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(54) **EDGE-LIT BACKLIGHT UNIT WITH THIN PROFILE**

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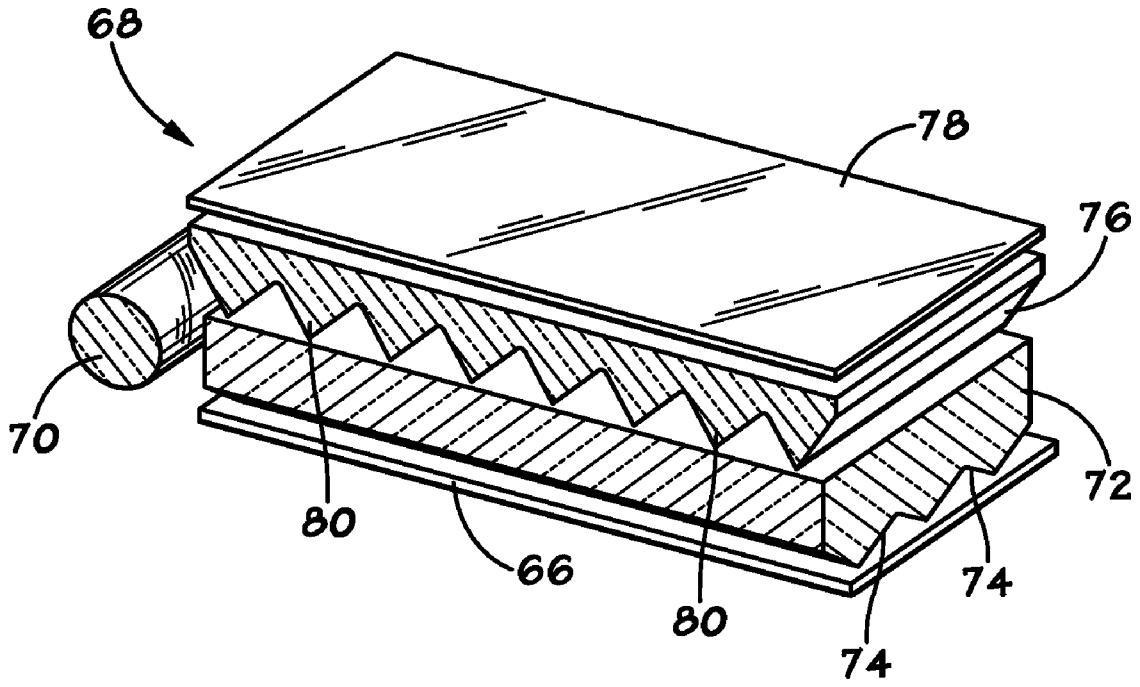
(57) **ABSTRACT**

An edge-lit backlight unit for a display is provided. In one embodiment, the backlight unit may include a light guide configured to receive light from a source and emit such light in a broad distribution to a turning film disposed over the light guide. The turning film may be configured to redirect light received from the light guide toward a normal of the turning film. In one embodiment, the light guide may be configured such that peak light distribution therefrom occurs at an incident angle of approximately sixty degrees, with broad light distribution substantially occurring over an angular range between incident angles of thirty-five and eighty-five degrees. Additionally, in one embodiment, the turning film may include multiple prisms that receive and redirect the light emitted from the light guide, and that include apex angles of less than or about sixty degrees. Additional edge-lit backlight units and methods are also disclosed.



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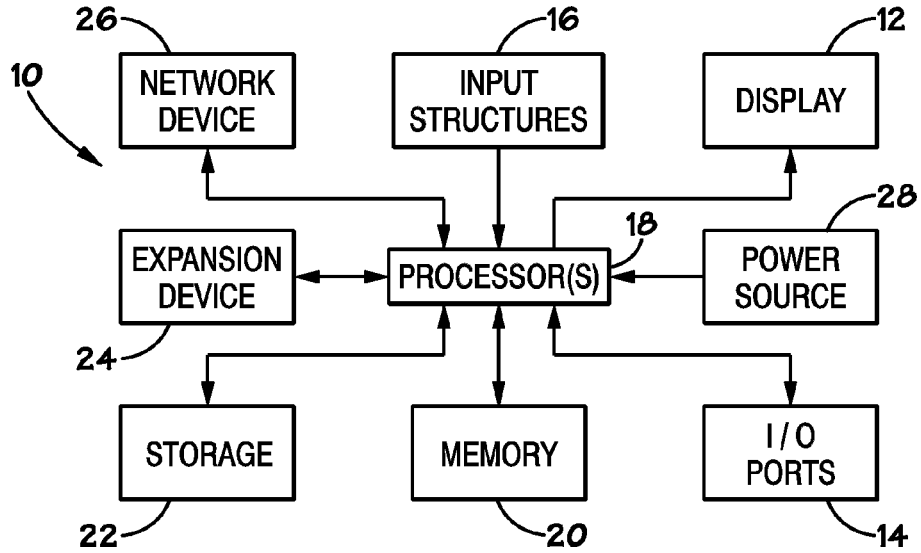
10
26
NETWORK DEVICE
16
INPUT STRUCTURES
12
DISPLAY
18
28
EXPANSION DEVICE
PROCESSOR(S)
POWER SOURCE
24
STORAGE
MEMORY
I/O PORTS
22
20
14

FIG. 1

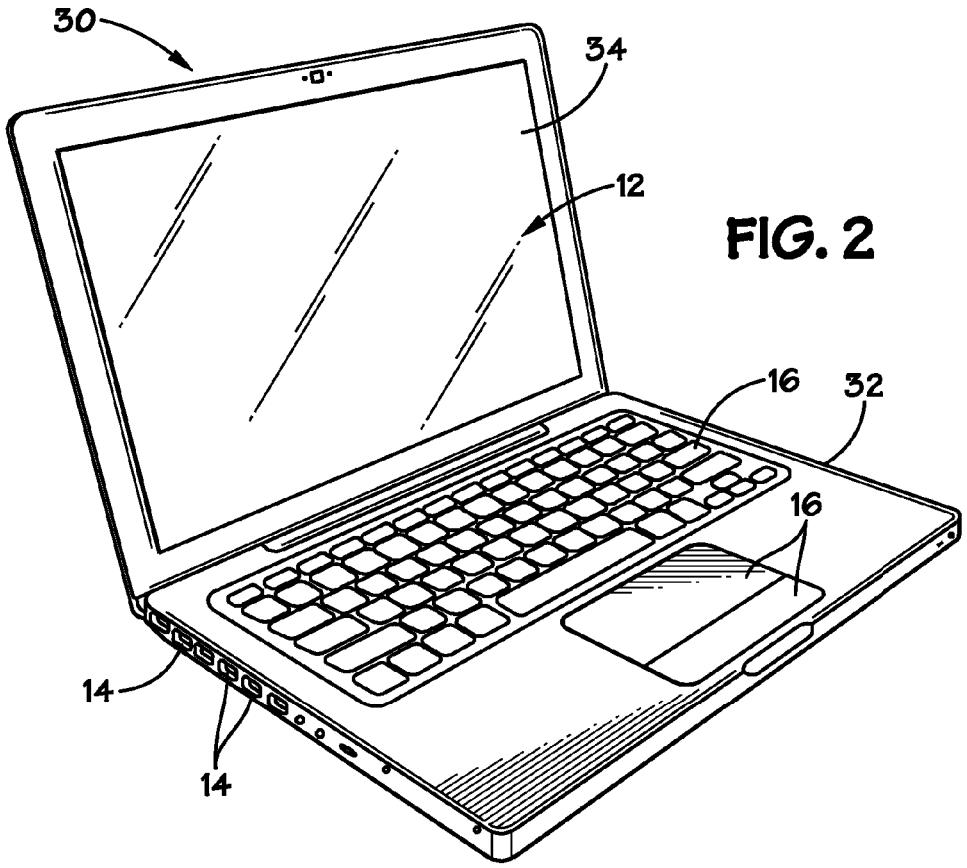
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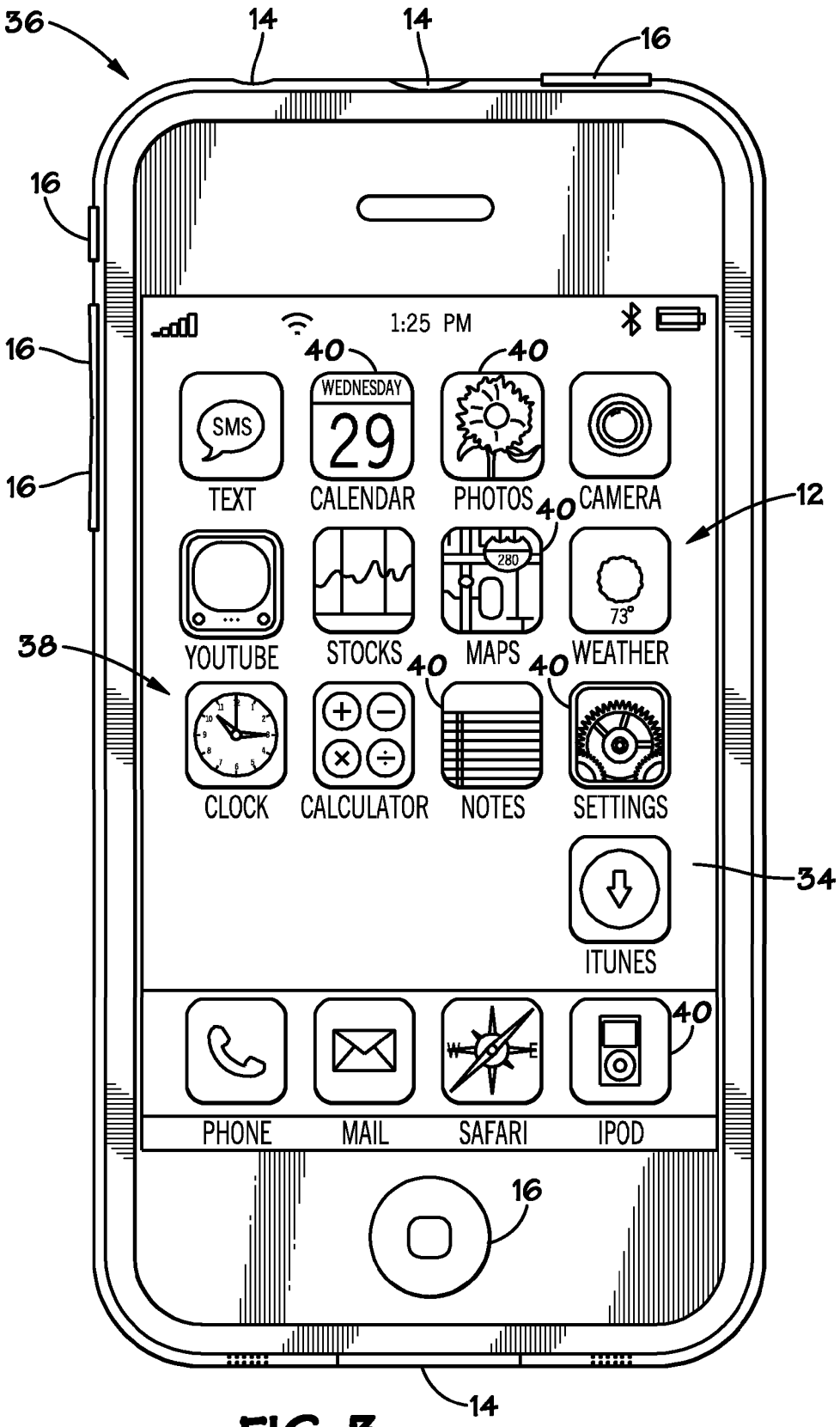
FIG. 2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1:25 PM
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WEDNESDAY
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TEXT
CALENDAR
PHOTOS
CAMERA
YOUTUBE
STOCKS
MAPS
WEATHER
CLOCK
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SETTINGS
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FIG. 3

