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Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US). **COUCH, Michael P.**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US).

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(74) Agents: **VIETZKE, Lance, L.** et al.; 3M Center, Office of Intellectual Property Counsel, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US).

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(71) Applicant (for all designated States except US): **3M INNOVATIVE PROPERTIES COMPANY** [US/US]; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US).

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(72) Inventors: **BROTT, Robert L.**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US). **SCHULTZ, John C.**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US). **NELSON, John C.**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US). **BRYAN, William J.**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US). **WEAVER, Billy L.**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US). **BRIGHAM, Scott E.**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US). **LUNDIN, David J.**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US). **MEIS, Michael A.**; 3M Center, Post Office Box 33427, Saint Paul, Minnesota 55133-3427 (US). **EHNES, Dale L.**; 3M Center,

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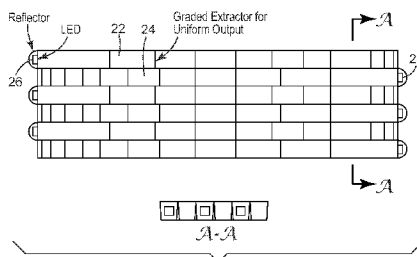
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(54) Title: BACKLIGHT MODULES FOR AUTOSTEREOSCOPIC 3D DISPLAY DEVICES AND SCANNING BACKLIGHTS FOR LCD DEVICES



(57) Abstract: Backlights for display devices, in particular scanning backlights for autostereoscopic 3D display devices. The backlights can include light rods, slats, or segments, arranged in parallel and used for light extraction from light sources such as a light emitting diodes. The light sources can be individually addressed and controlled in order to synchronize backlighting of right and left images to generate a corresponding 3D image.

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BACKLIGHT MODULES FOR AUTOSTEREOSCOPIC 3D DISPLAY DEVICES AND SCANNING BACKLIGHTS FOR LCD DEVICES

Background

As described in US Patent Application No. 2005/0276071, a field sequential autostereoscopic three-dimensional (3D) liquid crystal display (LCD) device can be made with a directional backlight illumination system. Such a display allows separate images to be presented to each eye by careful control of the angular output from two separate and time sequenced illumination sources, typically light emitting diodes (LEOs), at each edge of the display.

Summary

Disclosed are various features relating to scanning backlights for displays, which are particularly useful for autostereoscopic 3D display devices and LCD devices.

Brief Description of the Drawings

The accompanying drawings are incorporated in and constitute a part of this specification and, together with the description, explain the advantages and principles of the invention. In the drawings,

FIG. 1 is a diagram illustrating switching of light sources on opposite sides of a backlight for display of alternating right and left images;

FIG. 2 is a timing diagram illustrating a first scheme for switching of light sources in a backlight;

FIG. 3 is a timing diagram illustrating a second scheme for switching of light sources in a backlight;

FIG. 4 is a diagram of segmented light guides in a scanning backlight;

FIG. 5 is a diagram of combined segmented light guides in scanning backlight;

FIG. 6 is a diagram of a geometry of a tool used to make a segmented light guide in a scanning backlight;

FIG. 7 is a diagram of an exemplary 3D film;

FIG. 8 is a graph illustrating brightness at a viewer for an aligned 3D film;

FIG. 9 is a graph illustrating brightness at a viewer for a 20 micron offset 3D film;

FIG. 10 is a graph illustrating light guide efficiencies;

FIG. 11 is a graph illustrating a light guide angular distribution;

FIG. 12 is a diagram of LED light rods used in a scanning backlight;

5 FIG. 13 is a diagram of a series of slats used as light guides in a scanning backlight;

FIG. 14 is a diagram of a first structure to support light guide slats in a scanning backlight;

10 FIG. 15 is a diagram of a second structure to support light guide slats in a scanning backlight;

FIG. 16 is a diagram illustrating a method to fabricate a light guide with slats for a scanning backlight;

FIG. 17 is a cross-sectional diagram illustrating a method to create slats from a light guide for a scanning backlight;

15 FIG. 18 is a diagram illustrating an example of timing of a scanned slat backlight for left and right light sources illuminating left and right image data;

FIG. 19 is a diagram of light traps using a single row of LEDs for use in a scanning slat backlight;

20 FIG. 20 is a diagram of light traps using multiple rows of LEDs for use in a scanning slat backlight;

FIG. 21 is diagram of a wedge to control light output in a scanning slat backlight with embedded sources; and

FIG. 22 is a diagram of a narrow waveguide slat for a scanning backlight which collimates the light in both the thickness and the width of the slat.

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Detailed Description

Overview

30 There are several considerations with the type of autostereoscopic 3D display described in US Patent Application No. 2005/0276071 that are clarified in the present specification. An LCD is a sample and hold display device such that the image at any particular point is stable until that point is updated at the next image refresh time,

typically 1/60 of a second or faster. In such a sample and hold system, displaying different images, specifically alternating left and right images for an autostereoscopic 3D display, during sequential refresh periods of the display requires careful timing sequencing of the light sources so that for example the left light source is not on during the display of data for the right eye and vice versa. Separate light guides for left and right light sources as described in US Patent Application No. 2006/0132673 are one solution.

Another consideration of the system described in US Patent Application No. 2005/0276071 is the non-uniform light intensity extracted from a light guide with uniformly spaced extraction features and edge lit light sources. Separate light guides for left and right light sources as described in US Patent Application No. 2005/0276071 and No. 2006/0132673 are two solutions. A preferred solution is to maintain the non-uniformity to less than 10:1 and preferably less than 5:1 so that the display is visually uniform to at least 70% and preferably better than 80% uniformity. Alternately the interleaved channel solution to the segmented light guide could be used.

Another consideration of the system described in US Patent Application No. 2005/0276071 is reflection of light from the opposite end of the light guide causing visual confusion between the left and right sources or equivalently cross talk between left and right images resulting in poor 3D image quality. Light absorbing layers as described in US Patent Application No. 2006/0132673 is a solution. Preferred solutions are to extract most or all of the light on the first pass through the light guide thereby increasing system efficiency and minimizing or eliminating the need for antireflective regions around the light sources while keeping the non-uniformity to less than 10:1 and preferably less than 5:1.

Another consideration of the system described in US Patent Application No. 2005/0276071 is the thickness of the light guide which is not detailed in this application but is shown pictorially to be substantially thicker than the film plus LCD panel structure. Preferred solutions are a light guide 4 millimeters (mm) thick and, more preferably, 2mm or less thick.

Another consideration of the system described in US Patent Application No. 2005/0276071 is the feature to extract light from light guiding plate. A preferred solution is features at less than 10 degrees from horizontal and more preferably at 4 degrees from horizontal.

Another consideration of the system described in US Patent Application No. 2005/0276071 is the surface structure of the light guiding plate on which the double-sided prism sheet will rest. Preferably this surface will have microstructured features which are not aligned to the light extraction features on the bottom *of* the light guide. These features
5 are preferably lenticularly shaped to increase the vertical viewing volume and are oriented perpendicularly to the light extraction features on the bottom *of* the light guiding plate.

Another consideration *of* the system described in US Patent Application No. 2005/0276071 is the registration of the double-sided prism film to the extraction features of the light guiding plate. Preferably the vertically oriented features on the double-sided
10 prism film are aligned to the extraction feature direction and normal to the light propagation direction *of* the light guide to better than 5 degrees and preferably to better than 1 degree.

Another consideration concerns the overall efficiency *of* the system since some of the light is extracted away from the LCD panel. Preferably a reflective layer such as a
15 diffuse white reflector or more preferably a higher reflectivity film such as enhanced specular reflector (ESR) is placed behind the light guide to redirect backwards emitted light towards the LCD panel thereby increasing system light efficiency.

Scanning Backlight for 3D Display on LCD Panels

20 The preferred solution to solving the problem *of* a sample and hold display such as an LCD panel while maintaining adequate brightness in a 3D autostereoscopic display is to light the backlight of a 3D LCD imaging system with scanned LED backlights as described below.

An edge lit version of a 3D image viewer allows the sources to be moved from
25 behind the LCD panel to either side *of* the backlight using a light guide, either hollow or preferably solid to transport the light from the sources and uniformly distributed over the LCD panel viewing area. The light sources are preferably solid-state devices such as LEDs, laser diodes, and organic LEDs (OLEDs) which can be turned on and off and off in millisecond time durations to enable a scanned mode of operation in which the hollow
30 or solid light guides illuminated by the light sources are narrow relative to the height of the display. Some types of fluorescent bulbs such as hot cathode fluorescent lamps (HCFL) may also be capable of such operation.

Light extraction features are placed on the hollow or preferably solid light guides so as to direct the light from a specific source into a specific direction. While preferably, light from the left light source would be extracted to illuminate the left eye and similarly for the right light source, as in the example described in US Patent Application No.

5 2005/0276071, incorporated herein by reference, the converse may be true. In addition the light may be extracted to form non-autostereoscopic displays such that separate patterns of light and hence images are visible based on the viewer's location.

LCDs have a refresh or image update rate which is variable but for the purposes of this example, a 60Hz refresh rate is presumed. This means that a new image is presented
10 to the viewer every 1/60 second or 16.67 millisecond (msec). In the 3D system this means that at time $t=0$ (zero) the right image of frame 1 is presented. At time $t=16.67$ msec the left image of frame 1 is presented. At time $t=2*16.67$ msec the right image of frame 2 is presented and this process is repeated. The effective frame rate is half that of a normal imaging system because for each image a left and right view of that image must be
15 presented.

In this example, turning the LEDs on to light the right image (right LEDs) at time $t=0$ provides light to the right image. At time $t=16.67$ msec the second image (left image, left LEDs) starts to be put in place. The image replaces the "time $t=0$ image" from top to bottom which takes 16.67 msec to complete in this example. Non-scanned solutions turn
20 off all of the right LEDs and then turn on all of the left LEDs sometime during this transition, typically resulting in a display with low brightness because the image data must be stable or reasonably so over the entire image if the sequential left and right images are not to be illuminated with the incorrect light source which will lead to 3D cross talk and a poor 3D viewing.

25 The present feature proposes a different light source sequencing to provide a better image to the viewer. Instead of turning all the LEDs on one side on or off at a time, a different sequencing divides the light sources into "segments" or groups of two, three, or more, and the backlight control synchronizes turning non the light source with the presence of valid image data on the display.

30 FIG. 1 illustrates sequencing of the LEDs in such a scanned backlight. As shown in FIG. 1, the LEDs are divided into the following three segments: 12a and 12b for right and left segment 1; 14a and 14b for right and left segment 2; and 16a and 16b for right and

left segment 3. More than 3 segments are possible and may be preferred to increase the ON time for any particular segment as a fraction of the image display time; however, the example of three segments illustrates the concept. Following this scenario of three segments, when the second image (Left image of Frame 1) is starting to be displayed the right 1 LEDs 12b are turned off. After the top 1/3 of the image is replaced by the second image (Left Image of Frame 1) the left 1 segment of LEDs 12a is turned on and the right 2 segment 14b is turned off. After the second 1/3 of the image is replaced the left 2 segment of LEDs 14a is turned on and the right 3 segment 16b is turned off. This sequence continues as the alternating right and left images are displayed. This drive method allows the image transition to occur while no light is available; it also allows the light to stay on the maximum amount of time enhancing the brightness of the display.

A more preferred timing diagram of the backlight sequencing is shown in FIG. 2. The right LEDs are used to light the Right Image and the left LEDs are used to light the Left Image.

