



- (51) **International Patent Classification:**
G02F 1/13357 (2006.01) *G02F 1/01* (2006.01)
- (21) **International Application Number:**
PCT/CA2015/050278
- (22) **International Filing Date:**
7 April 2015 (07.04.2015)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
61/975,393 4 April 2014 (04.04.2014) US
- (72) **Inventor; and**
- (71) **Applicant : KITAI, Adrian** [CA/CA]; 1612 Birchwood Drive, Mississauga, Ontario L5J 1T6 (CA).
- (74) **Agent: HILL & SCHUMACHER;** 264 Avenue Road, Toronto, Ontario M4V 2G7 (CA).
- (81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,

DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) **Title:** HIGH PERFORMANCE SEAMLESS LIGHT EMITTING DIODE ILLUMINATED DISPLAY

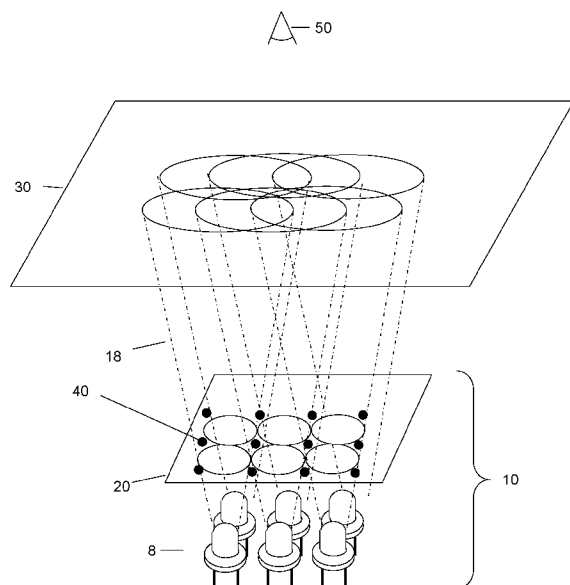


Figure 1

(57) **Abstract:** A display illumination module for the illumination of a rear-projection screen is provided in which a first array of light sources is positioned adjacent to a first face of an optical modulating array layer for modulating the transmission of light emitted by the first array light sources. The first array light sources emit light within a defined angular range, and the optical modulating array layer is positioned relative to the first array of light sources so that light from adjacent light sources does not overlap at the optical modulating array layer. A second array of light sources is positioned adjacent to a second side of the optical modulation array layer and is arranged such that light from the second array of light sources does not pass through said optical modulation array layer and said second array of light sources does not substantially block light from the first array of light sources passing through the optical modulating array layer. One or more display modules may be incorporated into a display system that includes a rear projection screen that is spatially offset from the optical modulating array layer so that light emitted from adjacent light sources in either the first or the second array of light sources overlaps on the screen.

HIGH PERFORMANCE SEAMLESS LIGHT EMITTING DIODE ILLUMINATED DISPLAY

FIELD

5 The present disclosure relates to display systems, and more particularly relates to modular liquid crystal display systems having light emitting diode illumination.

BACKGROUND

10 Light emitting diode (LED) technology enables high efficiency white, red, green and blue light sources with lifetimes of approximately 100,000 hours. White emitting LEDs are now in widespread use for liquid crystal display (LCD) backlighting and are entering general lighting markets. Red, green and blue LEDs are widely used in large video displays where each LED is directly viewed
15 and electrically controlled. LED displays are bright and can be large however the resolution measured in total pixel count depends on the number of LEDs. For example a full colour high resolution screen having 1080 rows and 1920 columns requires 6,220,800 LEDs. In many applications where high resolution colour displays are used, this approach is costly.

20 In conventional colour LCDs, the standard approach has been to use a bright white light source as a backlight, and to employ an addressable colour LC (liquid crystal) light modulator that includes a colour filter array to control the colour and brightness of each pixel. This technology has become the leading solution for television displays. LCDs are also used for smaller computer and
25 handheld displays. White LEDs have been adopted as a preferred backlight technology for LC displays of all sizes. This LC technology is limited by the glass

size of the LC modulator. Both plasma and liquid crystal displays rely on glass sheets and are not readily available in sizes above approximately 100 inches. Making much larger units is a challenge due to glass processing and transportation issues.

5 For larger displays such as video walls, the use of tiled LC or plasma displays is popular. Videowall displays are typically a set of flat panel displays placed as closely as possible to each other. The desired image may be spread across the set of displays, however there are gaps between the active areas of these displays that generally detract from the viewing experience. These gaps
10 are formed by the bezels surrounding each display and are often referred to as bezel gaps. Bezel gaps as small as a few millimeters are achievable with premium LC and plasma display videowalls and are often a few centimeters in lower price videowalls.

 A significant disadvantage of the aforementioned LED displays as well
15 as LCD-based and plasma based videowalls is the inability to economically produce large size, high resolution displays having no visible bezel gaps. Currently, seamless tiling between display units can be achieved using projection display systems. A technique known as edge blending allows multiple projectors to overlap their images on a single screen. Such systems
20 are not flat panels and are not suitable for certain applications such as wall mounted displays where a thin form factor is required.

 An array of projectors comprising LC light modulators backlit by LEDs has been identified as an approach to making displays of arbitrary sizes. US Patent Application US2008/0284677A1 (WHITEHEAD et al) publication date
25 Nov 20, 2008 teaches the use of an array of discrete modules, each comprising

a projector having a processor and a light modulator, projecting on a screen to form an image. Light from a given module may overlap with light from adjacent modules at the screen. The overall display size is dependent on the number of modules.

5 In U.S. Provisional Application No. 61/240,412 "LIGHT EMITTING DIODE ILLUMINATED DISPLAY" filed on September 8, 2009, the use of multiple LC light modulators, each containing arrays of LEDs is disclosed. Specifically the elimination of bezel-gaps using edge blending has been disclosed. This concept was further developed in PCT application No

10 PCT/CA2010/001407 "LIGHT EMITTING DIODE ILLUMINATED DISPLAY" filed Sept 8, 2010. In order to eliminate gaps between LC modulators the LEDs near the edges of each modulator may be tilted or splayed out to project light onto the screen located a short distance in front of the LC modulators such that all areas of the screen are illuminated. This approach is shown to form a

15 practical and thin display since only a short distance is required between the screen and the LC modulators.

 The use of arrays of LEDs behind each LC modulator reduces the number of LC modulators required and decreases system complexity and cost. One problem with this approach occurs because rear projection screens are

20 sensitive to the direction from which light strikes the screen. The screen image, as viewed by the viewer, will not maintain appropriate brightness levels as the viewer views the screen from a range of viewing angles. This causes image artifacts that the viewer notices at boundaries between adjacent LC light modulators. Other problems with this approach are high power consumption

25 due to light loss in the light modulators and screen, a lack of screen contrast

due to both ambient light reflecting off the screen, contrast limitations of the light modulators and the degradation of light modulators due to the high brightness LED arrays behind the LC light modulators.

It would therefore be advantageous to enable the use of multiple LC light modulators, each containing arrays of LEDs, to project an image onto a screen without visible image artifacts and without visible gaps between LC light modulators. Furthermore it would be an advantage to achieve a reduction in power consumption, an increase in screen contrast and a decrease in the degradation of the light modulators.

