese Kokai 4-34588(A). Some versions permit the 10 ambient environment to be viewed through the apparatus while information is added to the observer's view from the display. See, for example, U.S. patent 5,677,795.

In UK patent application GB 2 043 940 A, a ground-based craft-flight simulator is described, in which separate right and left light beams from a laser-scanning image 15 generator are fed to right and left projection lenses mounted on a helmet above the eyes of a wearer-trainee, and projected onto a retro-reflective viewing screen. A diffraction grating on the front of the screen adjusts the angle of the retro-reflected image, so that the projected beams are reflected onto a plane mirror mounted on the helmet between the projection lenses and the eyes of the viewer. Motors mounted on the helmet rotate the mirror, to achieve 20 scanning of the reflected light beams onto the screen to build up the display image.

A drawback of the known system is that it is complex and would be expensive to implement, limiting its applicability to specialized uses such as military or commercial pilot training.

25

Accordingly, it is, inter alia, an object of the invention to provide a simple, low-power, head-mounted projection display system.

Thereto, a system according to the invention is defined in Claim 1.

A simple low-power, head-mounted projection display system, particularly one which provides stereoscopic viewing, would be useful in a variety of applications, notably virtual reality systems, useful, for example, in education, training, and/or entertainment.

5 In accordance with one aspect of the invention, there is provided a head-mounted projection display system comprising head gear including at least one low-power projector positioned such that the images from the projector are directed away from the viewer's eyes. More specifically, the projector is mounted so as to project an image in a direction along the viewer's line-of-sight. Preferably, a pair of projectors are mounted on
10 opposite sides of the head gear, adjacent the viewer's eyes, and each projector is aimed to project an image in a direction along the viewer's line-of-sight.

A further advantage of the system according to the invention is that stereoscopic viewing is possible.

15 Further aspects of the invention are defined in the dependent Claims.

The projected image is directed to a high-gain, retro-reflective viewing screen, which returns light from the low power projector(s) at sufficient brightness for the viewer to see the projected image(s). Due to the small angle of return (on the order of about 1-2
20 degrees), each eye sees only the image from its adjacent projector, enabling stereoscopic viewing in the event that separate images are projected by each projector, without the attenuation, temporal or optical manipulation common to known stereoscopic display systems.

25 The retro-reflective viewing screen is capable of having a wide viewing angle. This characteristic, together with the retro-reflectivity of the screen, permits a single viewer or multiple viewers, each with their own headgear, to see the same image or different images at large angles of view without significant degradation, making possible, for example, one or more viewers moving within the viewing space, or an audience of stationary viewers.

30 These and other, more detailed, aspects of the invention will now be described and illustrated with reference to the Figures.

Fig. 1 is a perspective view of one embodiment of the projection system of the invention, including a pair of low power projectors mounted on headgear, and a high-gain, retro-reflective screen;

Fig. 2 is a schematic cross-section view of one of the low power projectors of
5 Fig. 1;

Fig. 3 is a detailed cross-section view of a portion of the screen of Fig. 1; and

Fig. 4 is a schematic representation of a spherical viewing room with
transparent floor in accordance the invention.

10

In Fig. 1, two low power projectors 12 and 14 are mounted on the viewer's head close to each eye. Each projector is aimed at the viewing screen 16 along the direction of the line of sight of the adjacent eye of the viewer. The projectors 12 and 14 are stabilized and referenced to the viewer's head by means of a headband 18. Possible alternative headgear
15 include a hat or helmet.

The projectors each include a light source 20, an electro-optical light modulator 22, such as an LCD, and a projection lens 24, in the arrangement shown schematically in Fig. 2. Light may alternatively be supplied from a remote light source, e.g., via optical fibers.

20 Display information, such as video or computer generated display signals, are supplied to the modulator 22 via electrical cables, not shown.

The viewing screen 16 is retro-reflective. That is, it returns all incident light back to the source within a narrow angle (about 1-2 degrees). Consequently, regardless of
25 changes in the angle of incidence of the projected image caused by movement of the viewer's head, the screen will return the projected image to the viewer. The viewing screen also advantageously can have a very high gain, as high as 1600, for example, enabling the viewer to see the projected image at adequate brightness, despite the low power of the projectors. This low power not only reduces the cost of the system relative to more complex high power
30 systems, but also enables the use of battery powered operation, introducing portability and the possibility of inputting display information, such as computer generated information, by wireless link.