In addition to be sample-and-hold devices, LCD panels have a relatively long (compared to CRT) response time. That is the time to change from the old picture level to the new picture level can be several milliseconds to 10 milliseconds or more. Since this response time is a significant portion of the time required to display a completely new image, a further modification to the scanned backlight timing is presented in FIG. 2. To further reduce the cross talk due to the response time of the LCD the point where an LED segment is turned on can be delayed. For example, as shown the timing diagram of FIG.3, the right 1 LED segment 12b, rather than being turned on immediately after the first third of the image is drawn, is turned on after some delay which can be dependent on the response time of the LCD panel being used. Preferably this delay is a variable that can be tuned for particular LCD vendors, types and costs. The timing diagram of FIG. 3 shows the first segment being turned on approximately half-way into the drawing of the second third of the image, but the delay time can be set to any amount necessary to eliminate the cross talk caused by having the incorrect light source illuminate the displayed image. The same is true for each light source segment. Preferably, an LCD with a response time under 8 msec and more preferably under 2msec is used. Slower LCDs may be used but the LCD response time must be less than the frame update rate.

When considering a solid light guide for the above configuration, it is preferred to

use a light source that is sufficiently collimated to prevent the light from "fanning" out across the entire light guide aperture. The amount of collimation will depend upon the extraction methods.

Segmented Light Guide with Channel Segments for Autostereoscopic 3D LCD

5 Another method of implementing a scanned backlight is to use a segmented light guide with interleaved channel segments. Each channel segment will be illuminated with a source capable of being modulated at high data rates. Preferably the illumination source would be an LED, laser diode, OLED, or similar solid state device. The segmented light guide with interleaved channel segments is fabricated so that each alternate channel
10 segment has left and right directionality. The alternating channel light guide will reduce or eliminate design tradeoffs including uniformity, extraction efficiency, light guide thickness and directional extraction of light from the light guide. In particular providing uniform, efficient extraction of light from a thin light guide with controlled left/right light source extraction reduces or eliminates crosstalk in autostereoscopic 3D displays. The
15 extraction features on the left and right directing segments can be separately controlled in density to achieve both uniformity and high efficiency over large area displays. The ends opposite the LED sources can be blackened to prevent back reflections. Reflectance of the light injection area and source is thus not an issue for crosstalk since the light guide can be designed to extract most or all of the light from the light guide and thereby optimize
20 overall light extraction efficiency.

 In the present feature, alternate fiber-like segments independently form the left or right directed output distributions and the extraction features may be varied in density to provide a uniform brightness across the display. The overall advantage is to enable a large area, uniform and efficient 3D display. In one embodiment, a single light source injects
25 light into every other narrow light guide channel on one edge of the array. In another embodiment, several of the light guide channels on one side may be grouped together and illuminated by a light source.

 As shown in FIG. 4, every other light guide segment 22 and 24 has a light source 26 and 28 at the end on opposite sides. Alternatively, as shown in FIG. 5, light segments
30 30, three segments in this example, are illuminated by a single LED source 32. Timing of the illumination of particular segments within an LCD panel refresh frame can also be accomplished as described previously. Preferred sources from an optical efficiency point

of view are "white" LEDs, and typically the physical size of blue pumped white phosphor LED sources are currently in the range of approximately 0.5 to 2mm. The cross-section of each channel will be approximately equal. In order blend light distributions between alternate sections, vertical spreading elements (e.g., top surface lenticular and/or vertical spreading features on the extractor structure) may be included. Some physical separation on the order of individual section size between the LCD panel and light guide is desired to allow vertical distributions from alternate channels.

There are several options for the overall construction. The extractor features may be directly machined onto the master tool that forms the light guide channels, or the extractor strips may be laminated in registration to the bottom of the light guide channels. Molding methods such as injection or compression molding or web based microreplication may be used depending on feature size and overall display size. If a thinner light guide with extremely fine pitch sections is desired, several of the light guide sections may be joined together and illuminated with a single source. Further examples of these section are disclosed in US Patent No. 6,616,530, incorporated herein by reference.

There are many fabrication options possible for the segmented light guide backlight. Current roll based processes may be used and are more amenable to finer (approximately < 1 mm) feature sizes. Larger features may be better manufactured from flat tools by injection or compression molding. Combinations of finely structured extractors or directional diffusers may also be laminated to coarser light guide channels made by another process. It may also be possible to use approaches similar to those for fiber optic area illuminators. In addition to using prism extractor features, the cross-section of the segmented light guides may be decreased as a function of distance from the light source forming a tapered light guide. Such segments of "wedge" light guides extract light at high angles and may not need separate prism extractor features.

FIG. 6 is a diagram of an exemplary geometry of a tool used to make a segmented light guide in a scanning backlight. A typical geometry can be machined in copper roll tools and replicated by a continuous cast and cure (3C) process to make the Advanced Light Control Film (ALCF) product. For the light guide structure of the present feature, these type of channels will form the mold for the series of narrow light guides. The extractor features may be formed by similar technique as described above at the valleys of

the individual channels.

Lenticular Structures for 3D Displays

This feature relates to improving the uniformity of the display in an LCD backlight and in particular for a backlight for a 3D display. This feature uses microreplicated features, preferably lenticularly shaped and oriented normal, i.e. horizontally, to the wedge extraction features for a 3D light guide as described above. These features provide an increase in vertical viewing angle of the 3D effect and, more importantly, reduce "headlighting" of discrete light sources, such as LEDs, in the display. Headlighting in this sense is the visual appearance of the discrete light sources throughout the light guide leading to a non-uniform light extraction.

LED head lighting in a backlight, whether 3D or not, produces very non-uniform areas of the display. This effect would cause discrete light sources such as LEDs to be visible through the display producing an objectionable non-uniformity in the displayed image. The addition of lenticular and potentially other microreplicated features such as V-grooves, rectangular channels, etc. to the surface of the light guide eliminates the headlighting, providing a uniformly distributed light extraction pattern from the panel.

The headlighting effect for discrete Nichia NSSW0202B white LEDs and a 6.5 degree 3D light guide with a smooth upper surface was apparent in a light guide. Peak angular extraction for this light guide would be roughly 65 degrees and the non-uniformity caused by the discrete sources was clearly evident. The addition of lenticular structures normal to the extraction feature direction (horizontal in this picture) eliminated the headlighting effect for discrete sources such as LEDs, as was visibly apparent.

Matched Light Guide for 3D Autostereoscopic Display

This feature involves a matched light guide for a three-dimensional autostereoscopic display and a method of designing the same. By using optical modeling consisting of ray-tracing and analytic techniques, a light guide that couples light from LED sources into a two-sided, microreplicated film ("3D Film") can be designed. The following are key points for the design: the angular distribution needs to be centered about a fixed direction before the light enters the 3D Film; the distribution of light from the LEDs must be converted into a relatively narrow angular distribution; the extraction

of the light along the length of the guide is efficient; and a minimum of light traverses the entire length of the guide. United States Patent Application No. 2005/0276071 describes the design of a 3D Film, but does not address how to best create the light distribution that would use such a film.

5 It is desirable for the light reaching the viewer to be well-separated. That is, the image reaching the left eye should not reach the right eye and vice versa. In order to achieve this, the angular distribution of light leaving the light guide needs to be centered about a fixed angle, near 70 degrees for the example 3D Film. Light aimed at a lower angle tends to be transmitted in undesired directions. That is, if the main peak is towards
10 the left eye, then a large amount of light will be sent towards the right eye.

 It is also desirable that the distribution of light reaching the viewer be within a small angle about the desired direction in order to achieve good stereo separation. This may typically be about four degrees. By changing the width of the angular distribution leaving the light guide, the width of the distribution at the view is affected.

15 It is advantageous to extract as much light as possible from the light guide, that is, an optically efficient guide is desirable. However, aggressive extraction can lead to large non-uniformities in brightness along the length of the light guide.

 Finally, it is advantageous to minimize the amount of light that fully traverses the length of the light guide. Light that reaches the end of the light guide may be reflected
20 back in the opposite direction down the light guide. This light will then be sent to the wrong eye at the viewer, leading to cross talk.

 The present feature shows how to design for these desired characteristics of a light guide. FIG. 7 shows an example of a 3D Film from the top-down and as a perspective. In the 3D film, the prisms 60 function as turning elements, and the lenticular array 62 then
25 focuses the distribution to a canonical viewer at about 450mm viewing distance. This particular 3D Film has a differential pitch between the lenticular array and the prisms. The lenticular array has a pitch between the lenticular array and the prisms. The lenticular array has a pitch of 70.500 microns and the prisms have a pitch of 70.512 microns. The purpose of this differential pitch is to provide a slowly varying viewing angle as a
30 function of the width across the film. A viewer centered on the display would be looking straight at the center of the display, but for a 17-inch diagonal display, for example, the viewer is looking at an angle of about 22 degrees at the edge display. The lenticular array

would then be slightly misaligned with the prisms as the distance increases from the center of the display.

The angular distribution of the light at the viewer is determined by that entering the 3D Film. As shown FIG. 8, the overall direction is important. The design here is for the prisms and the lenticular array to be in alignment. This corresponds to a viewer looking directly at the center of the display. For this case it is desirable for light to exit at an angle about 4 degrees from the normal which corresponds to light striking, say, the left eye (positive viewing angles). Light traversing the opposite direction in the light guide (from a second set of sources) would then be directed at 4 degrees from normal but in the opposite direction, thus being seen by the right eye (negative viewing angles). For light centered about 70 degrees, almost all of the light is directed towards the left eye. For light centered about 60 degrees, a non-negligible fraction of the light is directed incorrectly; it is sent towards the right eye. This incorrectly directed light is can create cross talk. But this "cross talk" is greatly amplified for the case of the offset design. Consider the graph shown in FIG. 9, where it is desired to have the light centered about 10 degrees or so (the viewer is looking not at the center of the display, but towards one edge of the display). In this case, it is desired that light end up at about 14 degrees to reach the left eye. All designs have a great deal of light in the correct direction, but the 60 degree incidence case places a large amount of light in the incorrect direction. Indeed, the spread between the desired peak (14 degrees) and the spurious peak (-15 degrees) is not nearly as large as for the zero micron offset case. As the viewer looks towards the edge of the display, this effect becomes even worse. It is thus imperative that the angular distribution of the light incident on the 3D Film be centered nominally at 70 degrees.

Also shown in FIGS. 8 and 9 is the effect of the width of the angular distribution that is incident on the 3D Film. For a larger angular spread, the brightness at the viewer is reduced, but, somewhat counterintuitively, the width at the viewer is reduced. Thus, the viewing experience can be modified by controlling the angular distribution width as well as its main direction

The basic design of the light guide includes the following features. The light guide is fed from the ends via an array of white LEDs. The LEDs are air-coupled into a light guide slat that is about one inch tall, about 14 inches long and a few millimeters thick. Light bounces down this guide and would indeed be trapped completely by total internal

reflection were it not for the extraction features on the guide. The back surface of the light guide has shallow prisms molded into it. These prisms run vertically, and have a typical angle from horizontal of about 6.5 degrees. The prisms fill the length of the light guide. That is, there are not perfectly flat areas on the back of the guide. The front of the guide has a shallow lenticular array that is molded into it. This array runs horizontally along the guide and serves to provide some vertical spreading to the light, as well as to break up any direct imaging of the LED sources.

Within the confines of this design, one can vary the thickness of the light guide as well as the angle of the prismatic extractors. Large angles will lead to light being extracted more rapidly and completely as a function of length down the light guide. As light is traveling down the light guide, it will strike the prisms on the back of the light guide. This will tip the angular distribution of the light. Light that was at the edge of critical (light that is very near the critical angle) will thus be able to escape the guide after it is tipped by its interaction with the prisms.

The first thing to consider in the design of the light guide is the efficiency. There are the following three main metrics. The flux varies as a function of distance across the display. A measurement of this variation is the ratio of the maximum flux to the minimum flux (fluxMaxOverMin), which is a measurement of brightness uniformity. Preferably, fluxMaxOverMin is small. Another metric is the fraction of light making it to the end of the guide, endEff. Preferably, endEff is small, as this light has the possibility of coming back down the guide and contributing to cross talk. Yet another metric is the fraction of light making it out of the display towards the viewer - the overall efficiency OetEff. Preferably, OetEff is large (unity indicating extraction of all the light towards the viewer).

