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(71) Applicant: LEIA INC. [US/US]; 2440 Sand Hill Rd., Ste. 303, Menlo Park, California 94025 (US).

(72) Inventors: FATTAL, David A.; LEIA INC., 2440 Sand Hill Rd., Ste. 303, Menlo Park, California 94025 (US). LI, Xuejian; LEIA Inc., 2440 Sand Hill Rd., Ste 303, Men-

lo Park, California 94025 (US). AIETA, Francesco; LEIA Inc., 2440 Sand Hill Rd., Ste. 303, Menlo Park, California 94025 (US).

(74) Agent: JOHNSON, J. Michael; LEIA Inc., Intellectual Property Department, 18124 Wedge Pkwy, Suite 165, Reno, Nevada 89511 (US).

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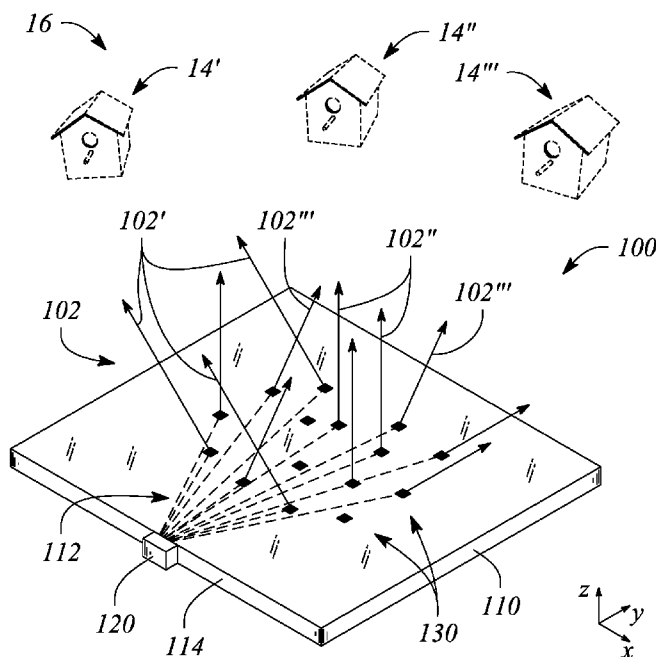


FIG. 3C

(57) Abstract: A static multiview display and method of static multiview display operation provide a static multiview image using diffractive gratings to diffractively scatter light from guided light beams having different radial directions. The static multiview display includes a light guide configured to guide plurality of guided light beams and a light source configured to provide the guided light beam plurality having the different radial directions. The static multiview display further includes a plurality of diffraction gratings configured to provide from a portion of the guided light beams directional light beams having intensities and principal angular directions corresponding to view pixels of the static multiview image.



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## STATIC MULTIVIEW DISPLAY AND METHOD

### CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims priority to U. S. Provisional Patent Application Serial No. 62/442,982, filed January 6, 2017, the entirety of which is incorporated by reference herein.

### STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

**[0002]** N/A

### BACKGROUND

**[0003]** Displays and more particularly ‘electronic’ displays are a nearly ubiquitous medium for communicating information to users of a wide variety of devices and products. For example, electronic displays may be found in various devices and applications including, but not limited to, mobile telephones (e.g., smart phones), watches, tablet computers, mobile computers (e.g., laptop computers), personal computers and computer monitors, automobile display consoles, camera displays, and various other mobile as well as substantially non-mobile display applications and devices. Electronic displays generally employ a differential pattern of pixel intensity to represent or display an image or similar information that is being communicated. The differential pixel intensity pattern may be provided by reflecting light incident on the display as in the case of passive electronic displays. Alternatively, the electronic display may provide or emit light to provide the differential pixel intensity pattern. Electronic displays that emit light are often referred to as active displays.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0004]** Various features of examples and embodiments in accordance with the principles described herein may be more readily understood with reference to the

following detailed description taken in conjunction with the accompanying drawings, where like reference numerals designate like structural elements, and in which:

**[0005]** Figure 1A illustrates a perspective view of a multiview display in an example, according to an embodiment consistent with the principles described herein.

**[0006]** Figure 1B illustrates a graphical representation of angular components of a light beam having a particular principal angular direction corresponding to a view direction of a multiview display in an example, according to an embodiment consistent with the principles described herein.

**[0007]** Figure 2 illustrates a cross-sectional view of a diffraction grating in an example, according to an embodiment consistent with the principles described herein.

**[0008]** Figure 3A illustrates a plan view of a static multiview display in an example, according to an embodiment consistent with the principles described herein.

**[0009]** Figure 3B illustrates a cross-sectional view of a portion of a static multiview display in an example, according to an embodiment consistent with the principles described herein.

**[0010]** Figure 3C illustrates a perspective view of a static multiview display in an example, according to an embodiment consistent with the principles described herein.

**[0011]** Figure 4 illustrates a plan view of a static multiview display in an example, according to an embodiment consistent with the principles described herein.

**[0012]** Figure 5A illustrates a plan view of a static multiview display including spurious reflection mitigation in an example, according to an embodiment consistent with the principles described herein.

**[0013]** Figure 5B illustrates a plan view of a static multiview display including spurious reflection mitigation in an example, according to another embodiment consistent with the principles described herein.

**[0014]** Figure 6A illustrates a plan view of a multiview display in an example, according to an embodiment consistent with the principles described herein.

**[0015]** Figure 6B illustrates a plan view of the static multiview display of Figure 6A in another example, according to an embodiment consistent with the principles described herein.

**[0016]** Figure 7A illustrates a plan view of a diffraction grating of a multiview display in an example, according to an embodiment consistent with the principles described herein.

**[0017]** Figure 7B illustrates a plan view of a set diffraction gratings organized as a multiview pixel in an example, according to another embodiment consistent with the principles described herein.

**[0018]** Figure 8 illustrates a block diagram of a static multiview display in an example, according to an embodiment consistent with the principles described herein.

**[0019]** Figure 9 illustrates a flow chart of a method of static multiview display operation in an example, according to an embodiment consistent with the principles described herein.

**[0020]** Certain examples and embodiments have other features that are one of in addition to and in lieu of the features illustrated in the above-referenced figures. These and other features are detailed below with reference to the above-referenced figures.

#### DETAILED DESCRIPTION

**[0021]** Examples and embodiments in accordance with the principles described herein provide display of a static or quasi-static three-dimensional (3D) or multiview image. In particular, embodiments consistent with the principles described display the static or quasi-static multiview image using a plurality of directional light beams. The individual intensities and directions of directional light beams of the directional light beam plurality, in turn, correspond to various view pixels in views of the multiview image being displayed. According to various embodiments, the individual intensities and, in some embodiments, the individual directions of the directional light beams are predetermined or 'fixed.' As such, the displayed multiview image may be referred to as a static or quasi-static multiview image.

**[0022]** According to various embodiments, a static multiview display configured to display the static or quasi-static multiview image comprises diffraction gratings optically connected to a light guide to provide the directional light beams having the individual directional light beam intensities and directions. The diffraction gratings are configured to emit or provide the directional light beams by or according to diffractive coupling or scattering out of light guided from within the light guide, the light being

guided as a plurality of guided light beams. Further, guided light beams of the guided light beam plurality are guided within the light guide at different radial directions from one another. As such, a diffraction grating of the diffraction grating plurality comprises a grating characteristic that accounts for or that is a function of a particular radial direction of a guided light beam incident on the diffraction grating. In particular, the grating characteristic may be a function of a relative location of the diffraction grating and a light source configured to provide the guided light beam. According to various embodiments, the grating characteristic is configured to account for the radial direction of the guided light beam to insure a correspondence between the emitted directional light beams provide by the diffraction gratings and associated view pixels in various views of the static or quasi-static multiview image being displayed.

**[0023]** Herein, a ‘multiview display’ is defined as an electronic display or display system configured to provide different views of a multiview image in different view directions. A ‘static multiview display’ is defined as a multiview display configured to display a predetermined or fixed (i.e., static) multiview image, albeit as a plurality of different views. A ‘quasi-static multiview display’ is defined herein as a static multiview display that may be switched between different fixed multiview images or between a plurality of multiview image states, typically as a function of time. Switching between the different fixed multiview images or multiview image states may provide a rudimentary form of animation, for example. Further, as defined herein, a quasi-static multiview display is a type of static multiview display. As such, no distinction is made between a purely static multiview display or image and a quasi-static multiview display or image, unless such distinction is necessary for proper understanding.

**[0024]** Figure 1A illustrates a perspective view of a multiview display 10 in an example, according to an embodiment consistent with the principles described herein. As illustrated in Figure 1A, the multiview display 10 comprises a diffraction grating on a screen 12 configured to display a view pixel in a view 14 within or of a multiview image 16 (or equivalently a view 14 of the multiview display 10). The screen 12 may be a display screen of an automobile, a telephone (e.g., mobile telephone, smart phone, etc.), a tablet computer, a laptop computer, a computer monitor of a desktop computer, a camera display, or an electronic display of substantially any other device, for example.

**[0025]** The multiview display 10 provides different views 14 of the multiview image 16 in different view directions 18 (i.e., in different principal angular directions) relative to the screen 12. The view directions 18 are illustrated as arrows extending from the screen 12 in various different principal angular directions. The different views 14 are illustrated as shaded polygonal boxes at the termination of the arrows (i.e., depicting the view directions 18). Thus, when the multiview display 10 (e.g., as illustrated in Figure 1A) is rotated about the  $y$ -axis, a viewer sees different views 14. On the other hand (as illustrated) when the multiview display 10 in Figure 1A is rotated about the  $x$ -axis the viewed image is unchanged until no light reaches the viewer's eyes (as illustrated).

**[0026]** Note that, while the different views 14 are illustrated as being above the screen 12, the views 14 actually appear on or in a vicinity of the screen 12 when the multiview image 16 is displayed on the multiview display 10 and viewed by the viewer. Depicting the views 14 of the multiview image 16 above the screen 12 as in Figure 1A is done only for simplicity of illustration and is meant to represent viewing the multiview display 10 from a respective one of the view directions 18 corresponding to a particular view 14. Further, in Figure 1A only three views 14 and three view directions 18 are illustrated, all by way of example and not limitation.

**[0027]** A view direction or equivalently a light beam having a direction corresponding to a view direction of a multiview display generally has a principal angular direction given by angular components  $\{\theta, \phi\}$ , by definition herein. The angular component  $\theta$  is referred to herein as the 'elevation component' or 'elevation angle' of the light beam. The angular component  $\phi$  is referred to as the 'azimuth component' or 'azimuth angle' of the light beam. By definition, the elevation angle  $\theta$  is an angle in a vertical plane (e.g., perpendicular to a plane of the multiview display screen while the azimuth angle  $\phi$  is an angle in a horizontal plane (e.g., parallel to the multiview display screen plane).

**[0028]** Figure 1B illustrates a graphical representation of the angular components  $\{\theta, \phi\}$  of a light beam 20 having a particular principal angular direction corresponding to a view direction (e.g., view direction 18 in Figure 1A) of a multiview display in an example, according to an embodiment consistent with the principles described herein. In addition, the light beam 20 is emitted or emanates from a particular point, by definition

herein. That is, by definition, the light beam 20 has a central ray associated with a particular point of origin within the multiview display. Figure 1B also illustrates the light beam (or view direction) point of origin O.

**[0029]** Further herein, the term ‘multiview’ as used in the terms ‘multiview image’ and ‘multiview display’ is defined as a plurality of views representing different perspectives or including angular disparity between views of the view plurality. In addition, herein the term ‘multiview’ explicitly includes more than two different views (i.e., a minimum of three views and generally more than three views), by definition herein. As such, ‘multiview display’ as employed herein is explicitly distinguished from a stereoscopic display that includes only two different views to represent a scene or an image. Note however, while multiview images and multiview displays may include more than two views, by definition herein, multiview images may be viewed (e.g., on a multiview display) as a stereoscopic pair of images by selecting only two of the multiview views to view at a time (e.g., one view per eye).

**[0030]** In the multiview display, a ‘multiview pixel’ is defined herein as a set or plurality of view pixels representing pixels in each of a similar plurality of different views of a multiview display. Equivalently, a multiview pixel may have an individual view pixel corresponding to or representing a pixel in each of the different views of the multiview image to be displayed by the multiview display. Moreover, the view pixels of the multiview pixel are so-called ‘directional pixels’ in that each of the view pixels is associated with a predetermined view direction of a corresponding one of the different views, by definition herein. Further, according to various examples and embodiments, the different view pixels represented by the view pixels of a multiview pixel may have equivalent or at least substantially similar locations or coordinates in each of the different views. For example, a first multiview pixel may have individual view pixels corresponding to view pixels located at  $\{x_1, y_1\}$  in each of the different views of a multiview image, while a second multiview pixel may have individual view pixels corresponding to view pixels located at  $\{x_2, y_2\}$  in each of the different views, and so on.

**[0031]** In some embodiments, a number of view pixels in a multiview pixel may be equal to a number of views of the multiview display. For example, the multiview pixel may provide eight (8) view pixels associated with a multiview display having 8 different

views. Alternatively, the multiview pixel may provide sixty-four (64) view pixels associated with a multiview display having 64 different views. In another example, the multiview display may provide an eight by four array of views (i.e., 32 views) and the multiview pixel may include thirty-two 32 view pixels (i.e., one for each view). Further, according to some embodiments, a number of multiview pixels of the multiview display may be substantially equal to a number of pixels that make up a selected view of the multiview display.