10

SUMMARY

In a first aspect, there is provided a display illumination module comprising: a first array of light sources forming a backlight array, an optical modulating array layer positioned adjacent to and in front of the backlight array for modulating the transmission of light emitted from the backlight array, a second array of light sources comprising a flood light array positioned adjacent to and in front of the optical modulating array layer; wherein the optical modulating array layer is positioned relative to the array of backlight sources so that light emitted from a given backlight source does not or does not substantially overlap with light emitted from another backlight source within the optical modulating array layer and a rear projection screen positioned in front of the flood light array of one or more than one display illumination module such that it is illuminated by light from both the backlight array and the flood light array in each said display illumination module.

The display illumination module may further comprise an optically opaque layer provided between the array of backlight sources and the optical modulating array layer for preventing overlap of light from adjacent backlight sources within the optical modulation layer, the optically opaque layer having
5 defined therein an array of apertures allowing the propagation of light from each the backlight source to the optical modulation layer within the defined angular range. The said rear projection screen is placed a specified distance in front of the display illumination module or modules such that an image may be rendered on said screen by the display illumination module or module. The
10 screen may consist of a variety of known rear projection screen types. A polarizer may be bonded to the front or rear surface of the viewing surface of the screen to improve contrast.

The backlight and flood light sources are preferably light emitting diodes (LEDs) which may comprise an integrated focusing element, and may be white
15 or colour LEDs. The LEDs may be surface mounted or through-hole mounted onto a circuit board. Optical baffles may be included for restricting the defined angular range. The backlight and flood light LEDs may be supplied with steady electrical power from a power supply or a set of power supplies provides electrical power to the arrays of LEDs. In addition the backlight and/or the flood
20 light LEDs may be electrically controlled such that each said LED may have a variable and controlled brightness level determined by the electric current flowing at any instant in time through said LED.

The optical modulating array layer is preferably a liquid crystal modulator, and the liquid crystal modulator is preferably a colour liquid crystal
25 modulator. The light emitted from a given backlight source illuminates two or

more pixel elements and typically hundreds of pixel elements within the optical modulating array layer. The display illumination module may further comprise a housing for securing the arrays of light sources relative to the optical modulating array layer.

5 A distance between the array of backlight sources and the optical modulating array layer is preferably defined such that an area of the optical modulating array layer illuminated by a given light source is at least about 5 times larger than an effective emitter area of the given light source. The flood light array is preferably situated adjacent to the optical modulating array layer
10 and as close as possible to the said modulating array layer such that the flood light LEDs do not block light from the backlight array passing through the said modulating layer. In this manner the rear projection screen may be illuminated by a superposition of light originating from the backlight array that passes through the optical modulating array layer, and light from the flood light array.

15 The position and/or angular orientation of each light source within the array is preferably selected so that light emitted from a given light source and transmitted by the optical modulating array layer overlaps with light emitted by an adjacent light source beyond a defined spatial offset relative to the optical modulating array layer on the screen.

20 In another aspect, there is provided a display system comprising: one or more display modules as described above; and a rear-projection screen positioned to be illuminated by light from the one or more display illumination modules. A distance between the array of light sources and the optical modulating array layer of each the display illumination modules is preferably
25 chosen to prevent substantial blurring of an image projected onto the rear-

projection screen. The flood light array in each said display illumination module is preferably chosen to be capable of providing uniform or substantially uniform illumination of the rear-projection screen if all of the said flood light array LEDs are turned on.

5 The position and/or angular orientation of each backlight source within each of the one or more display illumination modules is preferably selected so that light emitted from a given backlight source and transmitted by the optical modulating array layer overlaps with light emitted by an adjacent backlight source at the rear projection screen. The position and/or angular orientation of

10 each flood light source within each of the one or more display illumination modules is preferably selected so that light emitted from a given flood light source overlaps with light emitted by an adjacent floodlight source at the rear projection screen. The position of each display illumination module is preferably selected so that light emitted from a given light source at an edge of a given

15 display illumination module overlaps with light emitted by an adjacent light source in an adjacent display illumination module at the rear projection screen.

In an embodiment disclosed herein there is provided a method of display illumination, comprising:

20 arranging a first array of light sources, wherein each light source of said first array of light sources is configured to emit light within a defined angular range;

 positioning an optical modulating array layer adjacent to said first array of light sources for modulating a transmission of light emitted from said first

25 light sources, wherein said optical modulating array layer is positioned relative

to said first array of light sources so that light emitted from a given light source in said first array of light sources does not substantially overlap with light emitted from another light source from said first array of light sources within said optical modulating array layer; and

5 positioning a second array of light sources on an opposite side of said optical modulating array layer relative to said first array of light sources, said second array of light sources being positioned to emit light in a same general direction as the modulated light from said first array of light sources.

A further understanding of the functional and advantageous aspects of
10 the
invention can be realized by reference to the following detailed description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

15 Embodiments will now be described, by way of example only, with reference to the drawings, in which:

Figure 1 is a schematic diagram of a display produced in accordance with the present invention.

Figure 2 shows details of the portion of the liquid crystal (LC) modulator
20 and screen associated with one light emitting diode (LED) backlight array.

Figure 3 is a schematic diagram of a set of three modules arranged behind one continuous screen in a display produced in accordance with the present invention.

Figure 4 is a schematic diagram of a flood light array on a printed circuit
25 board providing for large openings.

Figure 5 is an embodiment of a flood light array showing a detail of one element of the flood light array

Figure 6 is another embodiment of a flood light formed in strips showing a detail of one strip of the flood light.

5

DETAILED DESCRIPTION

Generally speaking, described herein are display systems with LED backlighting and LED flood lighting. As required, embodiments of the present invention are disclosed herein. However, the disclosed embodiments are
10 merely exemplary, and it should be understood that the invention may be embodied in many various and alternative forms. The Figures are not to scale and some features may be exaggerated or minimized to show details of particular elements while related elements may have been eliminated to prevent obscuring novel aspects. Therefore, specific structural and functional
15 details disclosed herein are not to be interpreted as limiting but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention.

As used herein, the terms, “comprises” and “comprising” are to be construed as being inclusive and open ended, and not exclusive. Specifically,
20 when used in this specification including claims, the terms, “comprises” and “comprising” and variations thereof mean the specified features, steps or components are included. These terms are not to be interpreted to exclude the presence of other features, steps or components.

As used herein, the terms “about” and “approximately”, when used in
25 conjunction with ranges of dimensions of particles, compositions of mixtures

other physical properties or characteristics, are meant to cover slight variations that may exist in the upper and lower limits of the ranges of dimensions so as to not exclude embodiments where on average most of the dimensions are satisfied but where statistically dimensions may exist outside
5 this region. It is not the intention to exclude embodiments such as these from the present invention.

In a first embodiment, a display illumination module is provided that includes an array of light sources that emit light over a selected angular range and are arranged to backlight an optical modulating array layer without mutual
10 overlap. The transmission of light from each light source is modulated by the optical modulating array layer and may be employed to illuminate a rear projection viewing screen. In addition a second LED array or flood light array which is located in front of the optical modulating array layer also illuminates the rear projection screen. The separation distance between the optical modulation
15 array layer and the flood light array is preferably as small as possible.

