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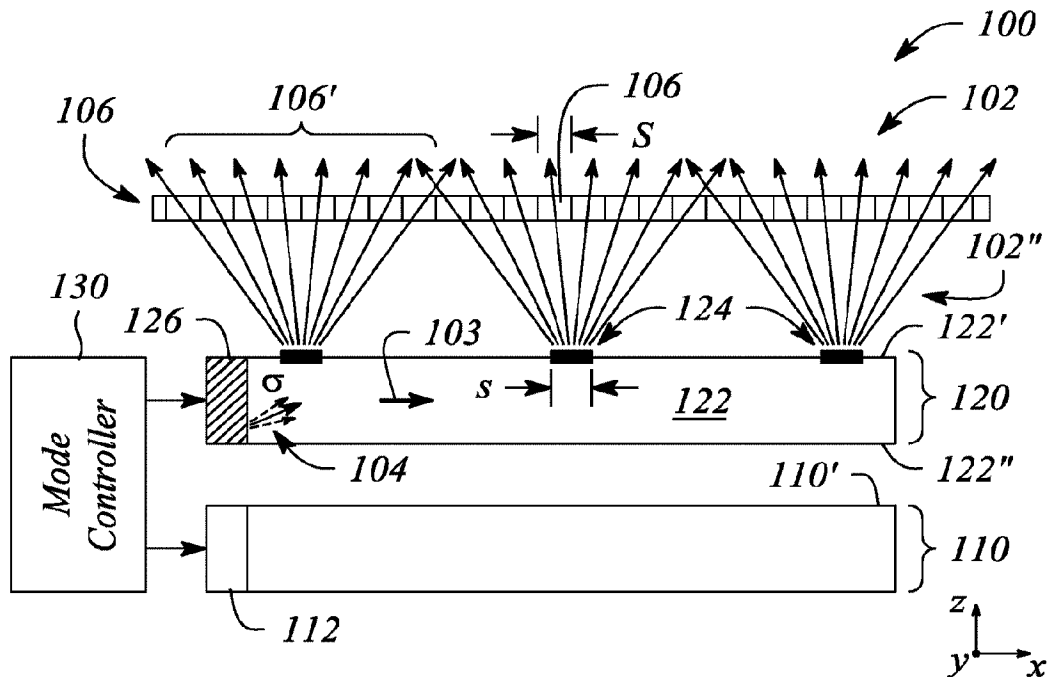
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A time-multiplexed backlight and display employ a broad-angle backlight to provide broad-angle emitted light corresponding to a 2D portion of a displayed image, a multiview backlight to provide directional emitted light corresponding to a multiview portion of the displayed image, and a mode controller configured to time-multiplex the 2D portion and the multiview portion by activating the broad-angle backlight and the multiview backlight in sequential manner as a composite image.

[Continued on next page]

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TIME-MULTIPLEXED BACKLIGHT, MULTIVIEW DISPLAY, AND METHOD

BACKGROUND

[0001] Electronic displays are a nearly ubiquitous medium for communicating information to users of a wide variety of devices and products. Among the most commonly found electronic displays are the cathode ray tube (CRT), plasma display panels (PDP), liquid crystal displays (LCD), electroluminescent displays (EL), organic light-emitting diode (OLED) and active matrix OLEDs (AMOLED) displays, electrophoretic displays (EP) and various displays that employ electromechanical or electrofluidic light modulation (e.g., digital micromirror devices, electrowetting displays, etc.). In general, electronic displays may be categorized as either active displays (i.e., displays that emit light) or passive displays (i.e., displays that modulate light provided by another source). Among the most obvious examples of active displays are CRTs, PDPs and OLEDs/AMOLEDs. Displays that are typically classified as passive when considering emitted light are LCDs and EP displays. Passive displays, while often exhibiting attractive performance characteristics including, but not limited to, inherently low power consumption, may find somewhat limited use in many practical applications given the lack of an ability to emit light.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] 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:

[0003] Figure 1A illustrates a perspective view of a multiview display in an example, according to an embodiment consistent with the principles described herein.

[0004] Figure 1B illustrates a graphical representation of the angular components of a light beam having a particular principal angular direction in an example, according to an embodiment consistent with the principles described herein.

[0005] Figure 2 illustrates a cross-sectional view of a diffraction grating in an example, according to an embodiment consistent with the principles described herein.

[0006] Figure 3A illustrates a cross-sectional view of a time-multiplexed backlight in an example, according to an embodiment consistent with the principles described herein.

[0007] Figure 3B illustrates a cross-sectional view of a time-multiplexed backlight in another example, according to an embodiment consistent with the principles described herein.

[0008] Figure 3C illustrates a perspective view of a time-multiplexed backlight in an example, according to an embodiment consistent with the principles described herein.

[0009] Figure 4 illustrates a cross-sectional view of a broad-angle backlight in an example, according to an embodiment consistent with the principles described herein.

[0010] Figure 5A illustrates a cross-sectional view of a portion of a multiview backlight including a multibeam element in an example, according to an embodiment consistent with the principles described herein.

[0011] Figure 5B illustrates a cross-sectional view of a portion of a multiview backlight including a multibeam element in an example, according to another embodiment consistent with the principles described herein.

[0012] Figure 6 illustrates a plan view of a multibeam element 124 in an example, according to an embodiment consistent with the principles described herein.

[0013] Figure 7 illustrates a cross-sectional view of a portion of a multiview backlight including a multibeam element in an example, according to another embodiment consistent with the principles described herein.

[0014] Figure 8 illustrates a cross-sectional view of a portion of a multiview backlight including a multibeam element in an example, according to another embodiment consistent with the principles described herein.

[0015] Figure 9 illustrates a cross-sectional view of a portion of a multiview backlight including a multibeam element in an example, according to another embodiment consistent with the principles described herein.

[0016] Figure 10 illustrates a block diagram of a time-multiplexed multiview display in an example, according to an embodiment consistent with the principles described herein.

[0017] Figure 11 illustrates a flow chart of a method of time-multiplexed backlight operation in an example, according to an embodiment consistent with the principles described herein.

[0018] Certain examples and embodiments may 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

[0019] Examples and embodiments in accordance with the principles described herein provide time-multiplexed backlighting or time-multiplexed, mode-switching backlighting with application to a time-multiplexed multiview display as well as methods of operation thereof. In particular, in accordance with the principles described herein, a time-multiplexed backlight is configured to provide broad-angle emitted light during a two-dimensional (2D) mode and directional emitted light comprising directional light beams during a multiview mode. The broad-angle emitted light may support the display of 2D information (e.g., a 2D image or text), while the directional light beams of the directional emitted light may support the display of multiview or three-dimensional (3D) information (e.g., a multiview image), for example. Further, in various embodiments, the 2D mode and the multiview mode of the time-multiplexed backlight are time-multiplexed or time-interlaced to provide the broad-angle emitted light in a first time interval and the directional emitted light in a second time interval, respectively. According to the time-multiplexing or time-interlacing, a time-multiplexed multiview display that includes the time-multiplexed backlight may provide a composite image that includes both a 2D content and multiview or 3D content.

[0020] According to various embodiments, the multiview mode of a time-multiplexed multiview display may provide so-called ‘glasses-free’ or autostereoscopic images, while the 2D mode may facilitate presenting of 2D information or content at a relatively higher native resolution than is available in the multiview mode, especially where the 2D information or content that does not include or benefit from a third dimension. As such, the composite image provided by time-multiplexing the 2D and multiview modes may provide both high resolution 2D and somewhat lower resolution,

multiview or 3D content simultaneously in the same image or on the same display. Uses of time-multiplexed backlighting in time-multiplexed multiview displays described herein include, but are 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.

[0021] Herein a ‘two-dimensional display’ or ‘2D display’ is defined as a display configured to provide a view of an image that is substantially the same regardless of a direction from which the image is viewed (i.e., within a predefined viewing angle or range of the 2D display). A liquid crystal display (LCD) found in many smart phones and computer monitors are examples of 2D displays. In contrast herein, a ‘multiview display’ is defined as an electronic display or display system configured to provide different views of a multiview image in or from different view directions. In particular, the different views may represent different perspective views of a scene or object of the multiview image. In some instances, a multiview display may also be referred to as a three-dimensional (3D) display, e.g., when simultaneously viewing two different views of the multiview image provides a perception of viewing a three-dimensional image.

[0022] 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 screen 12 to display a multiview image to be viewed. The multiview display 10 provides different views 14 of the multiview image in different view directions 16 relative to the screen 12. The view directions 16 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 16); and only four views 14 and four view directions 16 are illustrated, all by way of example and not limitation. Note that while the different views 14 are illustrated in Figure 1A as being above the screen, the views 14 actually appear on or in a vicinity of the screen 12 when the multiview image is displayed on the multiview display 10. Depicting the views 14 above the screen 12 is only for simplicity of illustration and is meant to represent viewing

the multiview display 10 from a respective one of the view directions 16 corresponding to a particular view 14.

[0023] 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 θ is referred to herein as the ‘elevation component’ or ‘elevation angle’ of the light beam. The angular component ϕ is referred to as the ‘azimuth component’ or ‘azimuth angle’ of the light beam. By definition, the elevation angle θ is an angle in a vertical plane (e.g., perpendicular to a plane of the multiview display screen while the azimuth angle ϕ is an angle in a horizontal plane (e.g., parallel to the multiview display screen plane).

[0024] Figure 1B illustrates a graphical representation of the angular components $\{\theta, \phi\}$ of a light beam 20 having a particular principal angular direction or simply ‘direction’ corresponding to a view direction (e.g., view direction 16 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.

[0025] 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).

[0026] A ‘multiview pixel’ is defined herein as a set of sub-pixels or ‘view’ pixels in each of a similar plurality of different views of a multiview display. In particular, a multiview pixel may have individual view pixels corresponding to or representing a view pixel in each of the different views of the multiview image. 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 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 located at $\{x_1y_1\}$ in each of the different views of a multiview image, while a second multiview pixel may have individual view pixels located at $\{x_2y_2\}$ in each of the different views, and so on. In some embodiments, a number of view pixels in a multiview pixel may be equal to a number of views of the multiview display.

[0027] Herein, a ‘light guide’ is defined as a structure that guides light within the structure using total internal reflection or ‘TIR’. 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.

[0028] Further herein, the term ‘plate’ when applied to a light guide as in a ‘plate light guide’ is defined as a piecewise 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.

[0029] 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.

[0030] As defined herein, a ‘non-zero propagation angle’ of guided light is an angle relative to a guiding surface of a light guide. 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, by definition herein. 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 less than the critical angle of total internal reflection within the light guide. In various embodiments, the light may be introduced or coupled into the light guide 122 at the non-zero propagation angle of the guided light.

[0031] According to various embodiments, guided light or equivalently a guided ‘light beam’ produced by coupling light into the light guide may be a collimated light beam. 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. 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.

[0032] 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. For example, the diffraction grating may include 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.

[0033] 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 scattering’ in that the diffraction grating may scatter light out of the light guide by diffraction. 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).

[0034] According to various examples described herein, a diffraction grating (e.g., a diffraction grating of a multibeam element, 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 θ_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 λ 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, θ_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 θ_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., $m = 1$).

[0035] 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 50 incident on the diffraction grating 30 at an incident angle θ_i . The incident light beam 50 may be a beam of guided light (i.e., a guided light beam) within the light guide 40. Also illustrated in Figure 2 is a directional light beam 60 diffractively produced and coupled-out by the diffraction grating 30 as a result of diffraction of the incident light beam 50. The directional light beam 60 has a diffraction angle θ_m (or ‘principal angular direction’ herein) as given by equation (1). The diffraction angle θ_m may correspond to a diffraction order ‘ m ’ of the diffraction grating 30, for example diffraction order $m = 1$ (i.e., a first diffraction order).

[0036] By definition herein, a ‘multibeam element’ is a structure or element of a backlight or a display that produces light that includes a plurality of light beams. In some embodiments, the multibeam element may be optically coupled to a light guide of a backlight to provide the plurality of light beams by coupling or scattering out a portion of light guided in the light guide. Further, the light beams of the plurality of light beams produced by a multibeam element have different principal angular directions from one another, by definition herein. In particular, by definition, a light beam of the plurality has a predetermined principal angular direction that is different from another light beam of the light beam plurality. As such, the light beam is referred to as a ‘directional light beam’ and the light beam plurality may be termed a ‘directional light beam plurality,’ by definition herein.

[0037] Furthermore, the directional light beam plurality may represent a light field. For example, the directional light beam plurality may be confined to a substantially conical region of space or have a predetermined angular spread that includes the different

principal angular directions of the light beams in the light beam plurality. As such, the predetermined angular spread of the light beams in combination (i.e., the light beam plurality) may represent the light field.

[0038] According to various embodiments, the different principal angular directions of the various directional light beams of the plurality are determined by a characteristic including, but not limited to, a size (e.g., length, width, area, etc.) of the multibeam element. In some embodiments, the multibeam element may be considered an ‘extended point light source’, i.e., a plurality of point light sources distributed across an extent of the multibeam element, by definition herein. Further, a directional light beam produced by the multibeam element has a principal angular direction given by angular components $\{\theta, \phi\}$, by definition herein, and described above with respect to Figure 1B.