Depending upon the application, the screen could cover a portion of a wall or an entire wall or room. The walls of the room could be curved, e.g., cylindrical or spherical. For example, Fig. 4 shows a spherical room 40 enclosing a transparent floor 42 and viewer 44. In the stereoscopic mode of the invention, such a room 40 could be used to project images 46 and 5 48 above and below viewer 44, for example, to train astronauts, since it would create a perception of floating in space.

In one embodiment, shown in Fig. 3, the screen is composed of a surface of an array of uniformly sized microspheres 30, adhered to a substrate 34 by a reflective paint 32.

10 The microspheres can be of any size above the wavelength of the light, and can also be of varying sizes. One way of constructing a large screen surface would be to blow the microspheres onto a substrate having a previously applied tacky base, e.g., wet reflective paint. As is known, one alternative to reflective microspheres is the so-called corner cube. Retro-reflective screens are also commercially available. Two examples are the 3M Special 15 Effects Projection screens #7610 and #7615.

The invention has been described in terms of a limited number of embodiments. Other embodiments, variations of embodiments and art-recognized equivalents will become apparent to those skilled in the art, and are intended to be encompassed within the scope of the 20 invention, as set forth in the appended claims.

CLAIMS:

1. A head-mounted projection display system comprising viewer headgear and a projection display screen (16), the headgear comprising at least one display image projector (12,14), and means (18) for mounting the projector adjacent an eye of the viewer in a manner to project an image in the direction of the line-of-sight of the viewer, and the screen (16) being
5 a retro-reflective screen.
2. The head-mounted projection display system of claim 1 in which the headgear comprises two projectors (12,14) mounted on opposite sides of the headgear.
- 10 3. The head-mounted projection display system of claim 1 in which the projection screen (16) comprises an array of reflective microspheres (30) on a substrate (34).
4. The head-mounted projection display system of claim 3 in which the substrate (34) is curved.
15
5. The head-mounted projection display system of claim 3 in which the substrate (34) is the wall of a room.
6. The head-mounted projection display system of claim 4 in which the substrate
20 (34) is spherically or hemispherically shaped.
7. The head-mounted projection display system of claim 5 in which the substrate is a spherically shaped room (40) enclosing a transparent floor (42).
- 25 8. The head-mounted projection display system of claim 1 in which the low power projector comprises an electro-optical light modulator (22) and a projection lens (24).
9. The head-mounted projection display system of claim 8 in which the electro-optical light modulator (22) comprises an LCD.

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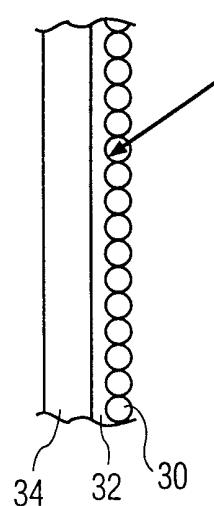
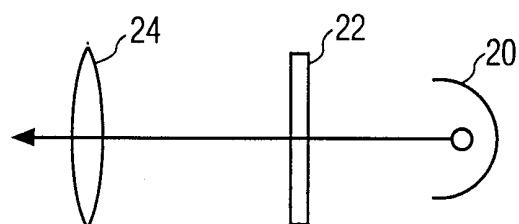
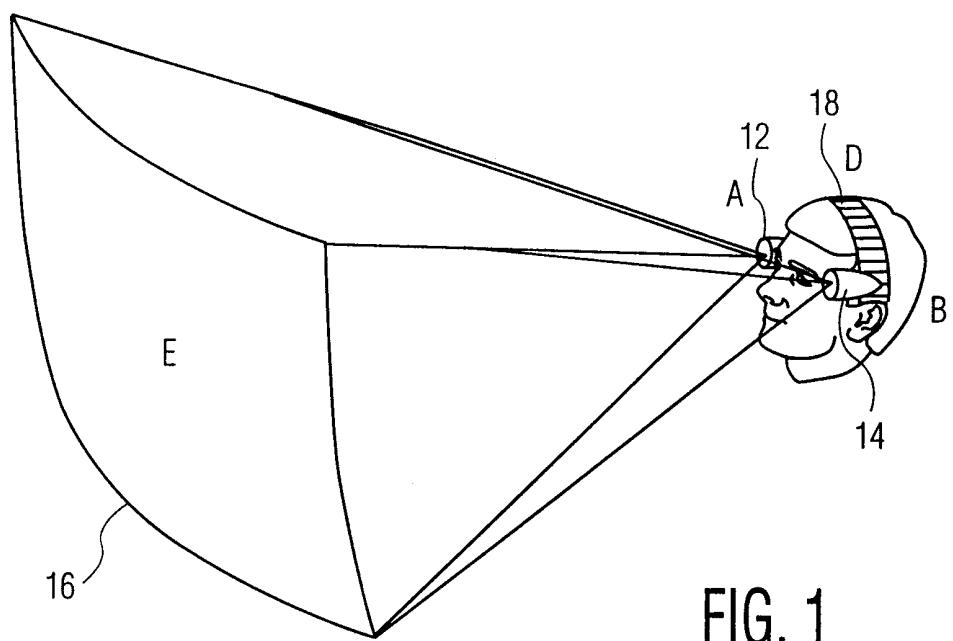