The rear-projection viewing screen is placed at a location where spatial overlap exists between light at the screen emitted from adjacent light sources from the backlight array. In addition the rear-projection viewing screen is simultaneously placed at a location where spatial overlap exists between light
20 at the screen emitted from adjacent light sources from the flood light array. As disclosed below, in a preferred embodiment, multiple display illumination modules may be arranged to illuminate a rear-projection screen in order to provide a composite display without the appearance of visible gaps between the portions of the rear-projection screen illuminated by the display illumination
25 modules.

For the purposes of illustration only, the embodiments below disclose the array of light sources as comprising an array of light emitting diodes. However, it is to be understood that the light sources may be any light sources that approximate point sources and provide light over a defined angular range. For example, alternative non-limiting examples of light sources include lasers with divergent beam patterns and illuminated optical fibers. The structure and operation of a display module according to one embodiment will now be described with reference to **Figure 1**.

Each display module **10** comprises a backlight array of white emitting LED light sources **8** which directly illuminate liquid crystal modulator **20**. Light from each LED illuminates a unique and separate portion of the colour LC modulator **20** and the light then proceeds to illuminate a portion of screen **30**. LC modulator **20** comprises an electrically addressable array of pixels and associated colour filters and is capable of transmitting spatially dependent, variable amounts of light of a set of substantially primary colours filtered from white light sources **8**, from substantially no light to a significant amount of light according to control voltages applied to pixels of the LC modulator **20**.

In addition, flood light LEDs are shown at **40**. Each flood light **40** is situated at a position just in front of LC modulator **20** that does not block light from the backlight array. Each flood light **40** is preferably a set of three primary colour LEDs or one tricolour LED which has separate red, green and blue light emitters that may be individually controlled by an electronic control means in order to produce a desired illumination on screen **30**, although each floodlight **40** could also be a single LED of a single colour such as white.

The flood array of LEDs **40** are wide divergence LEDs that have a wide beam spread. Preferably at each location shown at **40** in **Figure 1** there is a red, a green and a blue LED that individually have wide beam spreads. Such LEDs **40** will illuminate areas of the screen **30** that will generously overlap at the screen **30** with light from adjacent flood LEDs **40**. This allows the screen **30** to be substantially uniformly lit by the array of flood array LEDs **40**. Since the light from these LEDs **40** does not pass through the LC light modulator **20** their light is not attenuated by the LC light modulator **20** and substantial screen illumination is achievable even with relatively low power flood array LEDs **40** compared to the backlight LEDs **8** that are attenuated by the LC light modulator **20**.

By controlling the electric current through each flood array LED **40** individually, the intensity of light from each flood array LED **40** can be set to a level appropriate for the portion of the screen **30** showing a corresponding portion of the desired image on the screen **30** affected by the light from the flood light LED **40**. For example if the portion of the screen **30** is to be bright white then the relevant red, green and blue flood LEDs **40** would be substantially turned on. If the said portion of the screen is to contain detailed image content then the relevant flood LEDs **40** of each colour would be turned on only enough to provide illumination on the screen **30** relevant to the lowest intensity at the screen **30** in the portion of the image for each of the red, green and blue colour components. If the portion of the screen **30** is to show a black portion of an image then the relevant flood LEDs **40** of each colour would be turned off. If the portion of the screen **30** is to show a substantially green portion of an image then the relevant blue and red flood LEDs **40** would be

substantially turned off and the relevant green flood LED **40** would be turned on. Any detailed image content in the portion of the screen is then provided by superimposing screen illumination from the backlight array LEDs **8** that is controlled by the optical modulator array layer **20** onto screen illumination provided by the flood array LEDs **40**. The superposition of light from both backlight array LEDs **8** and flood light array LEDs **40** forms the final image on screen **30** and is viewed as shown by viewer **50**. Preferably as much as possible of the required light to form the desired screen image will be provided by the flood array LEDs **40** since this will reduce power consumption because these flood light array LEDs **40** may be lower power LEDs relative to the backlight array LEDs **40**. The display illumination module **10** includes at least one electrical driver for providing electrical power to the light emitting diodes. In an embodiment, each light emitting diode has a dedicated driver. A computer controller is included and is programmed to control the electrical power applied to the light emitting diodes in the first and second array of light sources.

Figure 2 shows a detail view of a liquid crystal (LC) light modulator array layer **20** and the screen **30**. An example of a pattern is shown in which four LC modulator elements **29** of light modulator array layer **20** are programmed to partially block light emitted by one selected backlight array LED **8**, giving rise to a light pattern **38** on screen **30**. Modulator elements **29** cast a shadow on screen **30** since they block LED light from the selected backlight array LED **8**, and the remaining modulator elements are programmed to pass light. In order to cast a clear shadow on screen **30**, each LED **8** of the backlight array should ideally be a point source or in practice a small enough source to be an approximation of a point source. If the LC light modulator array **20** is a colour

LC modulator containing arrays of colour filters and the LED is white then a set of primary colors is available to form full color light patterns or images on the screen **30**. The ultimate resolution of the display illumination module **10** shown in **Figure 1** is determined by the degree of sharpness of this shadow (**Figure 2**), which can be controlled by selecting the LED **8** emitter size and the spatial offset between the LED array **8** and the LC modulator array layer **20**.

Moreover, it is important to recognize that an appropriate resolution of the LC modulator array layers **20** will be determined by these parameters, and that increasing the resolution of the LC modulator **20** beyond a certain threshold value will not improve the final resolution of the display due to the shadow blurring effect.

Figure 3 shows a group of three LC light modulator array layers **20** with corresponding backlight LEDs **8** and floodlight LEDs **40** arranged behind a rear-projection screen **30**. The light reaching the screen **30** from the backlight LEDs **8** behind each two adjacent LC light modulator array layers **20** overlaps on the screen **30** to allow the image on the screen **30** to be continuous across the join between two adjacent light modulators **20**. In addition the light reaching the screen **30** from the flood light LEDs **40** situated just in front of each two adjacent LC light modulator array layers **20** overlaps on the screen **30** to allow the image on the screen **30** to be continuous across the join between two light modulator array layers **20**.

A polarizer **50** may optionally be optically bonded to the back or the front or both the back and the front of the viewing screen **30** to substantially reduce ambient light reflections from the screen **30** while allowing light from the display illumination module or modules **10** to pass through the said polarizer or

polarizers **50**. The polarizer or polarizers **50** are effective since light that passes from the LC modulator **20** is generally polarized, and provided the polarizer or polarizers pair **50** is placed such that its polarizing axis is parallel to the polarization axis of light emitted by the display illumination module or modules

5 **10**, an efficient transmission of light through polarizer or polarizer pair **50** is achievable.