**[0032]** Herein, a ‘light guide’ is defined as a structure that guides light within the structure using total internal reflection. In particular, the light guide may include a core that is substantially transparent at an operational wavelength of the light guide. In various examples, the term ‘light guide’ generally refers to a dielectric optical waveguide that employs total internal reflection to guide light at an interface between a dielectric material of the light guide and a material or medium that surrounds that light guide. By definition, a condition for total internal reflection is that a refractive index of the light guide is greater than a refractive index of a surrounding medium adjacent to a surface of the light guide material. In some embodiments, the light guide may include a coating in addition to or instead of the aforementioned refractive index difference to further facilitate the total internal reflection. The coating may be a reflective coating, for example. The light guide may be any of several light guides including, but not limited to, one or both of a plate or slab guide and a strip guide.

**[0033]** Further herein, the term ‘plate’ when applied to a light guide as in a ‘plate light guide’ is defined as a piece-wise or differentially planar layer or sheet, which is sometimes referred to as a ‘slab’ guide. In particular, a plate light guide is defined as a light guide configured to guide light in two substantially orthogonal directions bounded by a top surface and a bottom surface (i.e., opposite surfaces) of the light guide. Further, by definition herein, the top and bottom surfaces are both separated from one another and may be substantially parallel to one another in at least a differential sense. That is, within any differentially small section of the plate light guide, the top and bottom surfaces are substantially parallel or co-planar.

**[0034]** In some embodiments, the plate light guide may be substantially flat (i.e., confined to a plane) and therefore, the plate light guide is a planar light guide. In other

embodiments, the plate light guide may be curved in one or two orthogonal dimensions. For example, the plate light guide may be curved in a single dimension to form a cylindrical shaped plate light guide. However, any curvature has a radius of curvature sufficiently large to ensure that total internal reflection is maintained within the plate light guide to guide light.

**[0035]** Herein, a ‘diffraction grating’ is generally defined as a plurality of features (i.e., diffractive features) arranged to provide diffraction of light incident on the diffraction grating. In some examples, the plurality of features may be arranged in a periodic or quasi-periodic manner having one or more grating spacings between pairs of the features. For example, the diffraction grating may comprise a plurality of features (e.g., a plurality of grooves or ridges in a material surface) arranged in a one-dimensional (1D) array. In other examples, the diffraction grating may be a two-dimensional (2D) array of features. The diffraction grating may be a 2D array of bumps on or holes in a material surface, for example. According to various embodiments and examples, the diffraction grating may be a sub-wavelength grating having a grating spacing or distance between adjacent diffractive features that is less than about a wavelength of light that is to be diffracted by the diffraction grating.

**[0036]** As such, and by definition herein, the ‘diffraction grating’ is a structure that provides diffraction of light incident on the diffraction grating. If the light is incident on the diffraction grating from a light guide, the provided diffraction or diffractive scattering may result in, and thus be referred to as, ‘diffractive coupling’ in that the diffraction grating may couple light out of the light guide by diffraction. The diffraction grating also redirects or changes an angle of the light by diffraction (i.e., at a diffractive angle). In particular, as a result of diffraction, light leaving the diffraction grating generally has a different propagation direction than a propagation direction of the light incident on the diffraction grating (i.e., incident light). The change in the propagation direction of the light by diffraction is referred to as ‘diffractive redirection’ herein. Hence, the diffraction grating may be understood to be a structure comprising diffractive features that diffractively redirects light incident on the diffraction grating and, if the light is incident from a light guide, the diffraction grating may also diffractively couple out the light from the light guide.

**[0037]** Further, by definition herein, the features of a diffraction grating are referred to as ‘diffractive features’ and may be one or more of at, in and on a material surface (i.e., a boundary between two materials). The surface may be a surface of a light guide, for example. The diffractive features may include any of a variety of structures that diffract light including, but not limited to, one or more of grooves, ridges, holes and bumps at, in or on the surface. For example, the diffraction grating may include a plurality of substantially parallel grooves in the material surface. In another example, the diffraction grating may include a plurality of parallel ridges rising out of the material surface. The diffractive features (e.g., grooves, ridges, holes, bumps, etc.) may have any of a variety of cross-sectional shapes or profiles that provide diffraction including, but not limited to, one or more of a sinusoidal profile, a rectangular profile (e.g., a binary diffraction grating), a triangular profile and a saw tooth profile (e.g., a blazed grating).

**[0038]** As described further below, a diffraction grating herein may have a grating characteristic, including one or more of a feature spacing or pitch, an orientation and a size (such as a width or length of the diffraction grating). Further, the grating characteristic may selected or chosen to be a function of the angle of incidence of light beams on the diffraction grating, a distance of the diffraction grating from a light source or both. In particular, the grating characteristic of a diffraction grating may be chosen to depend on a relative location of the light source and a location of the diffraction grating, according to some embodiments. By appropriately varying the grating characteristic of the diffraction grating, both an intensity and a principal angular direction of a light beam diffracted (e.g., diffractively coupled-out of a light guide) by the diffraction grating (i.e., a ‘directional light beam’) corresponds to an intensity and a view direction of a view pixel of the multiview image.

**[0039]** According to various examples described herein, a diffraction grating (e.g., a diffraction grating of a multiview pixel, as described below) may be employed to diffractively scatter or couple light out of a light guide (e.g., a plate light guide) as a light beam. In particular, a diffraction angle  $\theta_m$  of or provided by a locally periodic diffraction grating may be given by equation (1) as:

$$\theta_m = \sin^{-1} \left( n \sin \theta_i - \frac{m\lambda}{d} \right) \quad (1)$$

where  $\lambda$  is a wavelength of the light,  $m$  is a diffraction order,  $n$  is an index of refraction of a light guide,  $d$  is a distance or spacing between features of the diffraction grating,  $\theta_i$  is an angle of incidence of light on the diffraction grating. For simplicity, equation (1) assumes that the diffraction grating is adjacent to a surface of the light guide and a refractive index of a material outside of the light guide is equal to one (i.e.,  $n_{out} = 1$ ). In general, the diffraction order  $m$  is given by an integer. A diffraction angle  $\theta_m$  of a light beam produced by the diffraction grating may be given by equation (1) where the diffraction order is positive (e.g.,  $m > 0$ ). For example, first-order diffraction is provided when the diffraction order  $m$  is equal to one (i.e.,  $m = 1$ ).

**[0040]** Figure 2 illustrates a cross-sectional view of a diffraction grating 30 in an example, according to an embodiment consistent with the principles described herein. For example, the diffraction grating 30 may be located on a surface of a light guide 40. In addition, Figure 2 illustrates a light beam (or a collection of light beams) 50 incident on the diffraction grating 30 at an incident angle  $\theta_i$ . The light beam 50 is a guided light beam within the light guide 40. Also illustrated in Figure 2 is a coupled-out light beam (or a collection of light beams) 60 diffractively produced and coupled-out by the diffraction grating 30 as a result of diffraction of the incident light beam 20. The coupled-out light beam 60 has a diffraction angle  $\theta_m$  (or ‘principal angular direction’ herein) as given by equation (1). The coupled-out light beam 60 may correspond to a diffraction order ‘ $m$ ’ of the diffraction grating 30, for example.

**[0041]** According to various embodiments, the principal angular direction of the various light beams is determined by the grating characteristic including, but not limited to, one or more of a size (e.g., a length, a width, an area, etc.) of the diffraction grating, an orientation, and a feature spacing. Further, a light beam produced by the diffraction grating has a principal angular direction given by angular components  $\{\theta, \phi\}$ , by definition herein, and as described above with respect to Figure 1B.

**[0042]** Herein, a ‘collimated light’ or ‘collimated light beam’ is generally defined as a beam of light in which rays of the light beam are substantially parallel to one another within the light beam (e.g., the guided light beam in the light guide). Further, rays of light that diverge or are scattered from the collimated light beam are not considered to be part of the collimated light beam, by definition herein. Moreover, herein a ‘collimator’ is

defined as substantially any optical device or apparatus that is configured to collimate light.

**[0043]** Herein, a 'collimation factor' is defined as a degree to which light is collimated. In particular, a collimation factor defines an angular spread of light rays within a collimated beam of light, by definition herein. For example, a collimation factor  $\sigma$  may specify that a majority of light rays in a beam of collimated light is within a particular angular spread (e.g., +/-  $\sigma$  degrees about a central or principal angular direction of the collimated light beam). The light rays of the collimated light beam may have a Gaussian distribution in terms of angle and the angular spread be an angle determined by at one-half of a peak intensity of the collimated light beam, according to some examples.

**[0044]** Herein, a 'light source' is defined as a source of light (e.g., an optical emitter configured to produce and emit light). For example, the light source may comprise an optical emitter such as a light emitting diode (LED) that emits light when activated or turned on. In particular, herein the light source may be substantially any source of light or comprise substantially any optical emitter including, but not limited to, one or more of a light emitting diode (LED), a laser, an organic light emitting diode (OLED), a polymer light emitting diode, a plasma-based optical emitter, a fluorescent lamp, an incandescent lamp, and virtually any other source of light. The light produced by the light source may have a color (i.e., may include a particular wavelength of light), or may be a range of wavelengths (e.g., white light). In some embodiments, the light source may comprise a plurality of optical emitters. For example, the light source may include a set or group of optical emitters in which at least one of the optical emitters produces light having a color, or equivalently a wavelength, that differs from a color or wavelength of light produced by at least one other optical emitter of the set or group. The different colors may include primary colors (e.g., red, green, blue) for example.

**[0045]** Further, as used herein, the article 'a' is intended to have its ordinary meaning in the patent arts, namely 'one or more'. For example, 'a diffraction grating' means one or more diffraction gratings and as such, 'the diffraction grating' means 'the diffraction grating(s)' herein. Also, any reference herein to 'top', 'bottom', 'upper', 'lower', 'up', 'down', 'front', 'back', 'first', 'second', 'left' or 'right' is not intended to be a limitation herein. Herein, the term 'about' when applied to a value generally means

within the tolerance range of the equipment used to produce the value, or may mean plus or minus 10%, or plus or minus 5%, or plus or minus 1%, unless otherwise expressly specified. Further, the term 'substantially' as used herein means a majority, or almost all, or all, or an amount within a range of about 51% to about 100%. Moreover, examples herein are intended to be illustrative only and are presented for discussion purposes and not by way of limitation.

**[0046]** According to some embodiments of the principles described herein, a multiview display configured to provide multiview images and more particularly static multiview images (i.e., a static multiview display) is provided. Figure 3A illustrates a plan view of a static multiview display 100 in an example, according to an embodiment consistent with the principles described herein. Figure 3B illustrates a cross-sectional view of a portion of a static multiview display 100 in an example, according to an embodiment consistent with the principles described herein. In particular, Figure 3B may illustrate a cross section through a portion of the static multiview display 100 of Figure 3A, the cross section being in an  $x$ - $z$  plane. Figure 3C illustrates a perspective view of a static multiview display 100 in an example, according to an embodiment consistent with the principles described herein. According to some embodiments, the illustrated static multiview display 100 is configured to provide purely a static multiview image, while in others the static multiview display 100 may be configured to provide a plurality of multiview images and therefore functions as (or is) a quasi-static multiview display 100. For example, the static multiview display 100 may be switchable between different fixed multiview images or equivalently between a plurality of multiview image states, as described below.

**[0047]** The static multiview display 100 illustrated in Figures 3A-3C is configured to provide a plurality of directional light beams 102, each directional light beam 102 of the plurality having an intensity and a principal angular direction. Together, the plurality of directional light beams 102 represents various view pixels of a set of views of a multiview image that the static multiview display 100 is configured to provide or display. In some embodiments, the view pixels may be organized into multiview pixels to represent the various different views of the multiview images.

**[0048]** As illustrated, the static multiview display 100 comprises a light guide 110. The light guide may be a plate light guide (as illustrated), for example. The light guide 110 is configured to guide light along a length of the light guide 110 as guided light or more particularly as guided light beams 112. For example, the light guide 110 may include a dielectric material configured as an optical waveguide. The dielectric material may have a first refractive index that is greater than a second refractive index of a medium surrounding the dielectric optical waveguide. The difference in refractive indices is configured to facilitate total internal reflection of the guided light beams 112 according to one or more guided modes of the light guide 110, for example.

**[0049]** In some embodiments, the light guide 110 may be a slab or plate optical waveguide comprising an extended, substantially planar sheet of optically transparent, dielectric material. The substantially planar sheet of dielectric material is configured to guide the guided light beams 112 using total internal reflection. According to various examples, the optically transparent material of the light guide 110 may include or be made up of any of a variety of dielectric materials including, but not limited to, one or more of various types of glass (e.g., silica glass, alkali-aluminosilicate glass, borosilicate glass, etc.) and substantially optically transparent plastics or polymers (e.g., poly(methyl methacrylate) or 'acrylic glass', polycarbonate, etc.). In some examples, the light guide 110 may further include a cladding layer (not illustrated) on at least a portion of a surface (e.g., one or both of the top surface and the bottom surface) of the light guide 110. The cladding layer may be used to further facilitate total internal reflection, according to some examples.