[0039] Herein a ‘collimator’ is defined as substantially any optical device or apparatus that is configured to collimate light. For example, a collimator may include, but is not limited to, a collimating mirror or reflector, a collimating lens, a diffraction grating, a tapered light guide, and various combinations thereof. According to various embodiments, an amount of collimation provided by the collimator may vary in a predetermined degree or amount from one embodiment to another. Further, the collimator may be configured to provide collimation in one or both of two orthogonal directions (e.g., a vertical direction and a horizontal direction). That is, the collimator may include a shape or similar collimating characteristic in one or both of two orthogonal directions that provides light collimation, according to some embodiments.

[0040] 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 σ may specify that a majority of light rays in a beam of collimated light is within a particular angular spread (e.g., $\pm \sigma$ 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 may be an angle determined by at one-half of a peak intensity of the collimated light beam, according to some examples.

[0041] 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. A ‘polarized’ light source is defined herein as substantially any light source that produces or provides light having a predetermined polarization. For example, the polarized light source may comprise a polarizer at an output of an optical emitter of the light source.

[0042] Herein, a ‘multiview image’ is defined as a plurality of images (i.e., greater than three images) wherein each image of the plurality represents a different view corresponding to a different view direction of the multiview image. As such, the multiview image is a collection of images (e.g., two-dimensional images) which, when display on a multiview display, may facilitate a perception of depth and thus appear to be an image of a 3D scene to a viewer, for example.

[0043] By definition, ‘broad-angle’ emitted light is defined as light having a cone angle that is greater than a cone angle of the view of a multiview image or multiview display. In particular, in some embodiments, the broad-angle emitted light may have a cone angle that is greater than about twenty degrees (e.g., $> \pm 20^\circ$). In other embodiments, the broad-angle emitted light cone angle may be greater than about thirty degrees (e.g., $> \pm 30^\circ$), or greater than about forty degrees (e.g., $> \pm 40^\circ$), or greater than

about fifty degrees (e.g., $> \pm 50^\circ$). For example, the cone angle of the broad-angle emitted light may be greater than about sixty degrees (e.g., $> \pm 60^\circ$).

[0044] In some embodiments, the broad-angle emitted light cone angle may defined to be about the same as a viewing angle of an LCD computer monitor, an LCD tablet, an LCD television, or a similar digital display device meant for broad-angle viewing (e.g., about ± 40 - 65°). In other embodiments, broad-angle emitted light may also be characterized or described as diffuse light, substantially diffuse light, non-directional light (i.e., lacking any specific or defined directionality), or as light having a single or substantially uniform direction.

[0045] Embodiments consistent with the principles described herein may be implemented using a variety of devices and circuits including, but not limited to, one or more of integrated circuits (ICs), very large scale integrated (VLSI) circuits, application specific integrated circuits (ASIC), field programmable gate arrays (FPGAs), digital signal processors (DSPs), graphical processor unit (GPU), and the like, firmware, software (such as a program module or a set of instructions), and a combination of two or more of the above. For example, an embodiment or elements thereof may be implemented as circuit elements within an ASIC or a VLSI circuit. Implementations that employ an ASIC or a VLSI circuit are examples of hardware-based circuit implementations.

[0046] In another example, an embodiment may be implemented as software using a computer programming language (e.g., C/C++) that is executed in an operating environment or a software-based modeling environment (e.g., MATLAB[®], MathWorks, Inc., Natick, MA) that is further executed by a computer (e.g., stored in memory and executed by a processor or a graphics processor of a general purpose computer). Note that one or more computer programs or software may constitute a computer-program mechanism, and the programming language may be compiled or interpreted, e.g., configurable or configured (which may be used interchangeably in this discussion), to be executed by a processor or a graphics processor of a computer.

[0047] In yet another example, a block, a module or an element of an apparatus, device or system (e.g., image processor, camera, etc.) described herein may be implemented using actual or physical circuitry (e.g., as an IC or an ASIC), while another

block, module or element may be implemented in software or firmware. In particular, according to the definitions herein, some embodiments may be implemented using a substantially hardware-based circuit approach or device (e.g., ICs, VLSI, ASIC, FPGA, DSP, firmware, etc.), while other embodiments may also be implemented as software or firmware using a computer processor or a graphics processor to execute the software, or as a combination of software or firmware and hardware-based circuitry, for example.

[0048] 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 multibeam element’ means one or more multibeam elements and as such, ‘the multibeam element’ means ‘the multibeam element(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.

[0049] In accordance with some embodiments of the principles described herein, a time-multiplexed backlight is provided. Figure 3A illustrates a cross-sectional view of a time-multiplexed backlight 100 in an example, according to an embodiment consistent with the principles described herein. Figure 3B illustrates a cross-sectional view of a time-multiplexed backlight 100 in another example, according to an embodiment consistent with the principles described herein. In particular, Figure 3A illustrates the time-multiplexed backlight 100 during or according to a first or two-dimensional (2D) mode. Figure 3B illustrates the time-multiplexed backlight 100 during or according to a second or multiview mode. Figure 3C illustrates a perspective view of a time-multiplexed backlight 100 in an example, according to an embodiment consistent with the principles described herein. The time-multiplexed backlight 100 is illustrated in Figure 3C during the multiview mode, by way of example and not limitation. Further, the 2D and multiview modes may be time-multiplexed in time-sequential or time-interlaced

manner to provide the 2D and multiview modes in alternating first and second time intervals (e.g., alternating between Figures 3A and 3B), according to various embodiments. As such, the time-multiplexed backlight 100 may also be referred to as a 'time-multiplexed, mode-switching' backlight.

[0050] As illustrated, the time-multiplexed backlight 100 is configured to provide or emit light as emitted light 102. The emitted light 102 may be used to illuminate an electronic display that employs the time-multiplexed backlight 100, according to various examples and embodiments. For example, the emitted light 102 may be used to illuminate an array of light valves (e.g., light valves 106, described below) of the electronic display. Further, in some embodiments, the electronic display that employs the time-multiplexed backlight 100 may be configured to alternate between the display of a two-dimensional (2D) image and a multiview image using the emitted light 102 in or during sequential time intervals. Moreover, according to time-multiplexing or time-interlacing in the sequential time intervals, the 2D images and multiview images may be provided a composite image that includes both 2D and multiview content or information, as is described further below.

[0051] In particular, according to the two operational modes of the time-multiplexed backlight 100, the emitted light 102 may have or exhibit different characteristics, according to time multiplexing. That is, light emitted by the time-multiplexed backlight 100 as the emitted light 102 may comprise light that is either directional or substantially non-directional, according to the two different modes. For example, as described below in more detail, in the 2D mode, time-multiplexed backlight 100 is configured to provide the emitted light 102 as broad-angle emitted light 102'. Alternatively, in the multiview mode, the time-multiplexed backlight 100 is configured to provide the emitted light 102 as directional emitted light 102".

[0052] According to various embodiments, the directional emitted light 102" provided during the multiview mode comprises a plurality of directional light beams having principal angular directions that differ from one another. Further, directional light beams of the directional emitted light 102" have directions corresponding to different view directions of a multiview image. Conversely, the broad-angle emitted light 102' is largely non-directional and further generally has a cone angle that is greater than a cone

angle of a view of the multiview image or multiview display associated with the time-multiplexed backlight 100, according to various embodiments. During operation of the time-multiplexed backlight 100, the 2D mode may be activated in a first time interval and the multiview mode may be activated in a second time interval. Further, the first and second time intervals are interlaced with one another in a sequential manner according to time-multiplexing, in various embodiments.

[0053] The broad-angle emitted light 102' is illustrated in Figure 3A during the first time interval as dashed arrows for ease of illustration. However, the dashed arrows representing the broad-angle emitted light 102' are not meant to imply any particular directionality of the emitted light 102, but instead merely represent the emission and transmission of light, e.g., from the time-multiplexed backlight 100. Similarly, Figures 3B and 3C illustrate the directional light beams of the directional emitted light 102" during the second time interval as a plurality of diverging arrows. As described above, the different principal angular directions of directional light beams of the directional emitted light 102" emitted during the multiview mode correspond to respective view directions of a multiview image or equivalently of a multiview display. Further, the directional light beams may be or represent a light field, in various embodiments. In some embodiments, the broad-angle emitted light 102' and the directional emitted light 102" directional light beams of the emitted light 102 may be modulated (e.g., using light valves 106, as described below) to facilitate the display of information having one or both of 2D content and multiview or 3D image content.

[0054] As illustrated in Figures 3A-3C, the time-multiplexed backlight 100 comprises a broad-angle backlight 110. The illustrated broad-angle backlight 110 has a planar or substantially planar light-emitting surface 110' configured to provide the broad-angle emitted light 102' during the 2D mode (e.g., see Figure 3A). According to various embodiments, the broad-angle backlight 110 may be substantially any backlight having a light-emitting surface 110' configured to provide light to illuminate an array of light valves of a display. For example, the broad-angle backlight 110 may be a direct-emitting or directly illuminated planar backlight. Direct-emitting or directly illuminated planar backlights include, but are not limited to, a backlight panel employing a planar array of cold-cathode fluorescent lamps (CCFLs), neon lamps or light emitting diodes (LEDs)

configured to directly illuminate the planar light-emitting surface 110' and provide the broad-angle emitted light 102'. An electroluminescent panel (ELP) is another non-limiting example of a direct-emitting planar backlight. In other examples, the broad-angle backlight 110 may comprise a backlight that employs an indirect light source. Such indirectly illuminated backlights may include, but are not limited to, various forms of edge-coupled or so-called 'edge-lit' backlights.

[0055] Figure 4 illustrates a cross-sectional view of a broad-angle backlight 110 in an example, according to an embodiment consistent with the principles described herein. As illustrated in Figure 4, the broad-angle backlight 110 is an edge-lit backlight and comprises a light source 112 coupled to an edge of the broad-angle backlight 110. The edge-coupled light source 112 is configured to produce light within the broad-angle backlight 110. Further, as illustrated by way of example and not limitation, the broad-angle backlight 110 comprises a guiding structure 114 (or light guide) having a substantially rectangular cross section with parallel opposing surfaces (i.e., a rectangular-shaped guiding structure) along with a plurality of extraction features 114a. The broad-angle backlight 110 illustrated in Figure 4 comprises extraction features 114a at a surface (i.e., top surface) of the guiding structure 114 of the broad-angle backlight 110, by way of example and not limitation. Light from the edge-coupled light source 112 and guided within the rectangular-shaped guiding structure 114 may be redirected, scattered out of or otherwise extracted from the guiding structure 114 by the extraction features 114a to provide the broad-angle emitted light 102', according to various embodiments. The broad-angle backlight 110 is activated by activating or turning on the edge-coupled light source 112, e.g., illustrated in Figure 3A using cross-hatching.

[0056] In some embodiments, the broad-angle backlight 110, whether direct-emitting or edge-lit (e.g., as illustrated in Figure 4), may further comprise one or more additional layers or films including, but not limited to, a diffuser or diffusion layer, a brightness enhancement film (BEF), and a polarization recycling film or layer. For example, a diffuser may be configured to increase an emission angle of the broad-angle emitted light 102' when compared to that provided by the extraction features 114a alone. The brightness enhancement film may be used to increase an overall brightness of the broad-angle emitted light 102', in some examples. Brightness enhancement films (BEF)

are available, for example, from 3M Optical Systems Division, St. Paul, MN as a Vikuiti™ BEF II which are micro-replicated enhancement films that utilize a prismatic structure to provide up to a 60% brightness gain. The polarization recycling layer may be configured to selectively pass a first polarization while reflecting a second polarization back toward the rectangular-shaped guiding structure 114. The polarization recycling layer may comprise a reflective polarizer film or dual brightness enhancement film (DBEF), for example. Examples of DBEF films include, but are not limited to, 3M Vikuiti™ Dual Brightness Enhancement Film available from 3M Optical Systems Division, St. Paul, MN. In another example, an advanced polarization conversion film (APCF) or a combination of brightness enhancement and APCF films may be employed as the polarization recycling layer.

[0057] Figure 4 illustrates the broad-angle backlight 110 further comprising a diffuser 116 adjacent to guiding structure 114 and the planar light-emitting surface 110' of the broad-angle backlight 110. Further, illustrated in Figure 4 are a brightness enhancement film 117 and a polarization recycling layer 118, both of which are also adjacent to the planar light-emitting surface 110'. In some embodiments, the broad-angle backlight 110 further comprises a reflective layer 119 adjacent to a surface of the guiding structure 114 opposite to the planar light-emitting surface 110' (i.e., on a back surface), e.g., as illustrated in Figure 4. The reflective layer 119 may comprise any of a variety of reflective films including, but not limited to, a layer of reflective metal or an enhanced specular reflector (ESR) film. Examples of ESR films include, but are not limited to, a Vikuiti™ Enhanced Specular Reflector Film available from 3M Optical Systems Division, St. Paul, MN.