As shown in **Figure 1**, the backlight LEDs **8** may have an integrated lens to produce a desired radiation pattern. Such backlight LEDs **8** emit light within a cone **18** having a defined divergence angle, and the divergence angle can be

10 selected to provide the desired angular range as described above. LEDs **8** may be incorporated with an external focusing element and/or external aperture to produce the desired angular emission profile to illuminate the LC modulator array layer **20** without overlap between adjacent LEDs. The flood light array LEDs **40** also emit light in a cone with a defined divergence angle which is

15 preferably larger than the divergence angle of the backlight LEDs **8** to ensure that the illumination at the screen of each floodlight LED **40** overlaps with neighbouring flood light LEDs **40** illumination to produce a substantially uniform screen illumination at screen **30**. Thus, the uniformity of illumination at the screen **30** by the second array of light sources **40** is achieved by the wide beam

20 divergence angles as well as the positions and mounting angles of the individual light sources of the second array of light sources **40**. The controlling means applied to the second array of light sources **40** is to enable them to provide screen illumination appropriate to specific images to be displayed, and the control means is typically a computer processor programmed with

instructions to control the controllers which control the electrical power applied to the light emitting diodes in both the first and second light source arrays.

In applications that require high dynamic range and optimal contrast and minimum electrical power consumption, it is desirable to individually control the current/power supplied to each backlight LED **8** as well as to each flood light LED **40** in addition to modulating the transmission from each backlight LED **8** via the LC modulator array layer **20**. Such an approach provides a display with minimum power consumption by only providing power to each LED **8** and **40** on an as-needed basis.

As noted above, a full colour image may be produced on screen **30** by the superposition of light from flood light LEDs **40** and light from backlight LEDs **8**. Specifically white backlight LEDs **8** and a colour LC light modulator array layer **20** may be used. Alternatively, by employing a sufficient number of red, green and blue backlight LEDs **8** whose light is controlled by a monochrome LC light modulator array layer **20** it is also possible to produce a full colour image. In this case, all the backlight LED **8** light cones of a given colour overlap on screen **30** to provide the capability of achieving a homogeneous illumination of screen **30**. Each portion of screen **30** may therefore be illuminated by light from all three colours, and any desired full color picture may be created on the screen. For example, if the backlight LEDs are turned on and a dark region on the screen is desired, the light from all the backlight LEDs **8** illuminating that region of the screen must be blocked by the appropriate portions of the LC light modulator array layer **20**, and the flood LEDs **40** relevant to the proposed dark region on the screen must be substantially turned off.

Alternatively, if a pure green region on screen **30** is desired, only the light from the blue and red backlight LEDs illuminating that region must be blocked by the appropriate portions of the LC light modulator array layer **20** and only the relevant green flood light LEDs should be substantially turned on. If a yellow

5 region on the screen **30** is desired, only the light from all the blue backlight LEDs illuminating the region must be substantially blocked by the appropriate portions of the LC light modulator array layer **20** and the relevant blue flood light LEDs **40** should be substantially turned off. Finally, if a white region on the

10 screen **30** is desired then all three colours of light from backlight LEDs **8** and flood light LEDs **40** could be used to form the image on the said region of screen **30**.

The present display system is advantageous in that it enables a full color display with outstanding colour saturation, long life (about 100,000 hours), high efficiency (approximately ten (10) lumens/watt), high brightness (1000 cd/m²)

15 and a wide range of display sizes including, for example, displays of three (3) meters in length or more. It is to be understood that a wide variety of rear-projection screens may be employed, including, but not limited to, those that employ refractive or scattering behaviour or a combination thereof.

Optional polarizer **50** may be a linear polarizer. Polarizer **50** may be

20 assembled from one or more polarizer sheets that are optically bonded to a substantially transparent or semitransparent glass or plastic support layer. If more than one polarizer sheet is required to cover the viewing surface of the screen **30**, the sheets are preferably arranged to minimize any gaps between the sheets. This can render the joints between polarizer sheets invisible or

25 substantially invisible to the display viewer.

In order to further optimize the display system, each display illumination module **10** comprises an array of light sources such that the light sources at or near the outside edges of the display illumination module **10** may be brighter than the light sources further away from the edges of the light emitting module

5 **10**. The benefit of this is that the illumination of the screen **30** may otherwise be lower at or near the screen regions behind which the outside edges of the illumination LC modulator array layers **20** are situated. The LED arrays **8** and **40** and the LC modulator array layer **20** that form the display illumination module are preferably provided in a housing that supports the LC modulator

10 array layer **20** above the backlight LED array **8** and below the flood light LED array **8** and provides external electrical connections for driving the LED arrays and the LC modulator array layer **20** pixel elements. The backlight LEDs **8** are preferably directly mounted on a printed circuit board or boards and are optionally further positioned and/or secured through an opaque mounting layer

15 with apertures as described above.

An example of a circuit board and the flood LED assembly on said circuit board is shown in **Figure 4**. As shown in **Figure 4**, the red, green and blue flood light LEDs **40** comprise surface mounted LEDs mounted on a printed circuit board **60** that is provided with large openings **70** to allow the light from

20 each backlight LED **8** to pass through the opening. The openings **70** can be large circular holes as shown in **Figure 4**. The printed circuit board **60** may then be placed directly onto LC light modulator array layer **20**. The display system may further comprise a display driver for receiving an image or video signal to be displayed and providing the appropriate control voltages to the LC

25 modulator and the LEDs which are controlled by the video signal.

Further embodiments of flood lighting are shown in **Figures 5** and **6**. In **Figure 5**, an embodiment shown at **70** includes four-sided pyramids **72** which are located as shown in the spaces available between the portions of the LC light modulator array layer **20** that are being illuminated by the backlights LEDs **8**. Onto each face of the pyramids **72** is attached a full colour LED **74** whose emission is thereby directed so that the light from four full colour LEDs **74** attached to the four faces of each pyramid **72** travels in four directions and thereby enhances the spread of LED light to more uniformly illuminate screen **30**. Each of the full colour LEDs **74** contains a red, a green and a blue LED component. In this case each pyramid **72** therefore includes four (4) red LEDs, four (4) green LEDs and four (4) blue LEDs.

In **Figure 6** another embodiment is shown at **80** in which full rows of (may be a row of full color LEDs or a row comprising a repeating sequence of red, green and blue LEDs or a row of white LEDs) LEDs **82** are arranged in rows **84** set at angles as shown. Each row of LEDs **82** is tilted to an optimal angle so as to more uniformly illuminate the screen **30** (shown in **Figure 1**).

In a preferred embodiment in which a composite display system is provided, one or more display modules and rear-projection screen **30** are mounted within an external housing.

THEREFORE WHAT IS CLAIMED IS:

1. A display illumination module comprising:
 - a first array of light sources, wherein each light source of said first array of light sources is configured to emit light within a defined angular range;
 - an optical modulating array layer positioned adjacent to said first array of light sources for modulating a transmission of light emitted from said first light sources, wherein said optical modulating array layer is positioned relative to said first array of light sources so that light emitted from a given light source in said first array of light sources does not substantially overlap with light emitted from another light source from said first array of light sources within said optical modulating array layer; and
 - a second array of light sources positioned on an opposite side of said optical modulating array layer relative to said first array of light sources, and positioned to emit light in a same general direction as the modulated light from said first array of light sources.
2. The display illumination module according to claim 1 further comprising an optically opaque layer provided between said first array of light sources and said optical modulating array layer for preventing overlap of light from adjacent light sources within said optical modulating array layer, said optically opaque layer having defined therein an array of apertures allowing propagation of light from each said light source from first array of light sources to said optical modulating array layer within said defined angular range.