Referring to FIG. 10, the efficiencies of the light guide are shown. There are three main vertical sections to this graph: a 4mm thick light guide; a 6mm thick light guide; and a 2 mm thick light guide. For a given light guide thickness, the prism extractor angle is varied from three to nine degrees. As the prism angle becomes larger the extraction efficiency increases and a smaller amount of light reaches the end of the guide. However, the non-uniformity is worse. A smaller light guide thickness tends to magnify these effects, especially non-uniformity (large fluxMaxOverMin).

Efficiency although important, is not the only consideration; the angular distribution of the light must be controlled so that the 3D Film can function correctly (as

described above). The angular distribution should peak around 70 degrees or so, and have a fairly narrow width. Low angles and large widths lead to more light in the "wrong" half-space. That is, if light was intended to be transmitted to the right, then low angles and large widths will send light to the left as well as the right. Making sure that light distribution does not have much energy at angles less than 60 degrees is desired. By considering FIG. 11 and calculating the small end of the range given as the peak angle minus the delta angle, one can determine when the angular distribution has the majority of its light distributed at angles greater than about 60 degrees. For the 4mm guide, this is at about 4.5 degree prisms or less, for the 6mm guide for 4 degree prisms or less, and for the 2mm guide, almost never.

LED Light Rod for Scanning Backlight

A method of implementing a scanned backlight is to use a light rod illuminated with a source capable of being modulated at high data rates. Preferably the illumination source would be an LED, laser diode, OLED, or similar solid state device. By using a light guide rod to transport and extract light along its length, LEDs, laser diodes, OLEDs and similar solid state devices can efficiently illuminate large areas. The nature of using rods arranged behind the panel provides the ability to progressively scan the group of rods to implement a scanned backlight solution as discussed above.

With the advent of small, high brightness light sources such as LEDs, light rods can be used for backlighting the LCD panels. One advantage of these light sources, particularly LEDs, solid state lasers and OLEDs is the improved color gamut if red/green/blue and possibly additional colors such as white, cyan, magenta and yellow are used as the illumination source. There is an opportunity to further enhance the LCD performance. Merely having an array of spaced LEDs supplying the light to the LCD panel has proven to provide sufficient illumination levels. However, the nature of the LCD response to the TV signal is to exhibit "motion blur" in which rapidly moving objects visually appear to be blurred due to the sample and hold nature of an LCD panel.

One solution to solve the motion blur problem includes use of a HCFL (hot cathode fluorescent lamp) that will have a faster response time than the current CCFL (cold cathode) technology. By using the linear nature of the fluorescent lamps they can be used for line scanning of the light sources behind the LCD panel. The scanning of the

light behind the LCD can compensate for the motion blur. Using fluorescent lamps, however, does not make use of the solid state light source advantages, which include the following: no mercury; color gamut range; response time; and electronic control.

The light rod mimics the linear nature of fluorescent lamps by using solid state
5 light sources with the linear light rod light guides. The following are important aspects of this feature: Lumen level from the source (LED) and efficient light delivery to the LCD panel.

Commercially available LED packages, if bright enough, can simply be coupled into the linear light guide. For improved light injection, one may use a tapered light guide
10 at the injection point to capture the wide angle light and change the angles to allow total internal reflection (TIR) into and down the light guide. If additional light from each light guide is needed or if one desires to incorporate red/green/blue as well as additional colors, for example, white, cyan, magenta and yellow, into the end of a light guide, one can use the features disclosed in US patent No. 6,618,530, incorporated herein by reference, for
15 combining light sources into a single light guide end. Another way to increase the amount of light is to combine several LED die, possibly coated with phosphor(s) emitting at different and/or broader wavelengths in close proximity to each other so that the overall light injected is cumulative. If allowed to space out the LED light sources along the length of the light guide rod, one could provide additional light to the linear light guide by
20 periodically adding an LED injection sight with the incorporation of a diverter into the side of the linear light guide.

To mimic the fluorescent lamp with LEDs, one needs to incorporate a linear light guide. One version would be to use the HL (high luminance) Light Fiber product (3M Company). Its construction is one of core and cladding. The core is an extremely clear
25 acrylate surrounded by a fluropolymer cladding. Additionally the cladding is highly filled with TiO_2 for enhanced extraction of light. Although it has the right form factor, the extraction is around the whole diameter so additional materials may be needed to reflect light that is not aimed at the LCD panel. Another linear light guide could be the use of a clear PMMA rod. It is common to modify the rod shaped light guide with a stripe of
30 white paint or other white material to extract light more aggressively in a preferred direction. One could vary the extraction rate down the length of the guide by changing the modification to the strip of material. Similarly, one could machine the stripe surface with

extraction structures to accomplish the light extraction. If those extraction structures were engineered, optically smooth surfaces and close control of the extracted light are possible. This method is disclosed in the following US patents, all of which are incorporated herein by reference: 5,432,876; 5,845,038; and 6,367,941.

5 A tapered light guide for enhanced injection incorporates the angle provided by the taper and uses it to change the angle of the exiting light. The use of a harness coupler for having multiple LED injection into a given light guide is another method of transmitting multiple LED light into a linear light guide. The ability to pack many LED die into a tight package is disclosed in US Patent Application No. 2005/0140270, incorporated herein by
10 reference. This method allows for increased brightness by the addition of many die within the cross sectional area of the rod shaped light guide. If the linear rod needs more light than what can be provided into the ends, light can be injected periodically along the length by using a type of diverter.

 With the Light Fiber product (3M Company), one can get the linear rod form
15 factor, but it may not be able to efficiently deliver light in a controlled fashion to a specific target. Additional films or coatings may be required to redirect light that is not directed to the LCD panel. Another way to create a linear light guide is to modify an acrylic rod. By roughening the surface or adding a white stripe of material down the length, one can extract light from the guide. Other ways include the use of a rectangular,
20 linear guide that employs optically smooth notches. This use for extracting light provides more efficient light extraction to the target and is disclosed in US Patent No. 5,894,539, incorporated herein by reference. For improved angular control, while still using TIR for extracting, one can use techniques disclosed in US Patent No. 5,845,038, incorporated herein by reference. By adding additional rows of notches, one can provide a wider cone
25 of light, which helps provide uniform illumination to the back of the LCD panel.

 As shown in Fig. 12, the LED light rods can be used to form a scanning backlight assembly, which is controlled by an electronic system to deliver the scanning operation. The backlight includes several spaced light rods 18 illuminated in sequence to provide the scanning backlight. The light rods are configured for light to escape from one side, as
30 shown by the angle of illumination 20 and to be reflected by the opposite side.

Slats for Scanning Backlights

Another method of implementing a scanned backlight is to use thin, flat segments illuminated from the edge. Each channel segment will be illuminated with a source capable of being modulated at high data rates. Preferably the illumination source would be an LED, laser diode, OLED, or similar solid state device. The scanned backlight uses preferably solid state light sources such as LEDs, solid state lasers or OLEDs to illuminate the edge of a thin, narrow zone of a solid light guide or hollow cavity and time sequencing each horizontal zone and/or each left/right end of a zone as described previously. One use includes a scanning backlight for an LCD panel and, more particularly, as a scanning backlight for an autostereoscopic 3D display.

The thin, narrow zones of the light guide or cavity, termed "slats," have a width preferentially sized relative to the LCD panel response time so that entire backlight, which is composed of more than one approximately horizontally oriented slat, are completely lit within one display refresh. One or more slats are sequentially lit in synchronization with the display. The slat orientation is preferably aligned to the LCD panel update refresh method, commonly horizontal lines. While the slats would preferably be precisely aligned, meaning parallel to the display refresh, some misalignment will be acceptable in the most general case. The slats should not be exactly aligned to other features in the system, for example, microreplicated films or LCD pixel structures to avoid Moire.

There may be light coupled between adjacent slats, or no coupling may be allowed to maximize the scanning nature of the backlight while minimizing the visual appearance of the optical gap between slats. The slats may be physically distinct with a physical slot between slats or the slats may be optically defined, for example by a change in the index of refraction between slats but physically an otherwise uniform plane of material. The slat light source is preferably any small, bright source which can be rapidly turned on and off, for example LEDs. The light sources can be any type of LED or other light source emitting, for example, white light or primary colors of red, green and blue, and they can also emit additional colors, for example cyan, magenta, and/or yellow, for higher color gamut displays.

Additionally, for field sequential color applications, each slat can be lit by individual colors or combinations of colored light sources. For example, red light sources

may be turned on to sequentially illuminate the slats of the display as red image data is loaded. The same sequence is then applied for green, blue and other colored sources as desired.

Light injection from the light source may be air-coupled or index matched to the light guide. For example, a packaged device can be edge-coupled without index matching material into a solid light guide. Alternatively, packaged or bare die LEDs can be index matched and/or encapsulated in the edge of the light guide for increased efficiency. This feature may require additional optical features, e.g. injection wedge shape, on the ends of the light guide to efficiently transport the light. For autostereoscopic 3D displays, special light trapping features may be added to the edges of the slats to reduce or eliminate reflection from the opposite edge faces.

FIG. 13 illustrates an entire backlight 36 composed of several thin, relatively narrow light guides 38, termed "slats". In this example, eight slats are shown for illustrative purposes only. These slats are lit from the ends (40, 42) of the light guides 38, allowing the slat illumination to be time sequenced down the display, preferably in synchronization with the video signal as described previously. A preferable method of synchronization is to turn off the slats nearest the transition between new data and old data lines or, when this display update line is near the slat boundary, turn off the light sources for two adjacent slats. More than two slats may be turned off at one time, particularly if light is allowed to leak between adjacent slats to blend the backlight edges. In this construction, the slat and light source can be very thin compared to the backlight dimensions, enabling a backlight that is 4mm thick or more preferably 2mm or less thick, for example.

In backlight 36, the slats 38 are lit with a conventional green-red-green-blue (GRGB) sequence of LEDs. Rather than color LEDs, these could be white light sources, coherent light sources, and/or include more colors than red, green, and blue for a wider color gamut display. In the case of a non-3D scanning backlight, the LEDs on both ends of the top slat are turned on after the image has stabilized in that portion of the display, then the LEDs on both ends of the second slat are turned on, and the process repeats for the remaining slats, as noted previously in synchronization with the LCD display refresh. Alternatively, the LEDs can be sequenced in color and/or by side of the display. Color sequencing in which, for example, red, black, green, black, blue, black, green, black,

etc.colors are sequenced down the display enables a field sequential color solution to display color imagery.

The printed, etched or refractive extraction features will affect the slat-slat interface. For example, a diffusing reflective extraction feature will tend to scatter light into adjacent slats without some opaque or semi-opaque layer between slats. Conversely, refractive extraction features that control the direction of the extracted light may not require an opaque or partially opaque layer between the slats if the extraction features were designed to extract very little light towards the side of the slat. The extraction features can be an integral part of the slat light guide or part of a film layer separately applied to the light guide.

FIG. 14 is a side view of backlight 36, showing slight gaps 37 between the slats 38. These gaps can be physical gaps containing no material (air) between optically smooth surfaces of the light guide or the air gaps can have a specular behavior, for example through the use of an enhanced specular reflector (ESR), metallic coatings, etc., or the gaps can have diffusely behavior, for example through the use of light enhancement film (LEF), white ink, etc. between the slats. A partially transmitting layer may also be used for controlled light leakage between slats. The gaps can alternatively be optical gaps in which, for example, the physical gap is filled with a material with a different index of refraction and/or absorption or scattering compared to the bulk material of the light guide.