[0058] Referring again to Figures 3A-3C, the time-multiplexed backlight 100 further comprises a multiview backlight 120. As illustrated, the multiview backlight 120 comprises an array of multibeam elements 124. Multibeam elements 124 of the multibeam element array are spaced apart from one another across the multiview backlight 120, according to various embodiments. For example, in some embodiments, the multibeam elements 124 may be arranged in a one-dimensional (1D) array. In other embodiments, the multibeam elements 124 may be arranged in a two-dimensional (2D) array. Further, differing types of multibeam elements 124 may be utilized in the

multiview backlight 120 including, but limited to, active emitters and various scattering elements as set forth below in connection with Figures 5A-10. According to various embodiments, each multibeam element 124 of the multibeam element array is configured to provide a plurality of directional light beams having directions corresponding to different view directions of a multiview image during a multiview mode. In particular, directional light beams of the directional light beam plurality comprise the directional emitted light 102" provided during the multiview mode, according to various embodiments.

[0059] In some embodiments (e.g., as illustrated), the multiview backlight 120 further comprises a light guide 122 configured to guide light as guided light 104. The light guide 122 may be a plate light guide, in some embodiments. According to various embodiments, the light guide 122 is configured to guide the guided light 104 along a length of the light guide 122 according to total internal reflection. A general propagation direction 103 of the guided light 104 within the light guide 122 is illustrated by a bold arrow in Figure 3B. In some embodiments, the guided light 104 may be guided in the propagation direction 103 at a non-zero propagation angle and may comprise collimated light that is collimated according to a predetermined collimation factor σ , as illustrated in Figure 3B.

[0060] In various embodiments, the light guide 122 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. A difference in refractive indices is configured to facilitate total internal reflection of the guided light 104 according to one or more guided modes of the light guide 122, for example. In some embodiments, the light guide 122 may be a slab or plate optical waveguide comprising an extended, substantially planar sheet of optically transparent, dielectric material. According to various examples, the optically transparent material of the light guide 122 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 122 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 122. The cladding layer may be used to further facilitate total internal reflection, according to some examples.

[0061] In embodiments that include the light guide 122, a multibeam element 124 of the multibeam element array may be configured to scatter out a portion of the guided light 104 from within the light guide 122 and to direct the scattered out portion away from a first surface 122' of the light guide 122 or equivalent from a first surface of the multiview backlight 120 to provide the directional emitted light 102", as illustrated in Figure 3B. For example, the guided light portion may be scattered out by the multibeam element 124 through the first surface 122'. Further, as illustrated in Figures 3A-3C, a second surface of the multiview backlight 120 opposite to the first surface may be adjacent to the planar light-emitting surface 110' of the broad-angle backlight 110, according to various embodiments.

[0062] Note that the plurality of directional light beams of the directional emitted light 102", as illustrated in Figure 3B, is or represents the plurality of directional light beams having different principal angular directions, described above. That is, a directional light beam has a different principal angular direction from other directional light beams of the directional emitted light 102", according to various embodiments. Further, the multiview backlight 120 may be substantially transparent (e.g., in at least the 2D mode) to allow the broad-angle emitted light 102' from the broad-angle backlight 110 to pass or be transmitted through a thickness of the multiview backlight 120, as illustrated in Figure 3A by the dashed arrows that originate at the broad-angle backlight 110 and subsequently pass through the multiview backlight 120. In other words, the broad-angle emitted light 102' provided by the broad-angle backlight 110 is configured to be transmitted through the multiview backlight 120 during the 2D mode, e.g., by virtue of the multiview backlight transparency.

[0063] For example, the light guide 122 and the spaced apart plurality of multibeam elements 124 may allow light to pass through the light guide 122 through both the first surface 122' and the second surface 122". Transparency may be facilitated, at least in part, due to both the relatively small size of the multibeam elements 124 and the relatively large inter-element spacing of the multibeam element 124. Further, especially

when the multibeam elements 124 comprise diffraction gratings as described below, the multibeam elements 124 may also be substantially transparent to light propagating orthogonal to the light guide surfaces 122', 122'', in some embodiments. Thus, for example, light from the broad-angle backlight 110 may pass in the orthogonal direction through the light guide 122 with the multibeam element array of the multiview backlight 120, according to various embodiments.

[0064] In some embodiments (e.g., as illustrated in Figures 3A-3C), the multiview backlight 120 may further comprise a light source 126. As such, the multiview backlight 120 may be an edge-lit backlight, for example. According to various embodiments, the light source 126 is configured to provide the light to be guided within light guide 122. In particular, the light source 126 may be located adjacent to an entrance surface or end (input end) of the light guide 122. In various embodiments, the light source 126 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 126 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., a red-green-blue (RGB) color model). In other examples, the light source 126 may be a substantially broadband light source configured to provide substantially broadband or polychromatic light. For example, the light source 126 may provide white light. In some embodiments, the light source 126 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. As illustrated in Figure 3B, activation of the multiview backlight 120 may comprise activating the light source 126, illustrated using cross-hatching in Figure 3B.

[0065] In some embodiments, the light source 126 may further comprise a collimator (not illustrated). The collimator may be configured to receive substantially uncollimated light from one or more of the optical emitters of the light source 126. The collimator is further configured to convert the substantially uncollimated light into

collimated light. In particular, the collimator may provide collimated light having the non-zero propagation angle and being collimated according to a predetermined collimation factors, according to some embodiments. 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 122 to propagate as the guided light 104, described above.

[0066] As illustrated in Figures 3A-3B, the time-multiplexed backlight 100 further comprises a mode controller 130. The mode controller 130 is configured to time-multiplex the 2D mode and multiview mode by sequentially activating the broad-angle backlight 110 during a first time interval and activating the multiview backlight 120 during a second time interval. In particular, according to some embodiments, the mode controller 130 may be configured to switch between the 2D mode and the multiview mode by sequentially activating a light source 112 of the broad-angle backlight 110 to provide the broad-angle emitted light 102' during the 2D mode and a light source 126 of the multiview backlight 120 to provide the directional emitted light 102" during the multiview mode. Activating the light source 112 during the first time interval is illustrated by cross-hatching of the light source 112 in Figure 3A and activating the light source 126 during the second time interval is illustrated by cross-hatching of the light source 126 in Figure 3B.

[0067] In some embodiments, the mode controller 130 may be configured to switch between or time multiplex the 2D mode and the multiview mode at one or more predetermined frequencies, such as at a frequency selected to effectively display images of both modes concurrently via an array of light valves 106 for display to a viewer. By way of example, the array of light valves 106 may be an LCD panel operating at 120 Hz and the mode controller 130 may switch between the 2D mode and the multiview mode at 60 Hz (i.e., by sequentially activating each of the light source 112 of the broad-angle backlight 110 and the light source 126 of the multiview backlight 120 at about 60 Hz), to provide time-multiplexing. In another example, the LCD panel or light valve array may operate at 240 Hz and the 2D and multiview modes may be time-multiplexed at 120 Hz

by the mode controller 130. According to some embodiments, the 2D mode and the multiview mode may be time-multiplexed by the mode controller 130 at a maximum rate corresponding to the highest switching speed or frequency at which the array of light valves is capable of operating while still being capable of providing images to a viewer, i.e., dependent upon the type and technology of the display. In certain embodiments, time-multiplexing of 2D and multiview modes provides the 2D image and the multiview image that are superimposed with each other on a time-multiplexed multiview display to provide a composite image. If the switching rate or activation rate of the 2D and multiview modes at least exceeds for each mode the visual persistence of a viewer using the display, each of the 2D image and the multiview image will appear to the user as being constantly present and without perceptible flicker in the composite image. A switching rate of at least about 60 Hz for each of the 2D mode and the multiview mode will provide this visual persistence goal (i.e., about or less than 1 millisecond in each mode).

[0068] Further, as mentioned above and according to various embodiments, multiview backlight 120 comprises the array of multibeam elements 124. According to some embodiments (e.g., as illustrated in Figures 3A-3C), multibeam elements 124 of the multibeam element array may be located at the first surface 122' of the light guide 122 (e.g., adjacent to the first surface of the multiview backlight 120). In other embodiments (not illustrated), the multibeam elements 124 may be located within the light guide 122. In yet other embodiments (not illustrated), the multibeam elements 124 may be located at or on the second surface 122" of the light guide 122 (e.g., adjacent to the second surface of the multiview backlight 120). Further, a size of the multibeam element 124 is comparable to a size of a light valve of a multiview display configured to display the multiview image. That is, the multibeam element size is comparable to a light valve size of a light valve array in a multiview display that includes the time-multiplexed backlight 100 and multiview backlight 120 thereof, for example.

[0069] Figures 3A-3C also illustrate an array of light valves 106 (e.g., of the multiview display), by way of example and not limitation. In various embodiments, any of a variety of different types of light valves may be employed as the light valves 106 of the light valve array including, but not limited to, one or more of liquid crystal light

valves, electrophoretic light valves, and light valves based on or employing electrowetting. Further, as illustrated, there may be one unique set of light valves 106 for each multibeam element 124 of the array of multibeam elements. The unique set of light valves 106 may correspond to a multiview pixel 106' of the multiview display, for example.

[0070] Herein, the 'size' may be defined in any of a variety of manners to include, but not be limited to, a length, a width or an area. For example, the size of a light valve may be a length thereof and the comparable size of the multibeam element 124 may also be a length of the multibeam element 124. In another example, size may refer to an area such that an area of the multibeam element 124 may be comparable to an area of the light valve. In some embodiments, the size of the multibeam element 124 is comparable to the light valve size such that the multibeam element size is between about twenty-five percent (25%) and about two hundred percent (200%) of the light valve size. For example, if the multibeam element size is denoted ' s ' and the light valve size is denoted ' S ' (e.g., as illustrated in Figure 3B), then the multibeam element size s may be given by equation (1) as

$$\frac{1}{4}S \leq s \leq 2S \quad (2)$$

[0071] In other examples, the multibeam element size is greater than about fifty percent (50%) of the light valve size, or about sixty percent (60%) of the light valve size, or about seventy percent (70%) of the light valve size, or greater than about eighty percent (80%) of the light valve size, or greater than about ninety percent (90%) of the light valve size, and the multibeam element is less than about one hundred eighty percent (180%) of the light valve size, or less than about one hundred sixty percent (160%) of the light valve size, or less than about one hundred forty percent (140%) of the light valve size, or less than about one hundred twenty percent (120%) of the light valve size. For example, by 'comparable size', the multibeam element size may be between about seventy-five percent (75%) and about one hundred fifty (150%) of the light valve size. In another example, the multibeam element 124 may be comparable in size to the light valve where the multibeam element size is between about one hundred twenty-five percent (125%) and about eighty-five percent (85%) of the light valve size. According to some

embodiments, the comparable sizes of the multibeam element 124 and the light valve may be chosen to reduce, or in some examples to minimize, dark zones between views of the multiview display, while at the same time reducing, or in some examples minimizing, an overlap between views of the multiview display or equivalent of the multiview image.

[0072] Note that, as illustrated in Figure 3B, the size (e.g. width) of a multibeam element 124 may correspond to a size (e.g., width) of a light valve 106 in the light valve array. In other examples, the multibeam element size may be defined as a distance (e.g., a center-to-center distance) between adjacent light valves 106 of the light valve array. For example, the light valves 106 may be smaller than the center-to-center distance between the light valves 106 in the light valve array. Further, a spacing between adjacent multibeam elements of the multibeam element array may be commensurate with a spacing between adjacent multiview pixels of the multiview display. For example, an inter-emitter distance (e.g., center-to-center distance) between a pair of adjacent multibeam elements 124 may be equal to an inter-pixel distance (e.g., a center-to-center distance) between a corresponding adjacent pair of multiview pixels, e.g., represented by sets of light valves of the array of light valves 106. As such, the multibeam element size may be defined as either the size of the light valve 106 itself or a size corresponding to the center-to-center distance between the light valves 106, for example.

[0073] In some embodiments, a relationship between the multibeam elements 124 of the plurality and corresponding multiview pixels 106' (e.g., sets of light valves 106) may be a one-to-one relationship. That is, there may be an equal number of multiview pixels 106' and multibeam elements 124. Figure 3C explicitly illustrates by way of example the one-to-one relationship where each multiview pixel 106' comprising a different set of light valves 106 is illustrated as surrounded by a dashed line. In other embodiments (not illustrated), the number of multiview pixels 106' and multibeam elements 124 may differ from one another.

[0074] In some embodiments, an inter-element distance (e.g., center-to-center distance) between a pair of adjacent multibeam elements 124 of the plurality may be equal to an inter-pixel distance (e.g., a center-to-center distance) between a corresponding adjacent pair of multiview pixels 106', e.g., represented by light valve sets. In other embodiments (not illustrated), the relative center-to-center distances of pairs of

multibeam elements 124 and corresponding light valve sets may differ, e.g., the multibeam elements 124 may have an inter-element spacing (i.e., center-to-center distance) that is one of greater than or less than a spacing (i.e., center-to-center distance) between light valve sets representing multiview pixels 106'.