**[0050]** According to various embodiments, the light guide 110 is configured to guide the guided light beams 112 according to total internal reflection at a non-zero propagation angle between a first surface 110' (e.g., a 'front' surface) and a second surface 110" (e.g., a 'back' or 'bottom' surface) of the light guide 110. In particular, the guided light beams 112 propagate by reflecting or 'bouncing' between the first surface 110' and the second surface 110" of the light guide 110 at the non-zero propagation angle. Note, the non-zero propagation angle is not explicitly depicted in Figure 3B for simplicity of illustration. However, Figure 3B does illustrate an arrow pointing into a plane of the

illustration depicting a general propagation direction 103 of the guided light beams 112 along the light guide length.

**[0051]** As defined herein, a 'non-zero propagation angle' is an angle relative to a surface (e.g., the first surface 110' or the second surface 110") of the light guide 110. Further, the non-zero propagation angle is both greater than zero and less than a critical angle of total internal reflection within the light guide 110, according to various embodiments. For example, the non-zero propagation angle of the guided light beam 112 may be between about ten (10) degrees and about fifty (50) degrees or, in some examples, between about twenty (20) degrees and about forty (40) degrees, or between about twenty-five (25) degrees and about thirty-five (35) degrees. For example, the non-zero propagation angle may be about thirty (30) degrees. In other examples, the non-zero propagation angle may be about 20 degrees, or about 25 degrees, or about 35 degrees. Moreover, a specific non-zero propagation angle may be chosen (e.g., arbitrarily) for a particular implementation as long as the specific non-zero propagation angle is chosen to be less than the critical angle of total internal reflection within the light guide 110.

**[0052]** As illustrated in Figures 3A and 3C, the static multiview display 100 further comprise a light source 120. The light source 120 is located at an input location 116 on the light guide 110. For example, the light source 120 may be located adjacent to an edge or side 114 of the light guide 110, as illustrated. The light source 120 is configured to provide light within the light guide 110 as the plurality of guided light beams 112. Further, the light source 120 provides the light such that individual guided light beams 112 of the guided light beam plurality have different radial directions 118 from one another.

**[0053]** In particular, light emitted by the light source 120 is configured enter the light guide 110 and to propagate as the plurality of guided light beams 112 in a radial pattern away from the input location 116 and across or along a length of the light guide 110. Further, the individual guided light beams 112 of the guided light beam plurality have different radial directions from one another by virtue of the radial pattern of propagation away from the input location 116. For example, the light source 120 may be butt-coupled to the side 114. The light source 120 being butt-coupled may facilitate introduction of light in a fan-shape pattern to provide the different radial directions of the

individual guided light beams 112, for example. According to some embodiments, the light source 120 may be or at least approximate a ‘point’ source of light at the input location 116 such that the guided light beams 112 propagate along the different radial directions 118 (i.e., as the plurality of guided light beams 112).

**[0054]** In some embodiments, the input location 116 of the light source 120 is on a side 114 of the light guide 110 near or about at a center or a middle of the side 114. In particular, in Figures 3A and 3C, the light source 120 is illustrated at an input location 116 that is approximately centered on (e.g., at a middle of) the side 114 (i.e., the ‘input side’) of the light guide 110. Alternatively (not illustrated), the input location 116 may be away from the middle of the side 114 of the light guide 110. For example, the input location 116 may be at a corner of the light guide 110. For example, the light guide 110 may have a rectangular shape (e.g., as illustrated) and the input location 116 of the light source 120 may be at a corner of the rectangular-shaped light guide 110 (e.g., a corner of the input side 114).

**[0055]** In various embodiments, the light source 120 may comprise substantially any source of light (e.g., optical emitter) including, but not limited to, one or more light emitting diodes (LEDs) or a laser (e.g., laser diode). In some embodiments, the light source 120 may comprise an optical emitter configured produce a substantially monochromatic light having a narrowband spectrum denoted by a particular color. In particular, the color of the monochromatic light may be a primary color of a particular color space or color model (e.g., an RGB color model). In other examples, the light source 120 may be a substantially broadband light source configured to provide substantially broadband or polychromatic light. For example, the light source 120 may provide white light. In some embodiments, the light source 120 may comprise a plurality of different optical emitters configured to provide different colors of light. The different optical emitters may be configured to provide light having different, color-specific, non-zero propagation angles of the guided light corresponding to each of the different colors of light.

**[0056]** In some embodiments, the guided light beams 112 produced by coupling light from the light source 120 into the light guide 110 may be uncollimated or at least substantially uncollimated. In other embodiments, the guided light beams 112 may be

collimated (i.e., the guided light beams 112 may be collimated light beams). As such, in some embodiments, the static multiview display 100 may include a collimator (not illustrated) between the light source 120 and the light guide 110. Alternatively, the light source 120 may further comprise a collimator. The collimator is configured to provide guided light beams 112 within the light guide 110 that are collimated. In particular, the collimator is configured to receive substantially uncollimated light from one or more of the optical emitters of the light source 120 and to convert the substantially uncollimated light into collimated light. In some examples, the collimator may be configured to provide collimation in a plane (e.g., a 'vertical' plane) that is substantially perpendicular to the propagation direction of the guided light beams 112. That is, the collimation may provide collimated guided light beams 112 having a relatively narrow angular spread in a plane perpendicular to a surface of the light guide 110 (e.g., the first or second surface 110', 110"), for example. According to various embodiments, the collimator may comprise any of a variety of collimators including, but not limited to a lens, a reflector or mirror (e.g., tilted collimating reflector), or a diffraction grating (e.g., a diffraction grating-based barrel collimator) configured to collimate the light, e.g., from the light source 120.

**[0057]** Further, in some embodiments, the collimator may provide collimated light one or both of having the non-zero propagation angle and being collimated according to a predetermined collimation factor. Moreover, when optical emitters of different colors are employed, the collimator may be configured to provide the collimated light having one or both of different, color-specific, non-zero propagation angles and having different color-specific collimation factors. The collimator is further configured to communicate the collimated light to the light guide 110 to propagate as the guided light beams 112, in some embodiments.

**[0058]** Use of collimated or uncollimated light may impact the multiview image that may be provided by the static multiview display 100, in some embodiments. For example, if the guided light beams 112 are collimated within the light guide 110, the emitted directional light beams 102 may have a relatively narrow or confined angular spread in at least two orthogonal directions. Thus, the static multiview display 100 may provide a multiview image having a plurality of different views in an array having two

different directions (e.g., an  $x$ -direction and a  $y$ -direction). However, if the guided light beams 112 are substantially uncollimated, the multiview image may provide view parallax, but may not provide a full, two-dimensional array of different views. In particular, if the guided light beams 112 are uncollimated (e.g., along the  $z$ -axis), the multiview image may provide different multiview images exhibiting ‘parallax 3D’ when rotated about the  $y$ -axis (e.g., as illustrated in Figure 1A). On the other hand, if the static multiview display 100 is rotated around the  $x$ -axis, for example, the multiview image and views thereof may remain substantially unchanged or the same because the directional light beams 102 of the directional light beam plurality have a broad angular range within the  $y$ - $z$  plane. Thus, the multiview image provided may be ‘parallax only’ providing an array of views in only one direction and not two.

**[0059]** The static multiview display 100 illustrated in Figures 3A-3C further comprises a plurality of diffraction gratings 130 configured to emit directional light beams 102 of the directional light beam plurality. As mentioned above and according to various embodiments, the directional light beams 102 emitted by the plurality of diffraction gratings 130 may represent a multiview image. In particular, the directional light beams 102 emitted by the plurality of diffraction gratings 130 may be configured to create the multiview image to display information, e.g., information having 3D content. Further, the diffraction gratings 130 may emit the directional light beams 102 when the light guide 110 is illuminated from the side 114 by the light source 120, as is further described below.

**[0060]** According to various embodiments, a diffraction grating 130 of the diffraction grating plurality are configured to provide from a portion of a guided light beam 112 of the guided light beam plurality a directional light beam 102 of the directional light beam plurality. Further, the diffraction grating 130 is configured to provide the directional light beam 102 having both an intensity and a principal angular direction corresponding to an intensity and a view direction of a view pixel of the multiview image. In some embodiments, the diffraction gratings 130 of the diffraction grating plurality generally do not intersect, overlap or otherwise touch one another, according to some embodiments. That is, each diffraction grating 130 of the diffraction

grating plurality is generally distinct and separated from other ones of the diffraction gratings 130, according to various embodiments.

**[0061]** As illustrated in Figure 3B, the directional light beams 102 may, at least in part, propagate in a direction that differs from and in some embodiments is orthogonal to an average or general propagation direction 103 of a guided light beams 112 within the light guide 110. For example, as illustrated in Figure 3B, the directional light beam 102 from a diffraction grating 130 may be substantially confined to the  $x$ - $z$  plane, according to some embodiments.

**[0062]** According to various embodiments, each of the diffraction gratings 130 of the diffraction grating plurality has an associated grating characteristic. The associated grating characteristic of each diffraction grating depends on, is defined by, or is a function of a radial direction 118 of the guided light beam 112 incident on the diffraction grating from the light source 120. Further, in some embodiment, the associated grating characteristic is further determined or defined by a distance between the diffraction grating 130 and the input location 116 of the light source 120. For example, the associated characteristic may be a function of the distance  $D$  between diffraction grating 130a and input location 116 and the radial direction 118a of the guided light beam 112 incident on the diffraction grating 130a, as illustrated in Figure 3A. Stated differently, an associated grating characteristic of a diffraction grating 130 in the plurality of the diffraction gratings 130 depends on the input location 116 of the light source and a particular location of the diffraction grating 130 on a surface of the light guide 110 relative to the input location 116.

**[0063]** Figure 3A illustrates two different diffraction gratings 130a and 130b having different spatial coordinates  $(x_1, y_1)$  and  $(x_2, y_2)$ , which further have different grating characteristics to compensate or account for the different radial directions 118a and 118b of the plurality of guided light beams 112 from the light source 120 that are incident on the diffraction gratings 130. Similarly, the different grating characteristics of the two different diffraction gratings 130a and 130b account for different distances of the respective diffraction gratings 130a, 130b from the light source input location 116 determined by the different spatial coordinates  $(x_1, y_1)$  and  $(x_2, y_2)$ .

**[0064]** Figure 3C illustrates an example of a plurality of directional light beams 102 that may be provided by the static multiview display 100. In particular, as illustrated, different sets of diffraction gratings 130 of the diffraction grating plurality are illustrated emitting directional light beams 102 having different principal angular directions from one another. The different principal angular directions may correspond to different view directions of the static multiview display 100, according to various embodiments. For example, a first set of the diffraction gratings 130 may diffractively couple out portions of incident guided light beams 112 (illustrated as dashed lines) to provide a first set of directional light beams 102' having a first principal angular direction corresponding to a first view direction (or a first view) of the static multiview display 100. Similarly, a second set of directional light beams 102'' and a third set of directional light beams 102''' having principal angular directions corresponding to a second view direction (or a second view) and a third view direction (or third view), respectively of the static multiview display 100 may be provided by diffractive coupling out of portions of incident guided light beams 112 by respective second third sets of diffraction gratings 130, and so on, as illustrated. Also illustrated in Figure 3C are a first view 14', a second view 14'', and a third view 14''', of a multiview image 16 that may be provided by the multiview display 100. The illustrated first, second, and third views 14', 14'', 14''', represent different perspective views of an object and collectively are the displayed multiview image 16 (e.g., equivalent to the multiview image 16 illustrated in Figure 1A).

**[0065]** In general, the grating characteristic of a diffraction grating 130 may include one or more of a diffractive feature spacing or pitch, a grating orientation and a grating size (or extent) of the diffraction grating. Further, in some embodiments, a diffraction-grating coupling efficiency (such as the diffraction-grating area, the groove depth or ridge height, etc.) may be a function of the distance from the input location 116 to the diffraction grating. For example, the diffraction grating coupling efficiency may be configured to increase as a function of distance, in part, to correct or compensate for a general decrease in the intensity of the guided light beams 112 associated with the radial spreading and other loss factors. Thus, an intensity of the directional light beam 102 provided by the diffraction grating 130 and corresponding to an intensity of a

corresponding view pixel may be determined, in part, by a diffractive coupling efficiency of the diffraction grating 130, according to some embodiments.

**[0066]** Figure 4 illustrates a plan view of a static multiview display 100 in an example, according to an embodiment consistent with the principles described herein. In Figure 4, illumination volumes 134 in an angular space that is a distance  $D$  from input location 116 of the light source 120 at the side 114 of the light guide 110 are shown. Note that the illumination volume has a wider angular size as the radial direction of propagation of the plurality of light beams 112 changes in angle away from the  $y$ -axis and towards the  $x$ -axis. For example, illumination volume 134b is wider than illumination volume 134a, as illustrated.

**[0067]** Referring again to Figure 3B, the plurality of diffraction gratings 130 may be located at or adjacent to the first surface 110' of the light guide 110, which is the light beam emission surface of the light guide 110, as illustrated. For example, the diffraction gratings 130 may be transmission mode diffraction gratings configured to diffractively couple out the guided light portion through the first surface 110' as the directional light beams 102. Alternatively, the plurality of diffraction gratings 130 may be located at or adjacent to the second surface 110" opposite from a light beam emission surface of the light guide 110 (i.e., the first surface 110'). In particular, the diffraction gratings 130 may be reflection mode diffraction gratings. As reflection mode diffraction gratings, the diffraction gratings 130 are configured to both diffract the guided light portion and to reflect the diffracted guided light portion toward the first surface 110' to exit through the first surface 110' as the diffractively scattered or coupled-out directional light beams 102. In other embodiments (not illustrated), the diffraction gratings 130 may be located between the surfaces of the light guide 110, e.g., as one or both of a transmission mode diffraction grating and a reflection mode diffraction grating.