FIG. 4

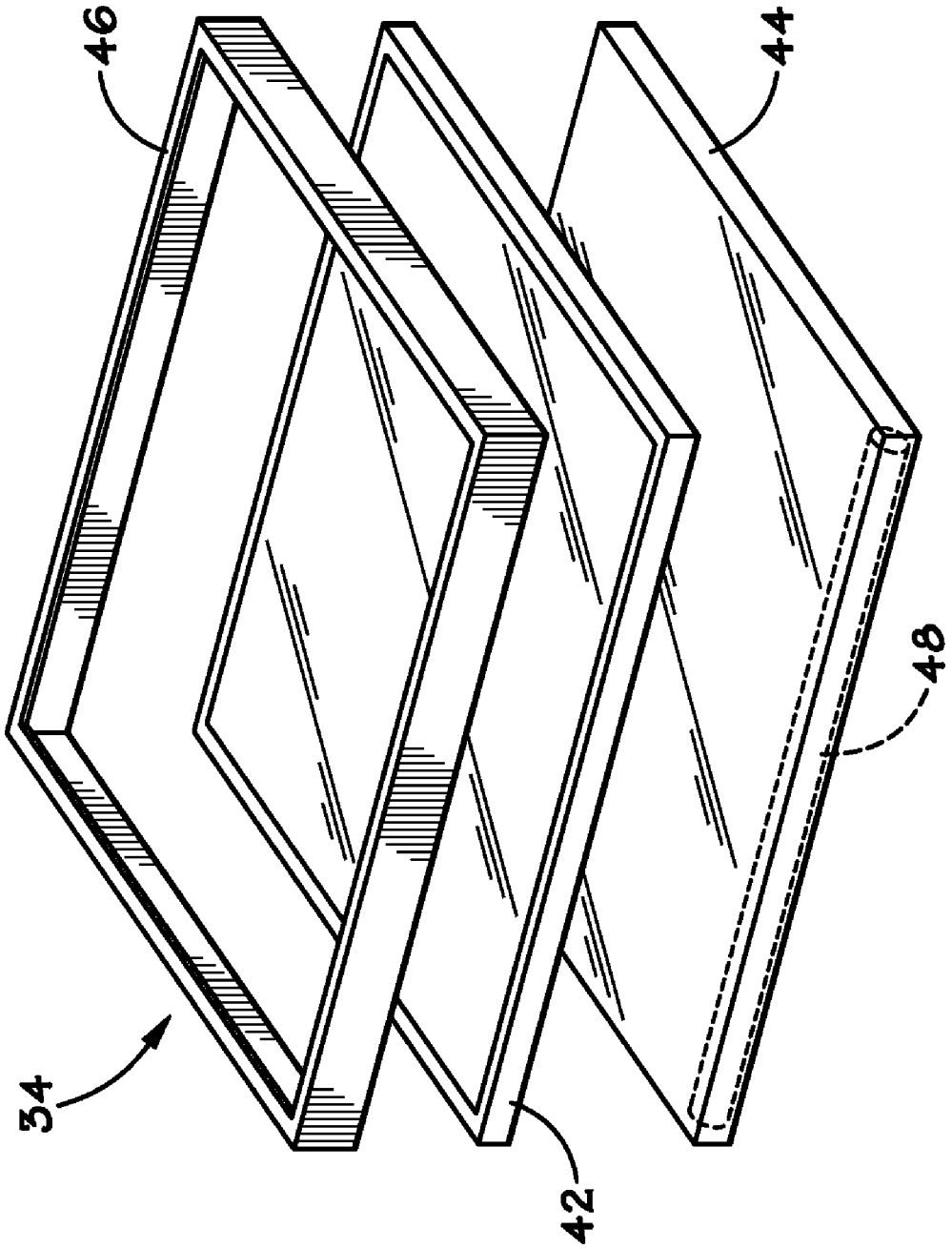
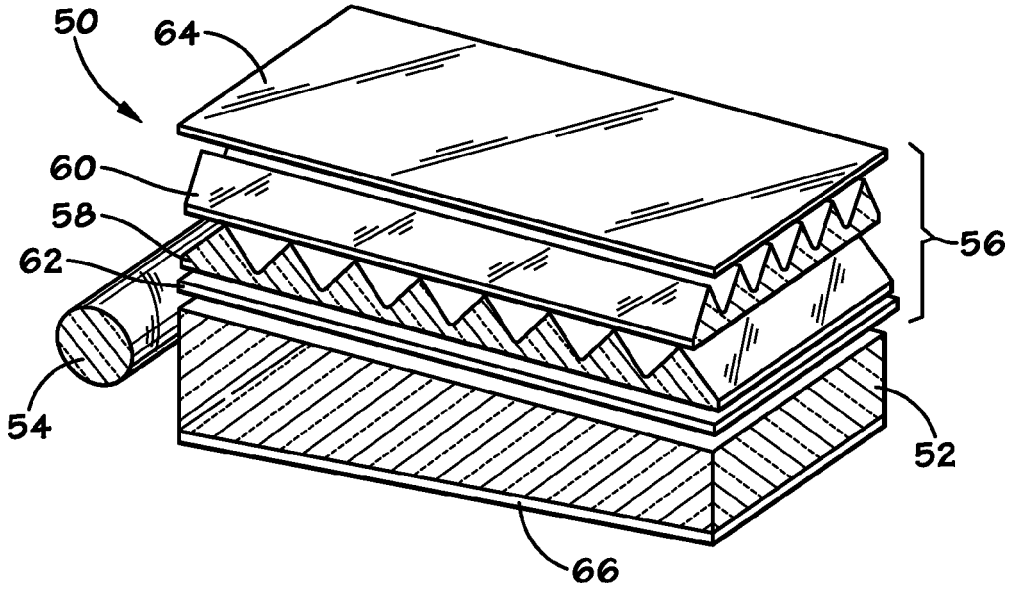