The side view in FIG. 14 shows the slats as individual sections of the light guide held in a plane behind an LCD display. Various mechanical support methods may be used to maintain the alignment of slats. A backing film, possibly with light extraction features and a highly reflective surface, e.g. ESR, can be laminated to the slats as shown in FIG. 14. The backing material of thin metal can be used as both a structural support for this film layer if needed and as a thermal spreading and/or dissipation layer for the light sources. In some cases the slats may have film layers on both flat sides as, for example, in the autostereoscopic 3D light guide shown in FIG. 15 with registered microreplicated features on both sides of the light guide. The slats may also be machined from a solid light guide as shown in FIG. 16 with material retained on the edges and possibly at regular or random locations within the lighted area to stiffen and support the slat structures.

FIG. 17 schematically shows an additional support feature or an alternative to

multiple discrete segments and attendant assembly, alignment, and long-term stability issues. For the support feature shown in FIG. 17, a solid film light guide may be machined, molded, cast, etc. into the slat structure with narrow features connecting the individual slats 44 providing mechanical support but very restricted light leakage between adjacent slats. As with the discrete slats of FIG. 13, various films or surface coatings can be used in the grooves to control light leakage between slats. While these grooves are shown with vertical edges, in practice a slight angle would simplify manufacture. As shown in the third example in FIG. 17, absorbing, diffusive and/or reflective features external to the light guide could be aligned with the grooves to mask the slat edges in the light guide.

In the example of FIG. 18, which shows scanned backlight illumination for an autostereoscopic display, a consideration with the alternating left/right lighting sequence is that any light completely traversing the light guide will partially reflect from the far end and create 3D image cross talk by appearing to be a spurious light source at the incorrect side (for that time instant) of the light guide. This left/right light guide cross talk can be solved or eliminated by efficient extraction of the light so relatively little light can be reflected from the far end and/or by creating a light trap at the far end. An exemplary light trap composed of an absorbing, opaque film or coating on the light guide end with openings for the LEDs is shown in FIG. 19 where the upper set of RGB LEDs 50 do not have a light trap feature and the lower set of LEDs 52 has this feature.

The LED sources for the scanning backlight concept are preferably small and closely spaced to minimize the spatial and color mixing distances needed to achieve a uniform backlight illumination. For example, Nichia NSSW-020B white emitting LEDs have an emitting surface of 1.9x0.45mm and a package size of 3.8x0.6mm. Mounting these at 7 LEDs/inch (25.4mm) requires a mixing length of less than 6mm.

As an alternative, multiple rows of LEDs for either narrow packaged devices or bare die can be placed at the edge of a slat light guide and still efficiently couple light into the light guide. FIG. 20 is a schematic version of this feature with two rows of RGB LEDs 54 and 56 with and without a light trap and with the rows offset from each other. More than two rows are possible if the light guide thickness can be increased or thinner devices used. The devices can also be oriented vertically to the light guide to enable very thin light guide sections. The alignment between the LEDs can be staggered as shown in

FIG 20, evenly spaced or some other pattern of LEDs to enhance LED spatial and color light mixing.

The light sources can be external to the light guide slats and simply illuminate the edge of an essentially co-planar light guide. Alternatively, the LEDs can be index matched or actually embedded in the edge of the light guide with appropriate features to efficiently collect and collimate the LED light into TIR modes of the light guide as shown in FIG. 21. The optical properties of the ESR lined wedge collimate the light injected into a light guide depending on the taper angle or the input edge dimensions versus the light guide dimensions. Specifically, for applications in scanning backlights for which TIR in the width of the waveguide is desirable, the ESR wedge can be tapered on the ends to produce an output beam collimated in the waveguide width as well as in the thickness as shown in FIGS. 21 and 22. Since the taper in the thickness and the ends can be adjusted independently, the beam output can be adjusted to arbitrary collimation and collimation profiles in the light guide. The tapered wedge feature can be applied to scanning waveguides, for example those made from individual slats as shown in FIG. 13 with the wedge as shown in FIG. 22. In this case the wedge will collimate the LED light to TIR in the thickness of the waveguide while the taper collimates the light to TIR in the width of the waveguide.

20 **Hollow Tube Scanning Backlight**

When considering a hollow, scanning backlight system, the scanning features may comprise hollow rectangular segments in which LED light sources are mounted at one or both ends of the segment. Each segment will have highly efficient, specular, diffuse and/or directed diffuse reflective films or coatings on the sides of the segment to distribute light over the length of the segment. One surface of the segment will be an emission surface, which may be a combination of specular or diffuse films that emit and reflect light to efficiently transmit the light down the segment. Prismatic films may be used to guide and/or extract light to improve uniformity. Light extraction features may be microreplicated or printed or etched features. Films containing these features may be placed in the hollow segment, laminated on one or more surfaces, or the reflective or emission surface may directly include these light extraction features. Extraction features may be in gradient patterns to improve uniformity. The hollow segments may be stacked

to form a planar surface so as to form a backlight panel system where individual segments are illuminated from one or both ends in a synchronous fashion with the video content to form a hollow tube scanning backlight. A non-interlaced (progressive) scan image display format is required.

What is claimed is:

1. A scanning backlight for a display device, comprising:
a light guide having a first side and a second side opposite the first side, and
5 having a first substantially planar surface extending between the first and second sides
and a second substantially planar surface opposite the first surface, wherein the first
surface
substantially extracts light and the second surface substantially refracts light;
a first plurality of light sources arranged along the first side of the light guide for
10 transmitting light into the light guide from the first side; and
a second plurality of light sources arranged along the second side of the light guide
for transmitting light into the light guide from the second side,
wherein the first and second plurality of light sources are divided into groups and
wherein the groups of light sources are selectively turned on and off in a particular
15 pattern.
2. The backlight of claim 1, wherein the first and second plurality of light sources
each comprise a light emitting diode.
- 20 3. The backlight of claim 1, wherein the groups are turned on and off based upon a
right and left images to be displayed on the display device.
4. The backlight of claim 1, wherein the groups are turned on and off in a sequential
order.
25
5. The backlight of claim 1, wherein the groups are turned on and off in an
alternating
order between the first and second sides.
- 30 6. A backlight with light rods for a display device, comprising:
a plurality of light rods, each light rod comprising an elongated portion having a
first end and a second end, wherein the elongated portion includes a first surface that

substantially extracts light and a second surface, opposite the first surface, that substantially refracts light; and

a light source at the first and second ends of each of the plurality of light rods for transmitting light into the light rods,

5 wherein the plurality of light rods are arranged substantially in parallel and with the first surfaces transmitting light in substantially the same direction to provide backlighting for a display device.

7. The backlight of claim 6, wherein each of the light sources comprise a light
10 emitting diode.

8. The backlight of claim 6, further comprising a reflector at the first and second ends of each of the plurality of light rods for containing the light sources.

15 9. The backlight of claim 6, wherein the elongated portion of each of the light rods has a circular cross-sectional shape.

10. The backlight of claim 9, wherein the first or second surface of each of the light rods has a series of notches.

20 11. The backlight of claim 6, wherein the elongated portion of each of the light rods has a rectangular cross-sectional shape.

12. The backlight of claim 11, wherein the first or second surface of each of the light
25 rods has a series of notches.

13. The backlight of claim 6, further including a transmissive film located adjacent the first surfaces of the plurality of light rods and a reflector located adjacent the second surfaces of the plurality of light rods.

30 14. The backlight of claim 6, further including a plurality of light sources located along the elongated portion of each of the light rods.

15. The backlight of claim 6, wherein each of the light rods comprises an acrylic rod.

16. The backlight of claim 6, wherein the light sources are divided into groups and
5 wherein the groups of light sources are selectively turned on and off in a particular pattern to form a scanning backlight.

17. A backlight with segments for a display device, comprising:
a light guide having a first side and a second side opposite the first side;
10 a plurality of segments extending between the first and second ends of the light guide, wherein each of the segments includes a first surface that substantially extracts light and a second surface, opposite the first surface, that substantially refracts light; and
a light source at one end of each of the segments for transmitting light into the light rods,
15 wherein the plurality of segments are arranged substantially in parallel and with the first surfaces transmitting light in substantially the same direction to provide backlighting for a display device.

18. The backlight of claim 17, wherein each of the light sources comprises a light
20 emitting diode.

19. The backlight of claim 17, wherein the light sources are located on opposite ends of each pair of adjacent segments.

20. The backlight of claim 17, wherein a single light source transmits light into a
25 plurality of the segments.

21. The backlight of claim 17, wherein the first surface of each of the segments includes a graded extractor that provides for substantially uniform extraction of light from the first surface.

30

22. The backlight of claim 17, further comprises a reflector at the first and second ends of each of the segments for containing the light sources.

23. The backlight of claim 17, wherein the light sources are divided into groups and wherein the groups of light sources are selectively turned on and off in a particular pattern to form a scanning backlight.

5

24. A backlight with slats for a display device, comprising:
a light guide having a first side and a second side opposite the first side;
a plurality of slats extending between the first and second ends of the light guide,
wherein each of the slats includes a first surface that substantially extracts light and a
10 second surface, opposite the first surface, that substantially refracts light; and
a light source at one end of each of the slats for transmitting light into the slats,
wherein the plurality of slats are arranged substantially in parallel and with the first
surfaces transmitting light in substantially the same direction to provide backlighting for a
display device.

15

25. The backlight of claim 24, wherein each of the light sources comprises a light emitting diode.

26. The backlight of claim 24, wherein each of the slats is optically coupled with
20 adjacent slats.

27. The backlight of claim 24, further including an air space between the slats.

28. The backlight of claim 24, wherein each of the light sources is air coupled to the
25 slats.

29. The backlight of claim 24, wherein each of the light sources is coupled to the slats through an index matching material.

30. The backlight of claim 24, further including a reflective film located adjacent the
30 second surfaces of the slats.

31. The backlight of claim 30, further including an adhesive material located between the reflective film and the second surfaces of the slats.

5 32. The backlight of claim 30, further including a heat sink attached to the reflective film.

33. The backlight of claim 24, further including a solid film light guide attached to one of the surfaces of the slats.

10 34. The backlight of claim 24, wherein the first or second ends of selected ones of the slats includes a light trap.

35. The backlight of claim 24, wherein the light sources are divided into groups and wherein the groups of light sources are selectively turned on and off in a particular pattern
15 to form a scanning backlight.

36. A backlight with a microreplicated structure for a display device, comprising:
a light guide having a first side and a second side opposite the first side, and
having a
20 first substantially planar surface extending between the first and second sides and
a second substantially planar surface opposite the first surface, wherein the first surface
substantially extracts light and the second surface substantially refracts light;
a first plurality of light sources arranged along the first side of the light guide for
25 transmitting light into the light guide from the first side; and
a second plurality of light sources arranged along the second side of the light guide
for transmitting light into the light guide from the second side,
wherein the first surface of the light guide includes microreplicated features.

30 37. The backlight of claim 36, wherein the microreplicated features comprise v-shaped grooves or rectangular-shaped channels.

38. The backlight of claim 36, wherein each of the microreplicated features has at least one dimension less than one millimeter.

39. The backlight of claim 36, wherein the microreplicated features are arranged to
5 provide substantially uniform extraction of light from the first surface of the light guide.

40. The backlight of claim 36, wherein the microreplicated features comprise lenticular structures arranged substantially perpendicular to the first surface of the light guide.