**[0068]** In some embodiments described herein, the principal angular directions of the directional light beams 102 may include an effect of refraction due to the directional light beams 102 exiting the light guide 110 at a light guide surface. For example, when the diffraction gratings 130 are located at or adjacent to second surface 110", the directional light beams 102 may be refracted (i.e., bent) because of a change in refractive

index as the directional light beams 102 cross the first surface 110', by way of example and not limitation.

**[0069]** In some embodiments, provision may be made to mitigate, and in some instances even substantially eliminate, various sources of spurious reflection of guided light 112 within the static multiview display 100, especially when those spurious reflection sources may result in emission of unintended direction light beams and, in turn, the production of unintended images by static multiview display 100. Examples of various potential spurious reflection sources include, but not limited to, sidewalls of the light guide 110 that may produce a secondary reflection of the guided light 112. Reflection from various spurious reflection sources within the static multiview display 100 may be mitigated by any of a number of methods including, but not limited to absorption and controlled redirection of the spurious reflection.

**[0070]** Figure 5A illustrates a plan view of a static multiview display 100 including spurious reflection mitigation in an example, according to an embodiment consistent with the principles described herein. Figure 5B illustrates a plan view of a static multiview display 100 including spurious reflection mitigation in an example, according to another embodiment consistent with the principles described herein. In particular, Figures 5A and 5B illustrate the static multiview display 100 comprising the light guide 110, the light source 120, and the plurality of diffraction gratings 130. Also illustrated is the plurality of guided light beams 112 with at least one guided light beam 112 of the plurality being incident on a sidewall 114a, 114b of the light guide 110. A potential spurious reflection of the guided light beam 112 by the sidewalls 114a, 114b is illustrated by a dashed arrow representing a reflected guided light beam 112'.

**[0071]** In Figure 5A, the static multiview display 100 further comprises an absorbing layer 119 at the sidewalls 114a, 114b of the light guide 110. The absorbing layer 119 is configured to absorb incident light from the guided light beams 112. The absorbing layer may comprise substantially any optical absorber including, but not limited to, black paint applied to the sidewalls 114a, 114b for example. As illustrated in 5A, the absorbing layer 119 is applied to sidewall 114b, while the sidewall 114a lacks the absorbing layer 119, by way of example and not limitation. The absorbing layer 119 intercepts and absorbs the incident guided light beam 112 effectively preventing or

mitigating the production of the potential spurious reflection from sidewall 114b. On the other hand, guided light beam 112 incident on the sidewall 114a reflects resulting in the production of the reflected guided light beam 112', illustrated by way of example and not limitation.

**[0072]** Figure 5B illustrates spurious reflection mitigation using controlled reflection angle. In particular, the light guide 110 of the static multiview display 110 illustrated in Figure 5B comprises slanted sidewalls 114a, 114b. The slanted sidewalls have a slant angle configured to preferentially direct the reflected guided light beam 112' substantially away from the diffraction gratings 130. As such, the reflected guided light beam 112' is not diffractively coupled out of the light guide 110 as an unintended directional light beam. The slant angle of the sidewalls 114a, 114b may be in the  $x$ - $y$  plane, as illustrated. In other examples (not illustrated), the slant angle of the sidewalls 114a, 114b may be in another plane, e.g., the  $x$ - $z$  plane to direct the reflected guided light beam 112' out a top or bottom surface of the light guide 110. Note that Figure 5B illustrates sidewalls 114a, 114b that include a slant along only a portion of thereof, by way of example and not limitation.

**[0073]** According to some embodiment, the static multiview display 100 may comprise a plurality of light sources 120 that are laterally offset from one another. The lateral offset of light sources 120 of the light source plurality may provide a difference in the radial directions of various guided light beams 102 at or between individual diffraction gratings 130. The difference, in turn, may facilitate providing animation of a displayed multiview image, according to some embodiments. Thus, the static multiview display 100 may be a quasi-static multiview display 100, in some embodiments.

**[0074]** Figure 6A illustrates a plan view of a static multiview display 100 in an example, according to an embodiment consistent with the principles described herein. Figure 6B illustrates a plan view of the static multiview display 100 of Figure 6A in another example, according to an embodiment consistent with the principles described herein. The static multiview display 100 illustrated in Figures 6A and 6B comprises a light guide 110 with a plurality of diffraction gratings 130. In addition, the static multiview display 100 further comprises a plurality of light sources 120 that are laterally

offset from each other and configured to separately provide guided light beams 112 having different radial directions 118 from one another, as illustrated.

**[0075]** In particular, Figures 6A and 6B illustrate a first light source 120a at a first input location 116a and a second light source 120b at a second input location 116b on the side 114 of the light guide 110. The first and second input locations 116a, 116b are laterally offset or shifted from one another along the side 114 (i.e., in an *x*-direction) to provide the lateral offset of respective first and second light sources 120a, 120b.

Additionally, each of the first and second light sources 120a, 120b of the plurality of light sources 120 provide a different plurality of guided light beams 112 having respective different radial directions from one another. For example, the first light source 120a may provide a first plurality of guided light beams 112a having a first set of different radial directions 118a and the second light source 120b may provide a second plurality of guided light beams 112b having a second set of different radial directions 118b, as illustrated in Figures 6A and 6B, respectively. Further, the first and second pluralities of guided light beams 112a, 112b generally have sets of different radial directions 118a, 118b that also differ from one another as sets by virtue of the lateral offset of the first and second light sources 120a, 120b, as illustrated.

**[0076]** Thus, the plurality of diffraction gratings 130 emit directional light beams representing different multiview images that are shifted in a view space from one another (e.g., angularly shifted in view space). Thus, by switching between the first and second light sources 120a, 120b, the static multiview display 100 may provide ‘animation’ of the multiview images, such as a time-sequenced animation. In particular, by sequentially illuminating the first and second light sources 120a, 120b during different sequential time intervals or periods, static multiview display 100 may be configured to shift an apparent location of the multiview image during the different time periods, for example. This shift in apparent location provided by the animation may represent an example of operating the static multiview display 100 as a quasi-static multiview display 100 to provide a plurality of multiview image states, according to some embodiments.

**[0077]** According to various embodiments, as described above with respect to Figures 3A-3C, the directional light beams 102 of the static multiview display 100 are emitted using diffraction (e.g., by diffractive scattering or diffractive coupling). In some

embodiments, the plurality of the diffraction gratings 130 may be organized as multiview pixels, each multiview pixel including a set of diffraction gratings 130 comprising one or more diffraction gratings 130 from the diffraction grating plurality. Further, as has been discussed above, the diffraction grating(s) 130 have diffraction characteristics that are a function of radial location on the light guide 110 as well as being a function of an intensity and direction of the directional light beams 102 emitted by the diffraction grating(s) 130.

**[0078]** Figure 7A illustrates a plan view of a diffraction grating 130 of a multiview display in an example, according to an embodiment consistent with the principles described herein. Figure 7B illustrates a plan view of a set of diffraction gratings 130 organized as a multiview pixel 140 in an example, according to another embodiment consistent with the principles described herein. As illustrated in Figures 7A and 7B, each of the diffraction gratings 130 comprises a plurality of diffractive features spaced apart from one another according to a diffractive feature spacing (which is sometimes referred to as a ‘grating spacing’) or grating pitch. The diffractive feature spacing or grating pitch is configured to provide diffractive coupling out or scattering of the guided light portion from within the light guide. In Figures 7A-7B, the diffraction gratings 130 are on a surface of a light guide 110 of the multiview display (e.g., the static multiview display 100 illustrated in Figures 3A-3C).

**[0079]** According to various embodiments, the spacing or grating pitch of the diffractive features in the diffraction grating 130 may be sub-wavelength (i.e., less than a wavelength of the guided light beams 112). Note that, while Figures 7A and 7B illustrate the diffraction gratings 130 having a single or uniform grating spacing (i.e., a constant grating pitch), for simplicity of illustration. In various embodiments, as described below, the diffraction grating 130 may include a plurality of different grating spacings (e.g., two or more grating spacings) or a variable diffractive feature spacing or grating pitch to provide the directional light beams 102, e.g., as is variously illustrated in Figures 3A-6B. Consequently, Figures 7A and 7B are not intended to imply that a single grating pitch is an exclusive embodiment of diffraction grating 130.

**[0080]** According to some embodiments, the diffractive features of the diffraction grating 130 may comprise one or both of grooves and ridges that are spaced apart from

one another. The grooves or the ridges may comprise a material of the light guide 110, e.g., the groove or ridges may be formed in a surface of the light guide 110. In another example, the grooves or the ridges may be formed from a material other than the light guide material, e.g., a film or a layer of another material on a surface of the light guide 110.

**[0081]** As discussed previously and shown in Figure 7A, the configuration of the diffraction features comprises a grating characteristic of the diffraction grating 130. For example, a grating depth of the diffraction grating may be configured to determine the intensity of the directional light beams 102 provided by the diffraction grating 130. Alternatively or additionally, discussed previously and shown in Figures 7A-7B, the grating characteristic comprises one or both of a grating pitch of the diffraction grating 130 and a grating orientation (e.g., the grating orientation  $\gamma$  illustrated in Figure 7A). In conjunction with the angle of incidence of the guided light beams, these grating characteristics determine the principal angular direction of the directional light beams 102 provided by the diffraction grating 130.

**[0082]** In some embodiments (not illustrated), the diffraction grating 130 configured to provide the directional light beams comprises a variable or chirped diffraction grating as a grating characteristic. By definition, the 'chirped' diffraction grating is a diffraction grating exhibiting or having a diffraction spacing of the diffractive features (i.e., the grating pitch) that varies across an extent or length of the chirped diffraction grating. In some embodiments, the chirped diffraction grating may have or exhibit a chirp of the diffractive feature spacing that varies linearly with distance. As such, the chirped diffraction grating is a 'linearly chirped' diffraction grating, by definition. In other embodiments, the chirped diffraction grating of the multiview pixel may exhibit a non-linear chirp of the diffractive feature spacing. Various non-linear chirps may be used including, but not limited to, an exponential chirp, a logarithmic chirp or a chirp that varies in another, substantially non-uniform or random but still monotonic manner. Non-monotonic chirps such as, but not limited to, a sinusoidal chirp or a triangle or sawtooth chirp, may also be employed. Combinations of any of these types of chirps may also be employed.

**[0083]** In other embodiments, diffraction grating 130 configured to provide the directional light beams 102 is or comprises a plurality of diffraction gratings (e.g., sub-gratings). For example, the plurality of diffraction gratings of the diffraction grating 130 may comprise a first diffraction grating configured to provide a red portion of the directional light beams 102. Further, the plurality of diffraction gratings of the diffraction grating 130 may comprise a second diffraction grating configured to provide a green portion of the directional light beams 102. Further still, the plurality of diffraction gratings of the diffraction grating 130 may comprise a third diffraction grating configured to provide a blue portion of the directional light beams 102. In some embodiments, individual diffraction gratings of the plurality of diffraction gratings may be superimposed on one another. In other embodiments, the diffraction gratings may be separate diffraction gratings arranged next to one another, e.g., as an array.

**[0084]** More generally, the static multiview display 100 may comprise one or more instances of multiview pixels 140, which each comprise sets of diffraction gratings 130 from the plurality of diffraction gratings 130. As shown in Figure 7B, the diffraction gratings 130 of the set that makes up a multiview pixel 140 may have different grating characteristics. The diffraction gratings 130 of the multiview pixel may have different grating orientations, for example. In particular, the diffraction gratings 130 of the multiview pixel 140 may have different grating characteristics determined or dictated by a corresponding set of views of a multiview image. For example, the multiview pixel 140 may include a set of eight (8) diffraction gratings 130 that, in turn, correspond to 8 different views of the static multiview display 100. Moreover, the static multiview display 100 may include multiple multiview pixels 140. For example, there may be a plurality of multiview pixels 140 with sets of diffraction gratings 130, each multiview pixels 140 corresponding to a different one of 2048 x 1024 pixels in each of the 8 different views.

**[0085]** In some embodiments, static multiview display 100 may be transparent or substantially transparent. In particular, the light guide 110 and the spaced apart plurality of diffraction gratings 130 may allow light to pass through the light guide 110 in a direction that is orthogonal to both the first surface 110' and the second surface 110", in some embodiments. Thus, the light guide 110 and more generally the static multiview

display 100 may be transparent to light propagating in the direction orthogonal to the general propagation direction 103 of the guided light beams 112 of the guided light beam plurality. Further, the transparency may be facilitated, at least in part, by the substantially transparency of the diffraction gratings 130.

**[0086]** In accordance with some embodiments of the principles described herein, a multiview display is provided. The multiview display is configured to emit a plurality of directional light beams provided by the multiview display. Further, the emitted directional light beams may be preferentially directed toward a plurality of views zones of the multiview display based on the grating characteristics of a plurality of diffraction grating that are included in one or more multiview pixels in the multiview display. Moreover, the diffraction gratings may produce different principal angular directions in the directional light beams, which corresponding to different viewing directions for different views in a set of views of the multiview image of the multiview display. In some examples, the multiview display is configured to provide or 'display' a 3D or multiview image. Different ones of the directional light beams may correspond to individual view pixels of different 'views' associated with the multiview image, according to various examples. The different views may provide a 'glasses free' (e.g., autostereoscopic) representation of information in the multiview image being displayed by the multiview display, for example.