FIG. 3

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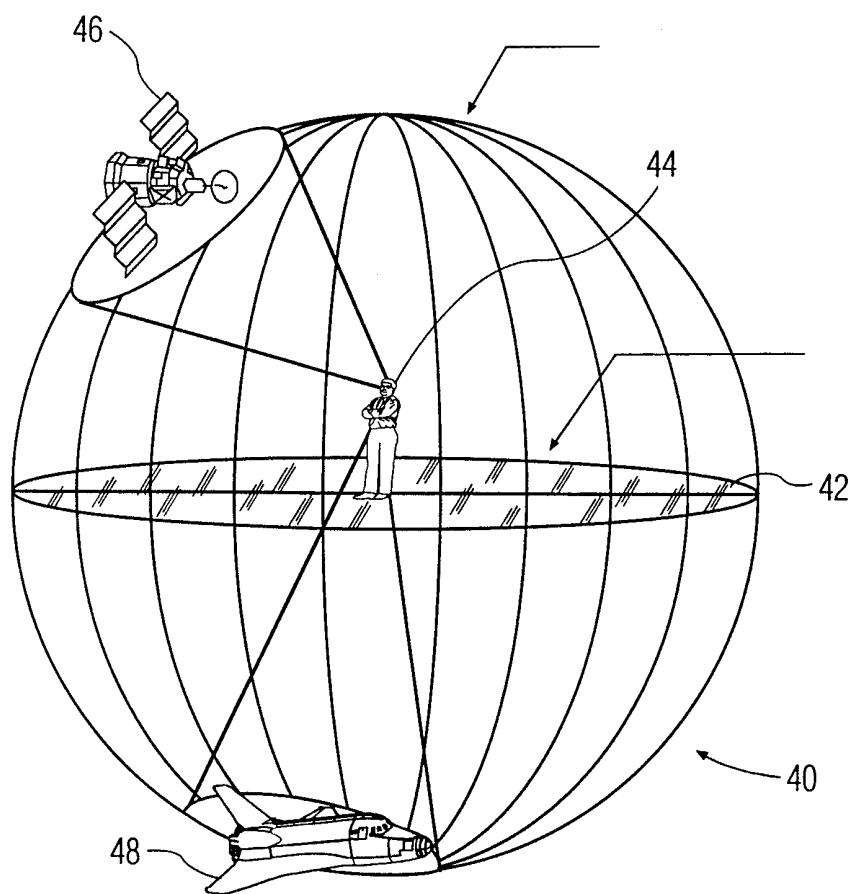


FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02B27/01

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 7 G02B

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 practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 92 18971 A (EVANS & SUTHERLAND COMPUTER) 29 October 1992 (1992-10-29) page 8, line 2 - line 6; figure 1 page 9, line 1 - line 4	1,2
A	page 9, line 23 -page 11, line 3; figures 3,4 ---	4
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A	GB 2 043 940 A (REDIFON SIMULATION LIMITED) 8 October 1980 (1980-10-08) cited in the application abstract; figure 1 ---	4
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Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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3 February 2000	10/02/2000
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 052 932 A (TRANI) 1 October 1991 (1991-10-01) column 3, line 46 - line 55; figures 1,3 ---	5-7
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 99/09188

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