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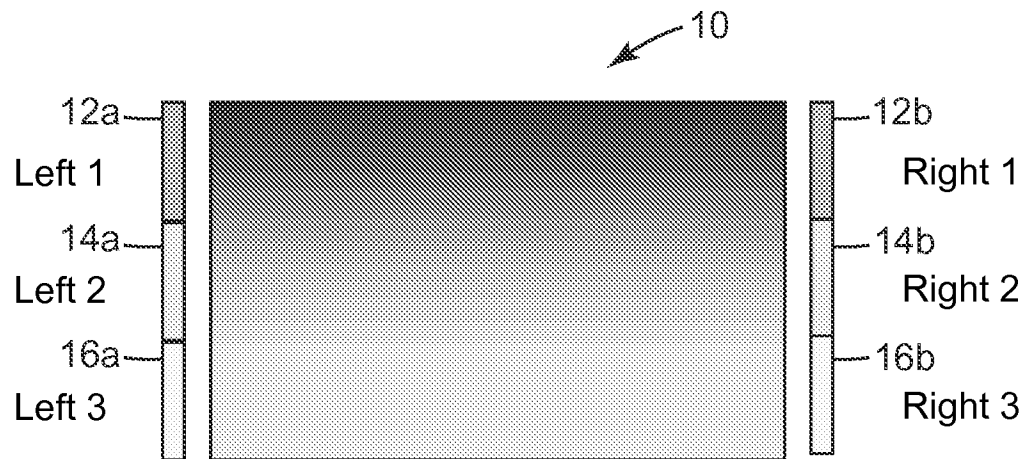


FIG. 1

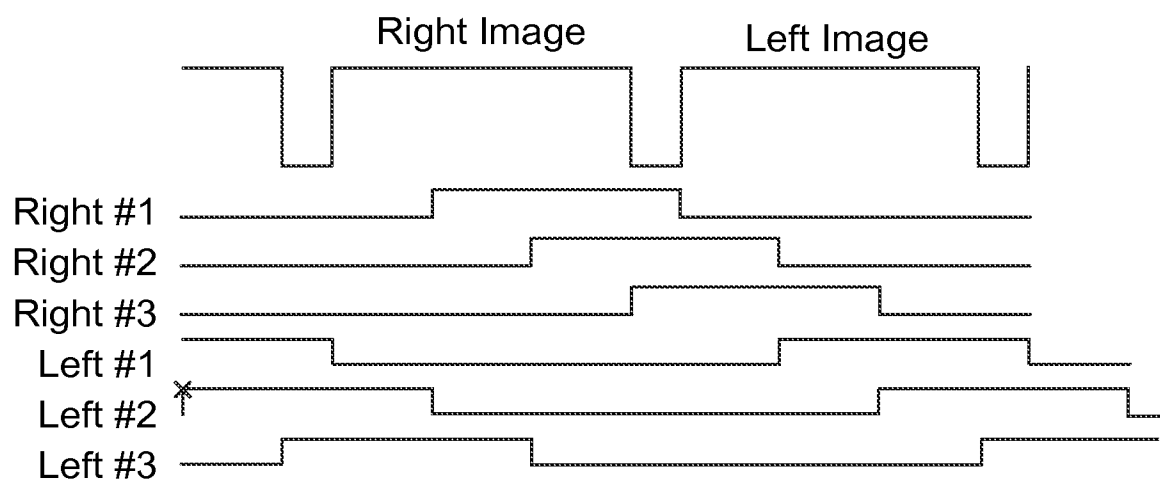


FIG. 2

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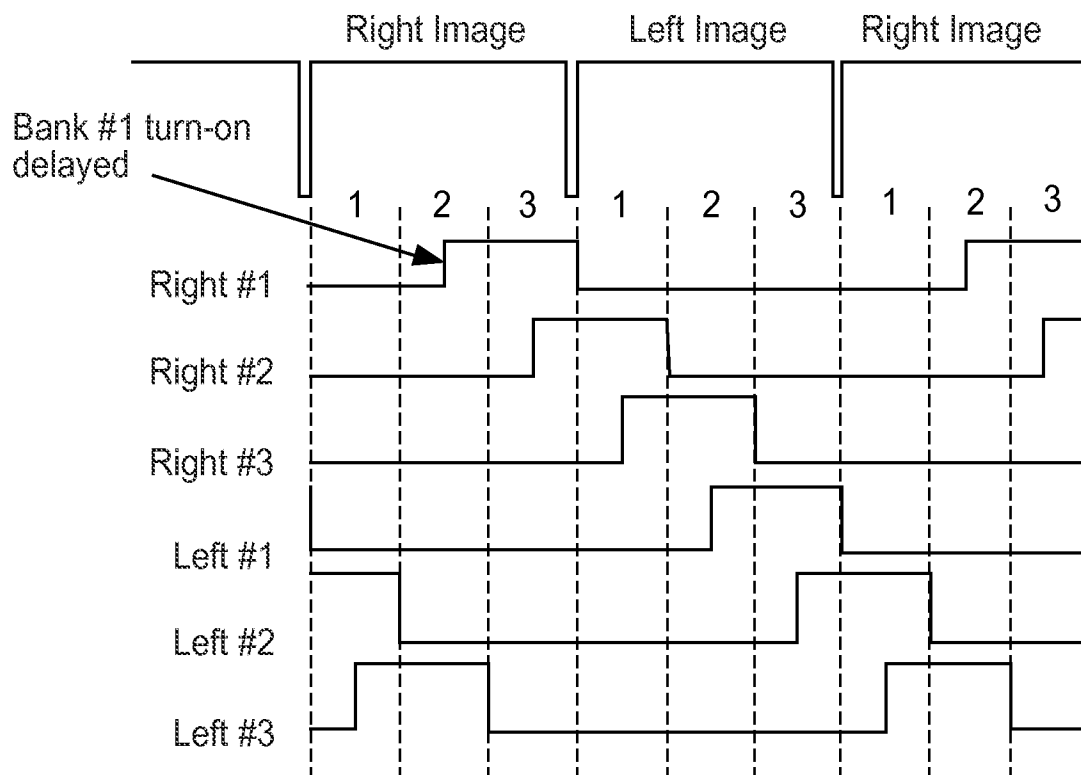