**[0087]** Figure 8 illustrates a block diagram of a static multiview display 200 in an example, according to an embodiment consistent with the principles described herein. According to various embodiments, the static multiview display 200 is configured to display a multiview image according to different views in different view directions. In particular, a plurality of directional light beams 202 emitted by the static multiview display 200 are used to display the multiview image and may correspond to pixels of the different views (i.e., view pixels). The directional light beams 202 are illustrated as arrows emanating from one or more multiview pixels 210 in Figure 8. Also illustrated in Figure 8 are a first view 14', a second view 14", and a third view 14"', of a multiview image 16 that may be provided by the static multiview display 200.

**[0088]** Note that the directional light beams 202 associated with one of multiview pixels 210 are either static or quasi-static (i.e., not actively modulated). Instead, the

multiview pixels 210 either provide the directional light beams 202 when they are illuminated or do not provide the directional light beams 202 when they are not illuminated. Further, an intensity of the provided directional light beams 202 along with a direction of those directional light beams 202 defines the pixels of the multiview image 16 being displayed by the static multiview display 200, according to various embodiments. Further, the displayed views 14', 14", 14''' within the multiview image 16 are static or quasi-static, according to various embodiments.

**[0089]** The static multiview display 200 illustrated in Figure 8 comprises an array of the multiview pixels 210. The multiview pixels 210 of the array are configured to provide a plurality of different views of the static multiview display 200. According to various embodiments, a multiview pixel 210 of the array comprises a plurality of diffraction gratings 212 configured to diffractively couple out or emit the plurality of directional light beams 202. The plurality of directional light beams 202 may have principal angular directions, which correspond to different views directions of different views in a set of views of the static multiview display 200. Moreover, grating characteristics of the diffraction gratings 212 may be varied or selected based on the radial direction of incident light beams to diffraction gratings 212, a distance to a light source that provides the incident light beams or both. In some embodiments, the diffraction gratings 212 and multiview pixels 210 may be substantially similar to diffraction gratings 130 and multiview pixel 140, respectively, of the static multiview display 100, described above.

**[0090]** As illustrated in Figure 8, the static multiview display 200 further comprises a light guide 220 configured to guide light. In some embodiments, the light guide 220 may be substantially similar to the light guide 110 described above with respect to the static multiview display 100. According to various embodiments, the multiview pixels 210, or more particularly the diffraction gratings 212 of the various multiview pixels 210, are configured to scatter or couple out a portion of guided light (or equivalently 'guided light beams 204', as illustrated) from the light guide 220 as the plurality of directional light beams 202 (i.e., the guided light may be the incident light beams discussed above). In particular, the multiview pixels 210 are optically connected

to the light guide 220 to scatter or couple out the portion of the guided light (i.e., guided light beams 204) by diffractive scattering or diffractive coupling.

**[0091]** In various embodiments, grating characteristics of the diffraction gratings 212 are varied based on or as a function of a radial direction of incident guided light beams 204 at the diffraction gratings 212, a distance between a light source that provides the guided light beams 204, or both. In this way, the directional light beams 202 from different diffraction gratings 212 in a multiview pixel may correspond to pixels of views of a multiview image provided by the static multiview display 200.

**[0092]** The static multiview display 200 illustrated in Figure 8 further comprises a light source 230. The light source 230 may be configured to provide the light to the light guide 110. In particular, the provided light (e.g., illustrated by arrows emanating from the light source 230 in Figure 8) is guided by the light guide 110 as a plurality of guided light beams 204. The guided light beams 204 of the guided light beam plurality have different radial directions from one another within the light guide 220, according to various embodiments. In some embodiments, the guided light beams 204 are provided with a non-zero propagation angle and, in some embodiments, having a collimation factor to provide a predetermined angular spread of the guided light beams 204 within the light guide 220, for example. According to some embodiments, the light source 230 may be substantially similar to one of the light source(s) 120 of the static multiview display 100, described above. For example, the light source 230 may be butt-coupled to an input edge of the light guide 220. The light source 230 may radiate light in a fan-shape or radial pattern to provide the plurality of guided light beams 204 having the different radial directions.

**[0093]** In accordance with other embodiments of the principles described herein, a method of static multiview display operation is provided. Figure 9 illustrates a flow chart of a method 300 of static multiview display operation in an example, according to an embodiment consistent with the principles described herein. The method 300 of static multiview display operation may be used to provide one or both display of a static multiview image and display of a quasi-static multiview image, according to various embodiments.

**[0094]** As illustrated in Figure 9, the method 300 of static multiview display operation comprises guiding 310 the light along the light guide as a plurality of guided light beams having a common point of origin and different radial directions from one another. In particular, a guided light beam of the guided light beam plurality has, by definition, a different radial direction of propagation from another guided light beam of the guided light beam plurality. Further, each of the guided light beams of the guided light beam plurality has, by definition, a common point of origin. The point of origin may be a virtual point of origin (e.g., a point beyond an actual point of origin of the guided light beam), in some embodiments. For example, the point of origin may be outside of the light guide and thus be a virtual point of origin. According to some embodiments, the light guide along which the light is guided 310 as well as the guided light beams that are guided therein may be substantially similar to the light guide 110 and guided light beams 112, respectively, as described above with reference to the static multiview display 100.

**[0095]** The method 300 of static multiview display operation illustrated in Figure 9 further comprises emitting 320 a plurality of directional light beams representing a multiview image using a plurality of diffraction gratings. According to various embodiments, a diffraction grating of the diffraction grating plurality diffractively couples or scatters out light from the guided light beam plurality as a directional light beam of the directional light beam plurality. Further, the directional light beam that is coupled or scattered out has both an intensity and a principal angular direction of a corresponding view pixel of the multiview image. In particular, the plurality of directional light beams produced by the emitting 320 may have principal angular directions corresponding to different view pixels in a set of views of the multiview image. Moreover, intensities of directional light beams of the directional light beam plurality may correspond to intensities of various view pixels of the multiview image. In some embodiments, each of the diffraction gratings produces a single directional light beam in a single principal angular direction and having a single intensity corresponding to a particular view pixel in one view of the multiview image. In some embodiments, the diffraction grating comprises a plurality of diffraction grating (e.g., sub-gratings).

Further, a set of diffraction gratings may be arranged as a multiview pixel of the static multiview display, in some embodiments.

**[0096]** In various embodiments, the intensity and principal angular direction of the emitted 320 directional light beams are controlled by a grating characteristic of the diffraction grating that is based on (i.e., is a function of) a location of the diffraction grating relative to the common origin point. In particular, grating characteristics of the plurality of diffraction gratings may be varied based on, or equivalently may be a function of, radial directions of incident guided light beams at the diffraction gratings, a distance from the diffraction gratings to a light source that provides the guided light beams, or both.

**[0097]** According to some embodiments, the plurality of diffraction gratings may be substantially similar to the plurality of diffraction gratings 130 of the static multiview display 100, described above. Further, in some embodiments, the emitted 320 plurality of directional light beams may be substantially similar to the plurality of directional light beams 102, also described above. For example, the grating characteristic controlling the principal angular direction may comprise one or both of a grating pitch and a grating orientation of the diffraction grating. Further, an intensity of the directional light beam provided by the diffraction grating and corresponding to an intensity of a corresponding view pixel may be determined by a diffractive coupling efficiency of the diffraction grating. That is, the grating characteristic controlling the intensity may comprise a grating depth of the diffraction grating, a size of the gratings, etc., in some examples.

**[0098]** As illustrated, the method 300 of static multiview display operation further comprises providing 330 light to be guided as the plurality of guided light beams using a light source. In particular, light is provided to the light guide as the guided light beams having a plurality of different radial directions of propagation using the light source. According to various embodiments, the light source used in providing 330 light is located at a side of the light guide, the light source location being the common origin point of the guided light beam plurality. In some embodiments, the light source may be substantially similar to the light source(s) 120 of the static multiview display 100, described above. In particular, the light source may be butt-coupled to an edge or side of the light guide.

Further, the light source may approximate a point source representing the common point of origin, in some embodiments.

**[0099]** In some embodiments (not illustrated), the method of static multiview display operation further comprises animating the multiview image by guiding a first plurality of light guided light beams during a first time period and guiding a second plurality of guided light beams during a second time period during a second period. The first guided light beam plurality may have a common origin point that differs from a common origin point of the second guided light beam plurality. For example, the light source may comprise a plurality of laterally offset light sources, e.g., configured to provide animation, as described above. Animation may comprise a shift in an apparent location of the multiview image during the first and second time periods, according to some embodiments.

**[0100]** In some embodiments, the provided 330 light is substantially uncollimated. In other embodiments, the provided 330 light may be collimated (e.g., the light source may comprise a collimator). In various embodiments, the provided 330 light may be the guided having the different radial directions at a non-zero propagation angle within the light guide between surfaces of the light guide. When collimated within the light guide, the provided 330 light may be collimated according to a collimation factor to establish a predetermined angular spread of the guided light within the light guide.

**[0101]** Thus, there have been described examples and embodiments of a static multiview display and a method of static multiview display operation having diffraction gratings configured to provide a plurality of directional light beams representing a static or quasi-static multiview image from guided light beams having different radial directions from one another. It should be understood that the above-described examples are merely illustrative of some of the many specific examples that represent the principles described herein. Clearly, those skilled in the art can readily devise numerous other arrangements without departing from the scope as defined by the following claims.

## CLAIMS

What is claimed is:

1. A static multiview display comprising:  
a light guide configured to guide light beams;  
a light source at an input location on the light guide, the light source being configured to provide within the light guide a plurality of guided light beams having different radial directions from one another; and  
a plurality of diffraction gratings configured to emit directional light beams representing a static multiview image, each diffraction grating being configured to provide from a portion of a guided light beam of the guided light beam plurality a directional light beam having an intensity and a principal angular direction corresponding to an intensity and a view direction of a view pixel of the static multiview image.
2. The static multiview display of Claim 1, wherein the input location of the light source is on a side of the light guide at about a midpoint of the side.
3. The static multiview display of Claim 1, wherein a grating characteristic of the diffraction grating is configured to determine the intensity and the principal angular direction, the grating characteristic being a function of both a location of the diffraction grating on a surface of the light guide and the input location of the light source on a side of the light guide.
4. The static multiview display of Claim 3, wherein the grating characteristic comprises one or both of a grating pitch of the diffraction grating and a grating orientation of the diffraction grating, the grating characteristic being configured to determine the principal angular direction of the directional light beam provided by the diffraction grating.
5. The static multiview display of Claim 3, wherein the grating characteristic comprises a grating depth configured to determine the intensity of the directional light beam provided by the diffraction grating.

6. The static multiview display of Claim 1, wherein an emission pattern of a directional light beam of the directional light beam plurality is wider in a direction parallel to a direction of propagation of the guided light beam plurality than in a direction perpendicular to the direction of propagation of the guided light beam plurality.

7. The static multiview display of Claim 1, wherein the plurality of diffraction gratings are located on a surface of the light guide opposite to a light beam emission surface of the light guide.

8. The static multiview display of Claim 1, further comprising a collimator between the light source and the light guide, the collimator being configured to collimate light emitted by the light source, the plurality of guided light beams comprising collimated light beams.

9. The static multiview display of Claim 1, further comprising another light source at another laterally offset input location on the light guide, the other light source being configured to provide another plurality of guided light beams, wherein the plurality of guided light beams and the other plurality of guided light beams have different radial directions from one another, and wherein switching between the light source and the other light source is configured to animate the static multiview image, the static multiview display being a quasi-static multiview display.

10. The static multiview display of Claim 1, wherein the light guide is transparent to light propagating in a direction orthogonal a direction of propagation of a guided light beam of the guided light beam plurality within the light guide.

11. A static multiview display comprising:  
a plate light guide;  
a light source configured to provide a plurality of guided light beams having different radial directions from one another within the plate light guide; and  
an array of multiview pixels configured to provide a plurality of different views of a static multiview image, a multiview pixel comprising a plurality of diffraction gratings

configured to diffractively couple out light from the guided light beam plurality to provide directional light beams representing view pixels of the multiview pixel,

wherein a principal angular direction of a directional light beam provided by a diffraction grating of the diffraction grating plurality is a function of a grating characteristic, the grating characteristic being a function of a relative location of the diffraction grating and the light source.

12. The static multiview display of Claim 11, wherein the grating characteristic comprises one or both of a grating pitch and a grating orientation of the diffraction grating.

13. The static multiview display of Claim 11, wherein an intensity of the directional light beam provided by the diffraction grating and corresponding to an intensity of a corresponding view pixel is determined by a diffractive coupling efficiency of the diffraction grating.

14. The static multiview display of Claim 11, wherein the light source comprises a first optical emitter laterally offset from a second optical emitter along a side of the light guide, the first optical emitter being configured to provide a first plurality of guided light beams and the second optical emitter being configured to provide a second plurality of guided light beams.

15. The static multiview display of Claim 11, wherein the light guide is transparent in a direction orthogonal to a direction of propagation of a guided light beam of the guided light beam plurality within the light guide.

