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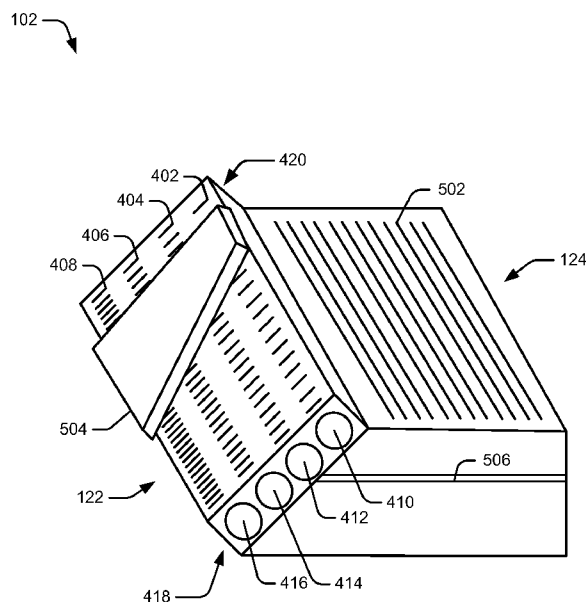
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[Continued on next page]

(54) Title: WIDE FIELD-OF-VIEW VIRTUAL IMAGE PROJECTOR

**Fig. 5**

(57) Abstract: A wide field-of-view virtual image projector includes a rod light guide 122 that is embossed with at least a first diffraction grating 402, 404, 406, 408 and a second diffraction grating 402, 404, 406, 408 that is substantially parallel to the first diffraction grating. The first diffraction grating is configured to receive a first light ray, and to project first diffracted light rays from the rod light guide at a first range of angles. The second diffraction grating is configured to receive a second light ray, and to project second diffracted light rays from the rod light guide at a second range of angles. The spatial frequencies of diffraction gratings 402, 404, 406, and 408 differ so that the diffracted light rays projected from each diffraction grating is projected at a different range of angles. Together, the different ranges of angles combine to form a wide field-of-view in the horizontal direction. The virtual image projector further includes a slab light guide 124 configured to receive the first diffracted light rays and the second diffracted light rays, and to diffract the first diffracted light rays and the second diffracted light rays out of the slab light guide to generate a virtual image with a wide field-of view.

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- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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WIDE FIELD-OF-VIEW VIRTUAL IMAGE PROJECTOR

BACKGROUND

[0001] A virtual image can be made by pointing a video projector into a light guide embossed with a grating to project the virtual image from a surface of the light guide. A pair of eyeglasses, or spectacles, can include a virtual image projector to project a virtual image in front of the eyes of a wearer of the eyeglasses. Virtual image projectors small enough to be placed on a pair of eyeglasses, however, typically project a virtual image with a narrow field-of-view.

SUMMARY

[0002] This document describes techniques and apparatuses for implementing a wide field-of-view virtual image projector. A wide field-of-view virtual image projector includes a rod light guide that is embossed with at least a first diffraction grating and a second diffraction grating that is substantially parallel to the first diffraction grating. The first diffraction grating is configured to receive first light rays, and to project first diffracted light rays from the rod light guide at a first range of angles. The second diffraction grating is configured to receive second light rays, and to project second diffracted light rays from the rod light guide at a second range of angles. The virtual image projector further includes a slab light guide configured to receive the first diffracted light rays and the second diffracted light rays, and to diffract the first diffracted light rays and the second diffracted light rays out of the slab light guide to generate a virtual image with a wide field-of view.

[0003] This summary is provided to introduce simplified concepts in a simplified form that are further described below in the Detailed Description. This summary is not intended to identify essential features of the claimed subject matter, nor is it intended for use in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Embodiments of techniques and apparatuses for implementing a wide field-of-view virtual image projector are described with reference to the following drawings. The same numbers are used throughout the drawings to reference like features and components:

Fig. 1 illustrates an example environment in which a wide field-of-view virtual image projector can be implemented.

Fig. 2 illustrates an example light guide embossed with a single diffraction grating.

Fig. 3 illustrates an example of the field-of-view of a light guide embossed with a

single diffraction grating.

Fig. 4 illustrates a more-detailed example of a rod light guide of a virtual image projector.

5 Fig. 5 illustrates a more-detailed example of a rod light guide and a slab light guide of a virtual image projector.

Fig. 6 illustrates a more-detailed example of a slab light guide of a virtual image projector.

Fig. 7 illustrates an example method for controlling a wide field-of-view virtual image projector.

10 Fig. 8 illustrates an example device in which techniques for a wide field-of-view virtual image projector can be implemented.

DETAILED DESCRIPTION

Overview

15 [0005] A virtual image can be made by pointing a video projector into a light guide embossed with a grating to project the virtual image from a surface of the light guide. A pair of eyeglasses, or spectacles, can include a virtual image projector to project a virtual image in front of the eyes of a wearer of the eyeglasses. A typical virtual image projector small enough to be placed on a pair of eyeglasses, however, projects a virtual image with a horizontal field-of-view of only 30 degrees.

20 [0006] This document describes techniques and apparatuses for implementing a wide field-of-view virtual image projector. A wide field-of-view virtual image projector includes a rod light guide that is embossed with at least a first diffraction grating and a second diffraction grating that is substantially parallel to the first diffraction grating. The first diffraction grating is configured to receive first light rays, and to project first
25 diffracted light rays from the rod light guide at a first range of angles. The second diffraction grating is configured to receive second light rays, and to project second diffracted light rays from the rod light guide at a second range of angles. The virtual image projector further includes a slab light guide configured to receive the first diffracted light rays and the second diffracted light rays, and to diffract the first diffracted light rays
30 and the second diffracted light rays out of the slab light guide to generate a virtual image with a wide field-of view.

[0007] In some embodiments, the virtual image projector may be coupled to a pair of eyeglasses to generate the virtual image with the wide field-of-view in front of a lens of

the eyeglasses so that a wearer of the eyeglasses, looking through the lens of the eyeglasses, sees the virtual image.

Example Environment

[0008] Fig. 1 is an illustration of an example environment 100 in which a wide field-of-view virtual image projector (herein a “virtual image projector”) can be implemented. Environment 100 can be implemented in a virtual image display device 102, which is illustrated, by way of example and not limitation, as a head-mounted display device 104 or a flat-panel display device 106. Head-mounted display device 104 can include a pair of eyeglass, sunglasses, goggles, or any other type of head-mounted display device. Flat-panel display device 106 may include any type of flat-panel display device that can generate virtual, three-dimensional (3D), and/or multi-view images, such as a television, a desktop computer, a laptop, a mobile computing device, or a tablet computing device.

[0009] Virtual image display device 102 includes processor(s) 108 and computer-readable media 110, which includes memory media 112 and storage media 114. Computer-readable media 110 also includes a controller 116. How controller 116 is implemented and used varies, and is described as part of the methods discussed below.