FIG. 3

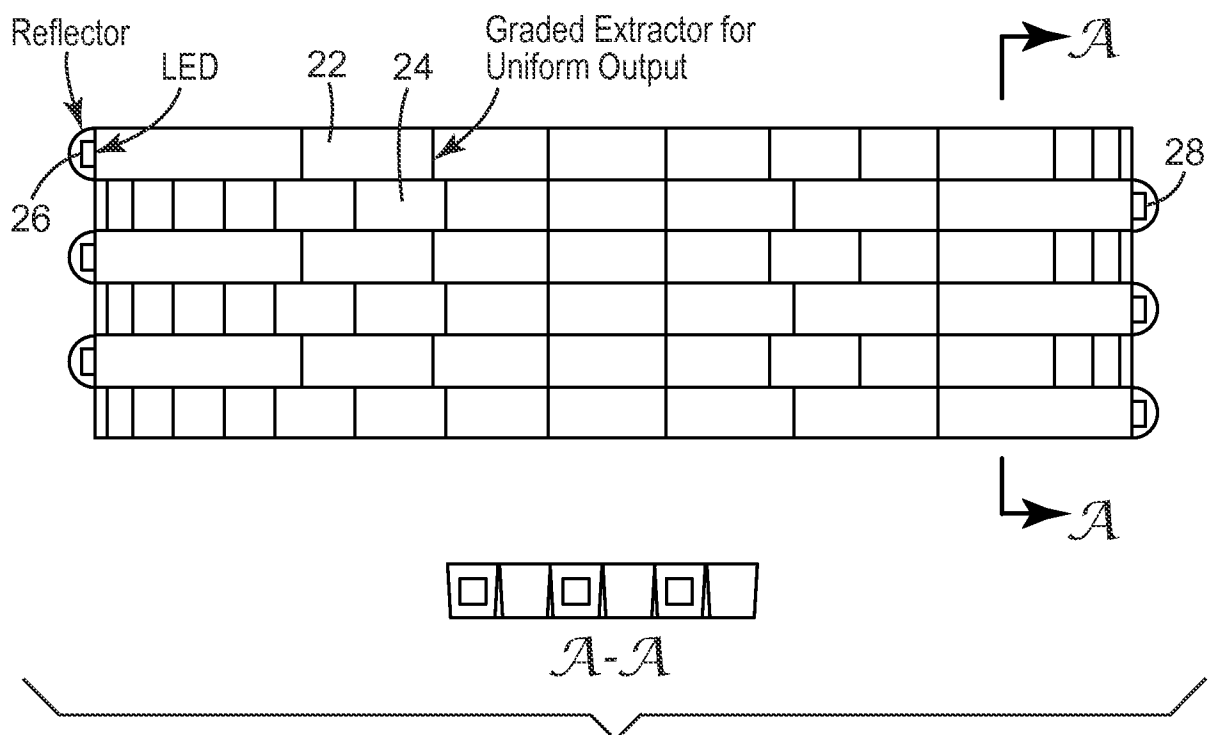


FIG. 4

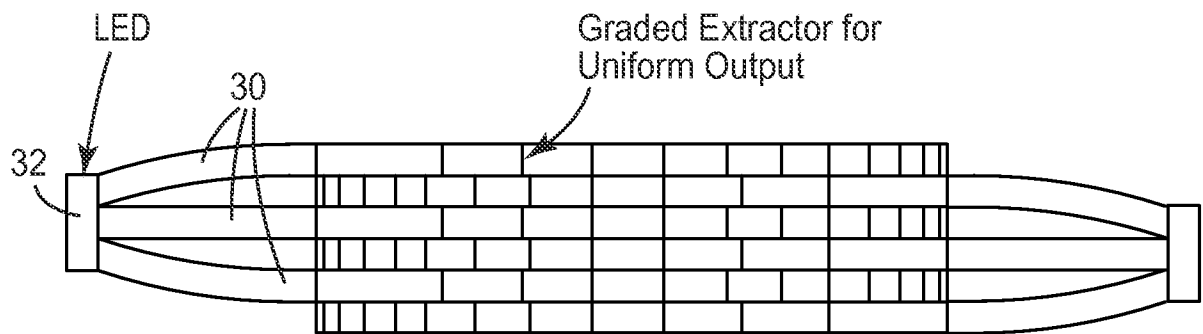


FIG. 5

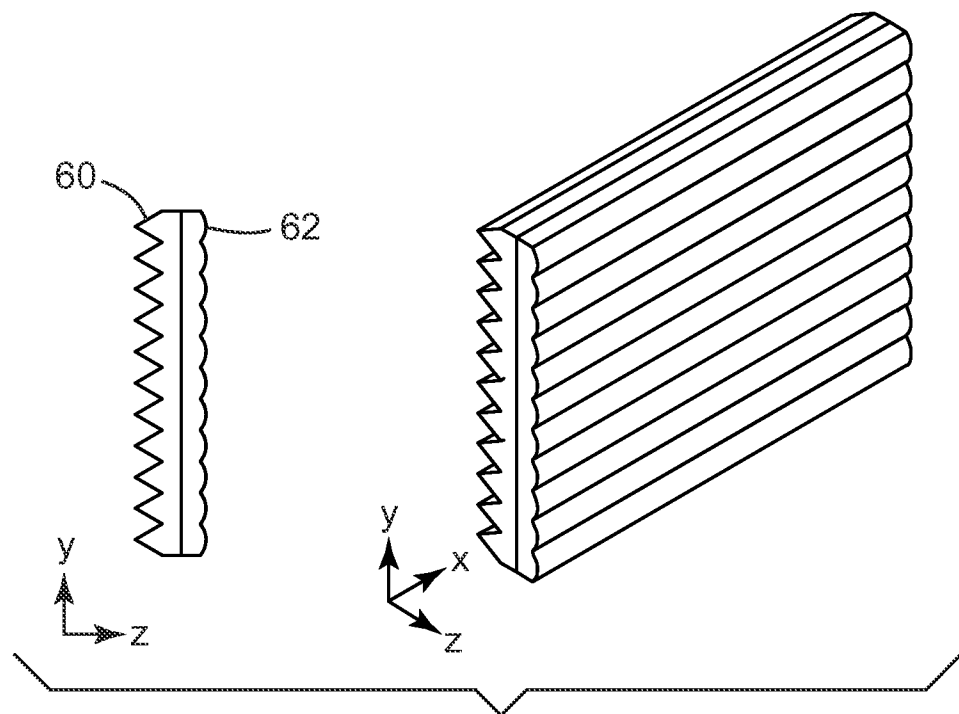


FIG. 7

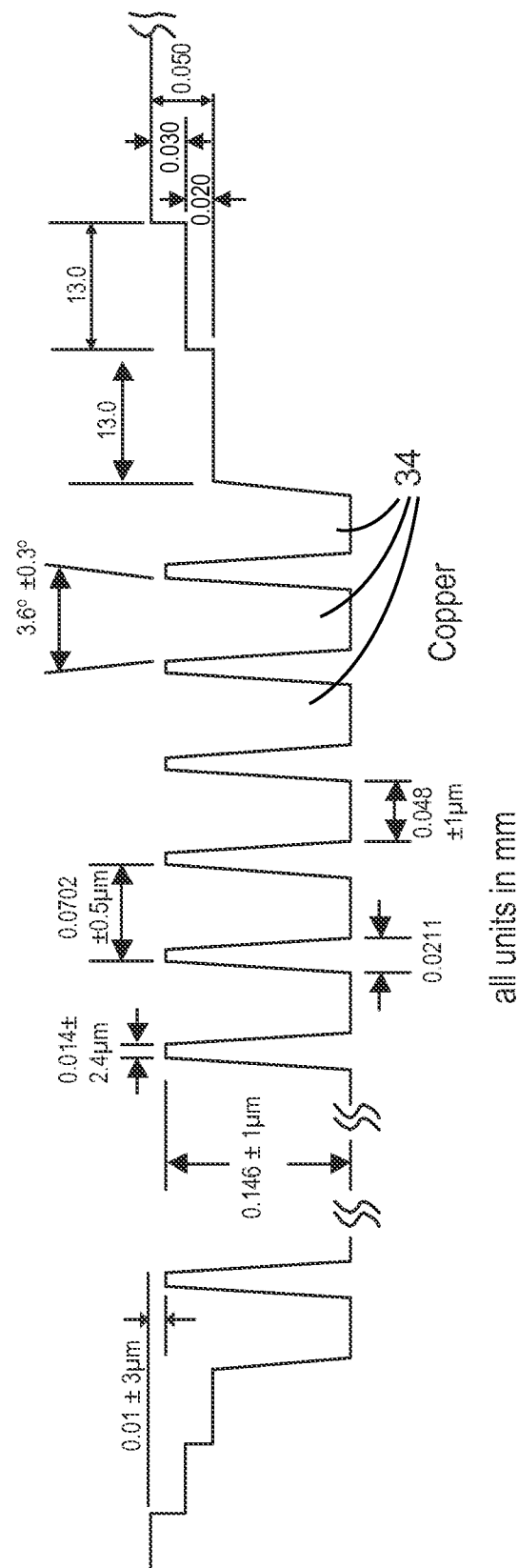


FIG. 6

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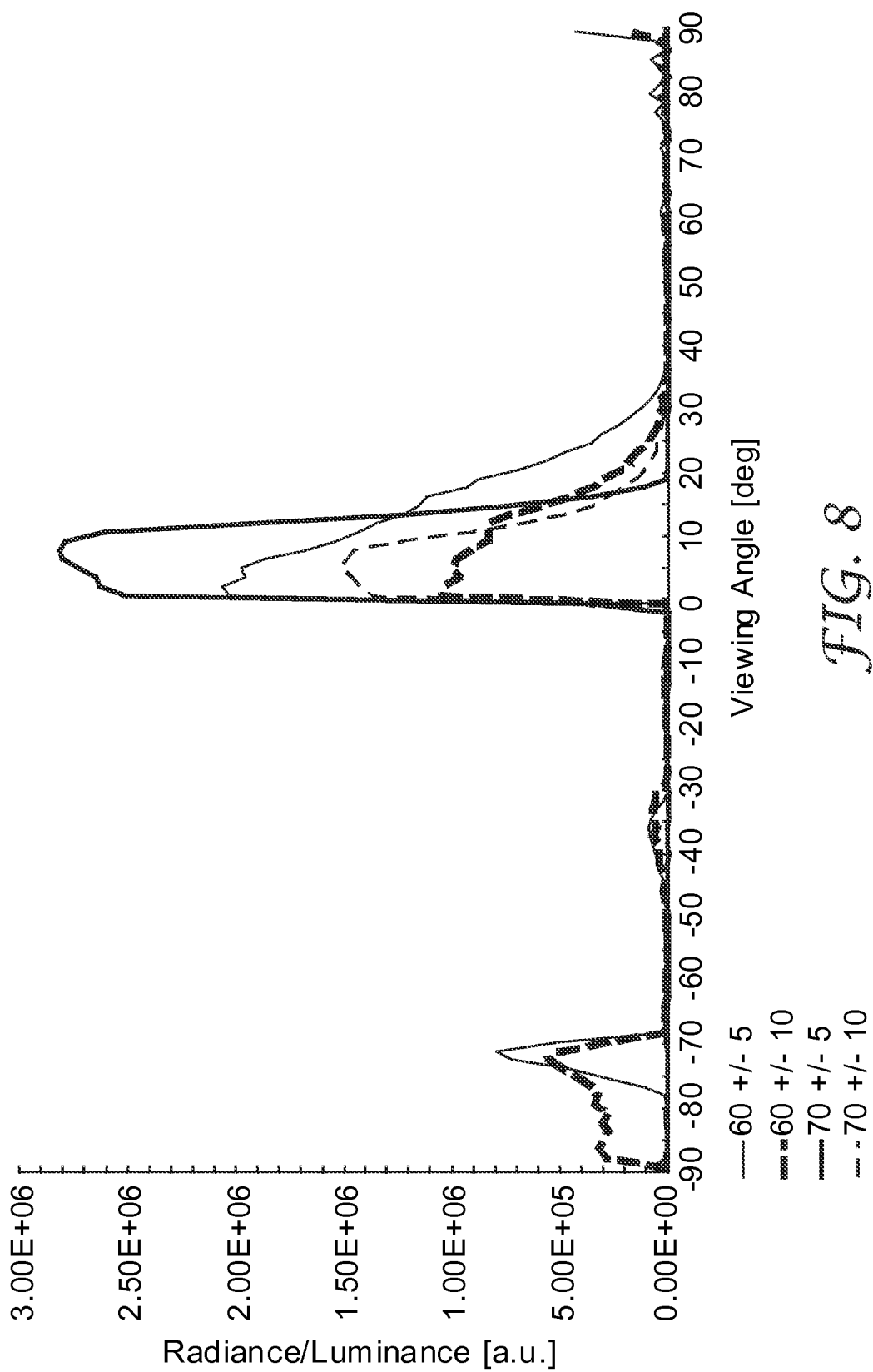