[0075] In some embodiments, a shape of the multibeam element 124 is analogous to a shape of the multiview pixel 106' or equivalently, a shape of a set (or 'sub-array') of the light valves 106 corresponding to the multiview pixel 106'. For example, the multibeam element 124 may have a square shape and the multiview pixel 106' (or an arrangement of a corresponding set of light valves 106) may be substantially square. In another example, the multibeam element 124 may have a rectangular shape, i.e., may have a length or longitudinal dimension that is greater than a width or transverse dimension. In this example, the multiview pixel 106' (or equivalently the arrangement of the set of light valves 106) corresponding to the multibeam element 124 may have an analogous rectangular shape. Figure 3C illustrates a perspective view of square-shaped multibeam elements 124 and corresponding square-shaped multiview pixels 106' comprising square sets of light valves 106. In yet other examples (not illustrated), the multibeam elements 124 and the corresponding multiview pixels 106' have various shapes including or at least approximated by, but not limited to, a triangular shape, a hexagonal shape, and a circular shape.

[0076] Further (e.g., as illustrated in Figure 3B), each multibeam element 124 may be configured to provide directional emitted light 102" to one and only one multiview pixel 106', according to some embodiments. In particular, for a given one of the multibeam elements 124, the directional emitted light 102" having different principal angular directions corresponding to the different views of the multiview display are substantially confined to a single corresponding multiview pixel 106' and the light valves 106 thereof, i.e., a single set of light valves 106 corresponding to the multibeam element 124, as illustrated in Figure 3B. As such, each multibeam element 124 of the broad-angle backlight 110 provides a corresponding plurality of directional light beams of the directional emitted light 102" that has a set of the different principal angular directions corresponding to the different views of the multiview image (i.e., the set of directional

light beams contains a light beam having a direction corresponding to each of the different view directions).

[0077] According to various embodiments, the multibeam elements 124 of the multiview backlight 120 may comprise any of a number of different structures configured to scatter out a portion of the guided light 104. For example, the different structures may include, but are not limited to, diffraction gratings, micro-reflective elements, micro-refractive elements, or various combinations thereof. In some embodiments, the multibeam element 124 comprising a diffraction grating is configured to diffractively couple or scatter out the guided light portion as the directional emitted light 102" comprising a plurality of directional light beams having the different principal angular directions. In some embodiments, a diffraction grating of a multibeam element may comprise a plurality of individual sub-gratings. In other embodiments, the multibeam element 124 comprising a micro-reflective element is configured to reflectively couple or scatter out the guided light portion as the plurality of directional light beams, or the multibeam element 124 comprising a micro-refractive element is configured to couple or scatter out the guided light portion as the plurality of directional light beams by or using refraction (i.e., refractively scatter out the guided light portion).

[0078] Figure 5A illustrates a cross-sectional view of a portion of a multiview backlight 120 including a multibeam element 124 in an example, according to an embodiment consistent with the principles described herein. Figure 5B illustrates a cross-sectional view of a portion of a multiview backlight 120 including a multibeam element 124 in an example, according to another embodiment consistent with the principles described herein. In particular, Figures 5A-5B illustrate the multibeam element 124 of the multiview backlight 120 comprising a diffraction grating 124a. The diffraction grating 124a is configured to diffractively couple or scatter out a portion of the guided light 104 as the plurality of directional light beams of the directional emitted light 102". The diffraction grating 124a comprises a plurality of diffractive features spaced apart from one another by a diffractive feature spacing (or a diffractive feature pitch or grating pitch) configured to provide diffractive scattering out of the guided light portion. According to various embodiments, the spacing or grating pitch of the diffractive features

in the diffraction grating 124a may be sub-wavelength (i.e., less than a wavelength of the guided light 104).

[0079] In some embodiments, the diffraction grating 124a of the multibeam element 124 may be located at or adjacent to a surface of the light guide 122. For example, the diffraction grating 124a may be at or adjacent to the first surface 122' of the light guide 122, as illustrated in Figure 5A. The diffraction grating 124a at the first surface 122' of the light guide 122 may be a transmission mode diffraction grating configured to diffractively scatter out the guided light portion through the first surface 122' as the directional light beams of the directional emitted light 102". In another example, as illustrated in Figure 5B, the diffraction grating 124a may be located at or adjacent to the second surface 122" of the light guide 122. When located at the second surface 122", the diffraction grating 124a may be a reflection mode diffraction grating. As a reflection mode diffraction grating, the diffraction grating 124a is configured to both diffract the guided light portion and reflect the diffracted guided light portion toward the first surface 122' to exit through the first surface 122' as the directional light beams of the directional emitted light 102". In other embodiments (not illustrated), the diffraction grating may be located between the surfaces of the light guide 122, e.g., as one or both of a transmission mode diffraction grating and a reflection mode diffraction grating. Note that, in some embodiments described herein, the principal angular directions of the directional light beams of the directional emitted light 102" may include an effect of refraction due to the directional light beams exiting the light guide 122 at a light guide surface. For example, Figure 5B illustrates refraction (i.e., bending) of the directional light beams due to a change in refractive index as the directional emitted light 102" crosses the first surface 122'. Also see Figures 6 and 7, described below.

[0080] According to some embodiments, the diffractive features of the diffraction grating 124a 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 122, e.g., may be formed in a surface of the light guide 122. 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 122.

[0081] In some embodiments, the diffraction grating 124a of the multibeam element 124 is a uniform diffraction grating in which the diffractive feature spacing is substantially constant or unvarying throughout the diffraction grating 124a. In other embodiments, the diffraction grating 124a may be a chirped diffraction grating. 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 or change in 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 multibeam element 124 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.

[0082] In some embodiments, the diffraction grating 124a may comprise a plurality or an array of diffraction gratings or equivalently a plurality or an array of sub-gratings. Further, according to some embodiments, a differential density of sub-gratings within the diffraction grating 124a between different multibeam elements 124 of the multibeam element plurality may be configured to control a relative intensity of the plurality of directional light beams of the directional emitted light 102" that is diffractively scattered out by respective different multibeam elements 124. In other words, the multibeam elements 124 may have different densities of sub-gratings within the diffraction gratings 124a, respectively, and the different sub-grating densities may be configured to control the relative intensity of the plurality of directional light beams. In particular, a multibeam element 124 having fewer sub-gratings within the diffraction grating 124a may produce a plurality of directional light beams of the directional emitted light 102" having a lower intensity (or beam density) than another multibeam element 124 having relatively more sub-gratings.

[0083] Figure 6 illustrates a plan view of a multibeam element 124 in an example, according to an embodiment consistent with the principles described herein. As illustrated, the multibeam element 124 comprises a diffraction grating 124a having a plurality of sub-gratings. In addition, the diffraction grating 124a has locations 123 without a sub-grating to facilitate control of a density of sub-gratings and, in turn, control a relative intensity of scattering by the diffraction grating 124a, as illustrated in Figure 6. Figure 6 also illustrates a size *s* of the multibeam element 124.

[0084] Figure 7 illustrates a cross-sectional view of a portion of a multiview backlight 120 including a multibeam element 124 in an example, according to another embodiment consistent with the principles described herein. Figure 8 illustrates a cross-sectional view of a portion of a multiview backlight 120 including a multibeam element 124 in an example, according to another embodiment consistent with the principles described herein. In particular, Figures 7 and 8 illustrate various embodiments of the multibeam element 124 comprising a micro-reflective element 124b. Micro-reflective elements used as or in the multibeam element 124 may include, but are not limited to, a reflector that employs a reflective material or layer thereof (e.g., a reflective metal) or a reflector based on total internal reflection (TIR). According to some embodiments (e.g., as illustrated in Figures 7-8), the multibeam element 124 comprising the micro-reflective element 124b may be located at or adjacent to a surface (e.g., the second surface 122") of the light guide 122. In other embodiments (not illustrated), the micro-reflective element 124b may be located within the light guide 122 between the first and second surfaces 122', 122". In some embodiments, micro-reflective element 124b of the multibeam element 124 may be configured to scatter guided light 104 incident from different directions, as illustrated in Figures 7 and 8 by a pair of arrows representing a first propagation direction 103 and a second propagation direction 103' of the guided light 104.

[0085] Figure 9 illustrates a cross-sectional view of a portion of a multiview backlight 120 including a multibeam element 124 in an example, according to another embodiment consistent with the principles described herein. In particular, Figure 9 illustrates a multibeam element 124 comprising a micro-refractive element 124c. According to various embodiments, the micro-refractive element 124c is configured to refractively couple or scatter out a portion of the guided light 104 from the light guide

122. That is, the micro-refractive element 124c is configured to employ refraction (e.g., as opposed to diffraction or reflection) to couple or scatter out the guided light portion from the light guide 122 as the directional emitted light 102" comprising the directional light beams, as illustrated in Figure 9. The micro-refractive element 124c may have various shapes including, but not limited to, a semi-spherical shape, a rectangular shape or a prismatic or an inverted prismatic shape (i.e., a shape having sloped facets). According to various embodiments, the micro-refractive element 124c may extend or protrude out of a surface (e.g., the first surface 122') of the light guide 122, as illustrated, or may be a cavity in the surface (not illustrated). Further, the micro-refractive element 124c may comprise a material of the light guide 122, in some embodiments. In other embodiments, the micro-refractive element 124c may comprise another material adjacent to, and in some examples, in contact with the light guide surface.

[0086] According to some embodiments of the principles described herein, a time-multiplexed multiview display is provided. The time-multiplexed multiview display is configured to emit modulated light corresponding to or representing pixels of a two-dimensional (2D) image comprising 2D information (e.g., 2D images, text, etc.) in a two-dimensional (2D) mode of the time-multiplexed multiview display. In a multiview mode, the time-multiplexed multiview display is configured to emit modulated directional emitted light corresponding to or representing pixels of different views (view pixels) of a multiview image. For example, the time-multiplexed multiview display may represent an autostereoscopic or glasses-free 3D electronic display in the multiview mode. For example, different ones of the modulated, differently directed light beams of the directional emitted light may correspond to different 'views' associated with the multiview information or multiview image, according to various examples. The different views may provide a 'glasses free' (e.g., autostereoscopic, holographic, etc.) representation of information being displayed by the time-multiplexed multiview display in the multiview mode, for example. Further, the first and multiview modes are time-multiplexed (e.g., interlaced) to allow time-interlaced presentation of 2D and multiview information superimposed on the time-multiplexed multiview display as composite images, according to various embodiments.

[0087] Figure 10 illustrates a block diagram of a time-multiplexed multiview display 200 in an example, according to an embodiment consistent with the principles described herein. The time-multiplexed multiview display 200 may be used to present as a composite image both 2D information and multiview information such as, but not limited to, 2D images, text, and multiview images, according to various embodiments. In particular, the time-multiplexed multiview display 200 illustrated in Figure 10 is configured to emit modulated light 202 comprising modulated broad-angle emitted light 202' during the 2D mode (2D), the modulated broad-angle emitted light 202' representing 2D pixels of a 2D image, for example. Further, during the multiview mode (Multiview) the time-multiplexed multiview display 200 illustrated in Figure 10 is configured to emit modulated light 202 comprising modulated directional emitted light 202" including directional light beams with different principal angular directions representing directional pixels of a multiview image. In particular, the different principal angular directions may correspond to the different view directions of different views of the multiview image displayed by time-multiplexed multiview display 200 in the multiview mode. According to various embodiments, the composite image is provided by time-multiplexing or time-interlacing the 2D mode and the multiview mode to combine the 2D pixel of the 2D image and the directional pixels of the multiview image on the time-multiplexed multiview display 200, as illustrated by circular arrows in Figure 10.

[0088] As illustrated in Figure 10, the time-multiplexed multiview display 200 comprises a broad-angle backlight 210. The broad-angle backlight 210 is configured to provide broad-angle emitted light 204 during the 2D mode. In some embodiments, the broad-angle backlight 210 may be substantially similar to the broad-angle backlight 110 of the time-multiplexed backlight 100, described above. For example, the broad-angle backlight may comprise a light guide having a light extraction layer configured to extract light from the rectangular-shaped light guide and to redirect the extracted light through the diffuser as the broad-angle emitted light 204.

[0089] The time-multiplexed multiview display 200 illustrated in Figure 10 further comprises a multiview backlight 220. As illustrated, the multiview backlight 220 comprises a light guide 222 and an array of multibeam elements 224 spaced apart from one another. The array of multibeam elements 224 is configured to scatter out guided

light from the light guide 222 as directional emitted light 206 during the multiview mode (Multiview). According to various embodiments, the directional emitted light 206 provided by an individual multibeam element 224 of the array of multibeam elements 224 comprises a plurality of directional light beams having different principal angular directions corresponding to view directions of the multiview image displayed by the time-multiplexed multiview display 200 in or during the multiview mode.

[0090] In some embodiments, the multiview backlight 220 may be substantially similar to the multiview backlight 120 of the above-described time-multiplexed backlight 100. In particular, the light guide 222 and multibeam elements 224 may be substantially similar to the above-described the light guide 122 and multibeam elements 124, respectively. For example, the light guide 222 may be a plate light guide. Further, a multibeam element 224 of the array of multibeam elements 224 may comprises one or more of a diffraction grating, a micro-reflective element and a micro-refractive element optically connected to the light guide 222 to scatter out the guided light as the directional emitted light 206, according to various embodiments.