[0010] Virtual image display device 102 also includes virtual image projector 118 that can be controlled by controller 116 to generate a wide field-of-view virtual image. When device 102 is implemented as head-mounted display device 104, virtual image projector 118 can be controlled to generate a wide field-of-view virtual image that can be viewed by a wearer of the head-mounted display device, referred to as “viewer” herein. For example, virtual image projector 118 may be coupled to the lens of a pair of eyeglasses to generate a virtual image of infinitely distant objects directly in front of the viewer’s eye to cause a lens of the viewer’s eye to adjust to an infinite or near-infinite focal length to focus on the objects. Virtual image projector 118 may be at least partially transparent so that the viewer can see external objects as well as virtual images when looking through a lens of head-mounted display device 104. In addition, it is to be appreciated that virtual image projector 118, in some embodiments, may be small enough to fit onto the lens of a pair of eyeglasses without being noticeable to a viewer wearing the eyeglasses.

[0011] In some cases, virtual image projector 118 can be implemented as two projectors to generate a virtual image in front of each of the viewer’s eyes. When two projectors are used, each virtual image projector 118 can project the same virtual image concurrently so that the viewer’s right eye and left eye receive the same image at the same time. Alternately, the projectors may project slightly different images concurrently, so

that the viewer receives a stereoscopic image (e.g., a three-dimensional image). For purposes of this discussion, however, virtual image projector 118 will be described as a single projector that generates a single virtual image.

[0012] Virtual image projector 118 includes an illuminator 120, a rod light guide 122, and a slab light guide 124. In some embodiments, rod light guide 122 and slab light guide 124 are polyhedral waveguides that transmit light by total internal reflection. The length of rod light guide 122 is substantially equal to the length of slab light guide 124. The height, however, of slab light guide 124 is significantly greater than the height of rod light guide 122. It is to be appreciated, however, that rod light guide 122 and slab light guide 124 are not limited to any specific size or shape.

[0013] Illuminator 120 can include a red laser, green laser, and blue laser. The red, green, and blue lasers may be semiconductor lasers, such as low-power diode lasers, or any other suitable lasers. The red, green, and blue lasers can be independently biased and modulated by controller 116. Illuminator 120 may also include merging optics that are configured to merge the monochromatic emission from each of the lasers to form a beam or ray of light. As described herein, the term “light ray” will be used to describe a “beam” or “ray” of light emitted by illuminator 120.

[0014] Fig. 2 illustrates an example 200 of a light guide 202 embossed with a single diffraction grating. In this example, an end face 204 of light guide 202 is positioned adjacent an illuminator 206 and is configured to receive a light ray 208 from illuminator 206. Light ray 208 passes through light guide 202 to opposite end face 210, where it encounters a redirection optic 212. Redirection optic 212 can be implemented as mirror or refractive structure, and is configured to vary an angle at which light rays are injected into light guide 202. In this example, redirection optic 212 reflects light ray 208 back into light guide 202 at an angle greater than the critical angle for total internal reflection. After reflecting off of redirection optic 212, light ray 208 propagates away from opposite end face 210 by total internal reflection. However, each time light ray 208 encounters a diffraction grating 214, part of light ray 208 is diffracted out of light guide 202 to form parallel diffracted light rays 216.

[0015] Light guide 202 projects diffracted light rays with a narrow field-of-view in the horizontal plane because it is equipped with a single diffraction grating. Consider, for example, Fig. 3, which illustrates an example 300 of the field-of-view light guide 202 embossed with single diffraction grating 214. In Fig. 3, a first light ray 302 exits light guide 202 when it encounters diffraction grating 214 if it exceeds the critical angle, which

is approximately 45 degrees. Additionally, a second light ray 304 propagating at an angle of more than 75° may also exit light guide 202 when it encounters diffraction grating 214. The range of angles at which single diffraction grating 214 of light guide 202 projects light rays, therefore, is approximately 30 degrees. This range of angles is substantially equal to the field-of-view of light guide 202. In accordance with various embodiments, therefore, rod light guide 122 is configured with at least two diffraction gratings that enable virtual image projector 118 to generate virtual images with a wide field-of-view in the horizontal direction.

[0016] Fig. 4 illustrates a detailed example of rod light guide 122 of virtual image projector 118. In this example, rod light guide 122 is embossed with diffraction gratings 402, 404, 406, and 408. It is to be noted, however, that rod light guide 122 may be embossed with less than or more than four different diffraction gratings. In one embodiment, for example, rod light guide 122 is embossed with two diffraction gratings. Gratings 402, 404, 406, and 408 are oriented substantially parallel to each other, and are each configured to receive a separate light ray at 410, 412, 414, and 416, respectively, of end face 418 of rod light guide 122 from illuminator 120 (not pictured). In an embodiment, rod light guide 122 is a single rod light guide (e.g., a single piece of glass). For example, diffraction gratings 402, 404, 406, and 408 can be embossed onto a single rod light guide. Alternately, rod light guide 122 may include multiple rod light guides stacked side by side, where each rod is embossed with a different diffraction grating. For example, a rod light guide embossed with diffraction grating 402 can be stacked next to a rod light guide embossed with diffraction grating 404, and so on.

[0017] Each of gratings 402, 404, 406, and 408 acts similar to diffraction grating 214 of light guide 202 illustrated in Fig. 2. For example, a light ray received at 410 of end face 418 passes through rod light guide 122 to opposite end face 420, where it encounters a first redirection optic (not pictured). Like redirection optic 212 of Fig. 2, first redirection optic can be implemented as a reflective mirror or refractive structure, and is configured to vary an angle at which light rays are injected into rod light guide 122. In this example, the first redirection optic reflects the light ray back into rod light guide 122 at an angle greater than the critical angle for total internal reflection. After reflecting off of the first redirection optic, the light ray propagates away from opposite end face 420 by total internal reflection. The light ray travels parallel to the sides of rod light guide 122 while reflecting off of the surface embossed with diffraction grating 402 and the surface opposite diffraction grating 402. However, each time the light ray encounters diffraction grating

402, part of the light ray is diffracted out of rod light guide 122 to form parallel diffracted light rays, as shown in Fig. 2. Similarly, each time a light ray injected at 412, 414, or 416 encounters diffraction grating 404, 406, or 408, respectively, part of the light ray is diffracted out of rod light guide 122 to form parallel diffracted light rays, as shown in Fig.

5 2.

[0018] In some embodiments, virtual image projector 118 also includes a second redirection optic (not pictured), which overlays the surface of rod light guide 122 that is embossed with the diffraction gratings. The second redirection optic is configured to reflect the diffracted light rays back through rod light guide 122 and out of the surface opposite the diffraction gratings of rod light guide 122. It is to be noted that gratings 402, 404, 406, and 408 are weak, so they do not alter the diffracted light rays reflected back through rod light guide 122. As will be described in more detail below, the second redirection optic directs the diffracted light rays into slab light guide 124.

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[0019] In accordance with various embodiments, the spatial frequencies of diffraction gratings 402, 404, 406, and 408 differ so that the diffracted light rays projected from each diffraction grating is projected at a different range of angles. In this example, grating 408 has a pitch short enough to project diffracted light rays at a range of angles between 30 degrees and 60 degrees to the surface normal. In contrast, grating 402 has a pitch long enough to project diffracted light rays at a range of angles between -60 degrees and -30 degrees. Similarly, grating 406 is configured to project diffracted light rays at a range of angles between 0 degrees to 30 degrees, and grating 404 is configured to project diffracted light rays at a range of angles between -30 and 0 degrees. Together, the different ranges of angles combine to form a wide field-of-view in the horizontal direction. In Fig. 4, for example, each diffraction grating projects light at a range of angles equal to 30 degrees. By using four diffraction gratings, therefore, the total range of angles is equal to 120 degrees. This enables rod light guide 122 to project light with a wide-field-of-view in the horizontal direction equal to 120 degrees. In embodiments, the ranges may overlap to smooth out any discontinuities.