FIG. 8

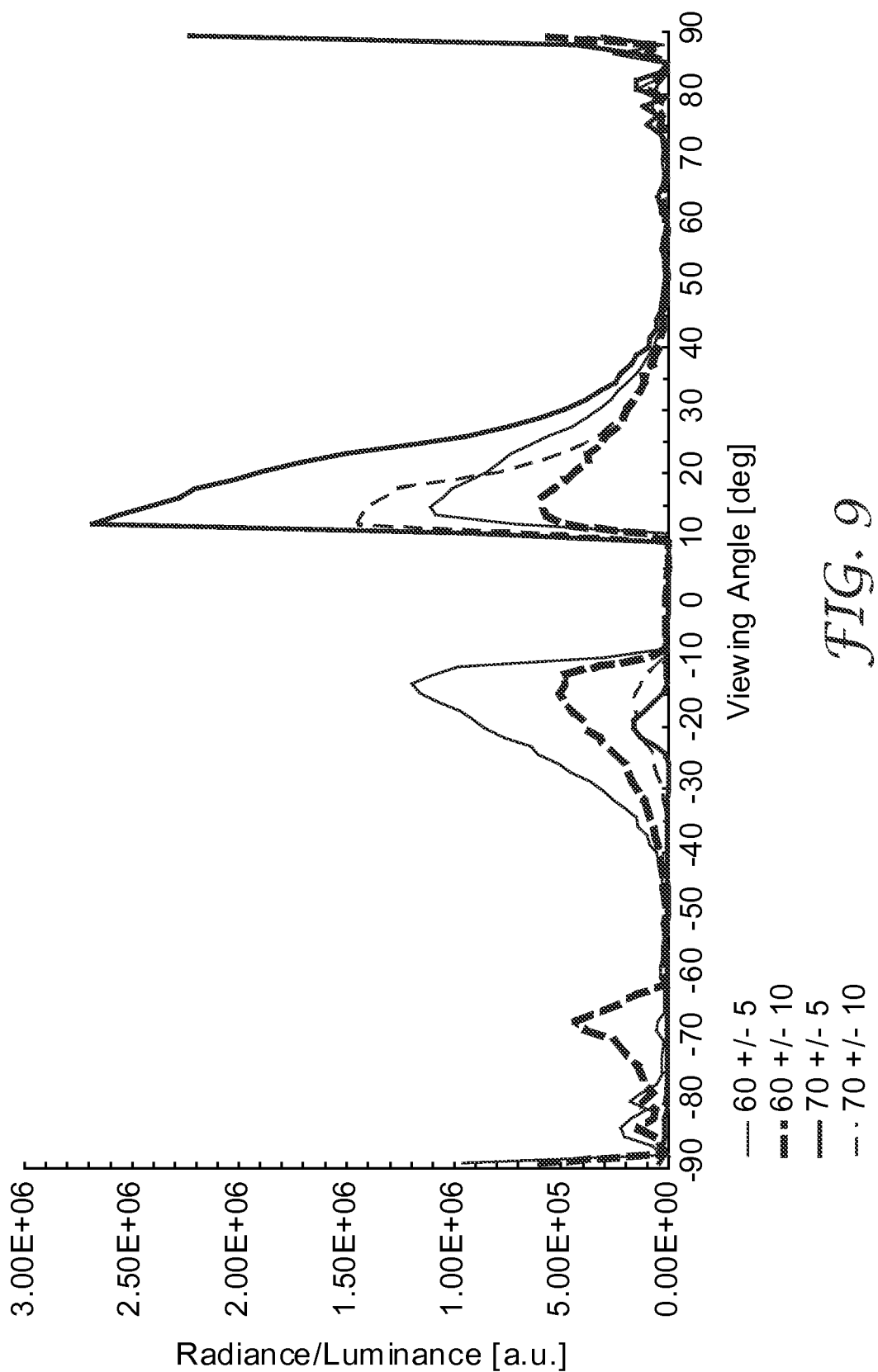


FIG. 9

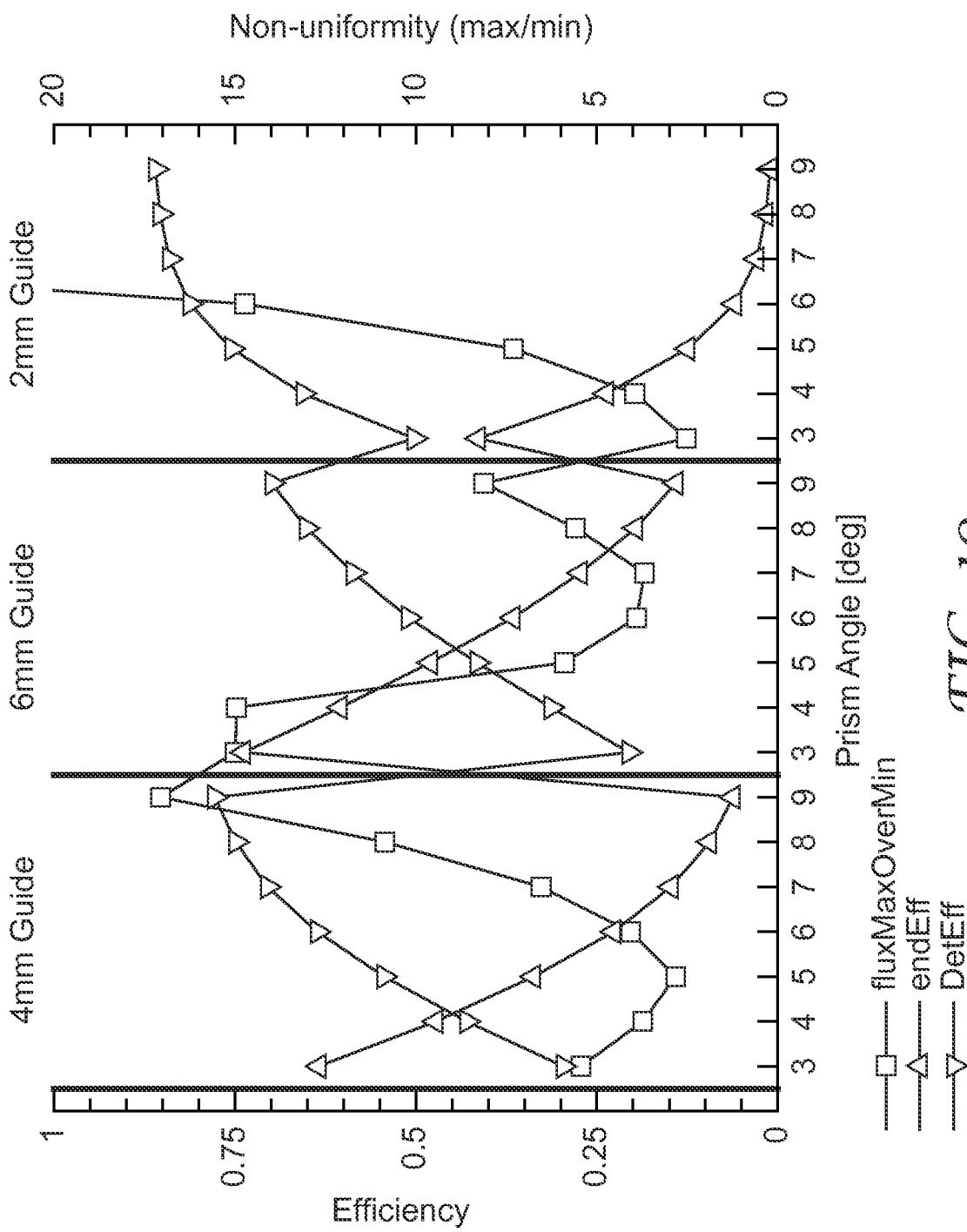


FIG. 10

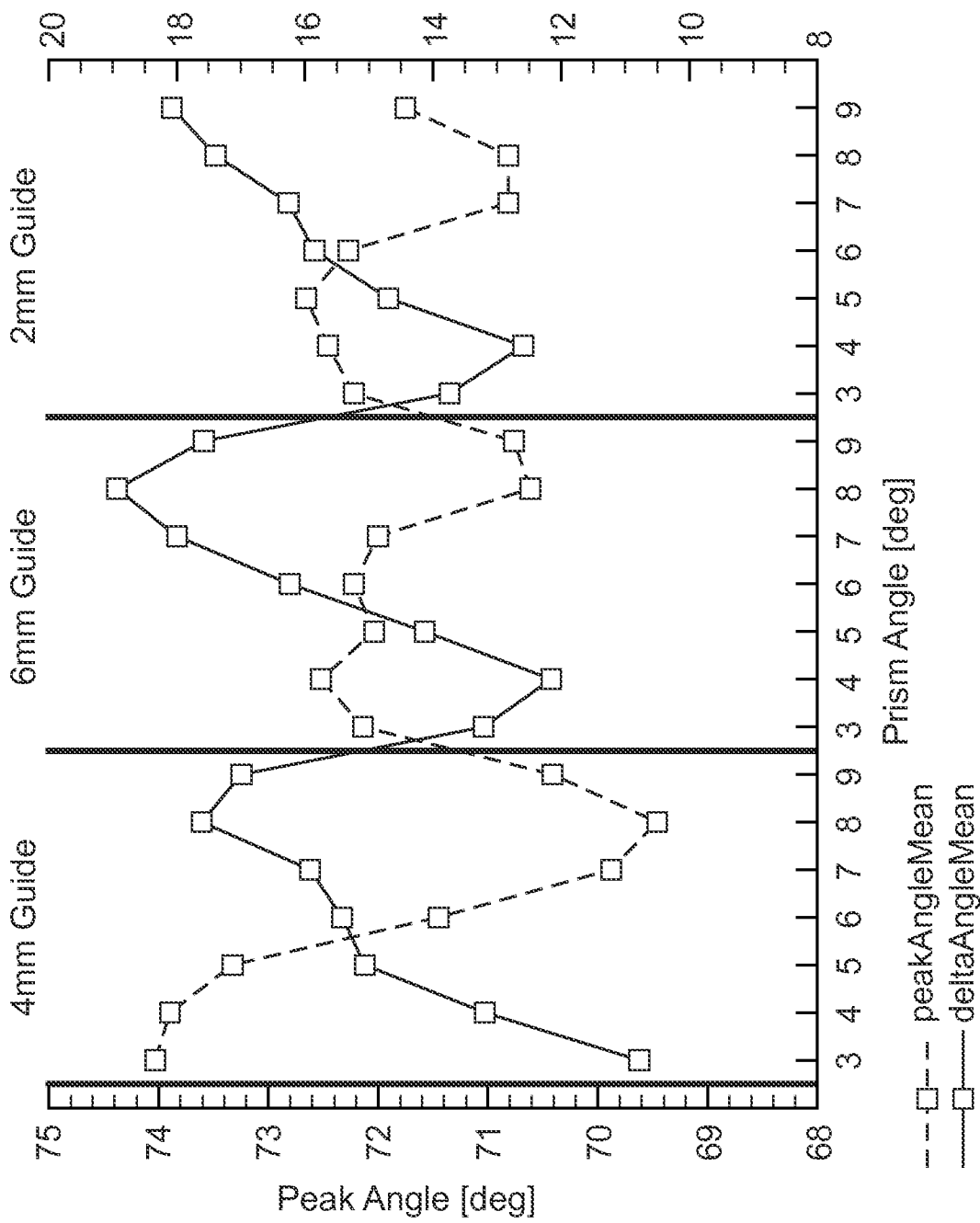
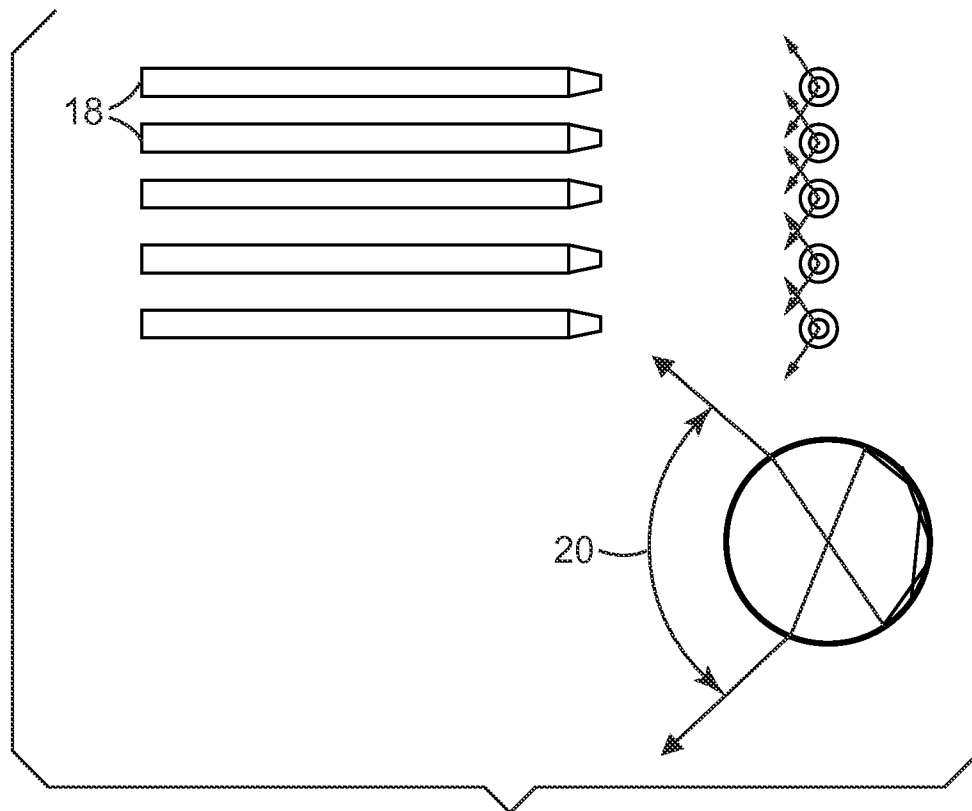


FIG. 11

*FIG. 12*

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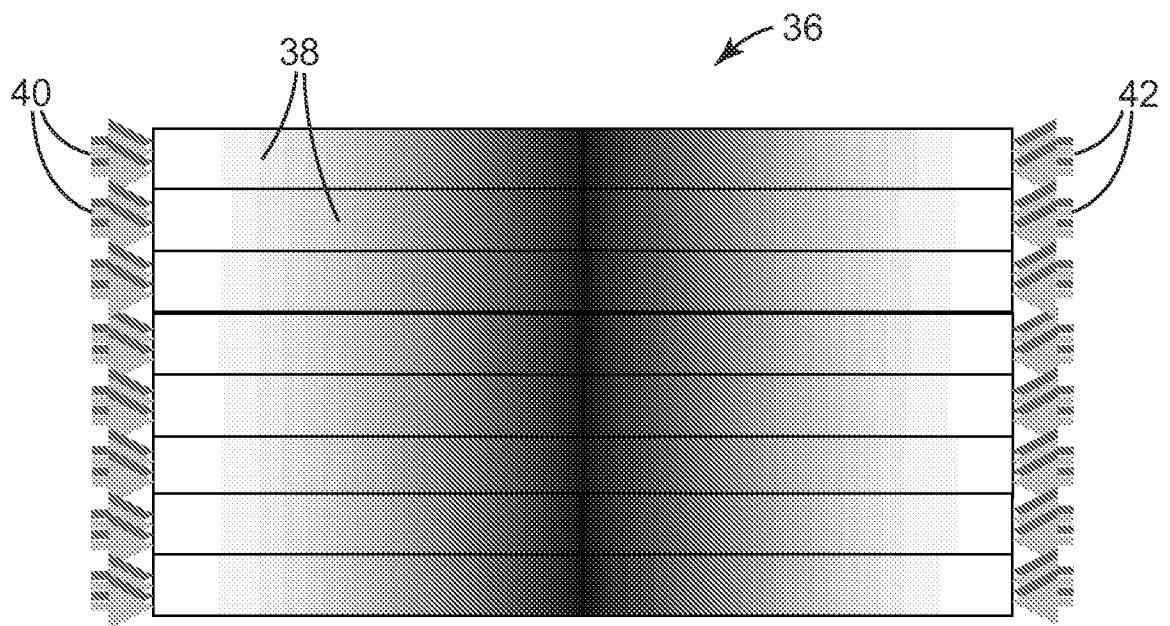