16. A method of static multiview display operation, the method comprising:  
guiding in a light guide a plurality of guided light beams having a common point of origin and different radial directions from one another; and  
emitting a plurality of directional light beams representing a static multiview image using a plurality of diffraction gratings, a diffraction grating of the diffraction grating plurality diffractively coupling out light from the guided light beam plurality as a

directional light beam of the directional light beam plurality having an intensity and a principal angular direction of a corresponding view pixel of the static multiview image, wherein the intensity and principal angular direction of the emitted directional light beam are controlled by a grating characteristic of the diffraction grating that is based on a location of the diffraction grating relative to the common origin point.

17. The method of static multiview display operation of Claim 16, wherein grating characteristic controlling the principal angular direction comprises one or both of a grating pitch and a grating orientation of the diffraction grating.

18. The method of static multiview display operation of Claim 16, wherein the grating characteristic controlling the intensity comprises a grating depth of the diffraction grating.

19. The method of static multiview display operation of Claim 16, further comprising providing light to be guided as the plurality of guided light beams using a light source, the light source being located at a side of the light guide, wherein the light source location is the common origin point of the guided light beam plurality.

20. The method of static multiview display operation of Claim 16, further comprising animating the static multiview image by guiding a first plurality of light guided light beams during a first time period and guiding a second plurality of guided light beams during a second time period during a second period, the first guided light beam plurality having a common origin point that differs from a common origin point of the second guided light beam plurality, wherein animation comprises a shift in an apparent location of the static multiview image during the first and second time periods.

