

A method and device for conducting and substantially evenly dispersing light from a light source

Field of the invention

The present invention generally relates to solutions for providing displays with backlighting. More particularly, but not by way of limitation, it relates to a method and device for conducting and substantially evenly dispersing light from a light source for providing a display with planar backlighting.

Background of the invention

In recent years, with the increased emphasis on and use of portable computers, more and more users are finding the need for and the desirability of owning handheld computer products. Handheld computer products, which are now widely available, commonly use liquid crystal displays. Unlike the bigger displays that are used in the larger notebook computers, most of the liquid crystal displays used in handheld computers are monochrome and are used with reflective back panels to allow the user to view the display in good lighting conditions. This is because the power consumption of a backlight can be relatively high, and therefore the use of a reflective back panel instead in a handheld display is often desirable for purposes of having longer stand-alone operating periods.

More recently, there has been an increasing demand for handheld displays to operate with backlighting. This is achieved by placing a backlight behind the liquid crystal display and replacing the reflective back panel with a transfective back panel. The transfective back panel will allow the user to view the display in good lighting conditions without the aid of the backlight. In poorer lighting conditions, the user can turn the backlight on and the transfective back panel will transmit the light into the viewing direction, thus enabling the user to view the display clearly. Usually, a small

intensity of light emitted by the backlight, ranging between 1 - 2 cd/m², is sufficient to aid the user to view the display in poor lighting conditions.

Currently, the commonly used commercially available light sources for backlighting solutions are the Cold Cathode Fluorescence Lamp (CCFL), the Electroluminescent Lamp (EL) and the Light Emitting Diode (LED). The CCFL is usually used with a light-guide to transform the light from the lamp into a planar light source to provide a backlighting solution for colour LCD displays. Although the CCFL has the highest efficiency in terms of light output and produces very high intensity white light that is required for use with colour displays, it also contributes to an expensive backlighting solution. Thus, the CCFL is not suitable for application in low-power and cost effective handheld products.

The EL panel is by far the most widely used light source for backlighting solutions in small handheld computing products. Although the power consumption of the EL panel is much lower than the CCFL, it still consumes up to several hundreds of milliwatts when used with medium sized displays. Currently, even an energy-efficient EL panel requires between 0.3 - 0.5 mW/cm² to produce 1 cd/m² of light. In addition, the EL has a relatively short half life, ranging from a thousand hours to a few thousands hours depending on the operating conditions.

The third solution, whereby the LED is used as a light source, is a popular choice among products having small displays such as pagers and handphones. In such products, the LED provides the best solution in terms of cost and power consumption. Usually, an efficient LED can produce a light output of 1cd/m² for as low as 0.1 - 0.2mW/cm² and thus can be seen to be 2 - 3 times more efficient than a backlighting solution employing an EL panel. Moreover, the driving circuit for the LED is simple and can consist merely of a constant voltage source with a current limiting resistor, and the half-life of the LED is also substantially longer when compared to either the EL or the CCFL.

LED backlighting solutions also include the use of light-guides to transform the light from the diodes into planar light sources. However, current LED backlighting

solutions require multiple LEDs arranged in a row to form a linear light source, and the collective cost of such an implementation can be expensive.

The present invention is intended to provide a solution to various prior art deficiencies, which include those present with the use of CCFL, EL and multiple LEDs to provide effective backlighting solutions.

Summary of the invention

The present invention provides a device for conducting and substantially evenly dispersing light from a light source. The device comprises a light source having at least one substantially point source. The device also comprises a light-guide having a first surface of predetermined thickness and width, a second surface for light to escape from the device, and a third surface having diffused patterns of varying surface areas arranged in a formation. This formation of diffused patterns provides the light-guide with a uniform planar illumination by evenly dispersing light from the point source. The device further comprises a layer of light reflecting material to reflect light from each of the diffused patterns.

The present invention also provides a method for conducting and substantially evenly dispersing light in a light-guide. The method comprises the steps of introducing light into the light-guide and evenly dispersing the light with diffused patterns having varying surface areas arranged in a formation on one surface of the light-guide. The method further comprises the steps of reflecting the light dispersed by the diffused patterns and exiting the light from the light-guide.