[0091] As illustrated, the time-multiplexed multiview display 200 further comprises a light valve array 230. The light valve array 230 is configured to modulate the broad-angle emitted light 204 to provide a two-dimensional (2D) image during the 2D mode and to modulate the directional emitted light 206 to provide a multiview image during the multiview mode. In particular, the light valve array 230 is configured to receive and modulate the broad-angle emitted light 204 to provide the modulated broad-angle emitted light 202' during the 2D mode. Similarly, the light valve array 230 is configured to receive and modulate the directional emitted light 206 during the multiview mode to provide the modulated directional emitted light 202". In some embodiments, the light valve array 230 may be substantially similar to the array of light valves 106, described above with respect to the time-multiplexed backlight 100. For example, a light valve of the light valve array may comprise a liquid crystal light valve. Further, a size of a multibeam element 224 of the array of multibeam elements 224 may be comparable to a size of a light valve of the light valve array 230 (e.g., between one quarter and two times the light valve size), in some embodiments.

[0092] In various embodiments, the multiview backlight 220 may be located between the planar light-emitting surface of the broad-angle backlight 210 and the light valve array 230. The multiview backlight 220 may be positioned adjacent to the broad-angle backlight 210 or separated by a narrow gap. Further, in some embodiments, the multiview backlight 220 and the broad-angle backlight 210 are superimposed or stacked such that a top surface of the broad-angle backlight 210 is substantially parallel to a bottom surface of the multiview backlight 220. As such, the broad-angle emitted light 204 from the broad-angle backlight 210 is emitted from the top surface of the broad-angle backlight 210 into and through the multiview backlight 220. According to various embodiments, the multiview backlight 220 is transparent to the broad-angle emitted light 204 emitted during the 2D mode.

[0093] The time-multiplexed multiview display 200 illustrated in Figure 10 further comprises a mode controller 240. In some embodiments, the mode controller 240 may be substantially similar to the mode controller 130 of the time-multiplexed backlight 100, described above. For example, the mode controller 240 is configured to sequentially activate the broad-angle backlight 210 and the multiview backlight 220. According to various embodiments, the 2D image and multiview image are superimposed on the time-multiplexed multiview display 200 as a composite image. As with the mode controller 130, above, the mode controller 240 of Figure 10 may be configured to switch between the 2D mode and the multiview mode by sequentially activating a light source of the broad-angle backlight 210 to provide broad-angle emitted light 204 during the 2D mode and a light source of the multiview backlight 220 to provide the directional emitted light 206 during the multiview mode. According to various embodiments, both the directional emitted light 206 and the broad-angle emitted light 204 may be modulated by the light valve array to provide the images comprising the multiview portion and the 2D portion of the composite image in a time-multiplexed manner.

[0094] In particular, the mode controller 240 may time-multiplex the 2D and multiview modes of the broad-angle backlight 210 and the multiview backlight 220 and simultaneously control modulation of the emitted light by the light valve array to produce the composite image, according to various embodiments. That is, mode switching between the 2D mode and the multiview mode may be implemented by time-multiplexing

the 2D images and the multiview images in a manner synchronized or coordinated with operation of the light valve array 230, to provide 2D and multiview content as the composite image.

[0095] For example, the two sets of images may be time-interlaced in connection with operating light valves of the light valve array 230 to display respective 2D or multiview images, so that it appears as if both images are being displayed simultaneously. In some embodiments, the mode controller 240 may synchronize control of light sources of the broad-angle backlight 210 and the multiview backlight 220 with control of light valves of the light valve array 230 to achieve time-interlaced display of the two images. In some embodiments, selected light valves of the light valve array 230 may be operated (turned off or on) to display the 2D imagery during the first time interval, followed by operation of selected light valves to display the multiview imagery during the second time interval. In practice, the rate of speed at which the mode controller 240 operates the 2D and multiview backlights is maintained at a level that allows the light valves of the light valve array 230 to switch fully open, or fully closed, as dictated by the physics of the light valves or pixels, such as the electric field(s) involved with the switching. The mode controller 130 discussed above in connection with Figures 3A-3C may operate consistent with one or more of the above techniques and principles, as well. In particular, the mode controller 240 may be implemented one or both of as hardware comprising circuitry (e.g., an ASIC) and modules comprising software or firmware that are executed by a processor or similar circuitry to various operational characteristics of the mode controller 240.

[0096] In accordance with other embodiments of the principles described herein, a method of time-multiplexed backlight operation is provided. In particular, the method of time-multiplexed backlight operation may have at least two modes, namely a 2D mode and a multiview mode, which are time-multiplexed or time-interlaced. The 2D mode may display a two-dimensional (2D) image, while the multiview mode may display a three-dimensional (3D) or a multiview image, according to various embodiments. Time-multiplexing combines the 2D image and the 3D or multiview image as a composite image having both 2D and multiview content or information.

[0097] Figure 11 illustrates a flow chart of a method 300 of time-multiplexed backlight operation in an example, according to an embodiment consistent with the

principles described herein. As illustrated in Figure 11, the method of time-multiplexed backlight operation comprises providing 310 broad-angle emitted light during a 2D mode using a broad-angle backlight. In some embodiments, the broad-angle backlight may be substantially similar to the broad-angle backlight 110 of the time-multiplexed backlight 100, described above. Further, the 2D mode and the emitted broad-angle light may be substantially similar to respective ones of the 2D mode (e.g., in Figures 3A-3C, and the 2D Mode of Figure 10) and the broad-angle emitted light 204, 102' described above with respect to the time-multiplexed backlights and displays, according to some embodiments.

[0100] The method 300 of time-multiplexed backlight operation further comprises providing 320 directional emitted light during a multiview mode using a multiview backlight having an array of multibeam elements spaced apart from one another. According to various embodiments, the directional emitted light comprises a plurality of directional light beams provided by each multibeam element of the multibeam element array. Directions of directional light beams of the directional light beam plurality correspond to different view directions of a multiview image, according to various embodiments. In some embodiments, the multiview backlight may be substantially similar to the multiview backlights described above, such as in connection with Figures 3A-3C and 11. Similarly, the multiview mode may be substantially similar to the multiview mode of the time-multiplexed backlight 100 described above with respect to Figures 3A-3C as well as the multiview mode of Figure 10, according to some embodiments. In some embodiments, the multiview backlight may be positioned adjacent to the emission surface of the broad-angle backlight and be transparent to the broad-angle emitted light during the 2D mode.

[0101] The method 300 of time-multiplexed backlight operation further comprises time-multiplexing 330 the 2D mode and the multiview mode using a mode controller to sequentially activate the broad-angle backlight during a first sequential time interval corresponding to the 2D mode and the multiview backlight during a second sequential time interval corresponding to the multiview mode. In some embodiments, the mode controller may be substantially similar to the mode controller 130, 240 described above. In particular, the mode controller may be implemented one or both of as hardware comprising circuitry (e.g., an ASIC) and modules comprising software or firmware that

are executed by a processor or similar circuitry to perform the actions of the mode controller.

[0102] In some embodiments (not illustrated), providing 320 the plurality of directional light beams comprises guiding light in a light guide as guided light and scattering out a portion of the guided light using multibeam elements of the multibeam element array. Further, each multibeam element of the multibeam element array may comprise one or more of a diffraction grating, a micro-refractive element, and a micro-reflective element, in some embodiments. In particular, the multiview elements of the multibeam element array may be substantially similar to the multibeam elements 124 of the above-described multiview backlight 120, in some embodiments. The method 300 of time-multiplexed backlight operation may further comprise providing light to the light guide, the guided light within the light guide being collimated according to a predetermined collimation factor as described above, in some embodiments.

[0103] According to some embodiments, the method 300 of time-multiplexed backlight operation further comprises modulating the broad-angle emitted light using an array of light valves to provide a 2D image during the 2D mode and modulating the plurality of directional light beams using the light valve array to provide a multiview image during the multiview mode. In some of these embodiments, the time-multiplexing the 2D mode and the multiview mode may superimpose the 2D image and multiview images to provide a composite image comprising both 2D content and multiview content. In some other embodiments, a size of a multibeam element of the multibeam element array may be configured as between one quarter and two times a size of a light valve of the light valve array. In some embodiments, the array of light valves may be substantially similar to the array of light valves 106, described above with respect to the time-multiplexed backlight 100.

[0104] Thus, there have been described examples and embodiments of a time-multiplexed backlight, a time-multiplexed multiview display, and a method of time-multiplexed backlight operation that provide a pair of modes configured to operate in a time-multiplexed or time-interlaced manner. It should be understood that the above-described examples are merely illustrative of some of the many specific examples and embodiments 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 time-multiplexed backlight comprising:
 - a broad-angle backlight configured to provide broad-angle emitted light from an emission surface during a two-dimensional (2D) mode;
 - a multiview backlight comprising an array of multibeam elements, each multibeam element of the multibeam element array being configured to provide a plurality of directional light beams having directions corresponding to different view directions of a multiview image during a multiview mode; and
 - a mode controller configured to time-multiplex the 2D and multiview modes by sequentially activating the broad-angle backlight during a first time interval and the multiview backlight during a second time interval,wherein the multiview backlight is disposed adjacent to the emission surface of the broad-angle backlight and is transparent to the broad-angle emitted light during the 2D mode.
2. The time-multiplexed backlight of Claim 1, wherein the multiview backlight further comprises:
 - a light guide configured to guide light as guided light; and
 - wherein the array of multibeam elements are spaced apart from one another across the light guide, each multibeam element of the multibeam element array being configured to scatter out a portion of the guided light from the light guide as the plurality of directional light beams.
3. The time-multiplexed backlight of Claim 2, wherein the light guide is configured to guide the guided light according to a predetermined collimation factor as collimated guided light.

4. The time-multiplexed backlight of Claim 2, wherein multibeam elements of the multibeam element array comprise one or more of a diffraction grating configured to diffractively scatter out the guided light, a micro-reflective element configured to reflectively scatter out the guided light, and a micro-refractive element configured to refractively scatter out the guided light.

5. The time-multiplexed backlight of Claim 4, wherein the diffraction grating of a multibeam element of the multibeam element array comprises a plurality of individual sub-gratings.

6. The time-multiplexed backlight of Claim 1, wherein the mode controller is configured to switch between the 2D mode and the multiview mode by sequentially activating a light source of the broad-angle backlight to provide the broad-angle emitted light during the 2D mode and a light source of the multiview backlight to provide the plurality of directional light beams during the multiview mode.

7. A time-multiplexed multiview display comprising the time-multiplexed backlight of Claim 1, the time-multiplexed multiview display further comprising:
an array of light valves configured to modulate the broad-angle emitted light during the 2D mode to provide a 2D image and to modulate the plurality of directional light beams during the multiview mode to provide the multiview image.

8. The time-multiplexed multiview display of Claim 7, wherein the mode controller is configured to sequentially activate the broad-angle backlight during the first time interval to provide the 2D image and the multiview backlight during the second time interval to provide the multiview image, the 2D image and the multiview image being superimposed with each other on the time-multiplexed multiview display to provide a composite image.

9. The time-multiplexed multiview display of Claim 7, wherein a size of each multibeam element of the multibeam element array is between one quarter and two times a size of a light valve of the light valve array.

10. A time-multiplexed multiview display comprising:
a broad-angle backlight configured to provide broad-angle emitted light;
a multiview backlight comprising an array of multibeam elements, each multibeam element being configured to provide directional light beams having directions corresponding to different view directions of a multiview image;
an array of light valves configured to modulate the broad-angle emitted light to provide a 2D image and to modulate the directional light beams to provide the multiview image; and
a mode controller configured to sequentially activate the broad-angle backlight and the multiview backlight, the 2D image and multiview image being superimposed on the time-multiplexed multiview display as a composite image.

11. The time-multiplexed multiview display of Claim 10, wherein the multiview backlight further comprises:
a light guide configured to guide light as guided light; and
wherein the array of multibeam elements are spaced apart from one another across the light guide, each multibeam element of the multibeam element array being configured to scatter out a portion of the guided light from the light guide as the directional light beams.

12. The time-multiplexed multiview display of Claim 11, wherein the light guide is configured to guide the guided light according to a collimation factor as collimated guided light, and wherein a size of each multibeam element of the multibeam element array is between one quarter and two times a size of a light valve of the light valve array.

13. The time-multiplexed multiview display of Claim 11, wherein each multibeam element of the multibeam element array comprises one or more of a diffraction grating configured to diffractively scatter out the guided light, a micro-reflective element configured to reflectively scatter out the guided light, and a micro-refractive element configured to refractively scatter out the guided light.

14. The time-multiplexed multiview display of Claim 11, wherein the mode controller is configured to activate a light source of the broad-angle backlight to provide the broad-angle emitted light and to activate a light source of the multiview backlight to provide directional light beams to sequentially activate the broad-angle backlight and the multiview backlight.

15. The time-multiplexed multiview display of Claim 10, wherein the multiview backlight is disposed between the broad-angle backlight and the light valve array, the multiview backlight being transparent to the broad-angle emitted light.