FIG. 5



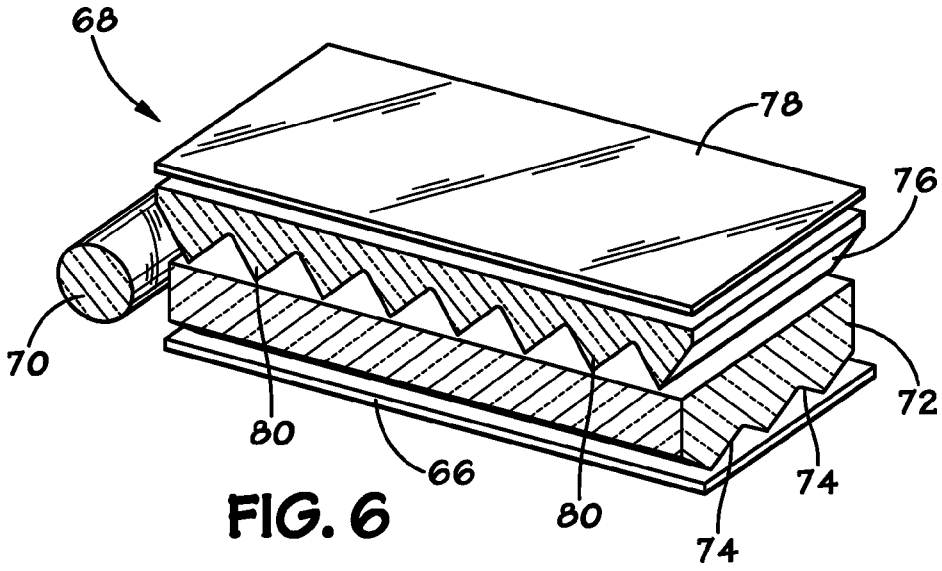


FIG. 6

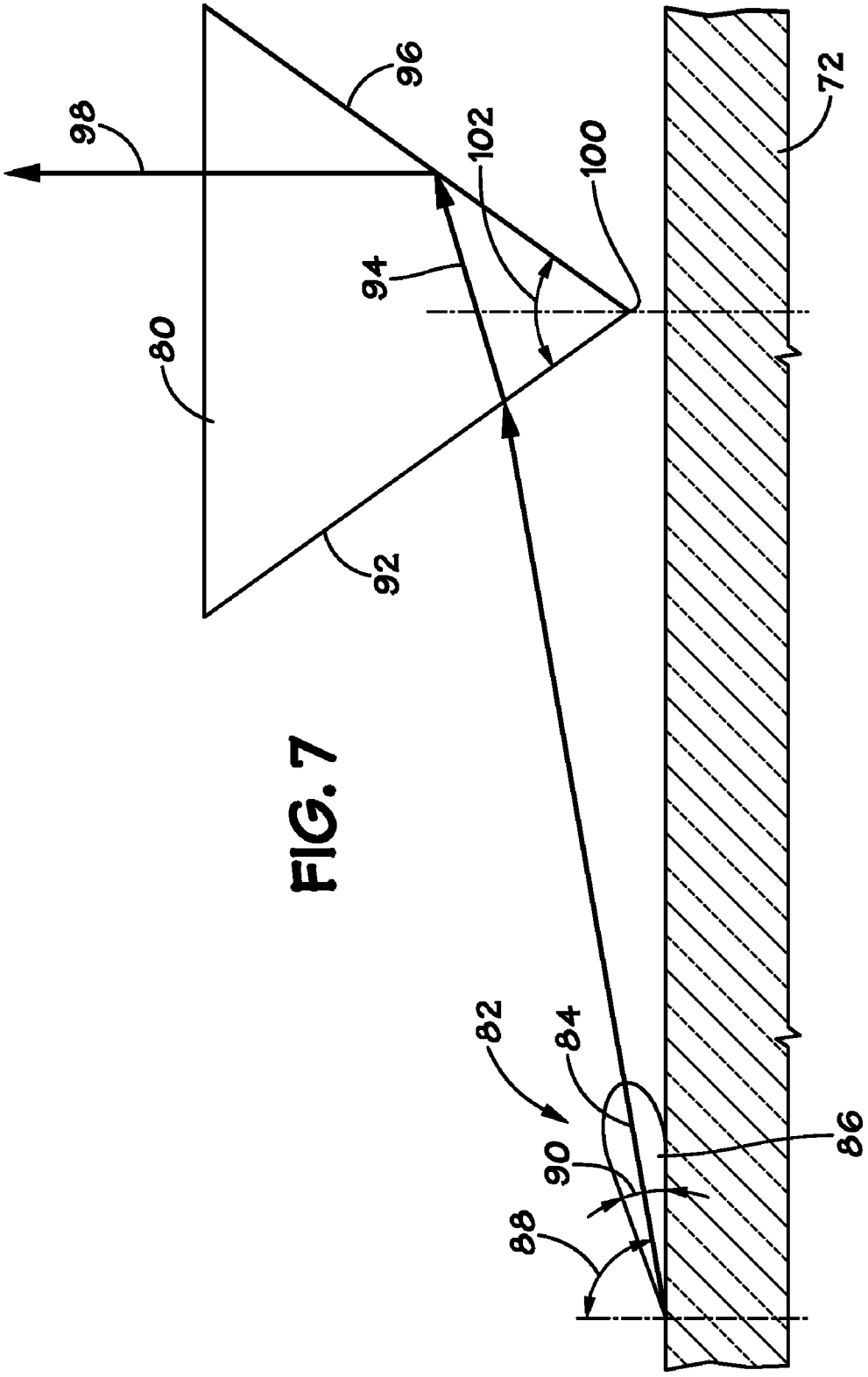


FIG. 7

FIG. 8

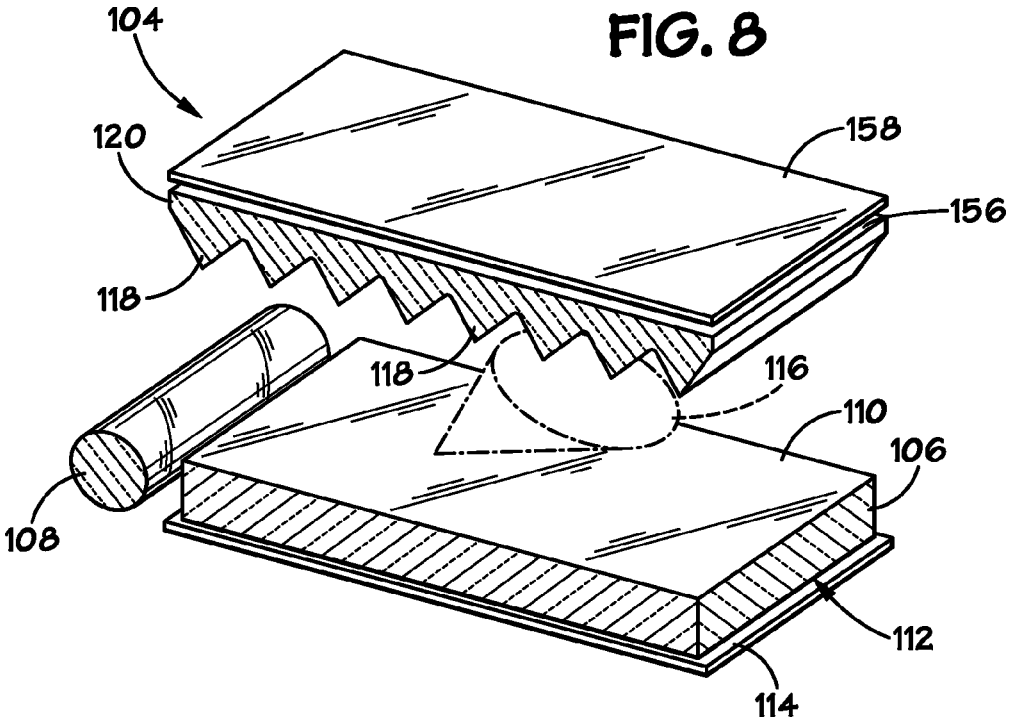

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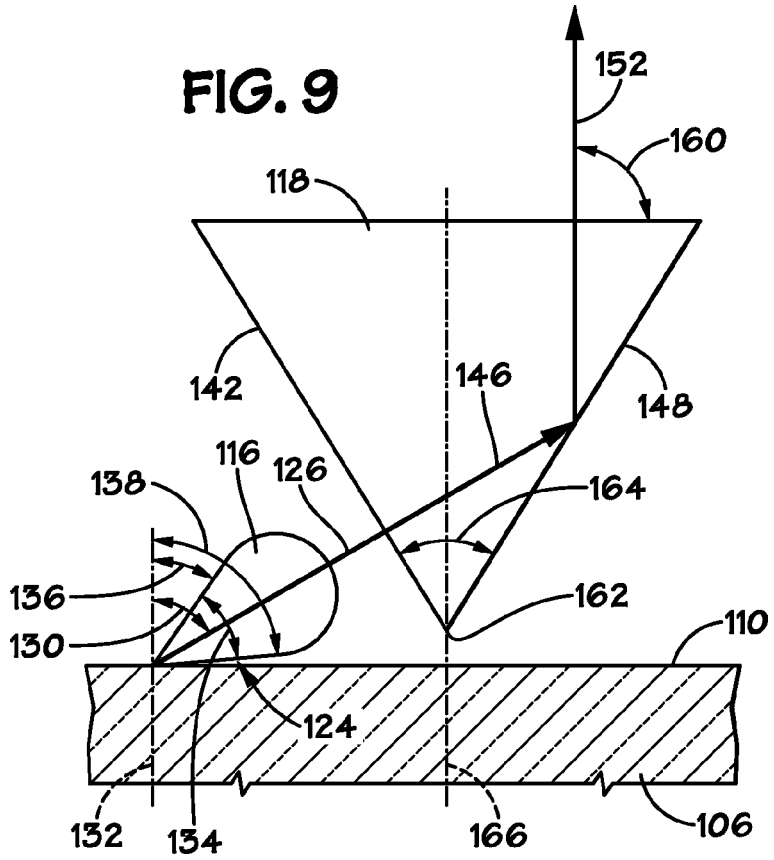
FIG. 9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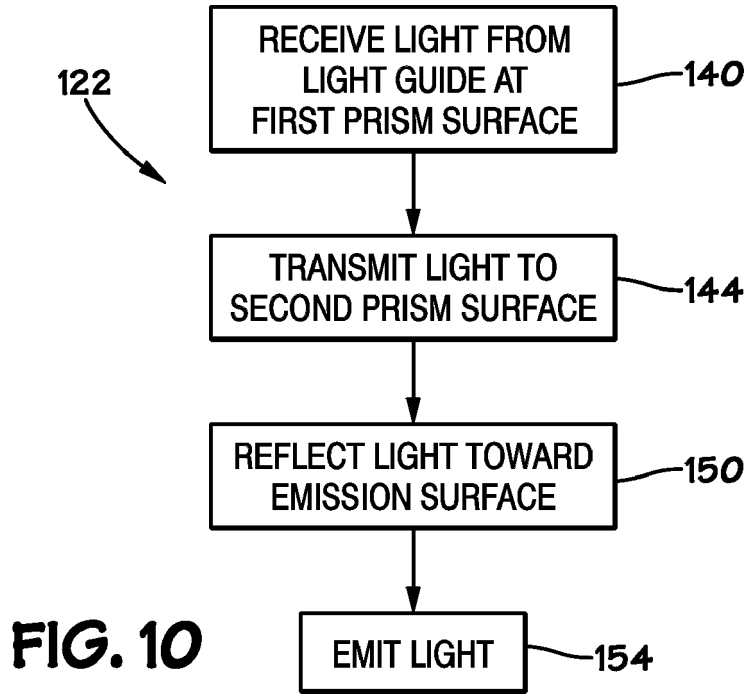
122
RECEIVE LIGHT FROM LIGHT GUIDE AT FIRST PRISM SURFACE
140
TRANSMIT LIGHT TO SECOND PRISM SURFACE
144
REFLECT LIGHT TOWARD EMISSION SURFACE
150
EMIT LIGHT
154

FIG. 10

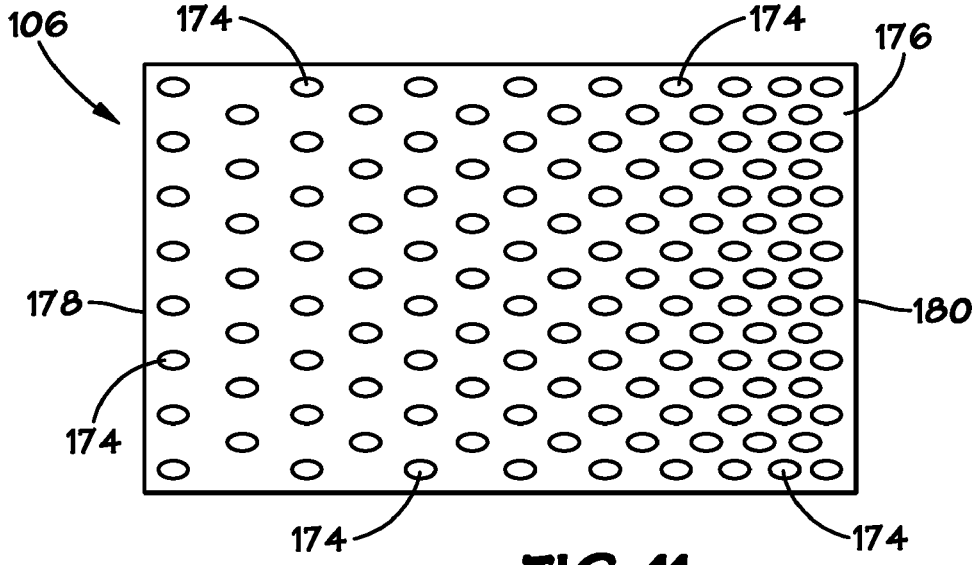
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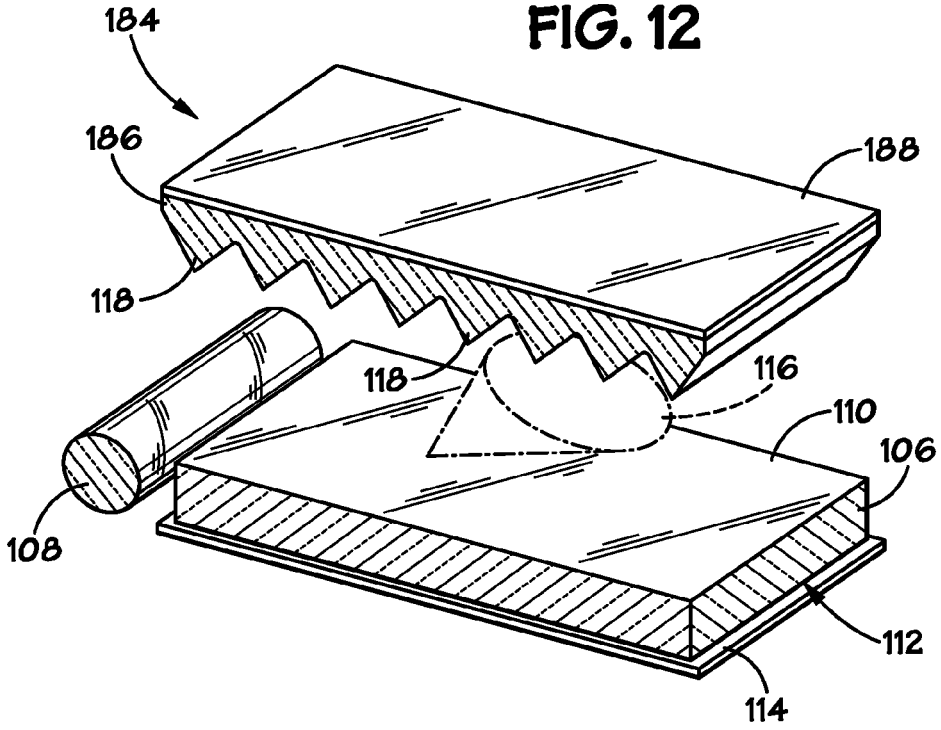
FIG. 11