3. The display illumination module according to any one of claims 1 and 2 wherein said light sources in said first array of light sources are an array of light emitting diodes.
4. The display illumination module according to claim 3 wherein said light emitting diodes emit light having a white color.
5. The display illumination module according to claim 3 wherein said light emitting diodes emit light having red, green and blue colors.
6. The display illumination module according to any one of claims 3, 4 or 5, wherein said light emitting diodes are surface mounted onto a circuit board.
7. The display illumination module according to any one of claims 3 to 6 wherein said light emitting diodes each comprise an integrated focusing element.
8. The display illumination module according to any one of claims 3 to 7 further comprising optical baffles for restricting said defined angular range.
9. The display illumination module according to any one of claims 3 to 8 further comprising at least one electrical driver for providing electrical power to said light emitting diodes, and including a controller programmed to control the electrical power applied to the light emitting diodes.

10. The display illumination module according to claim 5, wherein said array of light emitting diodes comprises one or more types of light emitting diodes, wherein each of said type of said light emitting diodes is configured to emit a different color, including at least one electrical driver for providing electrical power to said light emitting diodes, and including a controller programmed to control the electrical power applied to the light emitting diodes in said second array of light sources.

11. The display illumination module according to any one of claims 9 or 10, wherein said at least one electrical driver comprises one electrical driver for each light emitting diode in said array of light emitting diodes.

12. The display illumination module according to any one of claims 1 to 11 wherein said optical modulating array layer is a liquid crystal modulator.

13. The display illumination module according to claim 4 wherein said optical modulating array layer is a colored liquid crystal modulator.

14. The display illumination module according to claim 5 wherein said wherein said optical modulating array layer is a monochrome liquid crystal modulator.

15. The display illumination module according to any one of claims 1 to 14 wherein said light emitted from said given light source in said first array of light sources illuminates two or more pixel elements within said optical modulating array layer.

16. The display illumination module according to any one of claims 1 to 15 further comprising a housing for securing said first array of light sources relative to said optical modulating array layer.

17. The display illumination module according to any one of claims 1 to 16 wherein a distance between said first array of light sources and said optical modulating array layer is defined such that an area of said optical modulating array layer illuminated by a given light source is at least about 5 times larger than an effective emitter area of said given light source.

18. The display illumination module according to claim 5 wherein one or more of a position and an angular orientation of each light source within said first array of light sources is selected so that light emitted from a given light source of a given color and transmitted by said optical modulating array layer overlaps with light emitted by an adjacent light source of a common color beyond a defined spatial offset relative to said optical modulating array layer.

19. The display illumination module according to any one of claims 1 to 18 wherein said second array of light sources is mounted on said optical modulating array layer and mounted in such a way as to not substantially block light being transmitted from the first array of light sources through said optical modulating array layer, and including a support means for supporting said optical modulating array layer relative to said first array of light sources.

20. The display illumination module according to any one of claims 1 to 18, further comprising a support means for supporting said optical modulating array layer relative to said first array of light sources and said second array of light sources.

21. The display illumination module according to any one of claims 1 to 20 wherein said light sources in said second array of light sources are an array of light emitting diodes.

22. The display illumination module according to claim 21 wherein said light emitting diodes in said second array of light sources are red, green and blue light emitting diodes.

23. The display illumination module according to claim 21 wherein said light emitting diodes are white light emitting diodes.

24. The display illumination module according to any one of claims 1 to 23 wherein said second array of light sources includes a plurality of elongate strips, each elongate strip containing a plurality of light emitting diodes.

25. The display illumination module according to any one of claims 21 to 24 further comprising at least one electrical driver for providing electrical power to said light emitting diodes in said second array of light sources, and including a controller programmed to control the electrical power applied to the light emitting diodes in said second array of light sources.

26. The display illumination module according to claim 25, wherein said at least one electrical driver comprises one electrical driver for each light emitting diode in said second array of light emitting diodes.

27. A display system, comprising:

one or more display illumination modules according to any one of claims 1 to 26; and

a rear-projection screen positioned to be illuminated by light transmitted by said optical modulating array layers of said one or more display illumination modules, and light emitted by said second array of light sources in said one or more display illumination modules.

28. The display system according to claim 27 wherein a distance between said first array of light sources and said optical modulating array layer of each said display illumination module is chosen to prevent substantial blurring of an image projected onto said rear-projection screen.

29. The display system according to claims 27 or 28 wherein one or more of a position and an angular orientation of each light source within each of said one or more display illumination modules is selected so that light emitted from a given light source of a given color and transmitted by said optical modulating array layer overlaps with light emitted by an adjacent light source of a common color at said rear-projection screen.

30. The display system according to any one of claims 27 to 30 wherein a position of each display illumination module is selected so that light emitted from a given light source of a given color at an edge of a given display illumination module overlaps with light emitted by an adjacent light source of the same given color in an adjacent display illumination module at said rear-projection screen.

31. The display system according to any one of claims 27 to 30 wherein said rear-projection screen is selected from the group consisting of diffusing screens, refractive screens, sphere-based screens, and rear projection screens that incorporate a combination thereof.

32. The display system according to claim 31 including a polarizer bonded to either the front face or the back face or both faces of said rear-projection screen.

33. The display system according to any one of claims 27 to 32 wherein said second array of light sources is configured to produce an overlapping and substantially uniform illumination of said rear-projection screen.

34. The display system according to any one of claims 27 to 33, including a computer controller programmed to produce an image on the screen, and being programmed to turn on each light source in the second array of light sources just enough to provide illumination on the portion of the rear-projection screen substantially illuminated by each of said light sources as required to produce a lowest intensity at the rear-projection screen in that portion of the image, the

remaining image content to be supplied by said first array of light sources transmitted by said optical modulator array layer.

35. A method of display illumination, comprising:

arranging a first array of light sources, wherein each light source of said first array of light sources is configured to emit light within a defined angular range;

positioning an optical modulating array layer adjacent to said first array of light sources for modulating a transmission of light emitted from said first light sources, wherein said optical modulating array layer is positioned relative to said first array of light sources so that light emitted from a given light source in said first array of light sources does not substantially overlap with light emitted from another light source from said first array of light sources within said optical modulating array layer; and

positioning a second array of light sources on an opposite side of said optical modulating array layer relative to said first array of light sources, said second array of light sources being positioned to emit light in a same general direction as the modulated light from said first array of light sources.