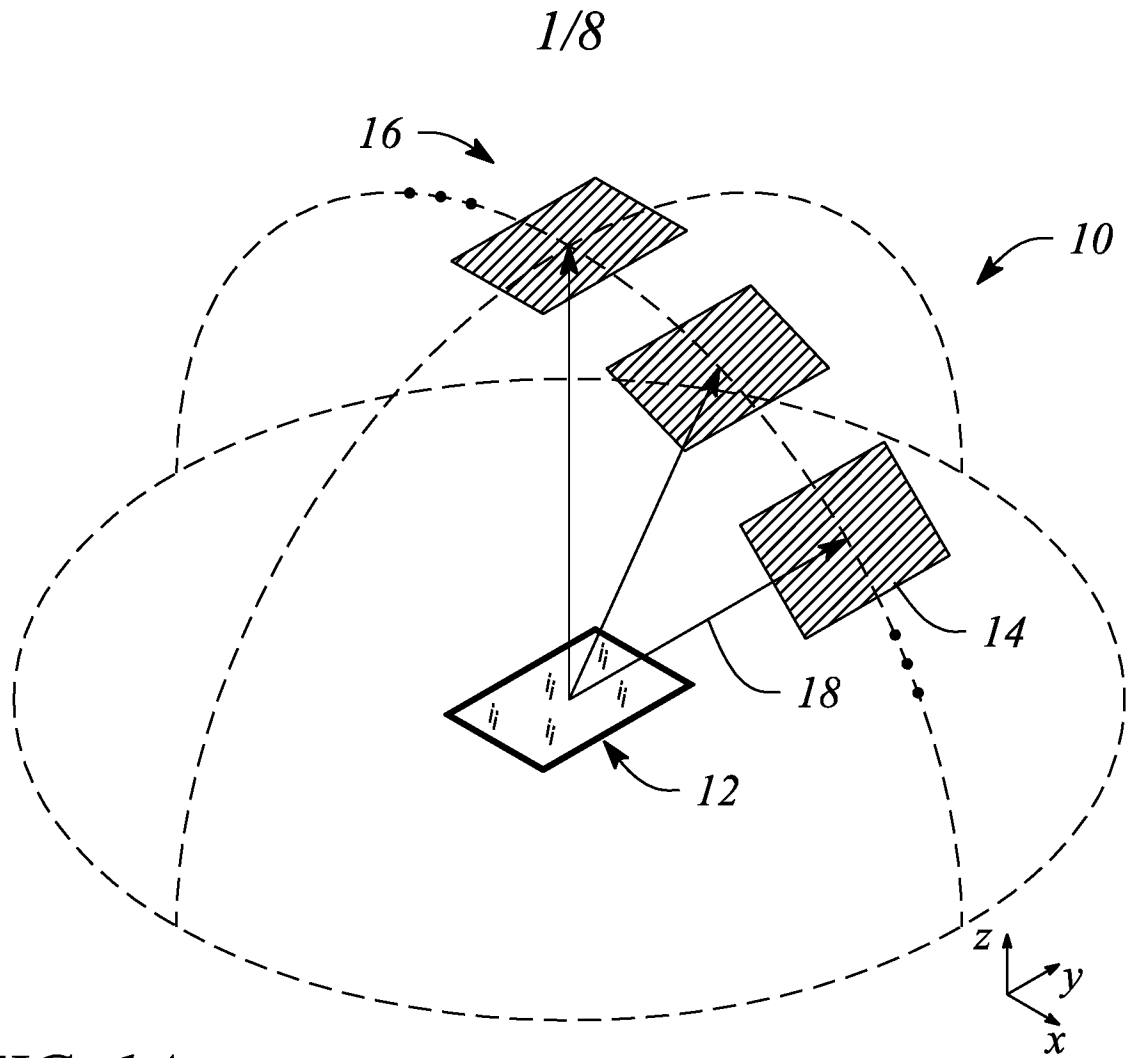


FIG. 1A

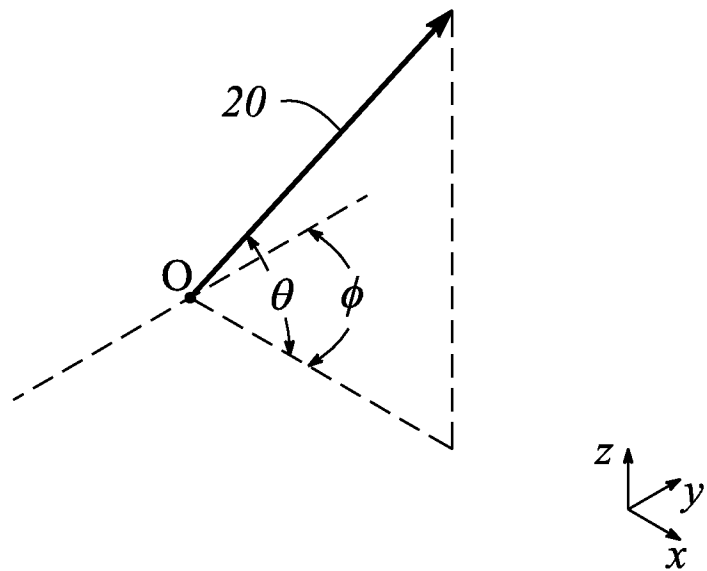


FIG. 1B

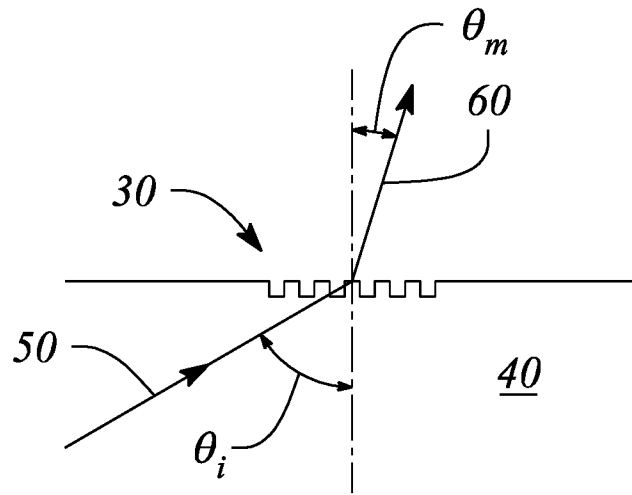


FIG. 2

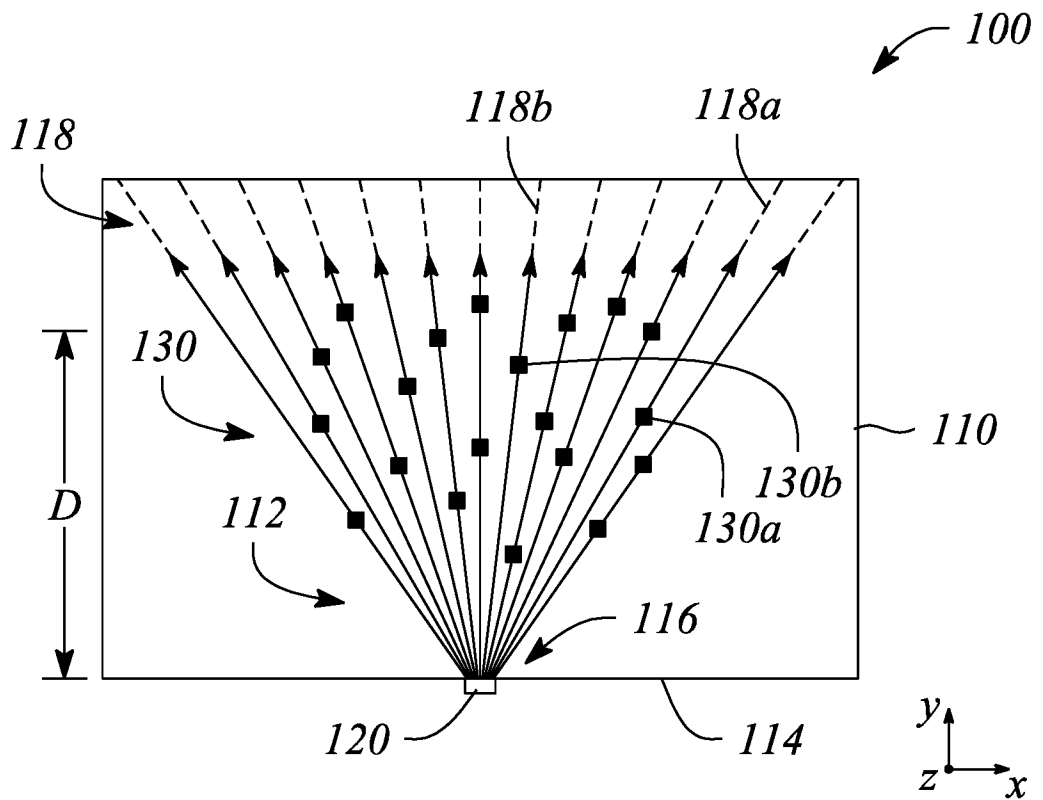


FIG. 3A

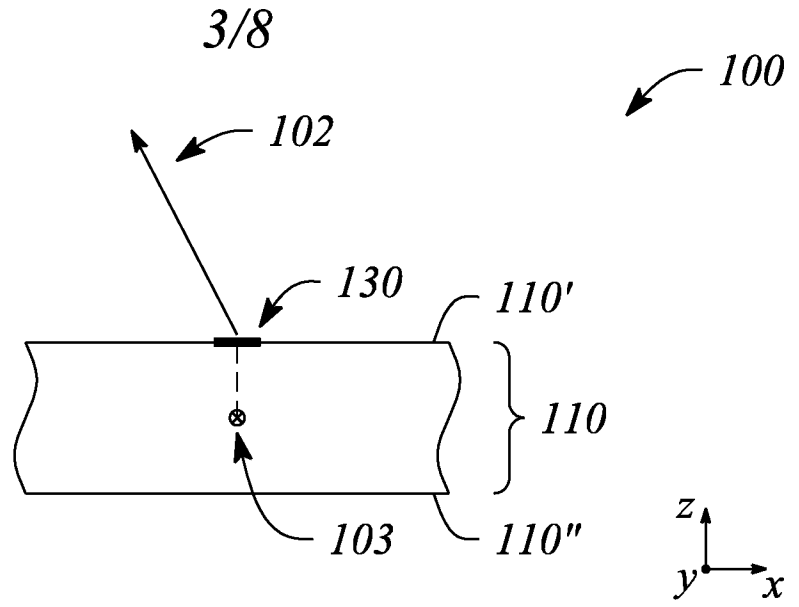


FIG. 3B

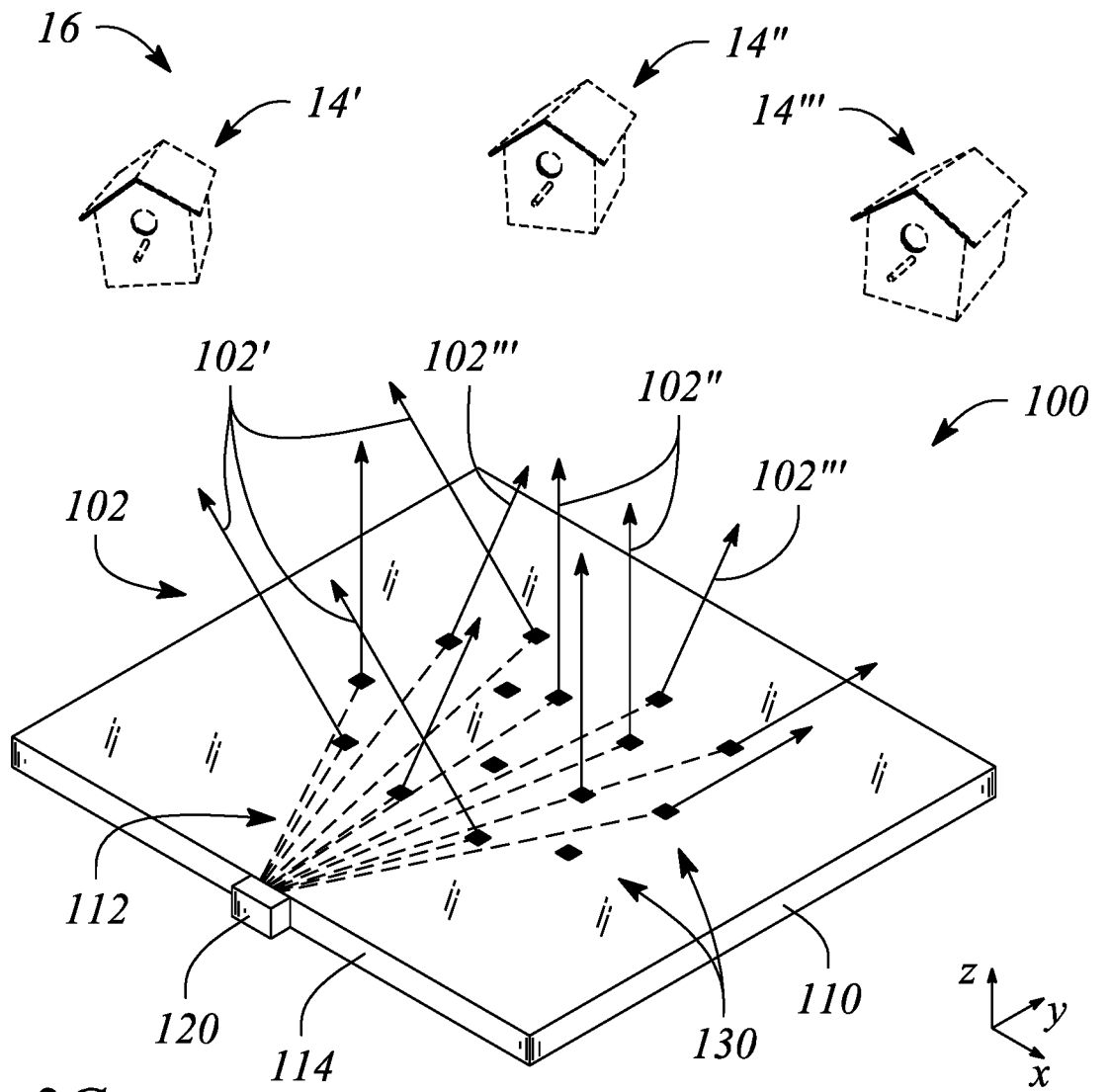


FIG. 3C

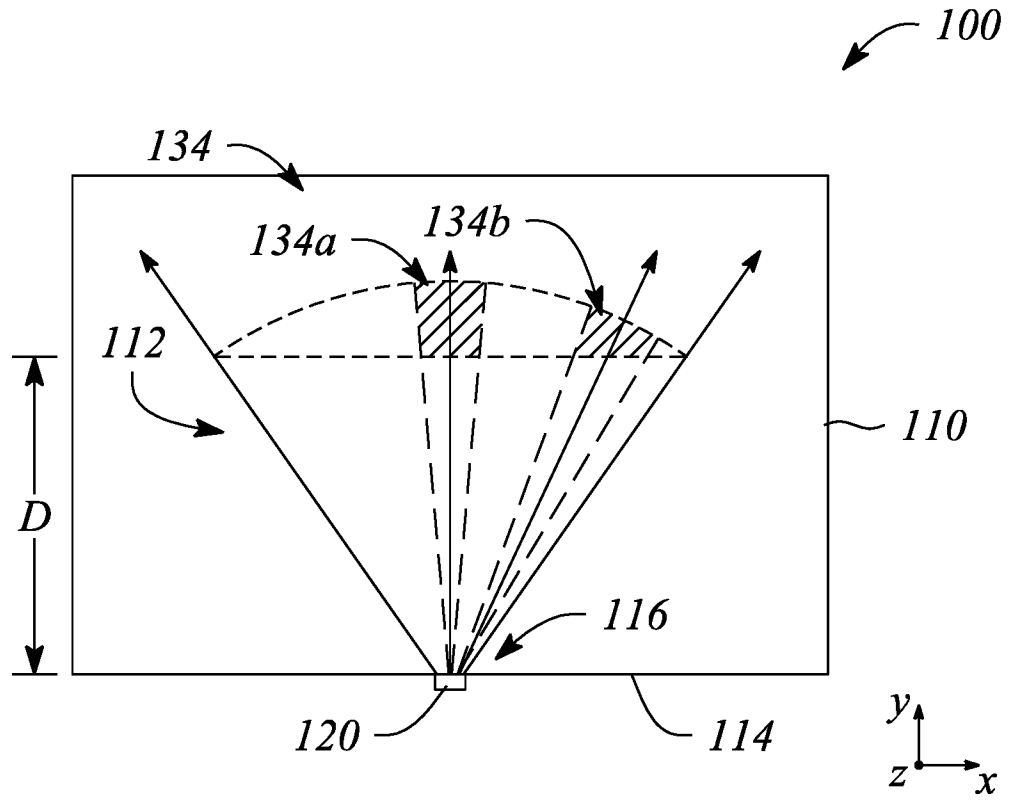


FIG. 4

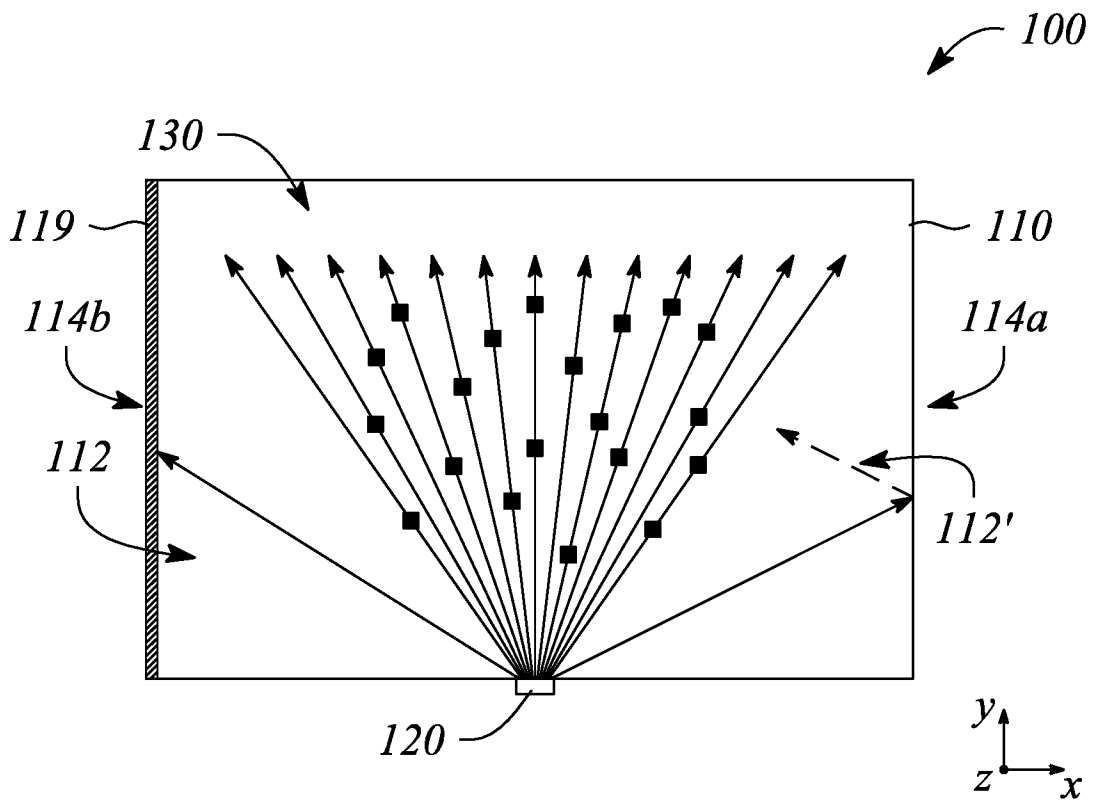


FIG. 5A

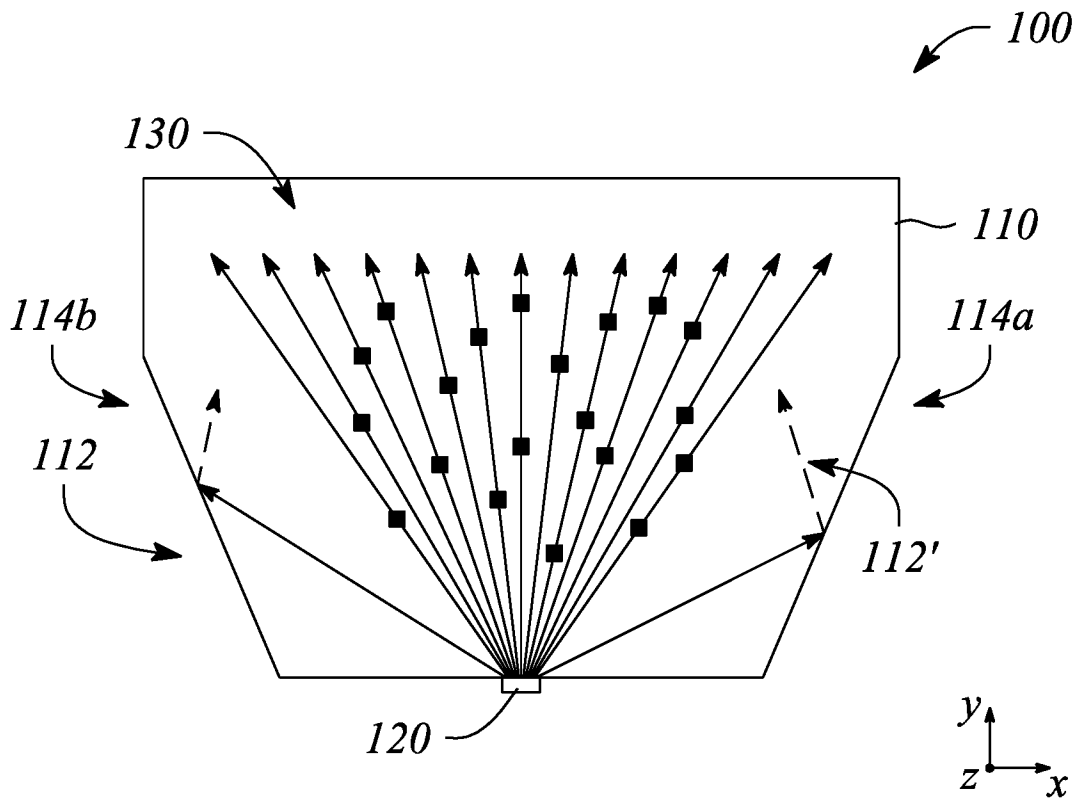


FIG. 5B

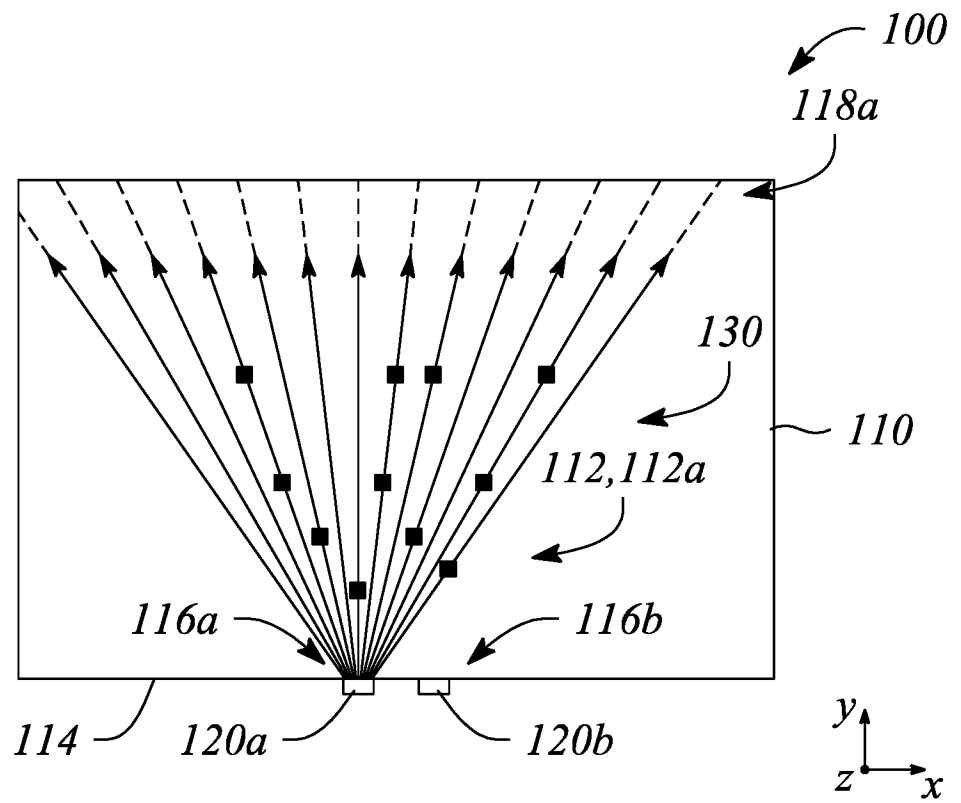


FIG. 6A

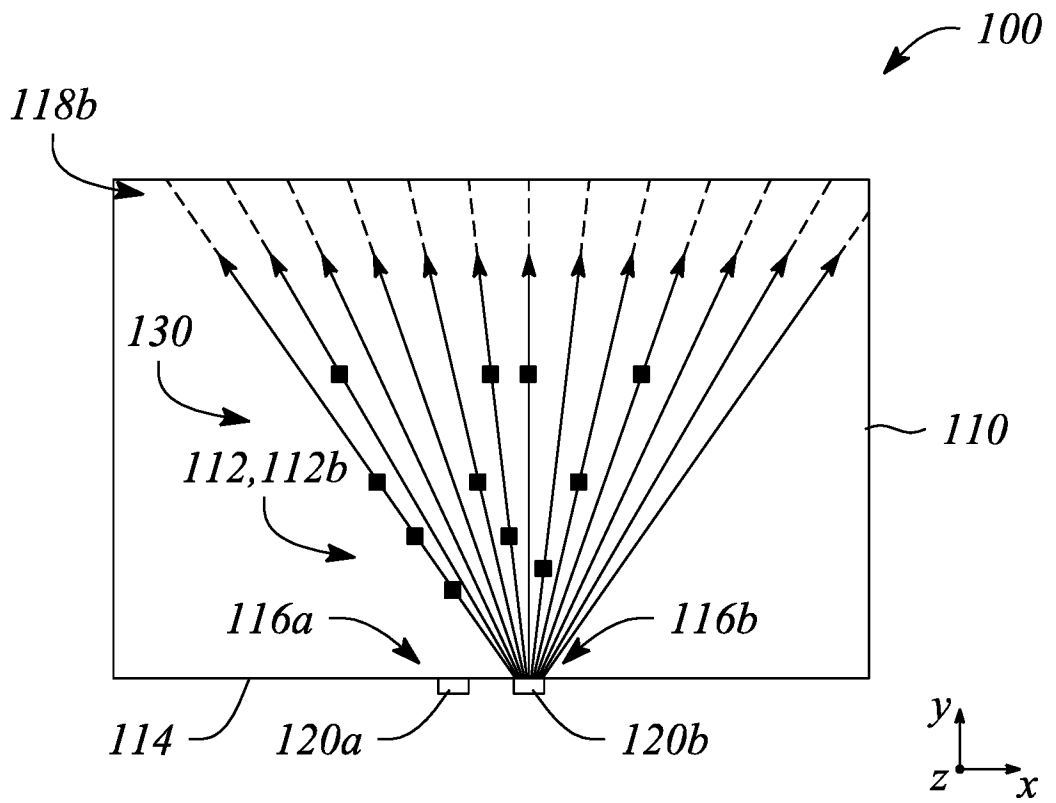


FIG. 6B

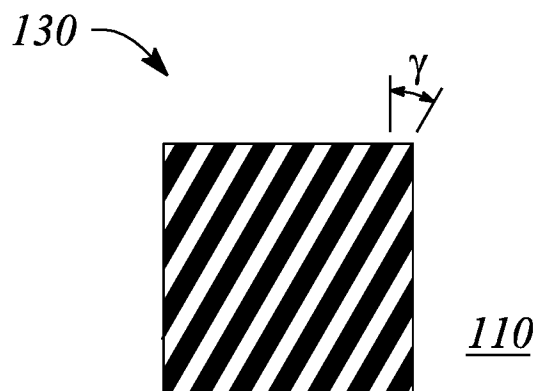


FIG. 7A

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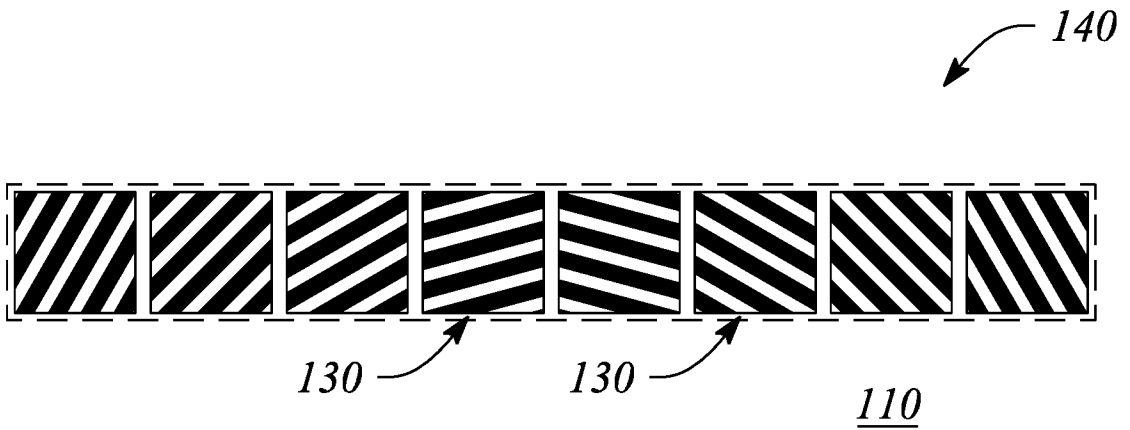


FIG. 7B

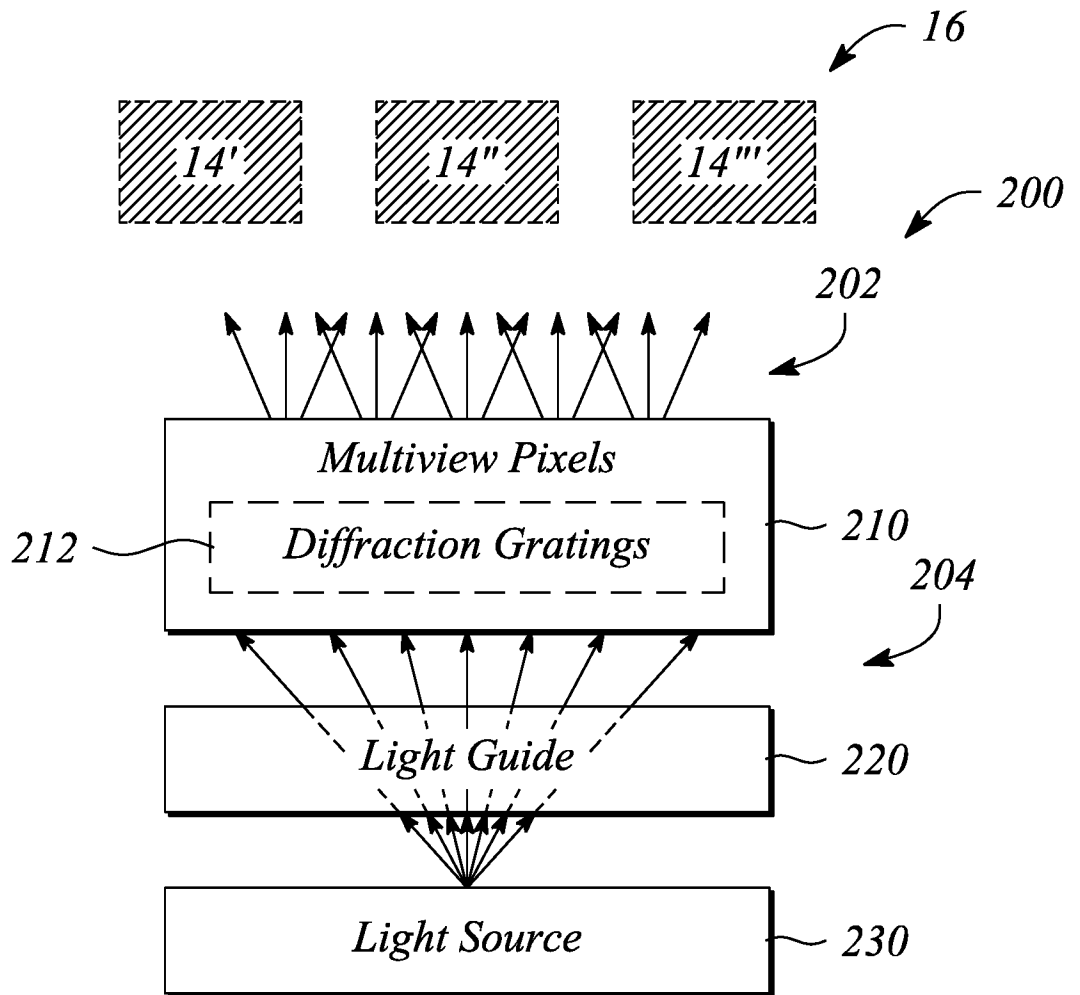


FIG. 8

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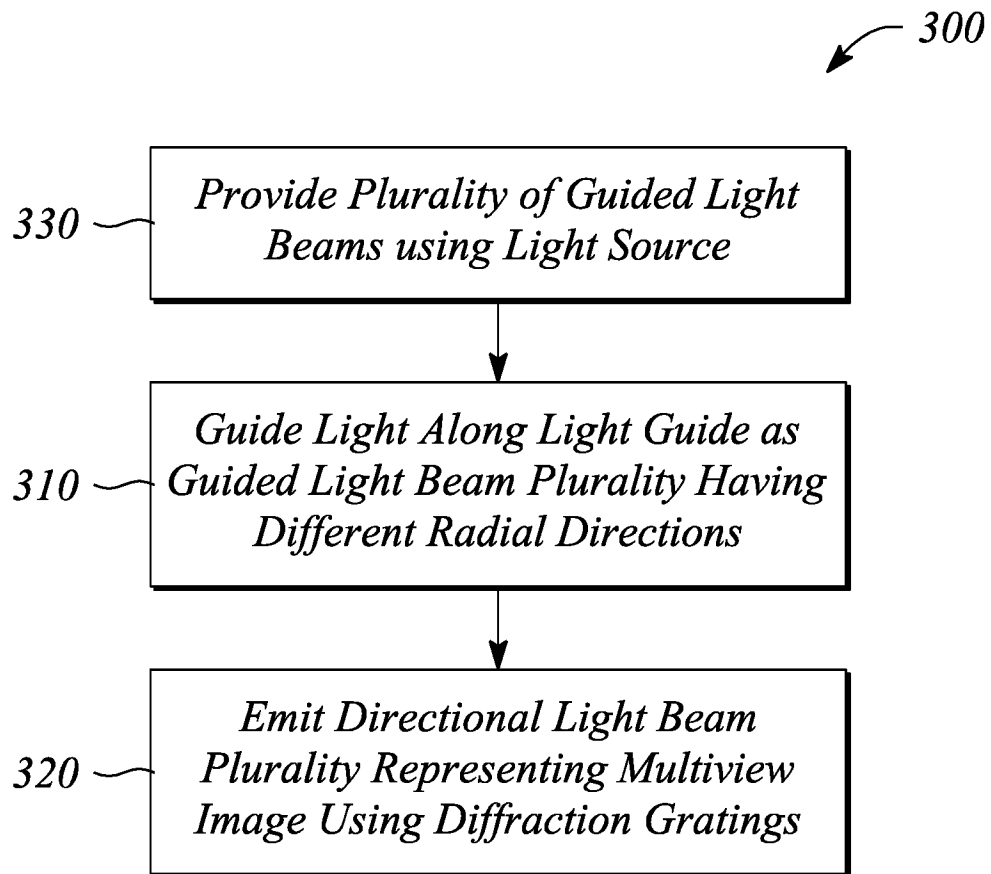


FIG. 9

## INTERNATIONAL SEARCH REPORT

International application No.  
**PCT/US2017/053817****A. CLASSIFICATION OF SUBJECT MATTER****F21V 8/00(2006.01)i, G02B 27/22(2006.01)i, G02B 27/42(2006.01)i**

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)  
F21V 8/00; G02B 27/22; G02F 1/13357; F21V 7/22; G02B 6/00; H04N 13/04; G02B 27/42Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched  
Korean utility models and applications for utility models  
Japanese utility models and applications for utility modelsElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