FIG. 12


184
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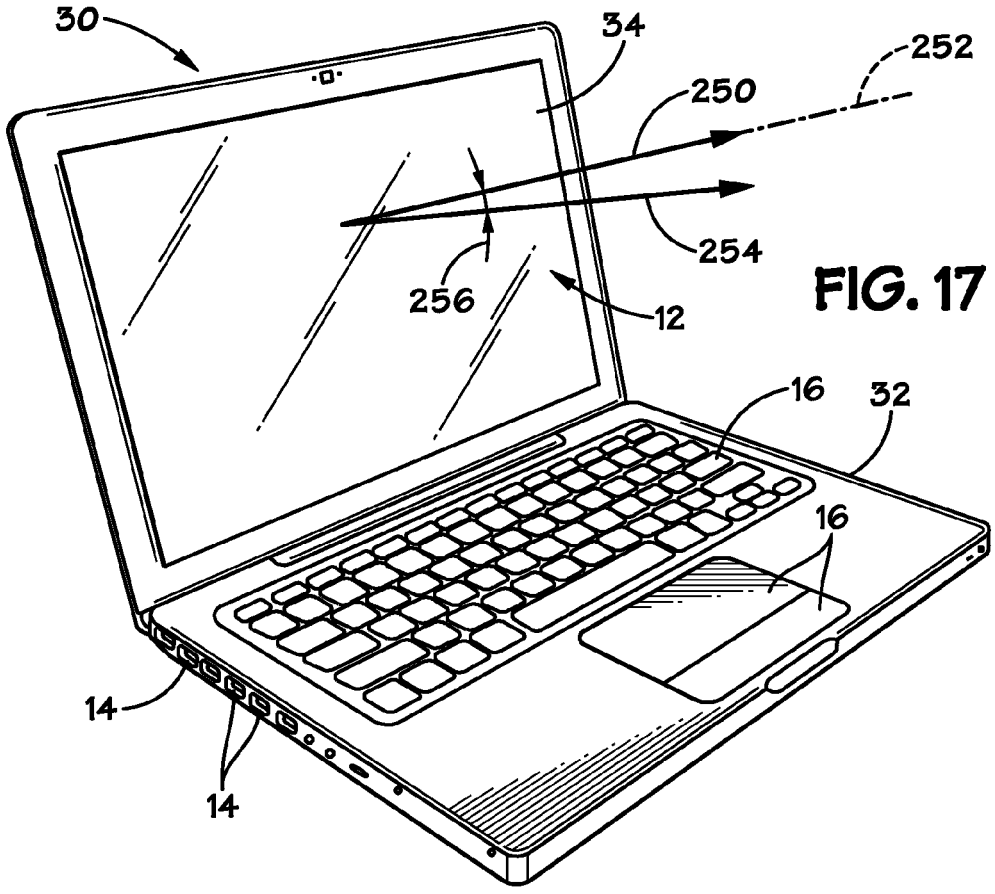
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252
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FIG. 17

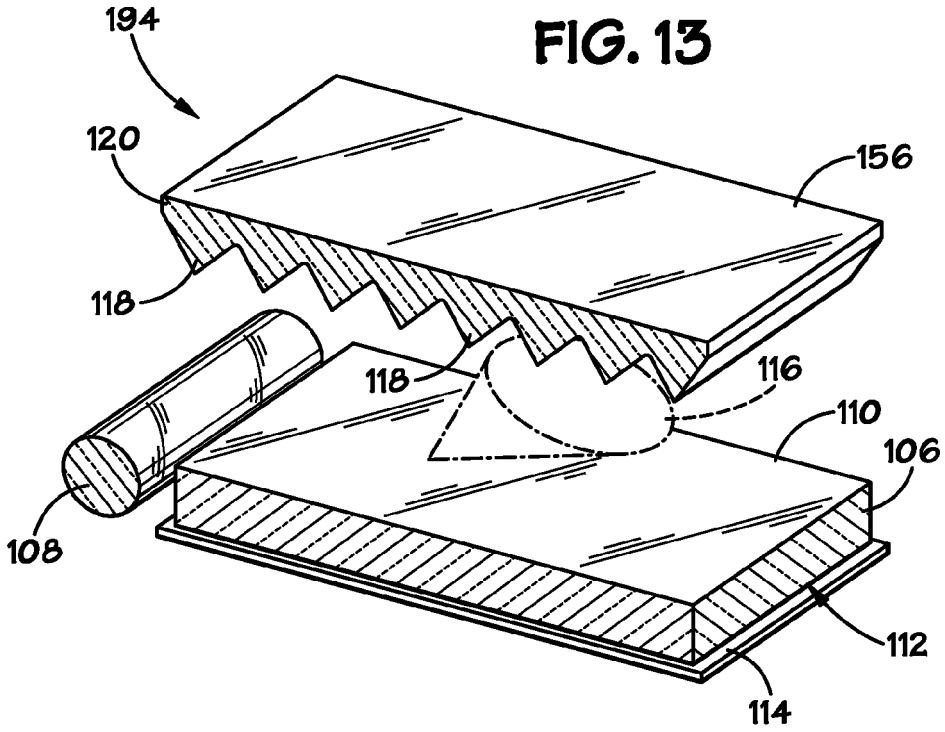
194
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FIG. 13

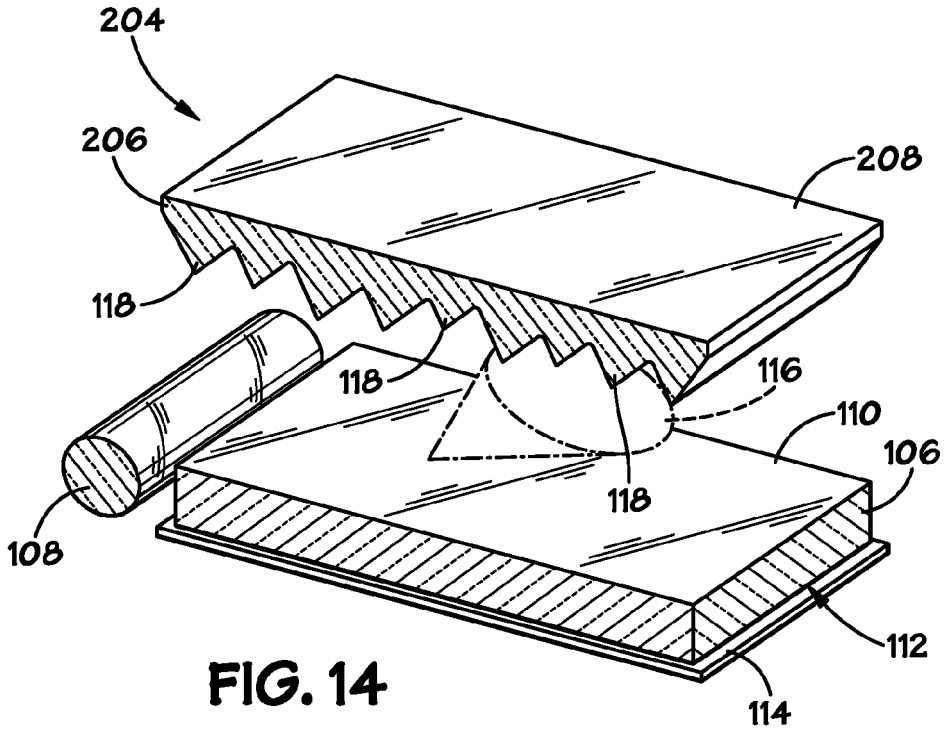
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FIG. 14

FIG. 15

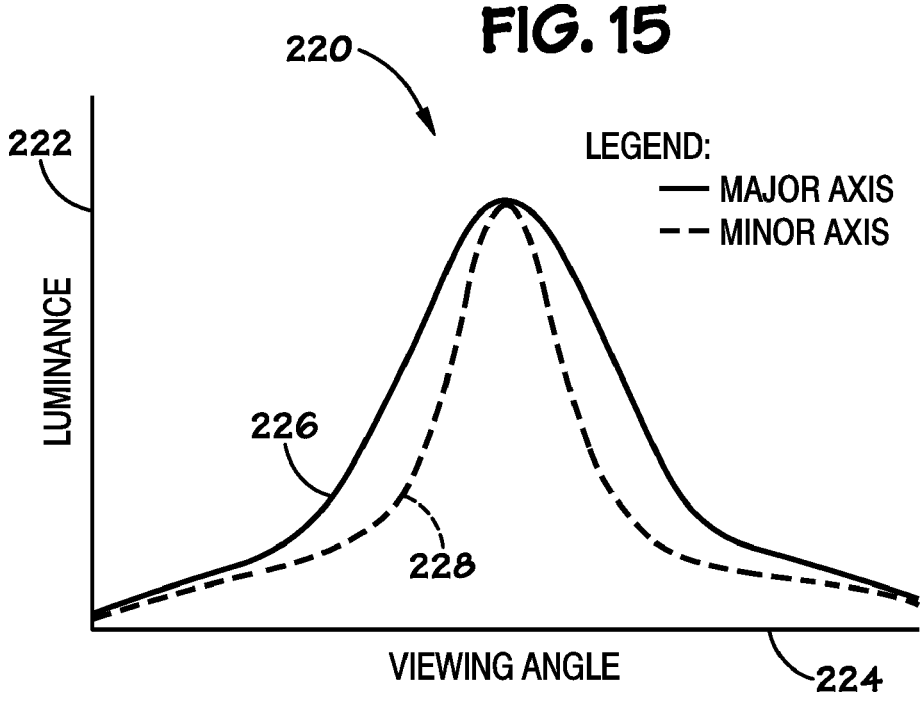
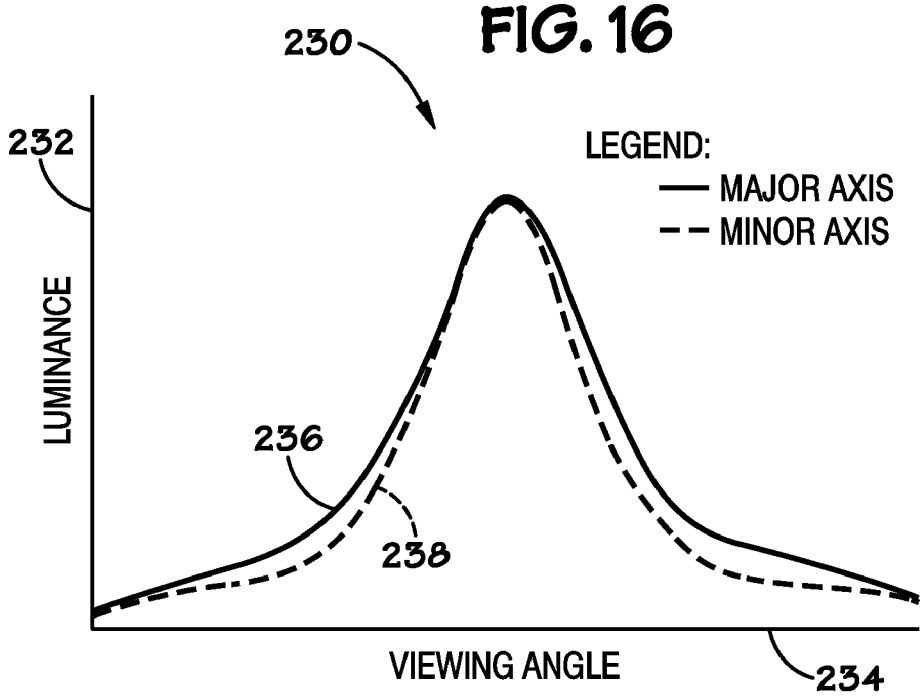

220
222
LEGEND:
MAJOR AXIS
MINOR AXIS
LUMINANCE
226
228
VIEWING ANGLE
224

FIG. 16


230
232
LEGEND:
MAJOR AXIS
MINOR AXIS
LUMINANCE
236
238
VIEWING ANGLE
234

EDGE-LIT BACKLIGHT UNIT WITH THIN PROFILE

BACKGROUND

[0001] 1. Technological Field

[0002] This relates generally to backlight units of electronic display panels, such as liquid crystal displays.