1/6

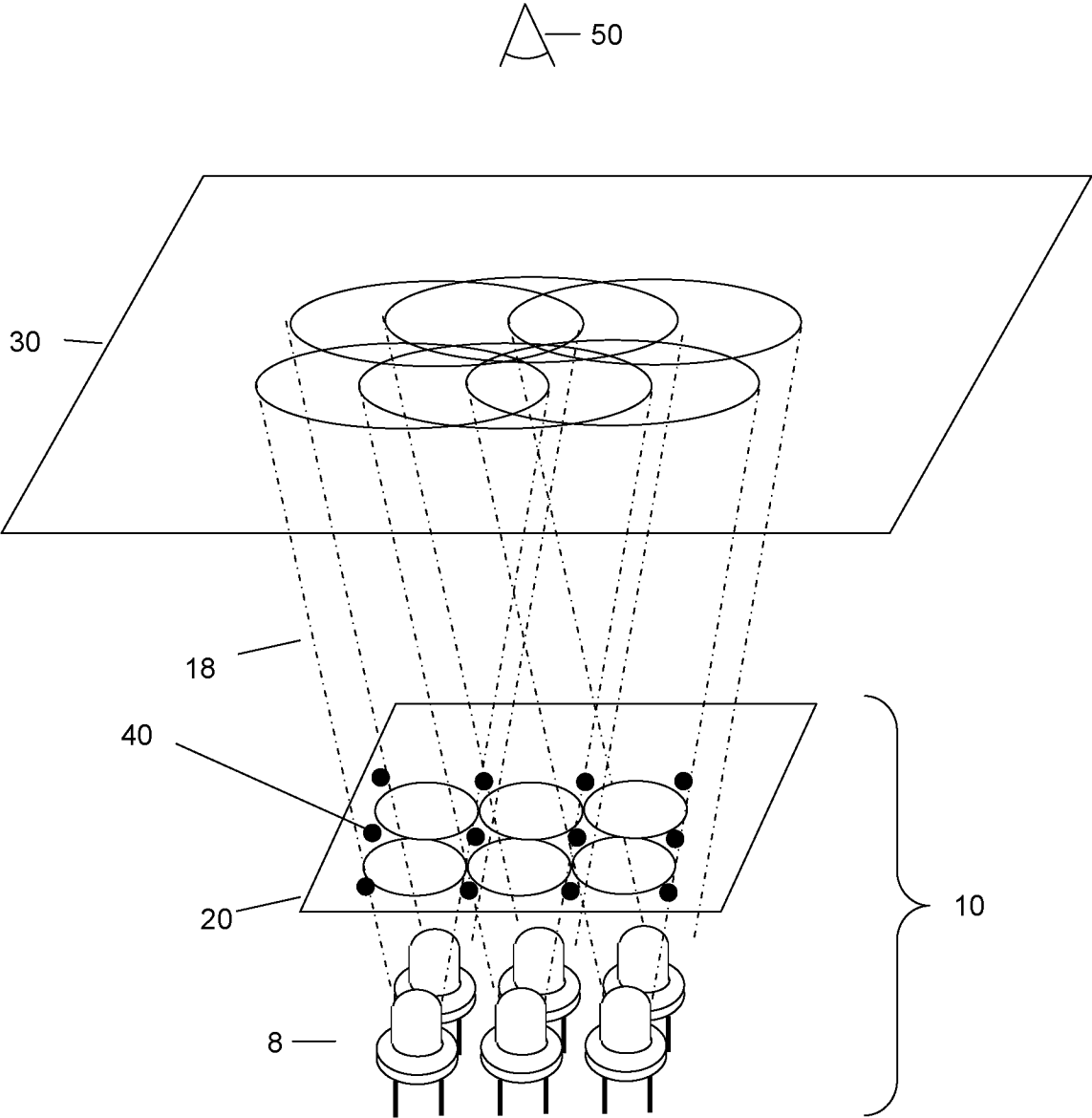


Figure 1

2/6

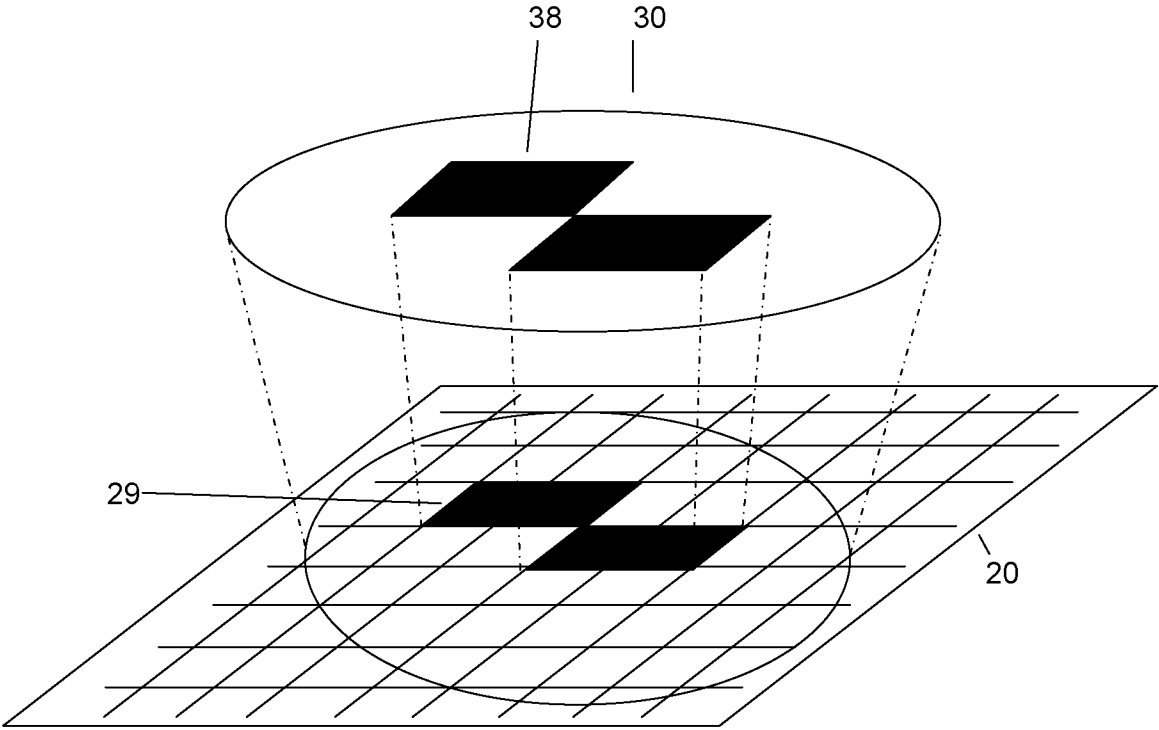


Figure 2

3/6

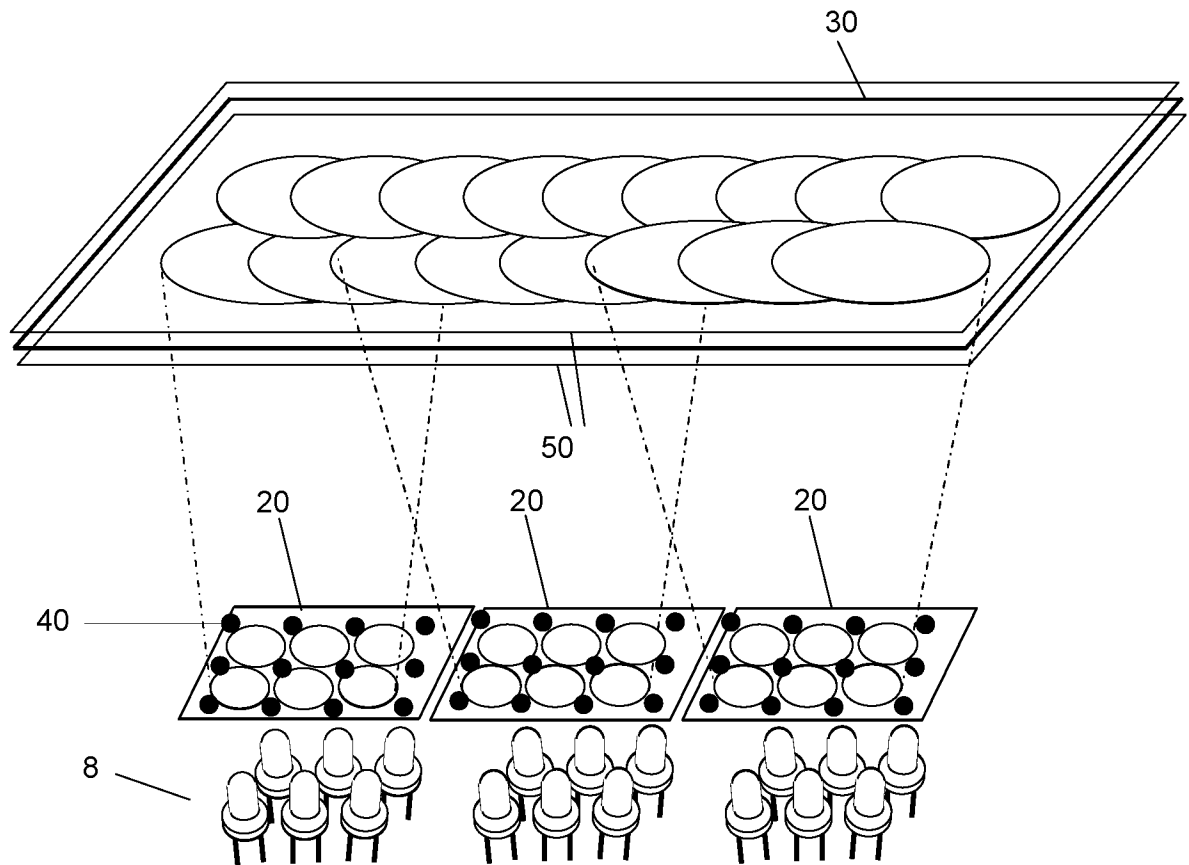


Figure 3

4/6

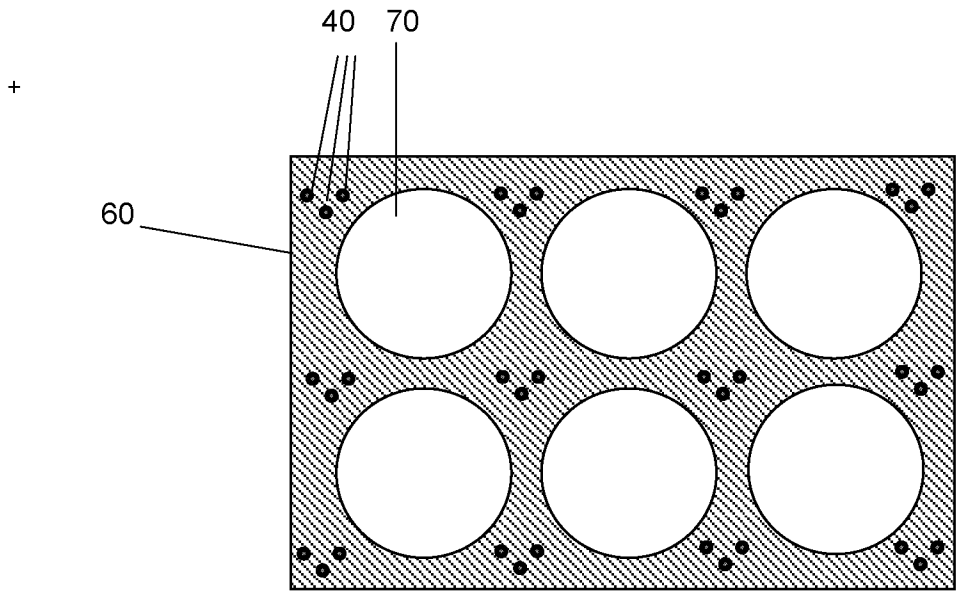


Figure 4

5/6

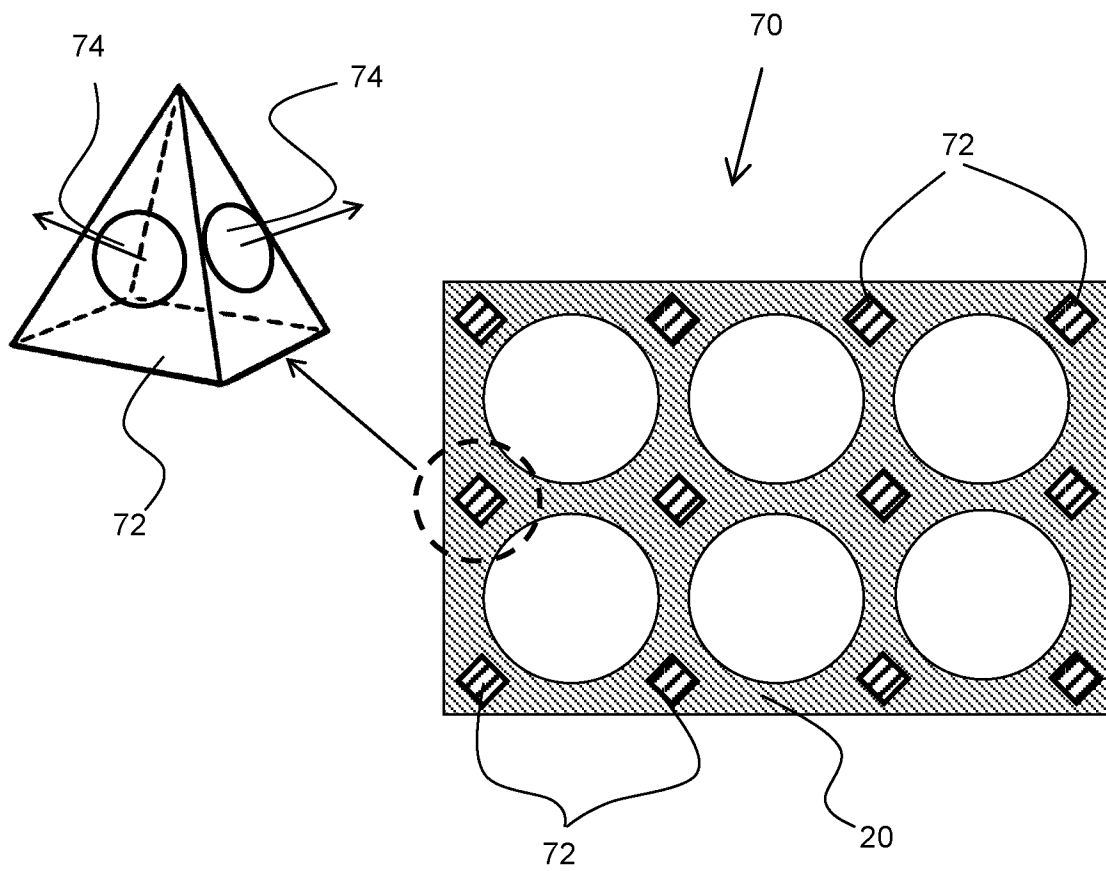


Figure 5

6/6

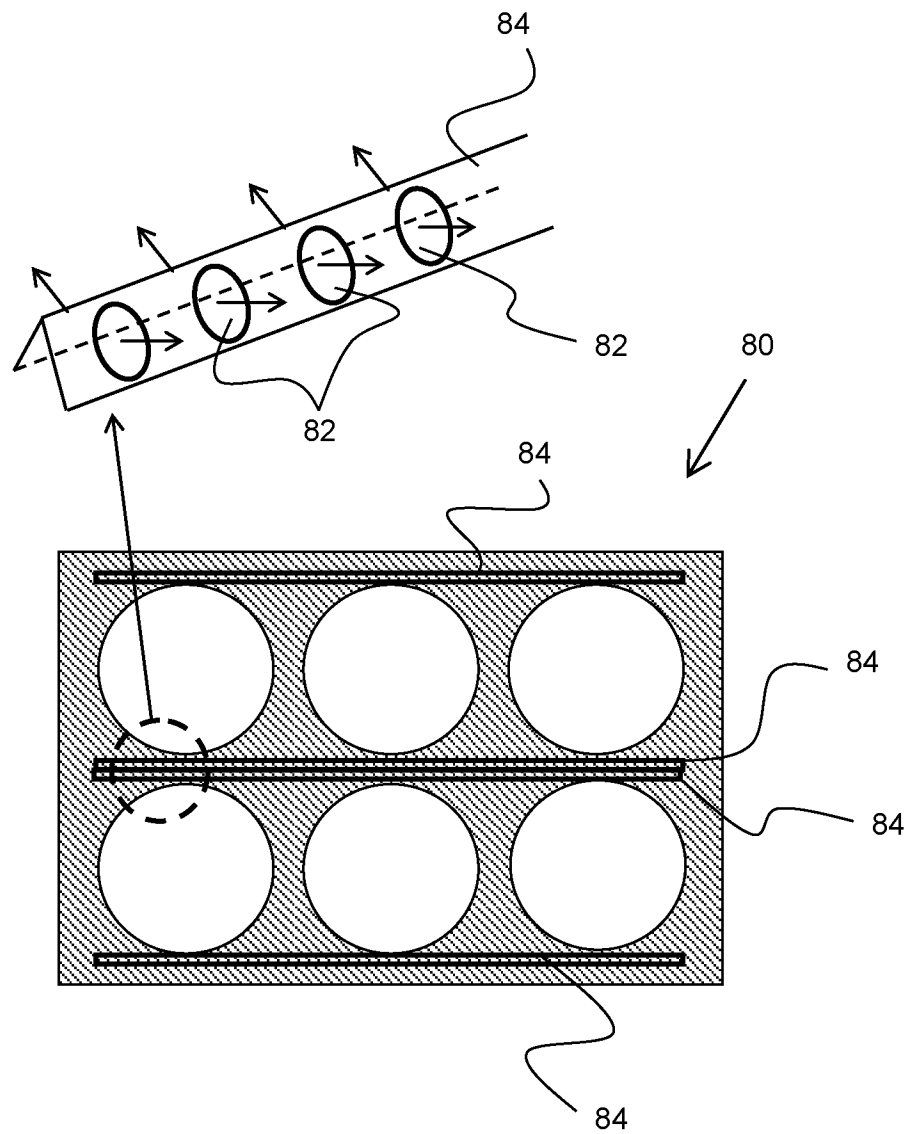


Figure 6

INTERNATIONAL SEARCH REPORT

 International application No.
PCT/CA2015/050278

 A. CLASSIFICATION OF SUBJECT MATTER
 IPC: **G02F 1/13357** (2006.01), **G02F 1/01** (2006.01)

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)
 G02F 1/13357 (2006.01), G02F 1/01 (2006.01)

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

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

Databases: QUESTEL ORBIT (FAMPAT); GOOGLE.

Keywords: Seamless/ tile(d)/ large (LED) display, LED illuminat(ed)/ backlight/ backlit, flood light(ing)/ LED, liquid crystal/ LC modulator/ layer, first/ second LED array, overlap, angular range.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO2011/029188 A1 (KITAD) 17 march 2011 (17-03-2011) * whole document *	1-35
A	US2010/0277696 A1 (HUEBNER) 04 November 2010 (04-11-2010) * whole document *	1-35