Brief description of the drawings

Figure 1 is an isometric view of a light-guide for use in backlighting solutions that has become known.

Figure 2 is a plan view of a light-guide for use with multiple LEDs to provide a backlighting solution that has become known as prior art.

Figure 3 is a plan view of the first preferred embodiment of the present invention.

Figure 4 is a directivity chart of the LED used as a point source in the embodiment of Figure 3.

Figure 5 is an enlarged plan view of the embodiment of Figure 3 to illustrate the light from an LED being coupled to a concavity.

Figure 6 is the plan view of the second preferred embodiment of the present invention.

Description of the preferred embodiments of the invention

As mentioned in the earlier section, a light-guide is usually used with a light source such as the CCFL or multiple LEDs to convert light from a linear source (CCFL), or point sources arranged to form a linear source (multiple LEDs), to planar sources for providing backlighting. As such, the design of a light-guide is critical in that it not only contributes to the efficiency of the backlighting solution but, as will be shown in the following description, also forms the basis for an improved and cost-effective alternative for a planar backlight employing a point source.

Light-guides are preferably made of optical grade material such as acrylic resin, polycarbonate, epoxies and glass, or generally materials which are light transmissible. The length and width of the light-guide usually takes the size of the display and the thickness ranges between 1 - 3 mm. A simplified isometric view of a light-guide that has become known is shown in Figure 1. Light emitted from a light source (not shown) is being directed, as indicated by an arrow 11, onto a surface 13 of a light-guide 12. The bottom surface 15 of the light-guide 12 is usually printed or engraved with diffused patterns (not shown) that may consist of geometric shapes of varying sizes and spacing, or lines, dashes and grids of varying thickness and spacing. These patterns are used to disperse light that travels along the light-guide 12. The dispersed light then exits from the top surface 14 and hence illuminates in the viewing direction 17. A white reflector 16 is placed beneath the light-guide 12 to prevent light loss from the bottom surface 15 due to the diffused patterns. Usually, a diffuser (not shown) is placed on the top surface 14 of the light-guide 12 to further provide diffused illumination from the surface 14.

A plan view of a prior art light-guide that has become known for use with multiple LEDs arranged rectilinearly to form a linear source (or a CCFL providing a linear

source) is shown in Figure 2. As can be seen from Figure 2, each of the diffused patterns 29 found on a light-guide 22 generally take the shape of a circle. These diffused circular patterns 29 gradually increase in size as they are increasingly displaced from a linear source 21. The reason for such an arrangement is that the size of the diffused circular pattern 29 determines the amount of light being dispersed. A larger surface area for a diffused circular pattern 29 therefore corresponds to a higher percentage of light dispersed. As light travels inward in the direction 28 away from the linear source 21, its intensity gets lower as it is being dispersed along the light-guide 22. Hence, larger diffused circular patterns 29 are required at locations further away from the linear source 21 to provide uniform illumination along the length of the light-guide 22. In addition, Figure 2 also shows that the diffused circular patterns 29 which are rectilinearly associated and equidistant from the linear source 21 have the same surface areas. This arrangement is necessary because the light from the linear source 21 travels through the light-guide 22 in waves of uniform intensity that are generally parallel to the linear source 21. Hence, in order to obtain a uniform planar illumination from the light-guide 22, the rectilinearly associated diffused circular patterns 29 have uniform surface areas.

As mentioned in the earlier section, the cost of the above described implementation of a backlighting solution can be relatively high. As such, a description of a light-guide forming part of the preferred embodiment of the present invention is offered below as a less expensive alternative backlighting solution.

As shown in the plan view in Figure 3 whereby diffused circular patterns 39 are formed on the surface of a first preferred embodiment, the arrangement of these diffused circular patterns 39 is vastly different from that of the light-guide 22 in Figure 2. In addition, the use of a single LED 31 as a point source with a light-guide 32 of a width of 40 mm in the preferred embodiment of the present invention is also apparent, as opposed to the multiple LEDs 21 shown in Figure 2, which are disposed 5 - 20 mm apart from each other and are for use with the light-guide 22 of similar width of 40 mm.