[0003] 2. Description of the Related Art

[0004] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present invention, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present invention. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0005] Liquid crystal displays (LCDs) are commonly used as screens or displays for a wide variety of electronic devices, including such consumer electronics as televisions, computers, and handheld devices (e.g., cellular telephones, audio and video players, gaming systems, and so forth). Such LCD devices typically provide a flat display in a relatively thin package that is suitable for use in a variety of electronic goods. In addition, such LCD devices typically use less power than comparable display technologies, making them suitable for use in battery-powered devices or in other contexts where it is desirable to minimize power usage.

[0006] LCDs typically include an LCD panel having, among other things, a liquid crystal layer and various circuitry for controlling orientation of liquid crystals within the layer to modulate an amount of light passing through the LCD panel. Further, while certain LCDs may operate by reflecting and modulating passage of light from a source positioned in front of the LCD panel (e.g., ambient light), many LCDs include a light source, such as an internal light source, that illuminates the LCD panel from behind. For example, in a direct-lit backlight configuration, a light source (e.g., a lamp or light emitting diodes) is provided behind, and directs light to, an LCD panel. To reduce the thickness of the LCD, an edge-lit backlight configuration may instead be used, in which the light source is oriented to illuminate an edge of a light guide, which in turn distributes such light to the LCD panel. While edge-lit backlights are generally thinner than direct-lit backlights, various conventional edge-lit backlights may exhibit certain disadvantages, such as reduced brightness and/or narrow acceptable viewing angles.

SUMMARY

[0007] Certain aspects of embodiments disclosed herein by way of example are summarized below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of certain forms an invention disclosed and/or claimed herein might take, and that these aspects are not intended to limit the scope of any invention disclosed and/or claimed herein. Indeed, any invention disclosed and/or claimed herein may encompass a variety of aspects that may not be set forth below.

[0008] The present disclosure generally relates to an edge-lit backlight unit for a display. In one embodiment, the edge-lit backlight unit includes a light guide that receives light from a light source, and emits this light in a broad distribution to a turning film. In one embodiment, the light guide includes anisotropic optical elements that refract light such that the light emitted to the turning film falls within a broad distribution, such as over a range of approximately fifty degrees. Additionally, the turning film may be configured to redirect this broad distribution of light toward a normal direction with respect to the backlight unit. In one embodiment, an edge-lit backlight unit may exhibit increased luminance, improved viewing angles, or both when compared to conventional edge-lit backlight units. Additionally, in one embodiment, the edge-lit backlight unit may be thinner than certain conventional edge-lit backlight units.

[0009] Various refinements of the features noted above may exist in relation to various aspects of the present invention. Further features may also be incorporated in these various aspects as well. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to one or more of the illustrated embodiments may be incorporated into any of the above-described aspects of the present invention alone or in any combination. Again, the brief summary presented above is intended only to familiarize the reader with certain aspects and contexts of embodiments of the present invention without limitation to the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Advantages of the present disclosure may become apparent upon reading the following detailed description and upon reference to the drawings in which:

[0011] FIG. **1** is a block diagram of exemplary components of an electronic device, in accordance with aspects of the present disclosure;

[0012] FIG. **2** is a perspective view of a computer in accordance with aspects of the present disclosure;

[0013] FIG. **3** is a perspective view of a handheld electronic device in accordance with aspects of the present disclosure;

[0014] FIG. **4** is an exploded view of a liquid crystal display (LCD) including a backlight unit in accordance with aspects of the present disclosure;

[0015] FIG. **5** depicts an example of a backlight unit including a wedge-shaped light guide and brightness enhancement films;

[0016] FIG. **6** depicts another example of a backlight unit including a light guide having prismatic features and a turning film having prisms configured to receive light from the light guide;

[0017] FIG. **7** generally illustrates the turning of a narrow distribution of light emitted from the light guide of FIG. **6** by a prism of the turning film also of FIG. **6**;

[0018] FIG. **8** is a partially exploded view generally depicting a backlight unit having a light guide that emits light over a broader distribution range than that of FIGS. **6** and **7**, in accordance with aspects of the present disclosure;

[0019] FIG. **9** generally illustrates the turning of the broad distribution of light emitted from the light guide of FIG. **8** by a prism of the turning film of FIG. **8** in accordance with aspects of the present disclosure;

[0020] FIG. **10** is a flowchart representative of operation of the prism of FIG. **9** in receiving and redirecting light from the light guide in accordance with aspects of the present disclosure;

[0021] FIG. **11** is a top plan view of the light guide of FIGS. **8** and **9**, which includes anisotropic optical elements to emit light over a broad distribution range in accordance with aspects of the present disclosure;

[0022] FIG. **12** is a partially exploded view generally depicting a backlight unit having a light guide that emits light over a broad distribution range and a multi-function film in accordance with aspects of the present disclosure;

[0023] FIG. **13** is a partially exploded view generally depicting a backlight unit that does not include a diffusion layer over a turning film of the backlight unit in accordance with aspects of the present disclosure;

[0024] FIG. **14** is a partially exploded view generally depicting a backlight unit having a turning film that includes differently-shaped prisms in accordance with aspects of the present disclosure;

[0025] FIG. **15** is a graph representing the luminance of the backlight unit of FIG. **6** as a function of viewing angle along its major and minor axes;

[0026] FIG. **16** is a graph generally representing the improvement in minor-axis luminance of a backlight unit emitting a broad distribution of light from a light guide to a turning film provided in accordance with aspects of the present disclosure; and

[0027] FIG. **17** is a perspective view of a computer generally depicting the possibility of biasing of the peak luminance direction of a backlight unit and a display in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0028] One or more specific embodiments will be described below. These described embodiments are provided only by way of example, and do not limit the scope of the present disclosure. Additionally, in an effort to provide a concise description of these exemplary embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0029] When introducing elements of various embodiments described below, the articles "a," "an," and "the" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements. Moreover, while the term "exemplary" may be used herein in connection to certain examples of aspects or embodiments of the presently disclosed subject matter, it will be appreciated that these examples are illustrative in nature and that the term "exemplary" is not used herein to denote any preference or requirement with respect to a disclosed aspect or embodiment. Additionally, it should be understood that references to "one embodiment," "an embodiment," "some embodiments," and the like are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the disclosed features.

[0030] The present application is generally directed to edge-lit backlight units for displays. Particularly, the present application discloses edge-lit backlight units that provide improved luminance in a thinner profile compared to certain traditional backlight units employing brightness enhancement films. Additionally, the presently disclosed backlight units may also exhibit better viewing angle performance than other traditional backlight units. As discussed in greater detail below, in some embodiments, edge-lit backlight units in accordance with the present techniques include a light guide that emits light in a broad distribution to a turning film, which generally operates to redirect such light out of the backlight unit, such as to an LCD panel of a display.

[0031] With these foregoing features in mind, a general description of electronic devices that may employ such an edge-lit backlight unit is provided below. As may be appreciated, electronic device may include various internal and/or external components which contribute to the function of the device. For instance, FIG. **1** is a block diagram illustrating components that may be present in one such electronic device **10**, and which may allow device **10** to function in accordance with the techniques discussed herein. Those of ordinary skill in the art will appreciate that the various functional blocks shown in FIG. **1** may include hardware elements (including circuitry), software elements (including computer code stored on a computer-readable medium, such as a hard drive or system memory), or a combination of both hardware and software elements. It should further be noted that FIG. **1** is merely one example of a particular implementation and is merely intended to illustrate the types of components that may be present in electronic device **10**. For example, in the presently illustrated embodiment, these components may include display **12**, I/O ports **14**, input structures **16**, one or more processors **18**, memory device **20**, non-volatile storage **22**, expansion card(s) **24**, networking device **26**, and power source **28**.

[0032] With regard to each of these components, it is first noted that display **12** may be used to display various images generated by device **10**. In various embodiments, display **12** may be a liquid crystal display (LCD), a cathode ray tube (CRT) display, or any other suitable display. Additionally, in certain embodiments of electronic device **10**, display **12** may be provided in conjunction with a touch-sensitive element, such as a touchscreen, that may be used as part of the control interface for device **10**.

[0033] I/O ports **14** may include ports configured to connect to a variety of external devices, such as a power source, headset or headphones, or other electronic devices (such as handheld devices and/or computers, printers, projectors, external displays, modems, docking stations, and so forth). I/O ports **14** may support any interface type, such as a universal serial bus (USB) port, a video port, a serial connection port, an IEEE-1394 port, an Ethernet or modem port, and/or an AC/DC power connection port.

[0034] Input structures **16** may include the various devices, circuitry, and pathways by which user input or feedback is provided to processor(s) **18**. Such input structures **16** may be configured to control a function of electronic device **10**, applications running on device **10**, and/or any interfaces or devices connected to or used by device **10**. For example, input structures **16** may allow a user to navigate a displayed user interface or application interface. Non-limiting examples of input structures **16** include buttons, sliders, switches, control pads, keys, knobs, scroll wheels, keyboards, mice, touchpads, and so forth. User interaction with input structures **16**, such as to interact with a user or application interface displayed on display **12**, may generate electrical signals indicative of user

input. These input signals may be routed via suitable pathways, such as an input hub or bus, to processor(s) **18** for further processing.

[0035] Additionally, in certain embodiments, one or more input structures **16** may be provided together with display **12**, such an in the case of a touchscreen, in which a touch sensitive mechanism is provided in conjunction with display **12**. In such embodiments, the user may select or interact with displayed interface elements via the touch sensitive mechanism. In this way, the displayed interface may provide interactive functionality, allowing a user to navigate the displayed interface by touching display **12**.

[0036] Processor(s) **18** may provide the processing capability to execute the operating system, programs, user and application interfaces, and any other functions of the electronic device **10**. Processor(s) **18** may include one or more microprocessors, such as one or more "general-purpose" microprocessors, one or more special-purpose microprocessors and/or ASICS, or some combination of such processing components. For example, processor(s) **18** may include one or more reduced instruction set (RISC) processors, as well as graphics processors, video processors, audio processors, and the like. As will be appreciated, processor(s) **18** may be communicatively coupled to one or more data buses or chipsets for transferring data and instructions between various components of electronic device **10**.