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[0020] In some embodiments, in order to generate a virtual image with a wide field-of-view, the output from rod light guide 122 is injected into slab light guide 124. Fig. 5 illustrates a more-detailed example of rod light guide 122 and slab light guide 124 of virtual image display device 102. In an embodiment, rod light guide 122 and slab light guide 124 may be a single piece of glass. In other embodiments, however, rod light guide 122 and slab light guide 124 are each separate light guides. As illustrated in Fig. 4, the

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length of rod light guide 122 is substantially equal to the length of slab light guide 124. The height, however, of slab light guide 124 is significantly greater than the height of rod light guide 122. In this example, the surface opposite the diffraction gratings of rod light guide 122 is oriented towards an entry surface of slab light guide 124. Slab light guide 124 is embossed with a diffraction grating 502 that is substantially perpendicular to diffraction gratings 402, 404, 406, and 408 of rod light guide 122. As described above, a second redirection optic 504 is configured to reflect diffracted light rays from rod light guide 122 into slab light guide 124. Second redirection optic 504 is shown partially cut off in Fig. 5, but it is to be appreciated that second redirection optic 504 runs the whole length of rod light guide 122. Slab light guide 124 receives the diffracted light rays from rod light guide 122, and projects the light rays to form a virtual image with a wide field-of-view.

[0021] It is to be noted that slab light guide 124 is thick enough to receive all the light from rod light guide 122 after it has reflected off of second redirection optic 504. However, light from any one grating of rod light guide 122 only partially fills a pupil of the slab. Thus, once the light rays have passed into slab light guide 124, they interact intermittently with diffraction grating 502 and therefore illuminate it at intervals. In some embodiments, therefore, slab light guide 124 is further configured with a partially-reflecting mirror 506. In this example, partially-reflecting mirror 506 is inserted into a plane of slab light guide 124 that is substantially parallel to the surface embossed with diffraction grating 502. Partially-reflecting mirror 506 is configured to reflect a portion, and transmit another portion, of each light ray that comes into contact with the partially-reflecting mirror.

[0022] By reflecting a portion, and transmitting another portion, of each light ray, partially-reflecting mirror 506 turns a single light ray into multiple light rays to ensure that the light projected by slab light guide 124 is uniform across its surface. Consider for example Fig. 6, which illustrates another view of slab light guide 124. In this example, a light ray 602 injected into slab light guide 124 encounters partially-reflecting mirror 506 at 604. When this occurs, partially-reflecting mirror 506 reflects a portion of light ray 602 towards the surface embossed with diffraction grating 502 as light ray 606, and transmits another portion of light ray 602 towards the surface opposite the diffraction gratings as light ray 608. Then, when light ray 606 comes into contact with diffraction grating 502, a portion of light ray 606 is projected from slab light guide 124 as diffracted light ray 610. This process then continues, where each time a light ray strikes partially-reflecting mirror

506 a portion is reflected, and another portion is transmitted. Thus, as illustrated by Fig. 6, partially-reflecting mirror 506 enables slab light guide 124 to turn one light ray into multiple light rays to project a virtual image with a wide field-of-view.

Example Method

5 [0023] Fig. 7 is flow diagram depicting an example method 700 for controlling a virtual image projector to generate a virtual image with a wide field-of-view. Block 702 receives data corresponding to a virtual image (e.g., video data corresponding to a movie or to television programming). For example controller 116 (Fig. 1) receives data corresponding to a virtual image.

10 [0024] Block 704 controls an illuminator to inject first light rays into a first diffraction grating of a rod light guide effective to diffract the first light rays out of the rod light guide at a first range of angles and into a slab light guide to generate the virtual image with a wide field-of-view. For example, controller 116 controls illuminator 120 to inject first light rays into first diffraction grating 402 (Fig. 5) of rod light guide 122 effective to
15 diffract the first light rays out of rod light guide 122 at a first range of angles and into slab light guide 124 to generate the virtual image with a wide field-of-view.

[0025] Block 706 controls the illuminator to inject second light rays into a second diffraction grating of the rod light guide effective to diffract the second light rays out of the rod light guide at a second range of angles and into a slab light guide to generate the
20 virtual image with the wide field-of-view. For example, controller 116 controls illuminator 120 to inject second light rays into second diffraction grating 404 (Fig. 5) of rod light guide 122 effective to diffract the second light rays out of rod light guide 122 at a second range of angles and into slab light guide 124 to generate the virtual image with the wide field-of-view. In various embodiments, the wide field-of-view of the virtual image is
25 equal to the sum of the first range of angles and the second range of angles.

Example Device

[0026] Fig. 8 illustrates various components of example device 800 that can be implemented as any type of client, server, and/or display device as described with reference to the previous Figs. 1-7 to implement techniques enabling a wide field-of-view
30 virtual image projector. In embodiments, device 800 can be implemented as one or a combination of a wired and/or wireless device, a head-mounted display device (e.g., eyeglasses, sunglasses, etc.) as a form of flat panel display, television, television client device (e.g., television set-top box, digital video recorder (DVR), etc.), consumer device, computer device, server device, portable computer device, user device, communication

device, video processing and/or rendering device, appliance device, gaming device, electronic device, and/or as another type of device. Device 800 may also be associated with a viewer (*e.g.*, a person or user) and/or an entity that operates the device such that a device describes logical devices that include users, software, firmware, and/or a combination of devices.

[0027] Device 800 includes communication devices 802 that enable wired and/or wireless communication of device data 804 (*e.g.*, received data, data that is being received, data scheduled for broadcast, data packets of the data, etc.). The device data 804 or other device content can include configuration settings of the device, media content stored on the device, and/or information associated with a user of the device. Media content stored on device 800 can include any type of audio, video, and/or image data. Device 800 includes one or more data inputs 806 via which any type of data, media content, and/or inputs can be received, such as user-selectable inputs, messages, music, television media content, recorded video content, and any other type of audio, video, and/or image data received from any content and/or data source.

[0028] Device 800 also includes communication interfaces 808, which can be implemented as any one or more of a serial and/or parallel interface, a wireless interface, any type of network interface, a modem, and as any other type of communication interface. The communication interfaces 808 provide a connection and/or communication links between device 800 and a communication network by which other electronic, computing, and communication devices communicate data with device 800.

[0029] Device 800 includes one or more processors 810 (*e.g.*, any of microprocessors, controllers, and the like), which process various computer-executable instructions to control the operation of device 800 and to enable techniques for implementing a wide field-of-view virtual image projector. Alternatively or in addition, device 800 can be implemented with any one or combination of hardware, firmware, a system-on-chip (SoC), or fixed logic circuitry that is implemented in connection with processing and control circuits which are generally identified at 812. Although not shown, device 800 can include a system bus or data transfer system that couples the various components within the device. A system bus can include any one or combination of different bus structures, such as a memory bus or memory controller, a peripheral bus, a universal serial bus, and/or a processor or local bus that utilizes any of a variety of bus architectures.