In Figure 3, the use of the LED 31 as a point source for the light-guide 32 of predetermined thickness of 1 - 3 mm and width of 40 mm, poses several challenges. As can be seen from Figure 4, which is the directivity chart of the LED 31 of Figure 3, the

light intensity decreases as the angular displacement from a directional reference 41 of the LED 31 increases. As such, a large amount of the light is found to concentrate in front of the LED 31 between 30 degrees to the left of the directional reference and 30 degrees to the right of the directional reference of the LED 31. If a single LED is used with the light-guide 22 in Figure 2, bright spots (sometimes termed as hot spots) will be observed along the directional reference of the LED 31, while dark spots (sometimes termed as cold spots) will be observed at the proximal areas to the extreme left and right of the directional reference of the LED 31. In order to remove these hot and cold spots, or at least make them less obvious to the viewer, so as to achieve a substantially uniform planar illumination, the following solutions are implemented in the preferred embodiments of the present invention.

In Figure 5, which illustrates an enlarged plan view surrounding the light source of the embodiment in Figure 3, the first preferred embodiment is shown to have a semi-circular concavity 58 formed on a surface 53 of a light-guide 52 to house an LED 51. When light from the LED 51 enters the light-guide 52, it will experience a refraction since the light-transmissible material used generally has a higher refractive index than air. As a result, light emitted from the LED 51 will generally bend towards the directional reference of the LED 51, causing the light to converge as it enters the light-guide 52. With the presence of the concavity 58, however, the degree of convergence of the light coupled to the light-guide 52 is reduced. This will subsequently reduce the contrast between the bright and dark spots as described in the previous section. In addition, although a large amount of the light emitted from the LED 51 is found to concentrate in front of the LED 51, some light can still escape from the side of the LED 51. If the concavity 58 is designed so as to enclose the LED 51, light escaping from the side of the LED 51 too can be captured and coupled to the light-guide 52. Even though the light emitted from the side of the LED 51 is very weak compared to the light emitted from the front of the LED 51, it nevertheless contributes to the useful light coupled to the light-guide 52.

The shape of the concavity 58 need not be confined to a semi-circle; a triangular concavity can also be used to converge the light emitted from the LED 51. Overall, the

purpose of the concavity is to increase the light captured and transmitted into, and reduce the degree of convergence of the light coupled to the light-guide 52.

In order to further reduce the contrast between the bright and dark spots, larger diffused circular patterns 39 of the first preferred embodiment are selectively placed on the light-guide 32 as shown in Figure 3. At the region close to, and along the directional reference of the LED 31 the surface areas of diffused circular patterns 39 are found to be smaller compared to the surface areas of the diffused circular patterns 39 found further away from the LED 31. In contrast, the spacings between each of the diffused circular patterns 39 found near and in front of the LED 31 are larger when compared to the spacings between each of the diffused circular patterns 39 found far away from the LED 31. However, the diffused circular patterns 39 found at the corners 38 of the light-guide 32, or at the proximal regions angularly displaced furthest away from the directional reference of the LED 31, where they receive lesser amount of light, are formed, in particular, with larger surface areas and placed in closer proximity to each other to disperse more light to eliminate the dark spots. As a result, a uniform illumination is achieved throughout the upper planar surface of the light-guide 32 to provide an even backlighting for a display to a width of 40 mm.

When the width of the display increases, a single LED might not be sufficient to adequately illuminate the whole display. Two or more narrower light guides, each with a single LED, can be arranged side by side contiguously in the form of a second preferred embodiment of the present invention as shown in Figure 6. The optimally predetermined width of a light-guide 62 formed from a pair of contiguously connected light-guides when used with LEDs 61 which are placed 30 mm apart, is 60 - 70 mm.

In order to achieve extremely low power consumption for the backlight solutions as described above by way of the two preferred embodiments using LEDs, very high efficiency and intensity LEDs are chosen as the point source. These LEDs are commercially available from a few manufacturers. For example, Hewlett-Packard produces amber, orange and red high intensity LEDs using AlInGaP material, and Nichia produces green and blue LEDs with GaInN material. These LEDs come in the form of either the through-hole, or the surface mount types. The surface mount LEDs have typical luminous intensity between 50 to 150 mcd, which are about an order of

magnitude higher than the ordinary LEDs. The typical luminous intensity of the through-hole LEDs can be as high as a few thousand mcds.