[0037] Programs or instructions executed by processor(s) **18** may be stored in any suitable manufacture that includes one or more tangible, computer-readable media at least collectively storing the executed instructions or routines, such as, but not limited to, the memory devices and storage devices described below. Also, these programs (e.g., an operating system) encoded on such a computer program product may also include instructions that may be executed by processor(s) **18** to enable device **10** to provide various functionalities, including those described herein.

[0038] The instructions or data to be processed by processor(s) **18** may be stored in a computer-readable medium, such as memory **20**. Memory **20** may include a volatile memory, such as random access memory (RAM), and/or a non-volatile memory, such as read-only memory (ROM). Memory **20** may store a variety of information and may be used for various purposes. For example, memory **20** may store firmware for electronic device **10** (such as basic input/output system (BIOS)), an operating system, and various other programs, applications, or routines that may be executed on electronic device **10**. In addition, memory **20** may be used for buffering or caching during operation of the electronic device **10**.

[0039] The components of device **10** may further include other forms of computer-readable media, such as non-volatile storage **22** for persistent storage of data and/or instructions. Non-volatile storage **22** may include, for example, flash memory, a hard drive, or any other optical, magnetic, and/or solid-state storage media. Non-volatile storage **22** may be used to store firmware, data files, software programs, wireless connection information, and any other suitable data.

[0040] The embodiment illustrated in FIG. **1** may also include one or more card or expansion slots. The card slots may be configured to receive one or more expansion cards **24** that may be used to add functionality, such as additional memory, I/O functionality, or networking capability, to electronic device **10**. Such expansion cards **24** may connect to device **10** through any type of suitable connector, and may be accessed internally or external to the housing of electronic device **10**. For example, in one embodiment, expansion cards **24** may include a flash memory card, such as a SecureDigital (SD) card, mini- or microSD, CompactFlash card, Multimedia card (MMC), or the like. Additionally, expansion cards **24** may include one or more processor(s) **18** of the device **10**, such as a video graphics card having a GPU for facilitating graphical rendering by device **10**.

[0041] The components depicted in FIG. **1** also include network device **26**, such as a network controller or a network interface card (NIC). In one embodiment, network device **26** may be a wireless NIC providing wireless connectivity over any 802.11 standard or any other suitable wireless networking standard. Network device **26** may allow electronic device **10** to communicate over a network, such as a personal area network (PAN), a local area network (LAN), a wide area network (WAN), or the Internet. Further, electronic device **10** may connect to and send or receive data with any device on the network, such as portable electronic devices, personal computers, printers, and so forth. Alternatively, in some embodiments, electronic device **10** may not include a network device **26**. In such an embodiment, a NIC may be added as one expansion card **24** to provide similar networking capability as described above.

[0042] Further, device **10** may also include power source **28**. In one embodiment, power source **28** may be one or more batteries, such as a lithium-ion polymer battery or other type of suitable battery. The battery may be user-removable or may be secured within the housing of electronic device **10**, and may be rechargeable. Additionally, power source **28** may include AC power, such as provided by an electrical outlet, and electronic device **10** may be connected to power source **28** via a power adapter. This power adapter may also be used to recharge one or more batteries of device **10**.

[0043] Electronic device **10** may take the form of a computer system or some other type of electronic device. Such computers may include computers that are generally portable (such as laptop, notebook, tablet, and handheld computers), as well as computers that are generally used in one place (such as conventional desktop computers, workstations and/or servers). In certain embodiments, electronic device **10** in the form of a computer may be a model of a MacBook®, MacBook® Pro, MacBook Air®, iMac®, Mac® mini, or Mac Pro® available from Apple Inc. of Cupertino, Calif. By way of example, electronic device **10** in the form of laptop computer **30** is illustrated in FIG. **2** in accordance with one embodiment. Depicted computer **30** includes housing **32**, display **12** (e.g., LCD **34** or some other suitable display), input/output ports **14**, and input structures **16**.

[0044] In one embodiment, input structures **16** (such as a keyboard and/or touchpad) may be used to interact with computer **30**, such as to start, control, or operate a graphical user interface (GUI) or applications running on computer **30**. For example, a keyboard and/or touchpad may allow a user to navigate a user interface or application interface displayed on display **12**.

[0045] As depicted, electronic device **10** in the form of computer **30** may also include various I/O ports **14** to allow connection of additional devices. For example, I/O ports **14** may include a USB port, a DVI port, or some other port suitable for connecting to another electronic device, a projector, a supplemental display, and so forth. In addition, computer **30** may include network connectivity, memory, and

storage capabilities, as described with respect to FIG. **1**. As a result, computer **30** may store and execute a GUI and other applications.

[0046] Although electronic device **10** is generally depicted in the context of a computer in FIG. **2**, electronic device **10** may also take the form of other types of electronic devices. In some embodiments, various electronic devices **10** may include cellular telephones, media players for playing music and/or video, personal data organizers, handheld game platforms, cameras, and/or combinations of such devices. For instance, as generally depicted in FIG. **3**, device **10** may be provided in the form of handheld electronic device **36** that includes various functionalities (such as the ability to take pictures, make telephone calls, access the Internet, communicate via email, record audio and/or video, listen to music, play games, connect to wireless networks, and so forth). By way of further example, handheld device **36** may be a model of an iPod® or iPhone® available from Apple Inc. In other embodiments, however, other types of handheld devices (such as other media players for playing music and/or video, personal data organizers, handheld game platforms, and/or combinations of such devices) may also be suitably provided as electronic device **10**.

[0047] Handheld device **36** of the presently illustrated embodiment includes an enclosure or body that protects the interior components from physical damage and shields them from electromagnetic interference. The enclosure may be formed from any suitable material such as plastic, metal or a composite material and may allow certain frequencies of electromagnetic radiation to pass through to wireless communication circuitry within handheld device **36** to facilitate wireless communication.

[0048] Handheld electronic device **36** also may include various input and output (I/O) ports **14** that allow connection of the handheld device **36** to external devices. For example, one I/O port **14** may be a port that allows the transmission and reception of data or commands between the handheld electronic device **36** and another electronic device, such as a computer. Such an I/O port **14** may be a proprietary port from Apple Inc. or may be an open standard I/O port.

[0049] In the depicted embodiment, the enclosure includes user input structures **16** through which a user may interface with the device. Each user input structure **16** may be configured to help control a device function when actuated. For example, in a cellular telephone implementation, one or more input structures **16** may be configured to invoke a "home" screen or menu to be displayed, to toggle between a sleep and a wake mode, to silence a ringer for a cell phone application, to increase or decrease a volume output, and so forth.

[0050] In the depicted embodiment, handheld device **36** includes display **12**, which may be in the form of LCD **34**. Such LCD **34** may be used to display graphical user interface (GUI) **38** that allows a user to interact with handheld device **36**. GUI **38** may include various layers, windows, screens, templates, or other graphical elements that may be displayed in all, or a portion, of LCD **34**. Generally, GUI **38** may include graphical elements that represent applications and functions of the electronic device, such as icons **40**, as well as other images representing buttons, sliders, menu bars, and the like. Icons **40** may correspond to various applications of the electronic device that may open upon selection of a respective icon **40**. Furthermore, selection of a particular icon **40** may lead to a hierarchical navigation process, such that selection of the particular icon **40** leads to a screen that includes one or more additional icons or other GUI elements. Icons **40** may be selected via a touchscreen included in display **12**, or may be selected by one or more user input structures **16**, such as a wheel or button. Of course, LCD **34** may also be used to display other data, images, or visual outputs.

[0051] One example of LCD display **34** is depicted in FIG. **4** in accordance with one embodiment. LCD display **34** generally includes LCD panel **42** and backlight unit **44**, which may be assembled within frame **46**. As may be appreciated, LCD panel **42** may include numerous pixels configured to selectively modulate the amount and color of light passing from backlight unit **44** through LCD panel **42**. For example, LCD panel **42** may include a liquid crystal layer, one or more thin film transistor layers configured to control orientation of liquid crystals of the liquid crystal layer via an electric field, and polarizing films, which cooperate to enable LCD panel **42** to control the amount of light emitted by each pixel. Additionally, LCD panel **42** may include color filters that allow specific colors of light to be emitted from the pixels (e.g., red, green, and blue). LCD panel **42** may be a twisted nematic (TN) panel, an in-plane switching (IPS) panel, a fringe-field switching (FFS) panel, a vertical alignment panel (e.g., a multi-domain vertical alignment (MVA) panel or a patterned vertical alignment (PVA) panel), variants of the foregoing types of panel, or any other suitable panel.

[0052] As discussed in greater detail below, backlight unit **44** includes light source **48**. Light from light source **48** is routed through portions of backlight unit **44** (e.g., a light guide and optical films) and generally emitted toward LCD panel **42**. In various embodiments, light source **48** may include a cold-cathode fluorescent lamp (CCFL), one or more light emitting diodes (LEDs), or any other suitable source(s) of light. Although various LCD displays **34** may be incorporated into computers **30** or handheld devices **36**, it is noted that other LCD displays **34** may be incorporated into televisions, computer monitors, and other types of devices.

[0053] More detailed examples of portions of backlight units are depicted in FIGS. **5** and **6**. In both of these figures, the illustrated backlight units are edge-lit backlight units. In such edge-lit backlight units, a light source is positioned to provide light to a lateral edge of a light guide, which emits light from an emission surface (e.g., an upper surface of the light guide). For instance, backlight unit **50** of FIG. **5** includes light guide **52**, such as a light guiding plate, positioned adjacent light source **54**. Although light source **54** is generally depicted as a portion of a CCFL, light source **54** may also or instead include any suitable light source, such as LEDs.

[0054] Light from light source **54** may generally propagate through light guide **52** via total internal reflection at upper and lower surfaces of light guide **52**, and may ultimately be emitted therefrom toward various optical films **56**. For example, light guide **52** may include certain optical features on either or both of the upper and lower surfaces of light guide **52** that disrupt total internal reflection, allowing light to pass from light guide **52** to optical films **56**. Such optical features may include, for example, printed dots or micro-lenses on either or both of the upper and lower surfaces of light guide **52**. In other instances, however, the generally wedge-shaped light guide **52** may gradually decrease the angle of incidence of the reflected light, eventually allowing the light to escape light guide **52**. Although depicted as generally wedge-shaped in FIG. **5**, it is noted that light guide **52** may be provided in other forms, such as a generally planar light guide.

[0055] For backlight units **50** in which light guide **52** includes printed dots or micro-lenses, such optical features typically scatter light over a very broad range of distribution (i.e., greater than ninety degrees). Optical films **56** may function to focus this very broad light distribution for output to an LCD panel, thereby increasing apparent brightness of the LCD panel. For instance, optical films **56** may include brightness enhancement films **58** and **60**, which generally increase "on-axis" brightness (i.e., the brightness of backlight unit **50** along a normal of an upper surface of backlight unit **50**). Such brightness enhancement films **58** and **60** typically include prisms formed on an upper surface of such films and generally directed away from light guide **52**, as generally depicted in FIG. **5**.