[0030] Device 800 also includes computer-readable storage media 814, such as one or more memory devices that enable persistent and/or non-transitory data storage (*i.e.*, in

contrast to mere signal transmission), examples of which include random access memory (RAM), non-volatile memory (*e.g.*, any one or more of a read-only memory (ROM), non-volatile RAM (NVRAM), flash memory, EPROM, EEPROM, etc.), and a disk storage device. A disk storage device may be implemented as any type of magnetic or optical storage device, such as a hard disk drive, a recordable and/or rewriteable compact disc (CD), any type of a digital versatile disc (DVD), and the like. Device 800 can also include a mass storage media device 816.

[0031] Computer-readable storage media 814 provides data storage mechanisms to store the device data 804, as well as various device applications 818 and any other types of information and/or data related to operational aspects of device 800. For example, an operating system 820 can be maintained as a computer application with the computer-readable storage media 814 and executed on processors 810. The device applications 818 may include a device manager, such as any form of a control application, software application, signal-processing and control module, code that is native to a particular device, a hardware abstraction layer for a particular device, and so on.

[0032] The device applications 818 also include any system components or modules to implement techniques using or enabling a wide field-of-view virtual image projector. In this example, the device applications 818 can include controller 116 for controlling a wide field-of-view virtual image projector.

Conclusion

[0033] This document describes various apparatuses and techniques for implementing a wide field-of-view virtual image projector. Although the invention has been described in language specific to structural features and/or methodological acts, it is to be understood that the invention defined in the appended claims is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as example forms of implementing the claimed invention.

CLAIMS

What is claimed is:

1. A virtual image projector comprising:

5 a rod light guide embossed with at least a first diffraction grating and a second diffraction grating that is substantially parallel to the first diffraction grating, the first diffraction grating configured to receive first light rays from an illuminator and to project first diffracted light rays from the rod light guide at a first range of angles, and the second diffraction grating configured to receive second light rays from the illuminator and to project second diffracted light rays from the rod light guide at a second range of angles;
10 and

a slab light guide configured to receive the first diffracted light rays and the second diffracted light rays, and to project the first diffracted light rays and the second diffracted light rays out of the slab light guide to generate a virtual image with a wide field-of-view.

2. A virtual image projector as described in claim 1, wherein the slab light
15 guide is embossed with a third diffraction grating that is substantially perpendicular to the first diffraction grating and the second diffraction grating, the third diffraction grating causing the first diffracted light rays and the second diffracted light rays to be projected out of the slab light guide to generate the virtual image with the wide field-of-view.

3. A virtual image projector as described in claim 1, wherein the wide field-
20 of-view is equal to the sum of the first range of angles and the second range of angles.

4. A virtual image projector as described in claim 1, wherein the first range of angles is different than the second range of angles.

5. A virtual image projector as described in claim 1, wherein the first diffraction grating has a first spatial frequency that is different than a second spatial
25 frequency of the second diffraction grating, wherein the first spatial frequency causes the first diffraction grating to project the first diffracted light rays at the first range of angles, and wherein the second spatial frequency causes the second diffraction grating to project the second diffracted light rays at the second range of angles

6. A virtual image projector as described in claim 1, wherein the slab light
30 guide is configured with a partially-reflecting mirror that is configured to reflect a portion, and transmit another portion, of each of the first diffracted light rays and the second diffracted light rays.

7. A virtual image projector as described in claim 1, wherein the rod light guide is further embossed with a third diffraction grating and a fourth diffraction grating,

the third diffraction grating and the fourth diffraction grating substantially parallel to the first diffraction grating and the second diffraction grating, the third diffraction grating configured to receive third light rays from the illuminator and to project third diffracted light rays from the rod light guide at a third range of angles, and the fourth diffraction
5 grating configured to receive fourth light rays from the illuminator and to project fourth diffracted light rays from the rod light guide at a fourth range of angles.

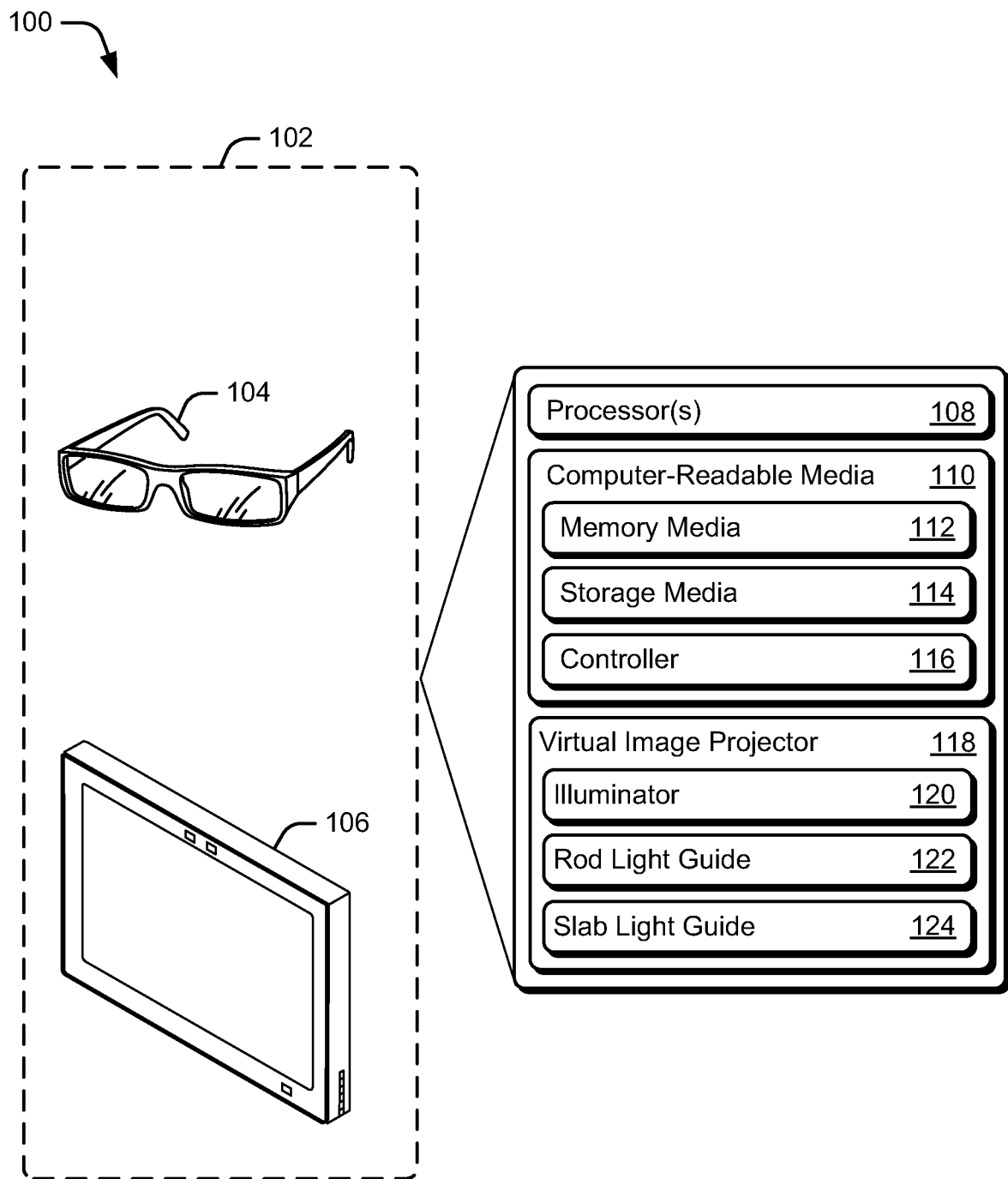
8. A virtual image projector as described in claim 1, wherein the virtual image projector is coupled to a pair of eyeglasses to generate the virtual image in front of a lens of the eyeglasses.