16. A method of operating a time-multiplexed backlight, the method comprising:

providing broad-angle emitted light during a 2D mode using a broad-angle backlight;

providing directional emitted light during a multiview mode using a multiview backlight having an array of multibeam elements, the directional emitted light comprising a plurality of directional light beams provided by each multibeam element of the multibeam element array; and

time multiplexing the 2D and multiview modes using a mode controller to sequentially activate the broad-angle backlight during a first sequential time interval corresponding to the 2D mode and the multiview backlight during a second sequential time interval corresponding to the multiview mode,

wherein directions of the plurality of directional light beams correspond to different view directions of a multiview image.

17. The method of operating a time-multiplexed backlight of Claim 16, wherein providing directional emitted light comprises:

guiding light in a light guide as guided light; and

scattering out a portion of the guided light as the directional emitted light using multibeam elements of the multibeam element array, each multibeam element of the multibeam element array comprising one or more of a diffraction grating, a micro-refractive element, and a micro-reflective element.

18. The method of operating a time-multiplexed backlight of Claim 17, further comprising providing light to the light guide, the guided light within the light guide being collimated according to a predetermined collimation factor.

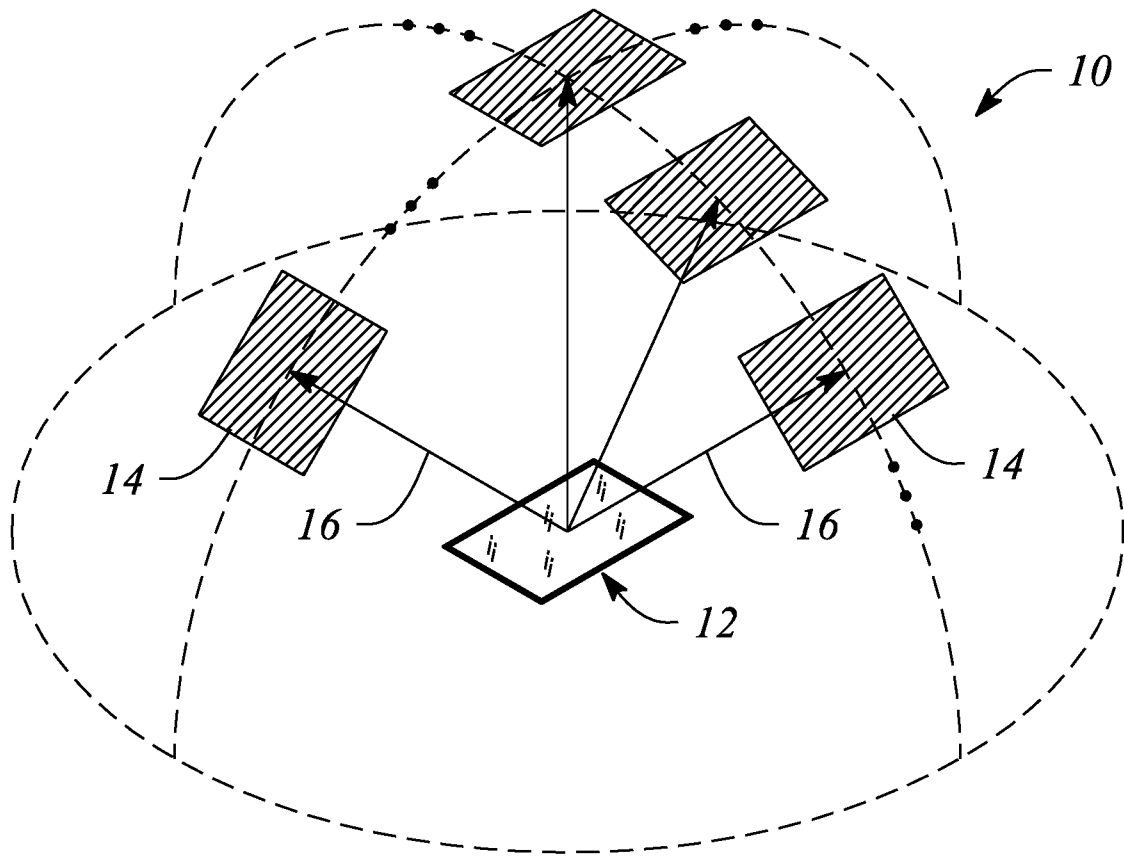
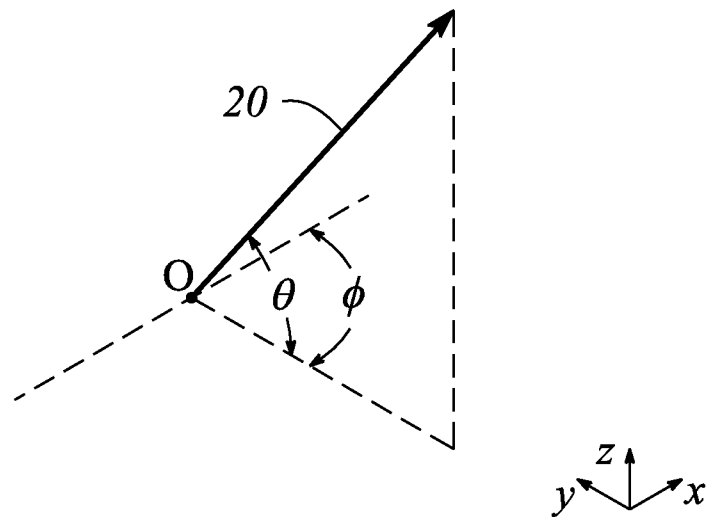
19. The method of operating a time-multiplexed backlight of Claim 16, further comprising:

modulating the broad-angle emitted light using an array of light valves to provide a 2D image during the 2D mode; and

modulating the plurality of directional light beams of the directional emitted light using the light valve array to provide a multiview image during the multiview mode,

wherein time-multiplexing the 2D mode and the multiview mode superimposes the 2D image and multiview images to provide a composite image comprising both 2D content and multiview content.

20. The method of operating a time-multiplexed backlight of Claim 19, wherein a size of a multibeam element of the multibeam element array is between one quarter and two times a size of a light valve of the light valve array.