[0056] Brightness enhancement films **58** and **60** generally increase on-axis brightness of backlight unit **50** by permitting certain received light to be emitted within a desired viewing range about the normal, while the other received light may be recycled by reflecting the light toward reflector **66**. For example, the lower surface of brightness enhancement film **58** may reflect light incident at an angle greater than the critical angle of the surface, and may refract light incident at an angle less than the critical angle. Of light refracted by the lower surface, some of this light may be reflected back toward light guide **52** by one or more surfaces of the prisms of brightness enhancement film **58**, while other light will be emitted from the prisms. Brightness enhancement film **60** may operate in a similar manner.

[0057] Light reflected from brightness enhancement films **58** and **60** may be again reflected by reflector **66** back toward brightness enhancement films **58** and **60**. This recycled light may then pass through the brightness enhancement films **58** and **60** or may again be reflected, depending on the angle at which the recycled light approached such films. Backlight unit **50** may also include diffuser layers **62** and **64** to scatter light and provide a more uniform light distribution from backlight unit **50**. Backlight unit **50**, and other backlights similarly having a light guide that emits light over a very broad distribution range and one or more brightness enhancement films for increasing on-axis brightness, is typically referred to as a "PMMA" backlight, generally named for the material commonly used to form light guide **52** (i.e., polymethyl-methacrylate, an acrylic glass). It is noted, however, that light guide **52** may be formed of other suitable materials.

[0058] In the example depicted in FIG. **6**, backlight unit **68** includes light source **70** configured to output light to light guide **72**. Light guide **72** includes a multiple micro-prisms **74** that disrupt total internal reflection of light received from light source **70**, causing such light to be emitted from light guide **72** (either directly or via reflection from reflector **66**) toward turning film **76** and diffuser layer **78**. Such backlight units including a light guide having micro-prisms and one or more turning films to redirect light from the light guide are typically referred to as prism backlight units. Unlike the very broad light distribution from light guide **52** discussed above with respect to the PMMA backlight of FIG. **5**, light guide **72** instead emits light from its upper surface to turning film **76** in a very narrow distribution range (i.e., less than or approximately equal to thirty degrees). Turning film **76** includes small prisms **80** formed on a lower surface of turning film **76** and generally projecting toward adjacent light guide **72**. Rather than operating to focus a very broad distribution of light, such as discussed above with respect to brightness enhancement films **58** and **60**, turning film **76** operates to receive the very narrow distribution of light and generally redirects such light toward a normal of a display including backlight unit **68**, thereby allowing on-axis viewing by a user of such a display.

[0059] Such operation may be better understood with reference to FIG. **7**, which generally depicts the redirection of light from light guide **72** by a single prism **80** in prism backlight unit **68**. In such units, rays of light **82** emitted from light guide **72** may be directed toward prism **80**. Light output from light guide **72** may include a peak direction of transmittance **84**, and such light may substantially fall within distribution range **86**. In backlight unit **68**, and in other prism backlight units, light is emitted from light guide **72** at a steep incident angle **88** (e.g., approximately seventy-five degrees) and falls within a narrow range of distribution generally represented by angle **90** (e.g., less than or approximately equal to thirty degrees).

[0060] Light **82** received at surface **92** of prism **80** is refracted toward surface **96**, as generally indicated by reference numeral **94**. Such light **82** may then be reflected by surface **96** and redirected to pass through turning film **76** (as well as additional layers of a display), as generally indicated by reference numeral **98**. Prism **80** may include apex **100** formed by the intersection of surfaces **92** and **96**, and apex **100** may define apex angle **102**. Traditionally, prism **80** is formed such that apex angle **102** is substantially equal to sixty-eight degrees.

[0061] As previously noted, displays including prism backlight units often exhibit greater brightness than PMMA backlight units when viewed from a typical viewing angle (e.g., at a normal to the backlight unit and display), while PMMA backlights typically provide better viewing angles (e.g., less image distortion when viewing, at a wide angle, an image on a display including a backlight) than prism backlight units. In accordance with the present techniques, however, various backlight units that may provide greater brightness than traditional PMMA backlight units and wider viewing angles than traditional prism backlight units are described below with reference to FIGS. **8-17**.

[0062] For example, backlight unit **104**, which may provide enhanced viewing angles in comparison to backlight unit **68**, is depicted in FIG. **8** in accordance with one embodiment. Backlight unit **104** includes light guide **106** configured to receive light on an edge thereof from light source **108**, such as one or more LEDs or a CCFL. Light guide **106** includes upper emission surface **110**, from which light is emitted toward other layers of backlight unit **104**, and lower surface **112**. Backlight unit **104** may also include reflector **114** configured to direct light toward emission surface **110**. Reflector **114** may include a specular reflector or a diffuse (e.g., Lambertian) reflector. As discussed in greater detail below, light guide **106** may be configured with anisotropic optical elements that allow light to escape light guide **106** in distribution range **116** broader than that of light emitted from light guide **72** discussed above. The light emitted from light guide **106** is generally directed toward prisms **118** formed on a lower surface of turning film **120**. Prisms **118** may be arranged on turning film **120** in a periodic manner or with some degree of apparent randomness. Additionally, prisms **118** may be substantially linear along their axial length, or may include curvature (e.g., a wave pattern).

[0063] Additional details with respect to backlight unit **104** are described below with reference to FIGS. **9-11** in accordance with one embodiment. FIG. **9** generally depicts details

regarding light emitted from light guide **106** and the redirection of such light by a single prism **118** in accordance with method **122** generally depicted in FIG. **10**. Additionally, FIG. **11** generally depicts an example of anisotropic optical features formed on a surface of light guide **106** for emitting light in a broad pattern suitable for turning by turning film **120**.

[0064] By way of example, and as generally depicted in FIG. **9**, light **124** may be emitted from emission surface **110** of light guide **106** toward prism **118**. Light **124** falls within distribution range **116**, which includes peak transmittance direction **126**. Whereas the distribution of light from light guide **72** is quite narrow and at a steep incident angle, light **124** emitted by light guide **106** falls over broader distribution range **116** and includes shallower incident angles. For instance, angle of incidence **130** of peak transmittance direction **126** may be between fifty degrees and seventy-five degrees measured from normal **132**, rather than approximately equal to seventy-five degrees as discussed above with respect to light guide **72**. More particularly, in certain embodiments, angle of incidence **130** may be between about fifty-five degrees to about sixty-five degrees, between about fifty-seven degrees to about sixty-three degrees, or may be substantially equal to sixty degrees.

[0065] Broad distribution range **116** may include an angular range, generally represented by angle **134**, greater than that provided by prism light guide **72**. For example, the angular range of distribution **116** within a plane perpendicular to both light source **108** and emission surface **110** of light guide **106** (e.g., the field of view depicted in FIG. **9**) may be greater than thirty degrees. In various embodiments, this angular range may be between about thirty-five degrees and about ninety degrees, such as approximately: thirty-five degrees, forty degrees, forty-five degrees, fifty degrees, fifty-five degrees, sixty degrees, sixty-five degrees, seventy degrees, seventy-five degrees, eighty degrees, eighty-five degrees, or ninety degrees. By way of further example, in one embodiment the angular range represented by angle **134** may be approximately fifty degrees wide, and may be substantially located between incidence angles of thirty-five degrees and eighty-five degrees with respect to normal **132**, as generally represented by angles **136** and **138**. Further, in this or other embodiments, distribution range **116** may be substantially centered on peak transmittance direction **126** (i.e., approximately half of the light within distribution **116** includes incident angles greater than angle **130**, while the other approximate half includes incident angles less than angle **130**).

[0066] As generally indicated by reference numeral **140** in FIG. **10**, light **124** from light guide **106** may be received at first surface **142** of prism **118**. Light **124** incident on first surface **142** may be refracted and transmitted to second surface **148** of prism **118**, as generally represented by reference numeral **144**. Refracted light **146** may be reflected from second surface **148**, as generally indicated by reference numeral **150**, and this reflected light **152** may be emitted from emission surface **156** of turning film **120**, as generally indicated by reference numeral **154**. Further, light **152** may then pass through any additional layers of backlight unit **104** or a display (e.g., LCD **34**), such as diffuser **158** (FIG. **8**) and various layers of LCD panel **42** (FIG. **4**). It is noted that diffuser **158** may function to partially scatter light received from turning film **120** and provide a more uniform light distribution from backlight unit **104**. Further, the inclusion of diffuser **158** may prevent or reduce the magnitude of moire patterns, which may otherwise result from interference between prisms **118** and pixels of LCD panel **42**, in images displayed by LCD **34**. In some embodiments, the haze value of diffuser **158** may be thirty percent or greater, although this value may be smaller in other embodiments.

[0067] First and second surfaces **142** and **148** of prism **118** may intersect at apex **162**, which generally defines apex angle **164**. In contrast to turning film **76** (FIG. **6**) having prisms **80** with apex angles **102** greater than sixty-five degrees (e.g., sixty-eight degrees), apex angle **164** of prism **118** depicted in FIG. **9** includes a smaller apex angle **164** less than sixty-five degrees, such as between about fifty degrees and sixty-five degrees. More particularly, in one embodiment apex angle **164** is substantially equal to sixty degrees, although other apex angles **164**, such as any other angle between about fifty degrees and sixty-five degrees, may be employed in full accordance with the present techniques.

[0068] Rays of light **152** may be emitted at various angles **160** with respect to the base of prism **118** or turning film **120**. The resulting angle **160** for a particular ray of light depends on various geometric parameters, such as angle of incidence **130** for the particular light ray emitted from light guide **106** and various aspects of prism **118** (e.g., apex angle **164**, base angles of prism **118**, and so forth). Some or all prisms **118** of turning film **120** may be symmetric about a line or plane of symmetry, as generally represented by reference numeral **166**, or may be asymmetric. For instance, such symmetric prisms **118** may include an axial cross-section generally in the form of an isosceles triangle, with substantially identical base angles that are different than apex angle **164**, or generally in the form of an equilateral triangle having base angles substantially identical to each other and to apex angle **164**. Prism **118** may be configured in some embodiments such that peak light distribution occurs along a common normal of the base of prism **118**, emission surface **156**, and LCD panel **42** (i.e., such that peak light distribution is orthogonal to such surfaces), or may be configured such that peak light distribution occurs at a non-perpendicular angle **160** with respect to such surfaces.

[0069] As noted above, and in contrast to light guide **72**, light guide **106** may include various anisotropic optical elements to provide a broader distribution of light at generally shallower angles of incidence to turning film **120**. For example, as depicted in FIG. **11** in accordance with one embodiment, light guide **106** includes anisotropic optical elements **174**, such as generally elongated (e.g., elliptical or ellipsoid) lenses, formed on surface **176** of light guide **106**. For example, such anisotropic optical elements **174** may be formed on one or both of emission surface **110** and lower surface **112** of light guide **106**. Light from light source **108** may be received at lateral surface **178** and may generally propagate through light guide **106** toward opposite surface **180** by way of total internal reflection. Anisotropic optical elements **174**, such as elongated lenses, may disrupt such total internal reflection and generally emit light in distribution patterns **116** as described above. Such elongated lenses or other anisotropic optical elements may be arranged in a pattern on surface **176** or may be randomized. Further, in one embodiment, the relative density of optical elements **174** on surface **176** may increase as a function of distance from lateral surface **178** to facilitate evenness of light emission from light guide **106**. Although anisotropic optical elements **174** are generally depicted as elongated lenses in the present illustrated embodiment, any other suitable anisotropic ele-

ments (e.g., various prisms) capable of providing light distribution **116** may be used in full accordance with the present techniques.