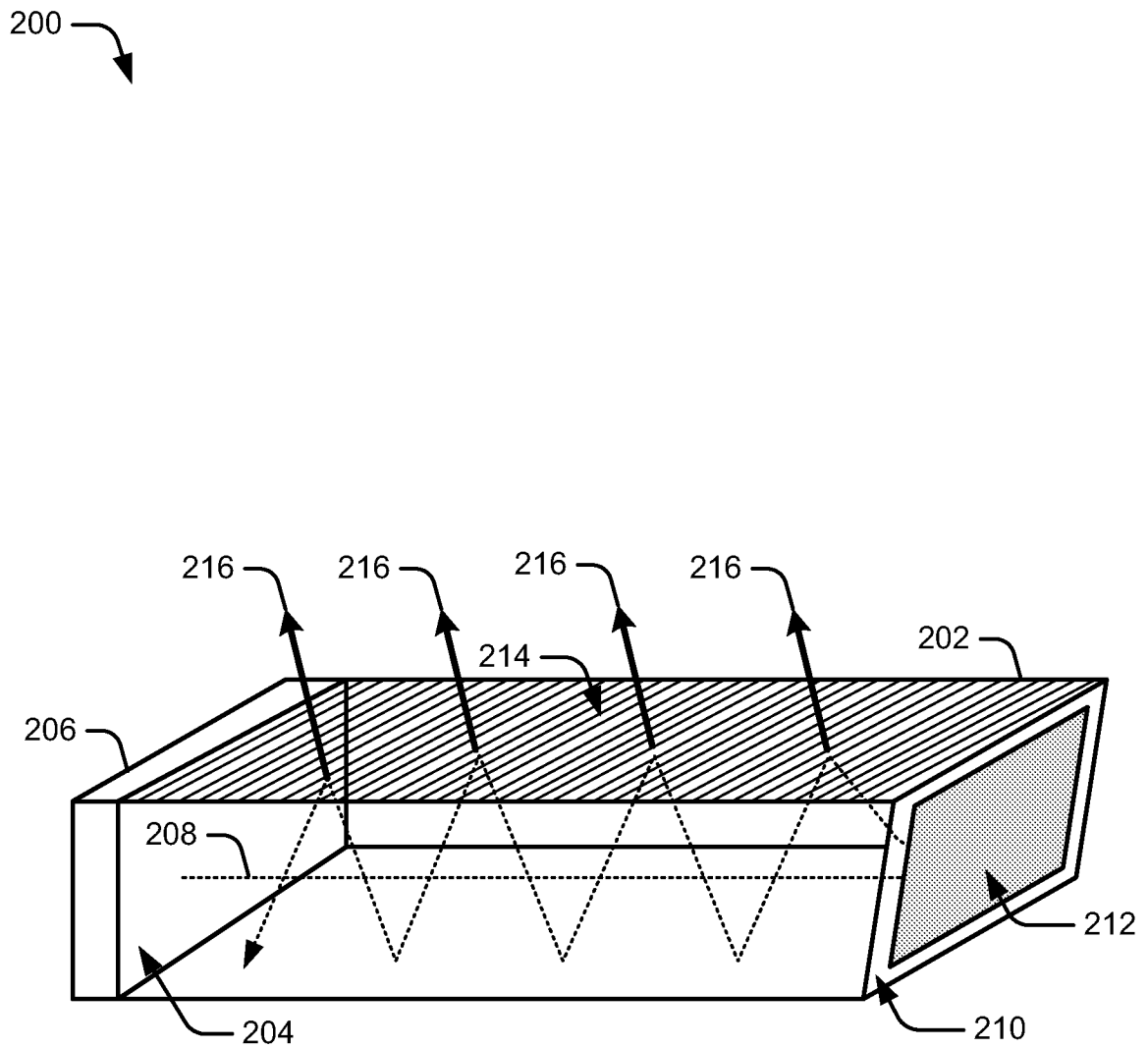
10 9. A method comprising:
receiving data corresponding to a virtual image;
controlling an illuminator to inject first light rays into a first diffraction grating of a rod light guide effective to diffract the first light rays out of the rod light guide at a first range of angles and into a slab light guide to generate the virtual image with a wide field-
15 of-view; and

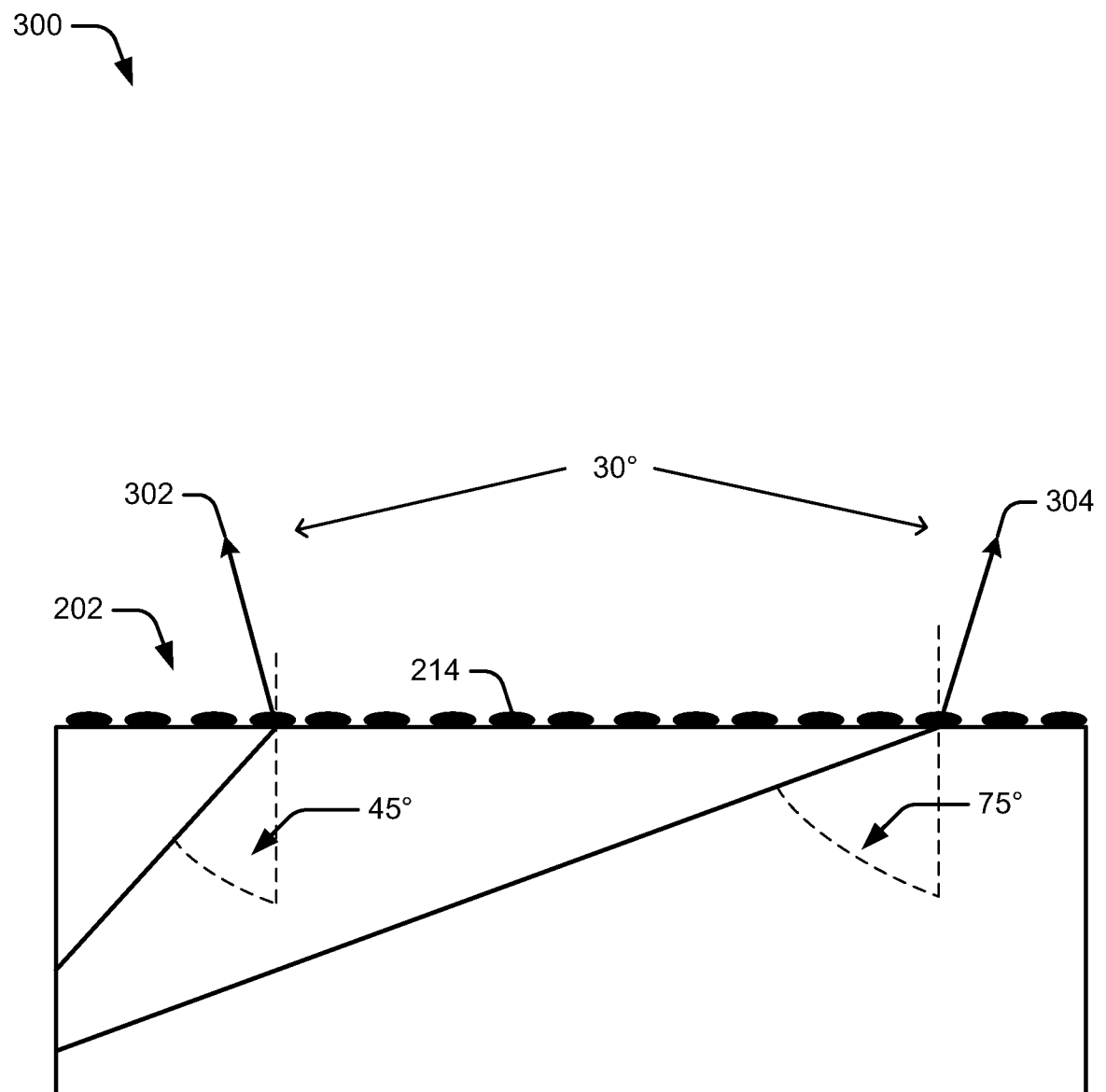
controlling the illuminator to inject second light rays into a second diffraction grating of the rod light guide effective to diffract the second light rays out of the rod light guide at a second range of angles and into the slab light guide to generate the virtual image with the wide field-of-view.