$1/8$ *FIG. 1A**FIG. 1B*

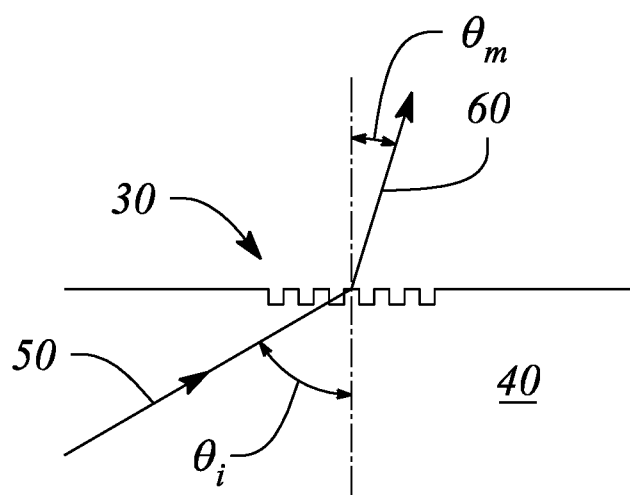


FIG. 2

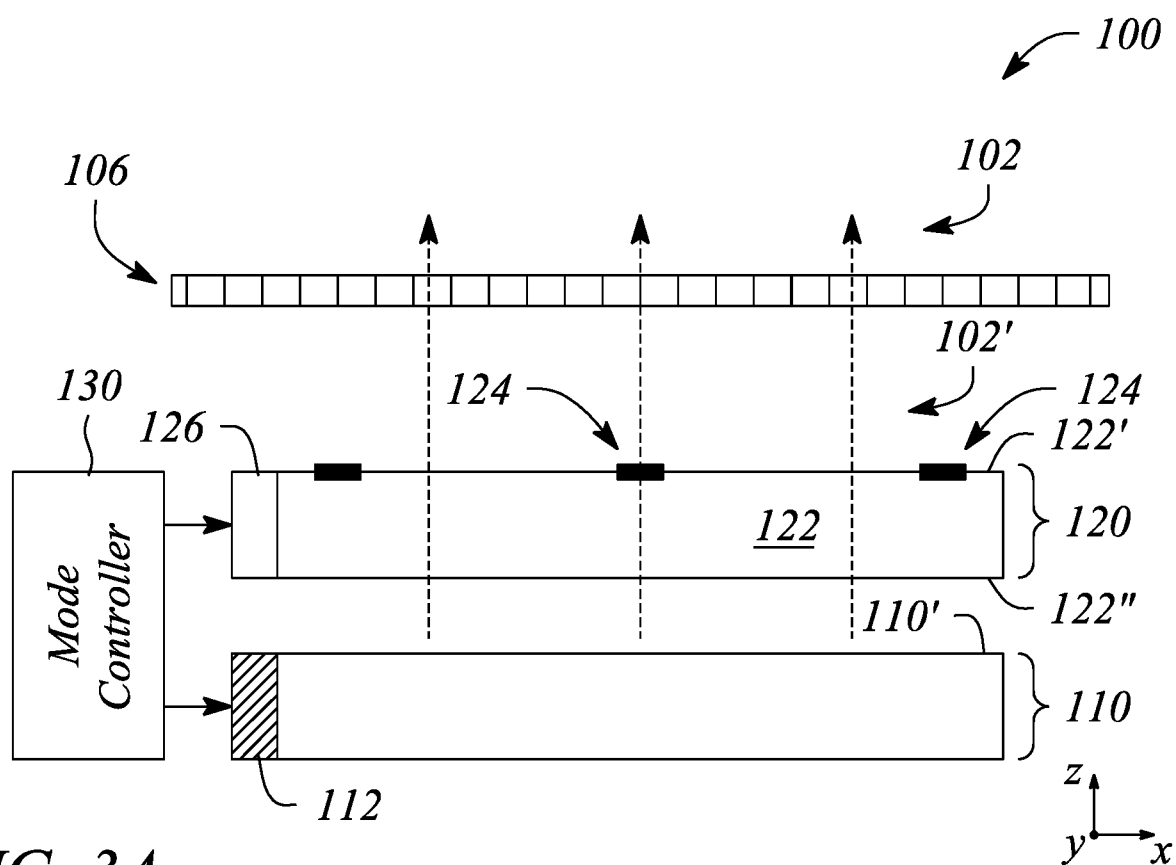


FIG. 3A

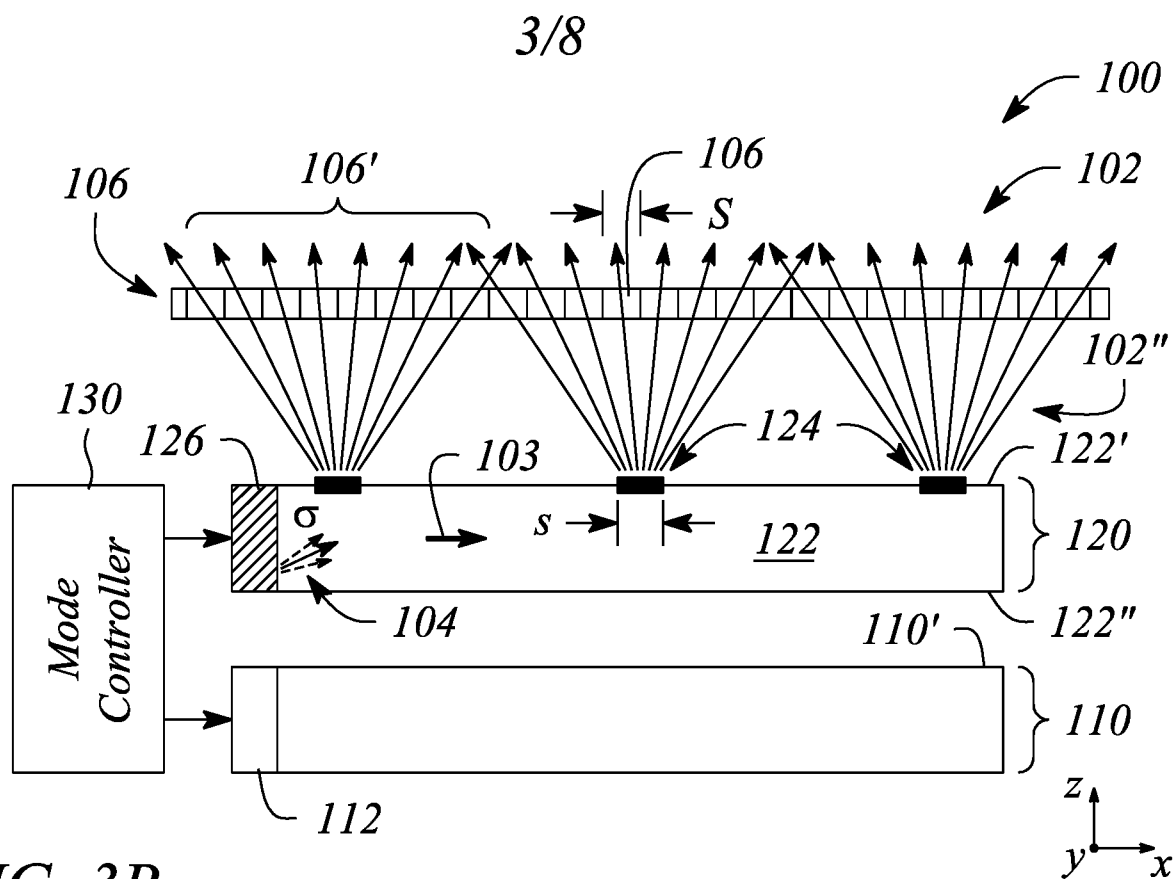


FIG. 3B

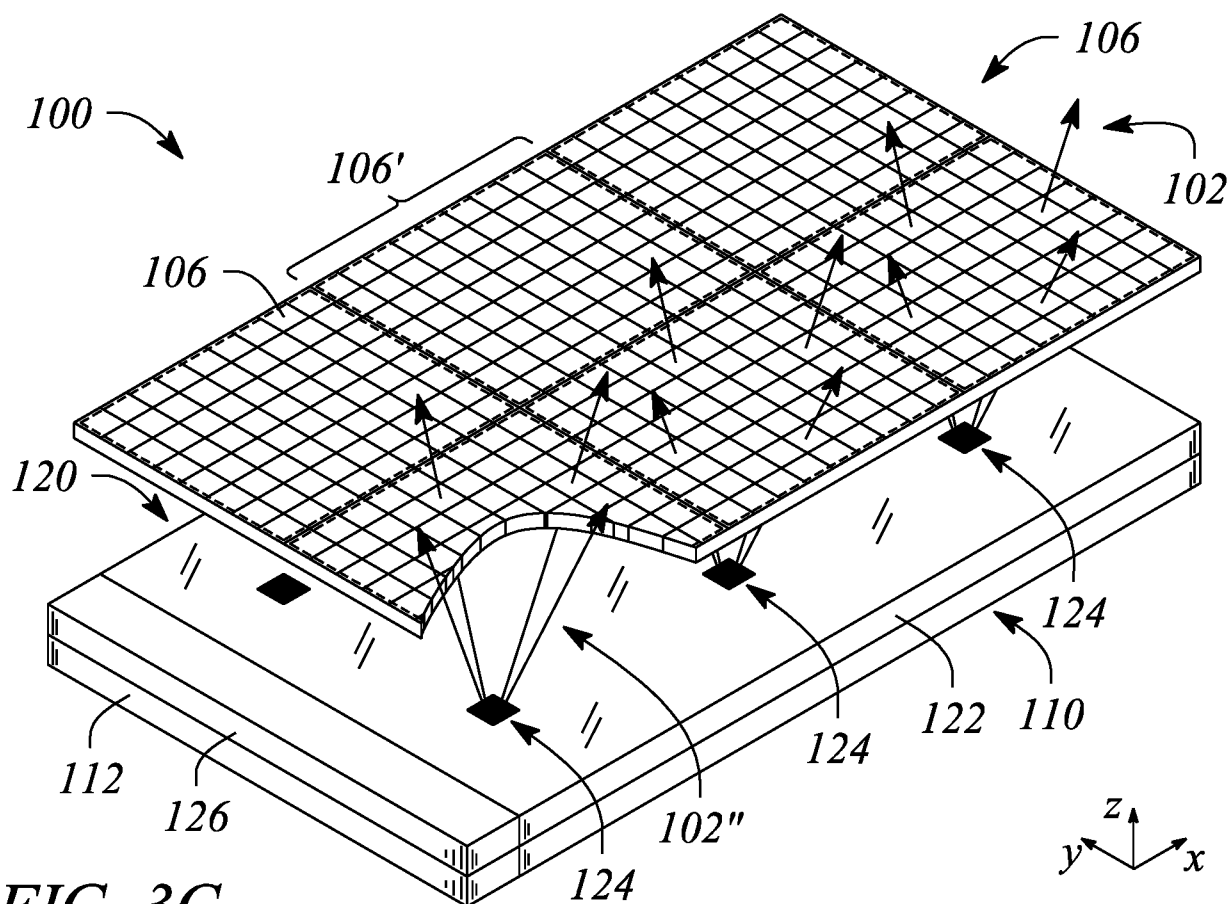


FIG. 3C

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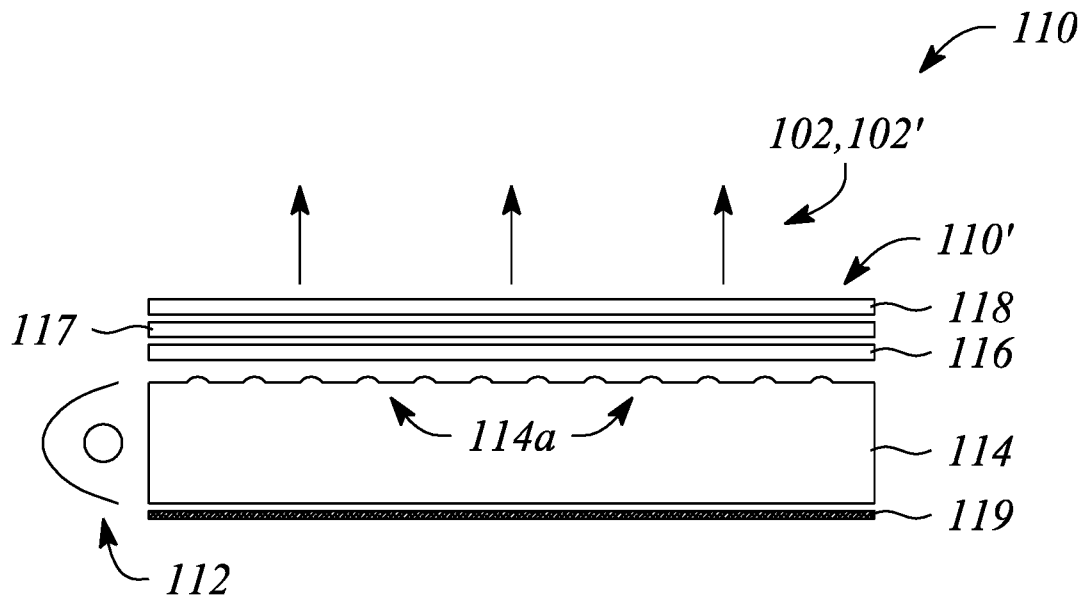


FIG. 4

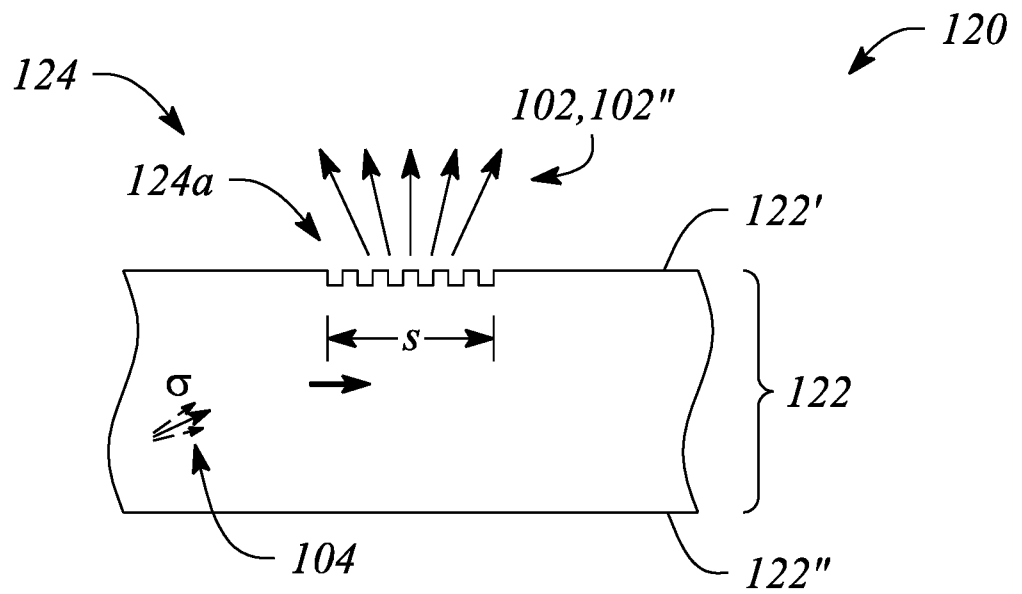


FIG. 5A

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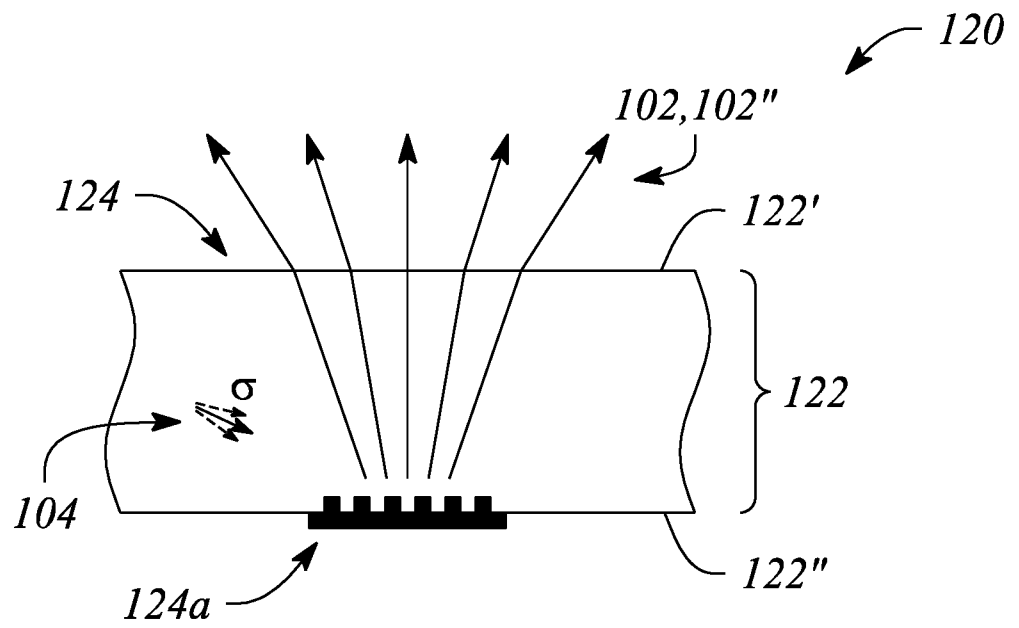