[0070] Additional embodiments of various backlight units in accordance with the present techniques are depicted in FIGS. **12-14**. For instance, as depicted in FIG. **12**, backlight unit **184** may include multi-function film **186** that operates to both turn and diffuse light received from light guide **106**. For example, light guide **106** may receive light from light source **108**, and may include emission surface **110** and lower surface **112** as generally described above. Light may be emitted from emission surface **110** within distribution range **116** and toward turning prisms **118** of multi-function film **186**. Prisms **118** may operate to redirect received the light in the manner discussed above with respect to FIGS. **9** and **10**. Additionally, multi-function film **186** may also include an integrated diffusion layer **188** for diffusing the redirected light, rather than a separate diffuser **158** (FIG. **8**). In some embodiments, the haze value of integrated diffusion layer **188** may be thirty percent or greater, although lesser values may be employed in other embodiments. The use of multi-function film **186**, rather than separate turning film **120** and diffuser **158**, may result in a reduction in the thickness of backlight unit **184** in comparison to backlight unit **104**.

[0071] In other embodiments, it may be desirable to omit diffusion layers (e.g., diffuser **158** and/or integrated diffusion layer **188**) over prisms **118**, as generally illustrated with respect to backlight unit **194** in FIG. **13**. In one such embodiment, diffusion may instead be accomplished by applying certain haze to some other layer of the display, such as a polarizing layer of LCD panel **42**. In yet another embodiment generally depicted in FIG. **14**, backlight unit **204** may include turning film **206** having prisms **118** different from one another, and generally provided with certain disorder that may, among other things, reduce or prevent moire patterns in images rendered on display **34** including such backlight unit **204**. The disorder of prisms **118** may be provided through variation of any suitable parameter, such as prism angles, height, orientation, and the like; by providing a random speckle pattern on surfaces of prisms **118**; or in some other fashion. As may be appreciated from the above discussion of other embodiments, light received by prisms **118** may be redirected and emitted from emission surface **208** of turning film **206**. Backlight unit **204** may include diffuser **158**, an integrated diffusion layer (e.g., diffusion layer **188**), or may omit such a diffusion layer over prisms **118**.

[0072] As generally depicted in FIGS. **15** and **16**, viewing angles for a display including an edge-lit backlight unit configured in accordance with the present techniques (e.g., backlight units **104**, **184**, **194**, and **204**) may be significantly improved in comparison to those for a display incorporating a traditional prism backlight unit, such as backlight unit **68**. In FIG. **15**, graph **220** generally depicts luminance (represented along vertical axis **222**) as a function of viewing angle (represented along horizontal axis **224**). Curve **226** generally represents the luminance of the display at different viewing angles along the major axis of the display (e.g., the horizontal axis), while curve **228** generally represents luminance at viewing angles along a minor axis (e.g., the vertical axis) of the display. As generally indicated in graph **220**, luminance of a display including a traditional prism backlight unit decreases at a significantly greater rate for changes in viewing angle along the minor axis than changes in the major axis.

[0073] Conversely, in one embodiment an edge-lit backlight unit configured in accordance with the present techniques may enable substantially uniform luminance response for changes in viewing angle along the major and minor axes of a display, as generally illustrated in FIG. **16**. Graph **230** depicts luminance of such a display as a function of viewing angle along vertical and horizontal axes **232** and **234** of graph **230**. Luminance response for variations in viewing angle along a major axis of the display is represented by curve **236**, while that for variance in viewing angle along a minor axis of the display is represented by curve **238**. As may be determined from a comparison of graphs **220** and **230**, improved viewing angles along a minor axis of a display may be obtained through use of an edge-lit backlight unit configured in accordance with the present techniques. Additionally, such an edge-lit backlight unit may provide peak luminance levels greater than that provided by traditional PMMA backlight units by significantly reducing the amount of light lost by the backlight unit. Still further, edge-lit backlight units in accordance with the present techniques may have fewer optical layers, and hence a thinner profile, than traditional PMMA backlight units. For instance, whereas PMMA backlight units may include two prism films and two diffusers, backlight unit **104** includes a single prism film (i.e., turning film **120**) and a single diffuser **158**, while backlight unit **194** includes a single prism film without a diffuser. In some embodiments, the presently disclosed backlight units may be thinner than traditional PMMA backlight units by twenty-five percent or even more.

[0074] With reference to FIG. **17** provided in accordance with one embodiment, it is noted that peak luminance may occur along normal **252** of display **12** of computer **30** (or of some other electronic device **10**), or at a non-orthogonal angle with respect to display **12**, depending on the configuration of the backlight unit. For instance, as generally discussed above with respect to FIG. **9**, prisms **118** of a turning film in accordance with the present techniques may output light such that peak luminance occurs along a common normal of the turning film and display **12**, as generally indicated by reference numeral **250**. In other embodiments, however, light guide **106**, prisms **118**, or other aspects of the backlight unit may be configured to provide biased angular performance, in which peak luminance (generally represented by reference numeral **254**) occurs at angle **256** with respect to normal **252**.

[0075] The specific embodiments described above have been shown by way of example, and it should be understood that these embodiments may be susceptible to various modifications and alternative forms. It should be further understood that the present techniques are not intended to be limited to the particular forms disclosed, but rather to cover all modifications, equivalents, and alternatives falling within the spirit and scope of this disclosure.

What is claimed is:

1. A display backlight unit comprising:

a light guide configured to receive light from a light source at a first surface and to emit the light from a second surface such that the light emitted from the second surface includes a peak incident angle of between forty-five degrees and seventy degrees; and

a turning film disposed over the second surface of the light guide, the turning film including a plurality of prisms configured to receive and redirect the light emitted from the second surface of the light guide.

2. The display backlight unit of claim 1, wherein the peak incident angle is between fifty-five and sixty-five degrees.

3. The display backlight unit of claim 2, wherein the peak incident angle is substantially sixty degrees.

4. The display backlight unit of claim 1, comprising the light source, wherein the light source includes at least one of a cold-cathode fluorescent lamp or a light-emitting diode.

5. The display backlight unit of claim 1, comprising a diffuser disposed over the turning film.

6. The display backlight unit of claim 1, wherein the turning film includes a diffusing portion configured to diffuse the redirected light received from the plurality of prisms.

7. A display backlight unit comprising:

a light guide configured to receive light from a light source and to emit the light from an emission surface of the light guide, wherein the light guide includes anisotropic optical elements configured to refract the light received from the light source; and

a redirection layer disposed over the emission surface for receiving the light from the emission surface of the light guide.

8. The display backlight unit of claim 7, wherein the anisotropic optical elements are disposed on at least one of the emission surface or an additional surface of the light guide opposite the emission surface.

9. The display backlight unit of claim 8, wherein the anisotropic optical elements include substantially ellipsoid lenses.

10. The display backlight unit of claim 7, wherein the anisotropic optical elements are configured to refract the light received from the light source such that the light emitted from the emission surface is substantially distributed over an angular range, measured within a plane perpendicular to the light source and the emission surface, of greater than thirty-five degrees and less than ninety degrees.

11. The display backlight unit of claim 10, wherein the angular range is less than sixty degrees.

12. The display backlight unit of claim 11, wherein the angular range is substantially centered at a sixty-degree incident angle with respect to a normal of the emission surface.

13. The display backlight unit of claim 12, wherein the angular range is substantially located between incident angles of thirty-five degrees and eighty-five degrees with respect to the normal.

14. A liquid crystal display comprising:

a liquid crystal display panel; and

an edge-lit backlight unit configured to output light to the liquid crystal display panel, the backlight unit including:

a light source;

a light guide configured to emit light received from the light source, the light guide including optical elements on at least one surface of the light guide that are configured to scatter the light emitted from the light guide within a primary distribution range of thirty degrees to eighty-five degrees measured with respect to a normal of an emission surface of the light guide, and wherein the optical elements are further configured to emit light at a peak incident angle between fifty-seven degrees and sixty-three degrees with respect to the normal;

a turning film disposed over the light guide and including a plurality of prisms configured to receive light emitted from the light guide and redirect such light toward the liquid crystal display panel, wherein the plurality of prisms includes prisms having apex angles of less than or approximately sixty degrees.

15. The liquid crystal display of claim 14, wherein each prism of the plurality of prisms is symmetric.

16. The liquid crystal display of claim 14, comprising a reflector disposed adjacent an additional surface of the light guide opposite the emission surface and configured to direct light incident on a reflective surface of the reflector toward the emission surface of the light guide.

17. The liquid crystal display of claim 14, wherein the reflector comprises at least one of a specular reflector or a diffuse reflector.

18. An electronic device comprising:

one or more input structures;

a storage structure capable of storing one or more executable routines;

a processor capable of receiving inputs from the one or more input structures and of executing the one or more executable routines; and

a liquid crystal display (LCD) capable of displaying an output of the processor, wherein the LCD includes:

a liquid crystal display panel; and

an edge-lit backlight unit configured to output light to the liquid crystal display panel, the backlight unit including:

a light guiding plate;

a light source adjacent a lateral edge of the light guiding plate; and

a turning film disposed over the light guiding plate, the turning film including a plurality of prisms on a surface of the turning film facing the light guiding plate;

wherein the light guiding plate is configured to receive light from the light source at the lateral edge such that the received light propagates through the light guiding plate and is redirected by lenses of the light guiding plate to emit light to the turning film, and wherein light emitted from an emission surface of the light guiding plate is distributed over an angular range of at least thirty degrees.

19. The electronic device of claim 18, wherein the edge-lit backlight unit includes only a single turning film.

20. The electronic device of claim 18, wherein the turning film is configured such that peak light distribution from the LCD occurs at a non-zero angle with respect to a normal of the LCD.

21. The electronic device of claim 18, wherein the electronic device includes at least one of a computer, a monitor, or a handheld electronic device.

22. A method of redirecting light in an edge-lit backlight unit, the method comprising:

receiving light emitted from a light guide of an edge-lit backlight unit on a first surface of a prism formed on a receiving surface of a turning film;

transmitting the received light to a second surface of the prism, the prism including an apex angle between the first and second surfaces of fifty degrees to sixty-five degrees;

reflecting the transmitted light from the second surface toward an emission surface of the turning film opposite the receiving surface; and

emitting the reflected light from the emission surface of the turning film.

23. The method of claim **22**, wherein emitting the reflected light from the emission surface of the turning film includes emitting the reflected light such that the emitted light exhibits a peak intensity substantially along a normal of the emission surface.

24. The method of claim **22**, wherein receiving light emitted from the light guide includes receiving light emitted from the light guide on respective first surfaces of a plurality of prisms formed on the receiving surface, the plurality of prisms including first and second prisms different from one another.

25. The method of claim **22**, wherein receiving light emitted from the light guide includes receiving light emitted from the light guide on respective first surfaces of a plurality of prisms of the receiving surface of the turning film, and wherein the receiving surface is configured to reduce moire effects on an image generated on a display including the display backlight unit.

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