eKOMPASS(KIPO internal) & Keywords: multiview, location, light guide, diffraction grating, principal angular**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2016-114929 A (OMRON CORP.) 23 June 2016 See paragraphs 10-60, 240-260, claim 1 and figures 1-6, 54.	1-20
Y	KR 10-2013-0017886 A (LG DISPLAY CO., LTD.) 20 February 2013 See paragraphs 7-20, claim 1 and figures 1-9.	1-20
A	US 2016-0195664 A1 (LEIA INC.) 07 July 2016 See paragraphs 18-37, claim 1 and figures 1-5.	1-20
A	US 2011-0141395 A1 (YUJI YASHIRO) 16 June 2011 See claims 1-20.	1-20
A	US 2008-0204663 A1 (TIBOR BALOGH) 28 August 2008 See claims 1-2 and figures 1-10.	1-20

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

\* Special categories of cited documents:

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"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

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Date of the actual completion of the international search

11 January 2018 (11.01.2018)

Date of mailing of the international search report

**11 January 2018 (11.01.2018)**

Name and mailing address of the ISA/KR

International Application Division  
Korean Intellectual Property Office  
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

Facsimile No. +82-42-481-8578

Authorized officer

JANG, Gijeong

Telephone No. +82-42-481-8364



**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/US2017/053817**

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