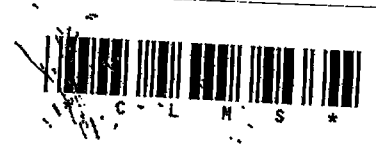
As mentioned in an earlier section, the diffused patterns used in the embodiments of the present invention should not be construed as limited to circular shapes. For example, other geometric shapes such as squares or triangles can also be applied to the diffused patterns, as long as the surface areas of these patterns are varied by using the same method as described in accordance with the present invention. As another example, diffused patterns of similar surface areas can be used throughout the light-guide. However, the density of these patterns must vary such that a higher density of patterns should be found at locations with lower light intensity, and conversely a lower density of patterns should be found at locations with higher light intensity. A further example pertains to the use of lines, dashes or grids for the diffused patterns instead of geometric shapes, whereby the thickness of such patterns are to be varied when considering the arrangement of the overall surface pattern to compensate for the variance in light intensities throughout the light-guide.



Claims

I claim:

1. A device for conducting and substantially evenly dispersing light from a light source, comprising:
 - a light source having at least one substantially point source;
 - a light-guide formed from a light-transmissible medium having:
 - a first surface of predetermined thickness and width optically couplable to the light source,
 - a second surface substantially planar and orthogonal to the first surface for providing an exit surface for light to escape from the device, and
 - a third surface substantially planar and parallel to the second surface having a plurality of diffused patterns formed on the third surface to disperse the light, whereby each of the plurality of diffused patterns is formed with a surface area substantially directly proportional to the radial displacement from the substantially point source and the angular displacement from the directional reference of the point source; and
 - a layer of light-reflecting material superposable on the third surface to reflect light dispersed from each of the diffused patterns.
2. The device as claimed in claim 1, wherein the light source comprises a single substantially point source.
3. The device as claimed in claim 2, wherein the substantially point source comprises a light emitting diode.
4. The device as claimed in claim 3, wherein the first surface is formed with a predetermined thickness and width.



5. The device as claimed in claim 4, wherein the first surface comprises a concavity to couple the light emitted from the light emitting diode.
6. The device as claimed in claim 5, wherein each of the plurality of diffused patterns formed on the third surface is generally circular.
7. The device as claimed in claim 6, wherein the plurality of circular patterns radially proximal to the light emitting diode are formed with increasing surface areas as the patterns are angularly displaced from the directional reference of said diode.
8. The device as claimed in claim 1, wherein the light source comprises a plurality of substantially point sources.
9. The device as claimed in claim 8, wherein each of the plurality of substantially point sources comprises a light emitting diode.
10. The device as claimed in claim 9, wherein the plurality of light emitting diodes are rectilinearly disposed in parallel with the first surface.
11. The device as claimed in claim 10, wherein the plurality of light emitting diodes are disposed with predetermined distances between adjacent light emitting diodes.
12. The device as claimed in claim 11, wherein the first surface is formed with a predetermined thickness and width.
13. The device as claimed in claim 12, wherein the first surface comprises a plurality of concavities to couple the light emitted from the light emitting diodes.





14. The device as claimed in claim 13, wherein each of the plurality of diffused patterns formed on the third surface is generally circular.
15. The device as claimed in claim 14, wherein the plurality of circular patterns radially proximal to each of the plurality of light emitting diodes are formed with increasing surface areas as the patterns are angularly displaced from the directional reference of each said diode.
16. A method for conducting and substantially evenly dispersing light in a light-guide having a first surface of predetermined thickness and width, a second surface substantially planar and orthogonal to the first surface for exiting light, and a third surface substantially planar and parallel to the second surface to disperse light from a light source, comprising the steps of:
 - introducing light into the light-guide by optically coupling a substantially point source to the first surface;
 - dispersing the light in the light-guide with a plurality of patterns having varying surface areas on the third surface for a substantially even dispersement, the surface areas of the patterns being substantially directly proportional to the radial displacement from the substantially point source and to the angular displacement from the directional reference of the point source;
 - reflecting the light dispersed by the patterns from the third surface; and
 - exiting the light from the light-guide through the second surface.