A	US2008/0284677 A1 (WHITEHEAD et al.) 20 November 2008 (20-11-2008) * whole document *	1-35

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* "A" "E" "L" "O" "P"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance earlier application or patent but published on or after the international filing date document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) document referring to an oral disclosure, use, exhibition or other means document published prior to the international filing date but later than the priority date claimed	"T" "X" "Y" "&"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art document member of the same patent family
--------------------------------------	--	--------------------------	--

 Date of the actual completion of the international search
 09 July 2015 (09-07-2015)

 Date of mailing of the international search report
 28 July 2015 (28-07-2015)

 Name and mailing address of the ISA/CA
 Canadian Intellectual Property Office
 Place du Portage I, C114 - 1st Floor, Box PCT
 50 Victoria Street
 Gatineau, Quebec K1A 0C9
 Facsimile No.: 001-819-953-2476

 Authorized officer

 Michal Bordovsky (819) 994-7533

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CA2015/050278

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
WO2011029188A1	17 March 2011 (17-03-2011)	WO2011029188A1 CA2772137A1 US2012236217A1	17 March 2011 (17-03-2011) 17 March 2011 (17-03-2011) 20 September 2012 (20-09-2012)
US2010277696A1	04 November 2010 (04-11-2010)	US2010277696A1 US8100540B2 US2012092623A1 US8567961B2	04 November 2010 (04-11-2010) 24 January 2012 (24-01-2012) 19 April 2012 (19-04-2012) 29 October 2013 (29-10-2013)
US2008284677A1	20 November 2008 (20-11-2008)	US2008284677A1 BRPI0619467A2 CA2632056A1 CA2632056C CN101416227A CN101416227B CN102081898A CN102081898B EP1969579A1 EP1969579A4 EP1969579B1 HK1130356A1 JP2009518668A JP5039710B2 KR20080087113A US2012320342A1 US8976080B2 US2012212707A1 WO2007065244A1	20 November 2008 (20-11-2008) 11 December 2012 (11-12-2012) 14 June 2007 (14-06-2007) 14 January 2014 (14-01-2014) 22 April 2009 (22-04-2009) 23 February 2011 (23-02-2011) 01 June 2011 (01-06-2011) 25 June 2014 (25-06-2014) 17 September 2008 (17-09-2008) 12 January 2011 (12-01-2011) 06 November 2013 (06-11-2013) 29 July 2011 (29-07-2011) 07 May 2009 (07-05-2009) 03 October 2012 (03-10-2012) 30 September 2008 (30-09-2008) 20 December 2012 (20-12-2012) 10 March 2015 (10-03-2015) 23 August 2012 (23-08-2012) 14 June 2007 (14-06-2007)