20 10. A method as described in claim 9, wherein the wide field-of-view is equal to the sum of the first range of angles and the second range of angles.

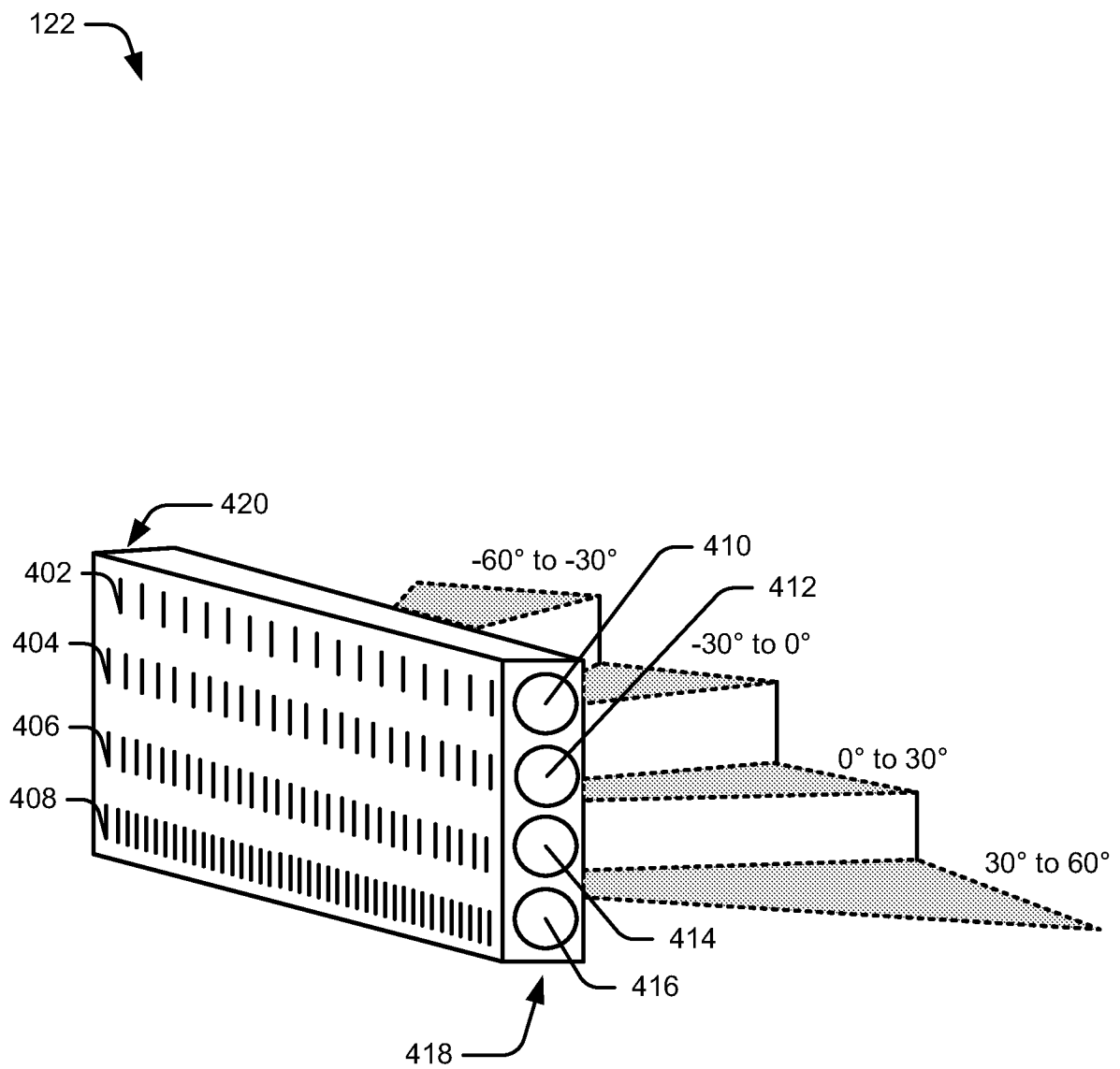
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**Fig. 1**