FIG. 13

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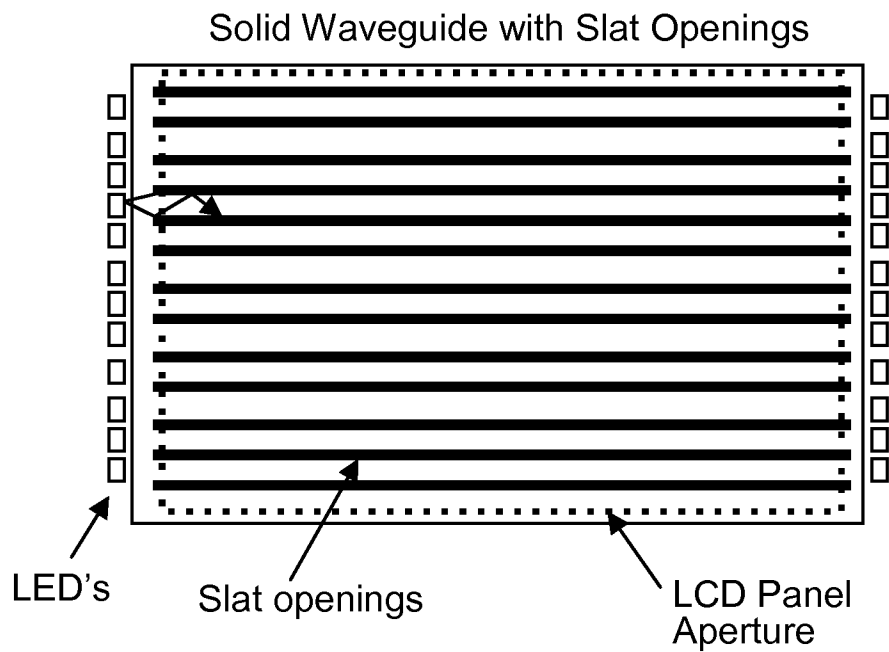
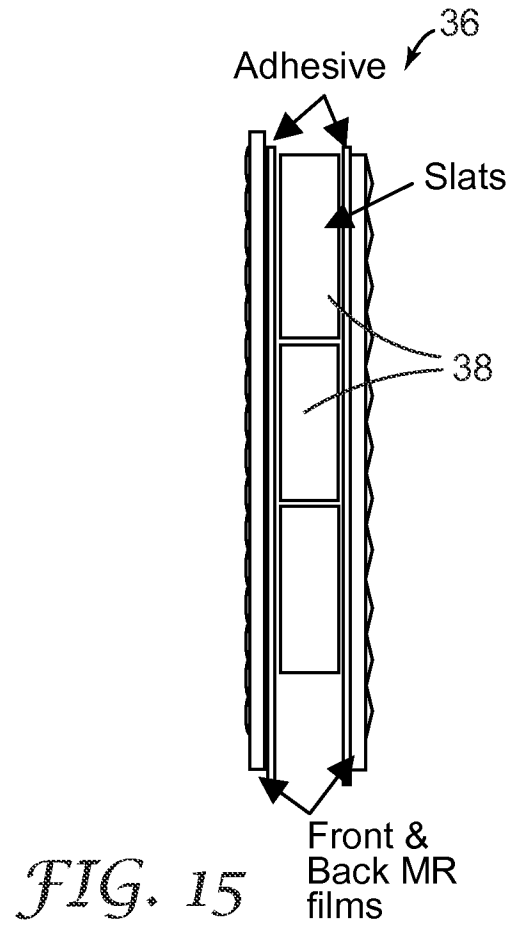
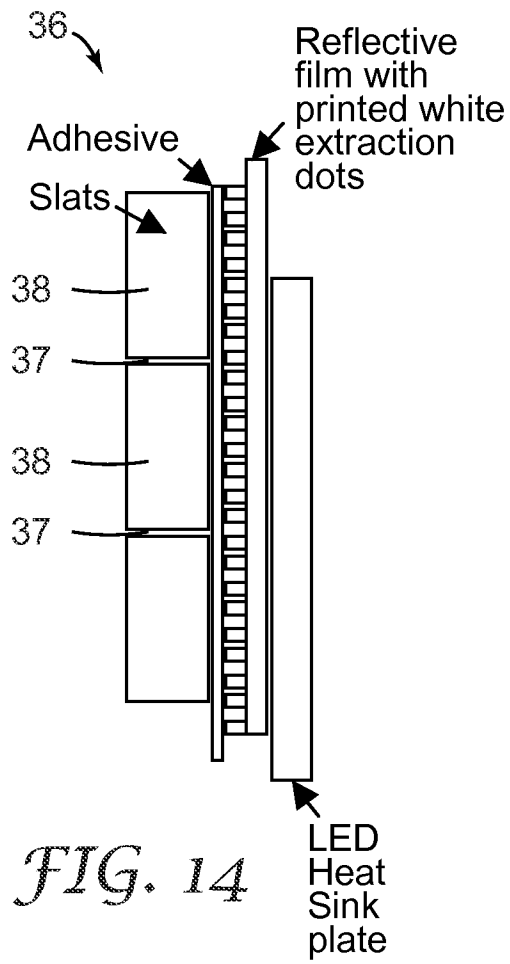


FIG. 16

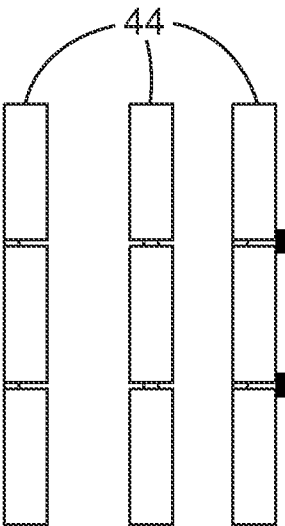


FIG. 17

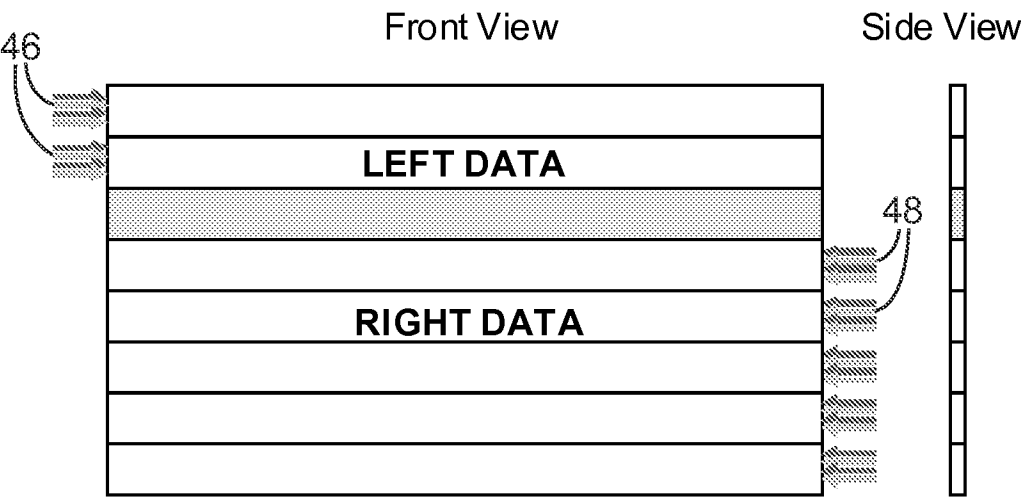


FIG. 18

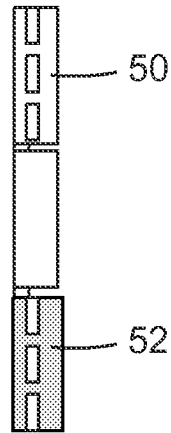


FIG. 19

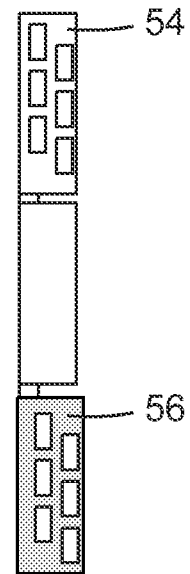


FIG. 20

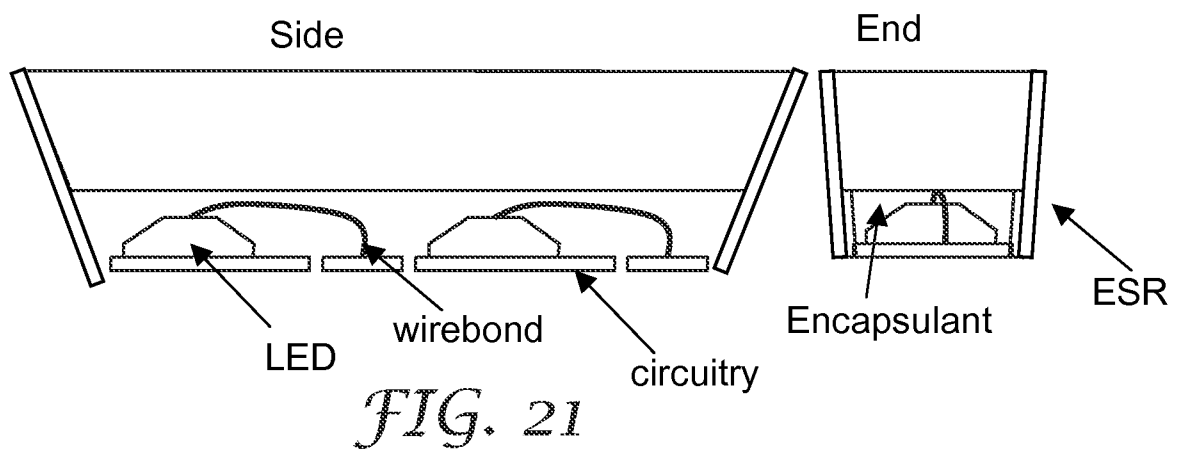


FIG. 21

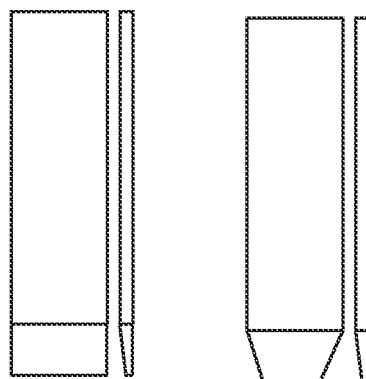


FIG. 22

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2007/079502**A. CLASSIFICATION OF SUBJECT MATTER****G02F 1/133(2006.01)i, G02F 1/1335(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 8 G02F 1/13, G02F 1/133, G02F 1/13357

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Utility models and applications for Utility models since 1975
Japanese Utility models and applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKIPASS (KIPO Internal)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2005-321754 A (MITSUBISHI ELECTRIC CORPORATION) 17 NOVEMBER 2005 See <45><46><47>, claims 1-4, 14-16, and figures 5, 20.	1-5, 36, 37, 39, 40
A	JP 2006-234916 A (CASIO COMPUTER CO., LTD.) 7 SEPTEMBER 2006 See <41><42>, claims 1-7, and figure 1.	1-5
X	JP 2005-114923 A (CASIO COMPUTER CO., LTD.) 28 APRIL 2005 See <76><77><78><79><80><81>, and figures 1, 6.	1-2, 36-40
A	KR10-2006-0093610 A (SAMSUNG SDI CO., LTD.) 25 AUGUST 2006 See the whole document.	1-40

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

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Date of the actual completion of the international search

05 MARCH 2008 (05.03.2008)

Date of mailing of the international search report

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Korean Intellectual Property Office
Government Complex-Daejeon, 139 Seonsa-ro, Seo-
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2007/079502

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP2005321754	17.11.2005	JP2005321754 JP2005321754A2 KR1020060071851 KR2006071851A US2006132673AA	17.11.2005 17.11.2005 27.06.2006 27.06.2006 22.06.2006
JP2006234916	07.09.2006	JP2006234916A2	07.09.2006
JP2005114923	28.04.2005	JP2005114923 JP2005114923A2 KR1020050033470 KR2005033470A TW240058B TW240058A US2005073625A1 US2005073625AA	28.04.2005 28.04.2005 12.04.2005 12.04.2005 21.09.2005 21.09.2005 07.04.2005 07.04.2005
KR2006034625A	24.04.2006	KR2006093610A	25.08.2006