FIG. 5B

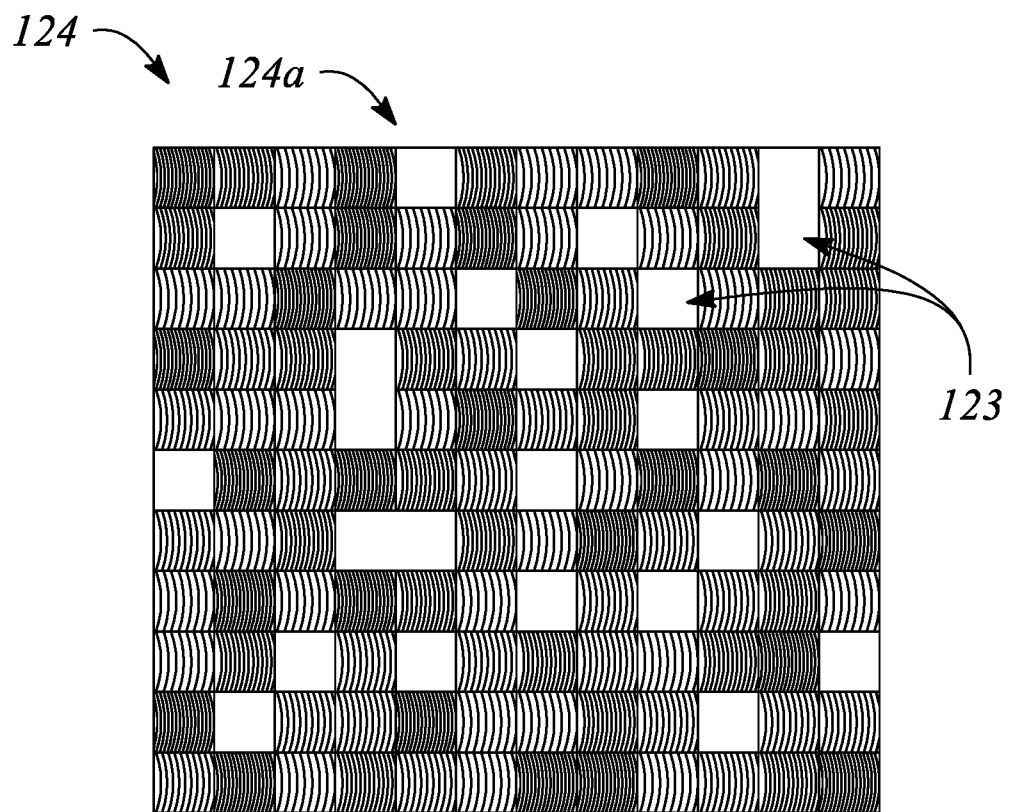


FIG. 6

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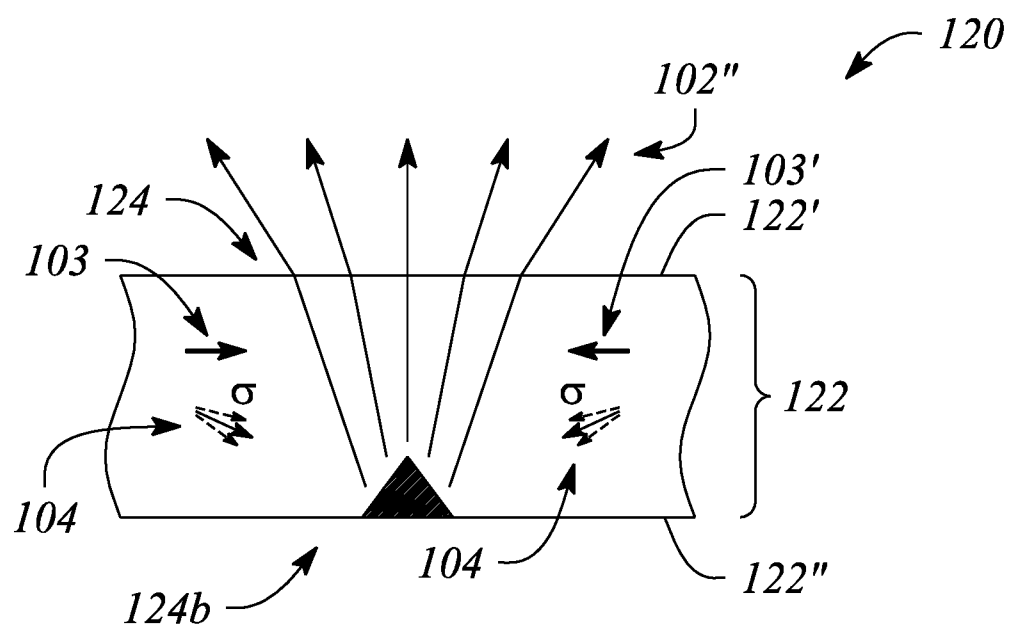


FIG. 7

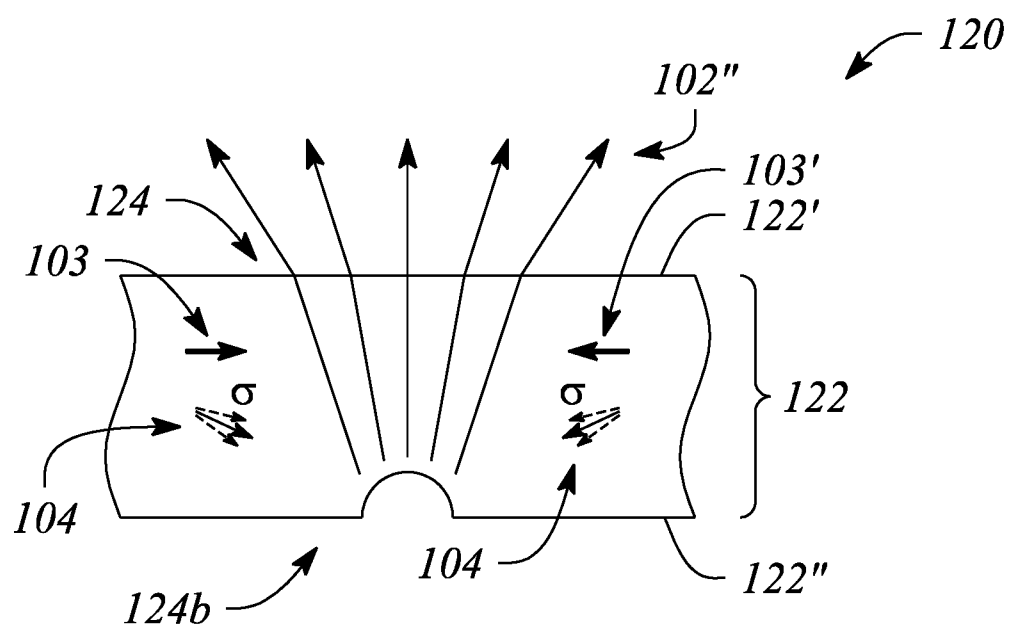


FIG. 8

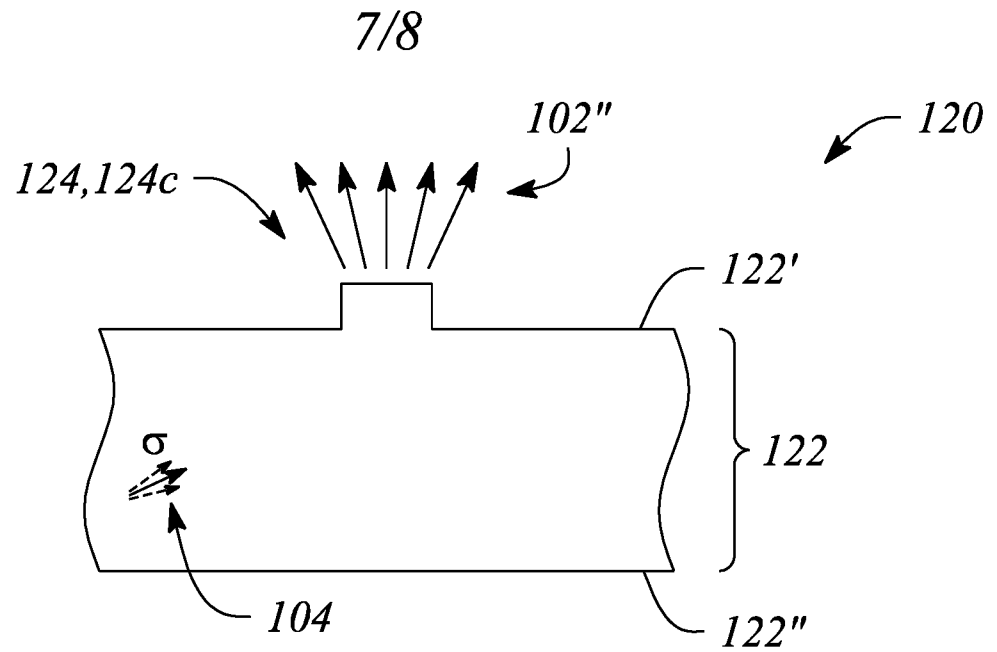


FIG. 9

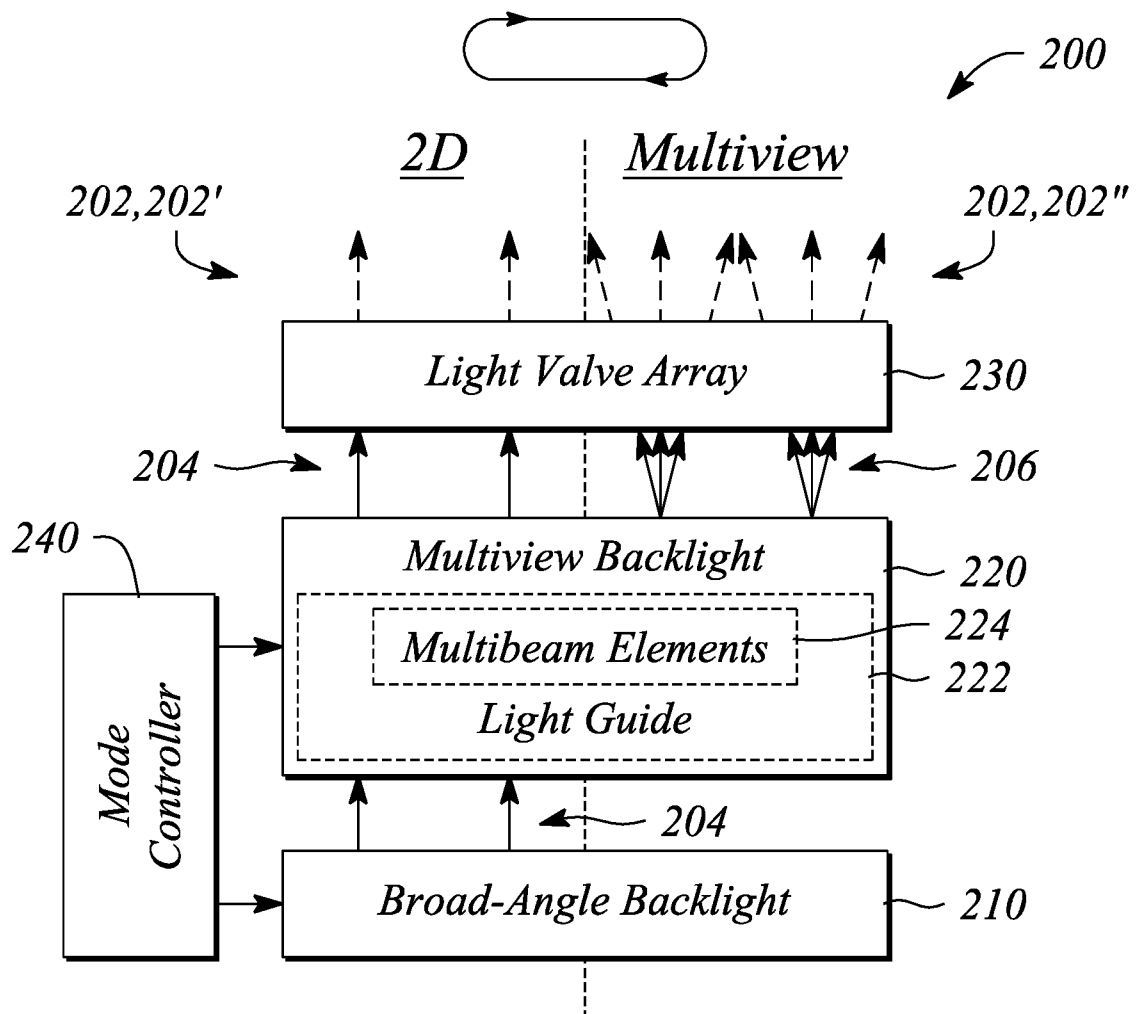
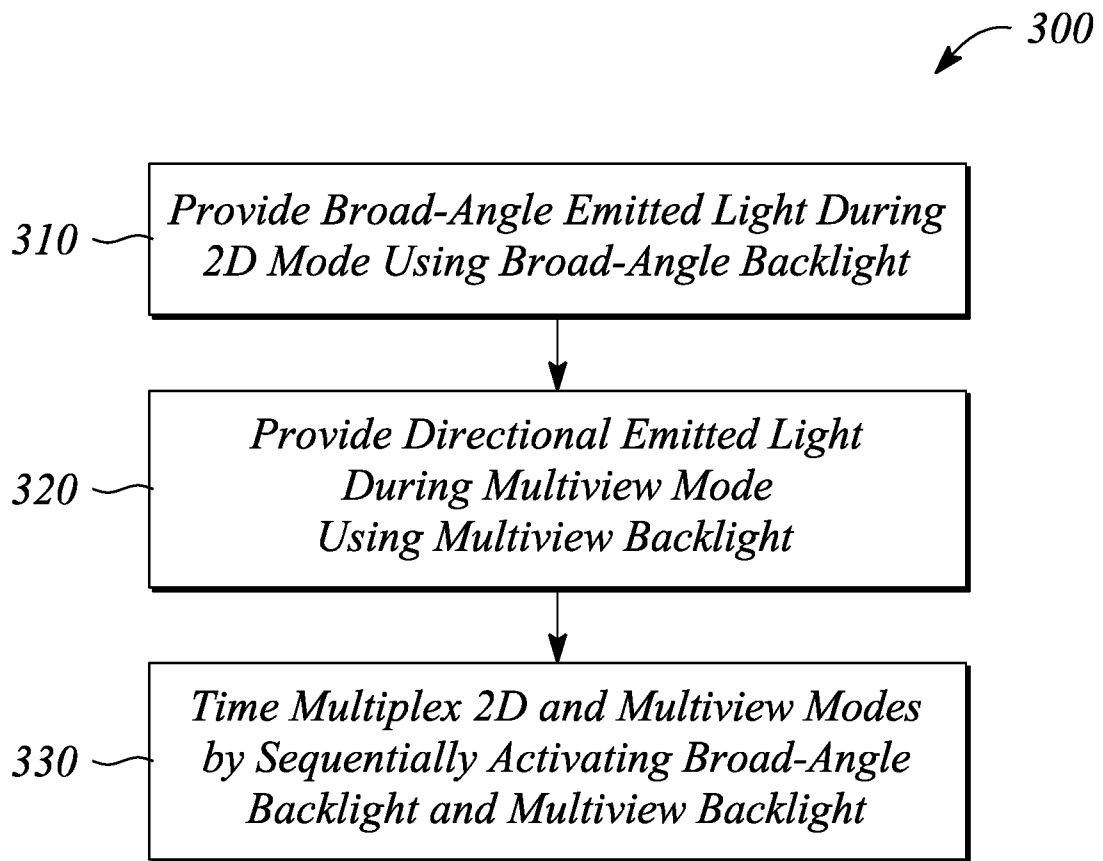


FIG. 10

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*FIG. 11*