**Fig. 2**

**Fig. 3**

4/8

**Fig. 4**

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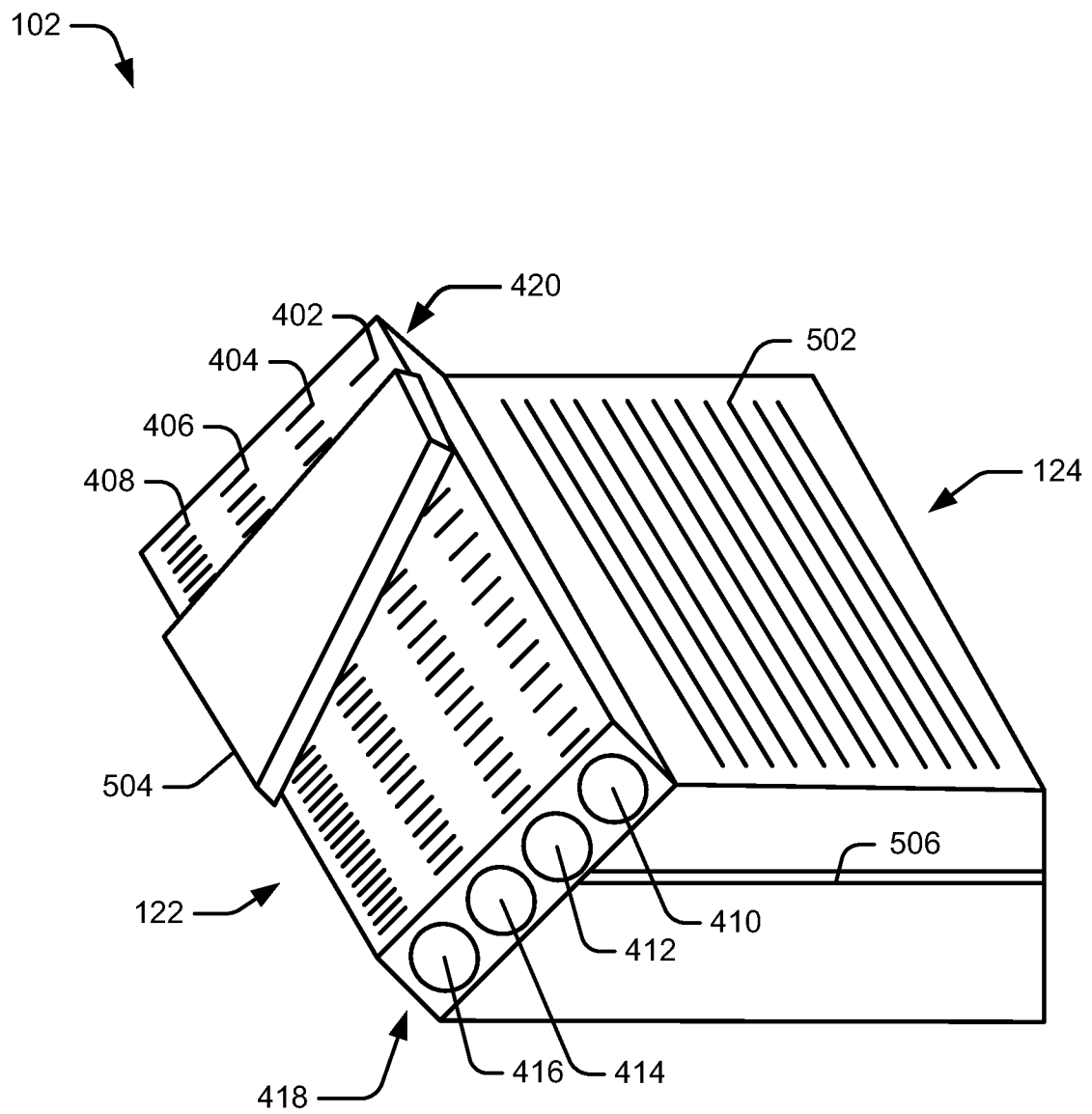


Fig. 5

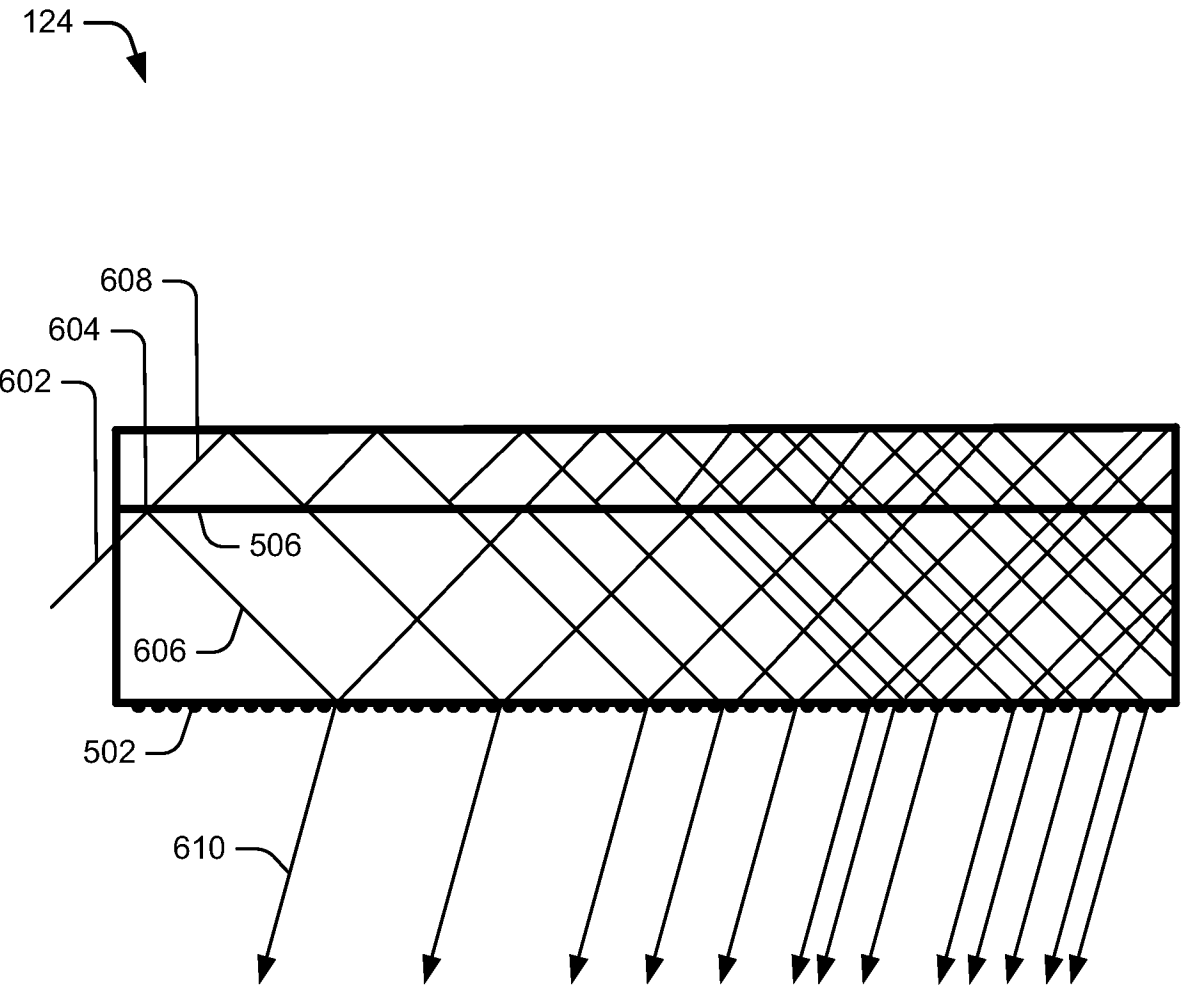
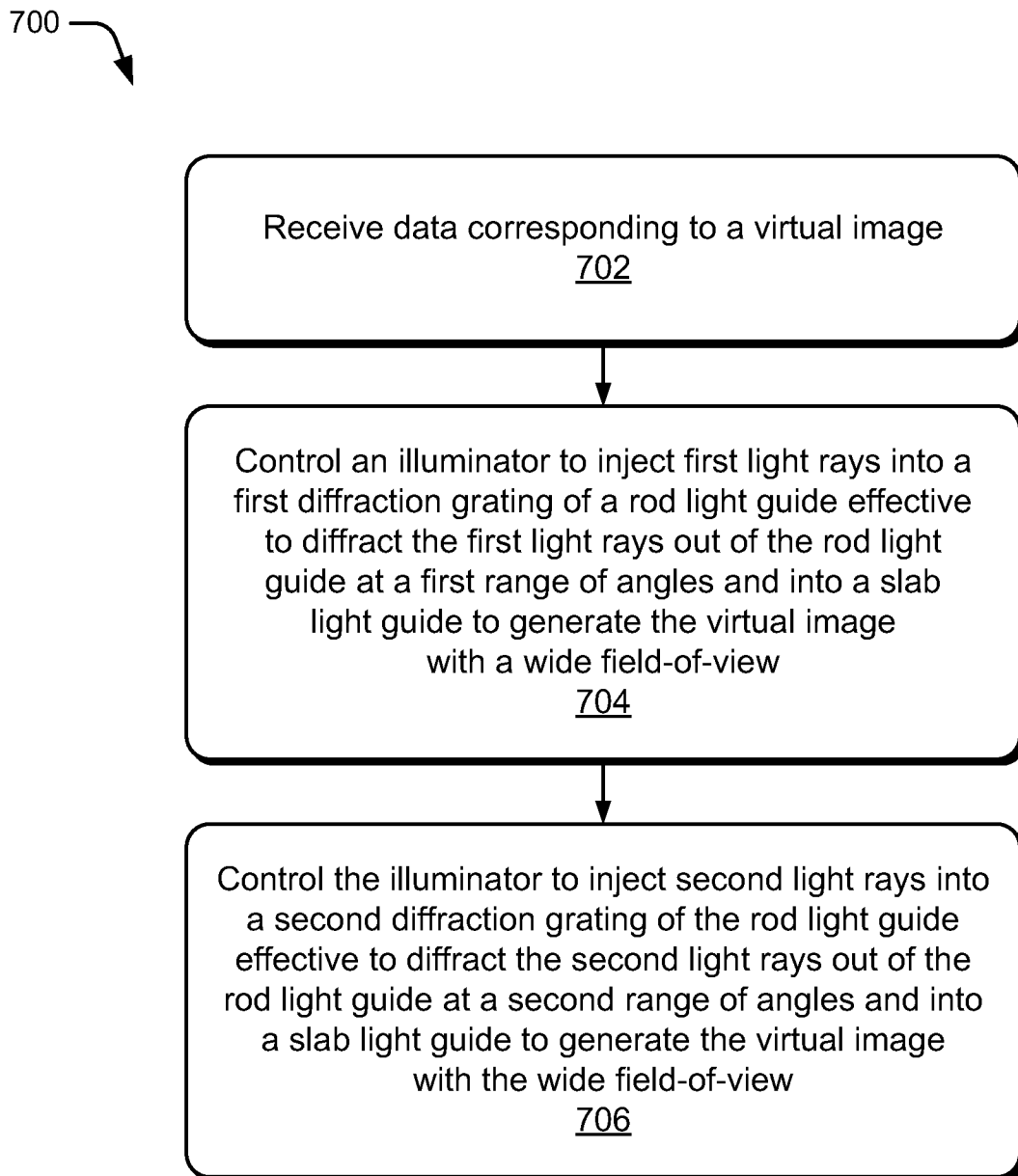
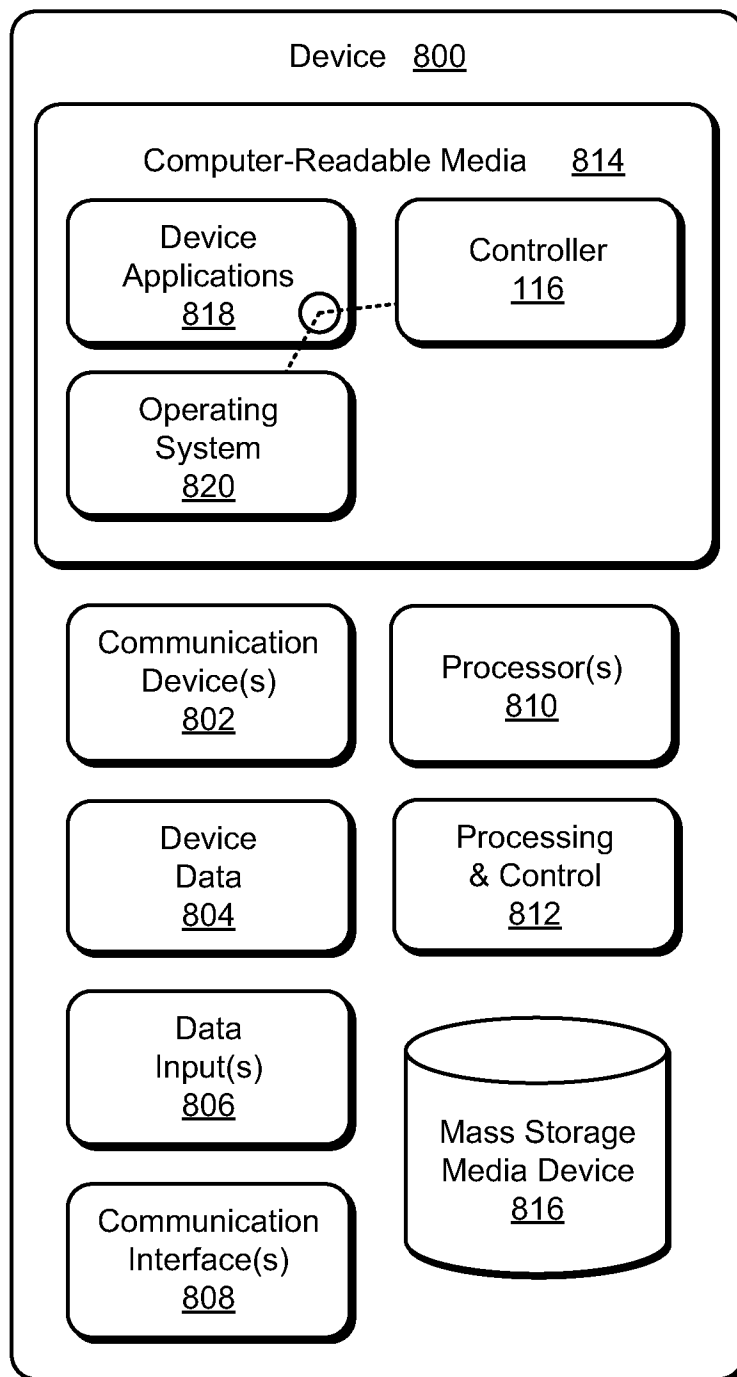


Fig. 6

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**Fig. 7**

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**Fig. 8**

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/042790

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B27/01 F21V8/00 G02B6/34 G02B27/42 G02B5/18
ADD.

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)
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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/235179 A1 (SIMMONDS MICHAEL DAVID [GB]) 29 September 2011 (2011-09-29) figure 4a	1-10
A	----- EP 2 381 290 A1 (BAE SYSTEMS PLC [GB]) 26 October 2011 (2011-10-26) figures 1,2 -----	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"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

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"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

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Date of the actual completion of the international search

1 August 2013

Date of mailing of the international search report

08/08/2013

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2013/042790

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011235179 A1	29-09-2011	EP 2376970 A1	19-10-2011
		US 2011235179 A1	29-09-2011
		WO 2010067116 A1	17-06-2010

EP 2381290 A1	26-10-2011	NONE	
