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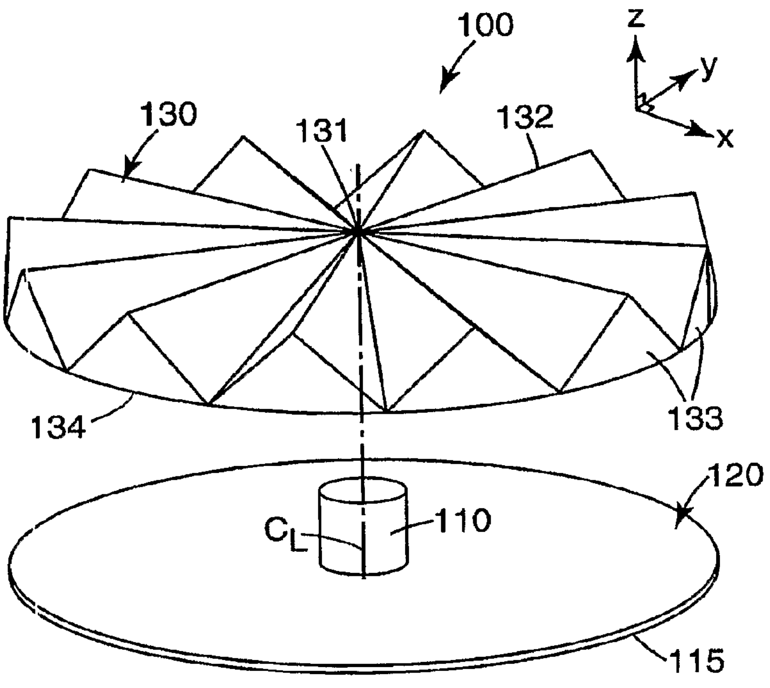
[Continued on next page]

(54) **Title:** LED EMITTER WITH RADIAL PRISMATIC LIGHT DIVERTER



(57) **Abstract:** An optical assembly includes a light emitting diode (LED) and a structured surface. The structured surface has a plurality of prismatic structures arranged radially with respect to a reference point, and is disposed relative to the LED such that the reference point is substantially aligned with a light emission axis of the LED. Arrays of such assemblies and backlights and displays including same are also disclosed.

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LED EMITTER WITH RADIAL PRISMATIC LIGHT DIVERTER

BACKGROUND

The present disclosure relates to LED light sources, particularly to such sources that include encapsulants, lenses, films, and the like that are shaped or otherwise configured to redirect light propagating initially along a light emitting axis into other directions. The resulting optical assembly is particularly useful, whether singly or in an array, in flat illumination sources (e.g., room lights), in backlights for liquid crystal display (LCD) devices and the like, such as TVs, computer monitors, personal digital assistants (PDAs), mobile telephones, and so forth.

SUMMARY

The present application discloses, *inter alia,* optical assemblies that include an LED and a structured surface. The structured surface includes a plurality of prismatic structures arranged radially with respect to a reference point. Preferably, the reference point is substantially aligned with a light emission axis of the LED. The light emission axis may correspond, for example, to a direction of maximum flux or brightness of the LED, or to an axis of symmetry of the LED or one of its components, such as the LED die or LED encapsulant (if present), or to an axis of symmetry of the light distribution of the LED, or to another selected direction associated with the LED.

In some cases, each of the prismatic structures has a prism apex that is substantially linear. The linear prism apices can all be oriented parallel to a reference plane, e.g., a reference plane perpendicular to the light emission axis of the LED, or the linear prism apices can be inclined in a conical arrangement relative to the light emission axis. In some cases, each of the prismatic structures has a prism apex that is curved. The curved prism apices can, if desired, be inclined in a funnel arrangement relative to the light emission axis. In some cases, the prismatic structures each have a prism apex, and the prism apices substantially intersect at the reference point. In some cases, the prismatic structures each has a prism apex with a first end proximate the reference point, but where the first ends of the prism apices are spaced apart from the reference point. In some cases, the LED includes an LED die disposed within an encapsulant, and the structured surface is disposed on the encapsulant, e.g., formed on an outer surface of the encapsulant or applied as a separate layer such as a film or cap to the encapsulant. In some cases, the optical assembly includes a reflective layer positioned to receive at least some LED light reflected by the structured surface.

Arrays of optical assemblies are also disclosed, wherein an array of LEDs is combined with an array of structured surfaces, each structured surface has a plurality of prismatic structures arranged radially with respect to a reference point. Preferably, the reference point for each structured surface is substantially aligned with a light emission axis of a corresponding LED. The LEDs can be disposed adjacent a reflective layer. If the LEDs each include an LED die disposed within an encapsulant, the structured surfaces can be formed individually on each of the encapsulants. Alternatively, the structured surfaces can be formed in a continuous optical film that extends over some or all of the LEDs in the array.

Backlights and displays incorporating the foregoing optical assemblies and arrays thereof are also disclosed.

These and other aspects of the present application will be apparent from the detailed description below. In no event, however, should the above summaries be construed as limitations on the claimed subject matter, which subject matter is defined solely by the attached claims, as may be amended during prosecution.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosure may be more completely understood in consideration of the following detailed description of various embodiments in connection with the accompanying drawings, in which:

FIG. 1 is a perspective view of an illustrative optical assembly;

FIG. 2 is a light flux leakage plot of the optical assembly shown in **FIG. 1**;

FIG. 3 is a perspective view of another illustrative optical assembly;

FIG. 4 is a light flux leakage plot of the optical assembly shown in **FIG. 3**;

FIG. 5 is a perspective view of another illustrative optical assembly;

FIG. 6 is a light flux leakage plot of the optical assembly shown in **FIG. 5**;

FIGS. 7-8 are perspective views of further illustrative optical assemblies;

FIG. 9 is a schematic sectional view of a further illustrative optical assembly;

FIG. 10 is a schematic perspective view of an LED light source; and

FIG. 11 is a schematic sectional view of an alternative LED light source.

While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention.

DETAILED DESCRIPTION

The present disclosure relates to optical assemblies that include an LED and a structured surface. The structured surface includes a plurality of prismatic structures arranged radially with respect to a reference point.

For the following defined terms, these definitions shall be applied, unless a different definition is given in the claims or elsewhere in this specification.

The recitation of numerical ranges by endpoints includes all numbers subsumed within that range (e.g. 1 to 5 includes 1, 1.5, 2, 2.75, 3, 3.80, 4, and 5).

As used in this specification and the appended claims, the singular forms "a", "an", and "the" include plural referents unless the content clearly dictates otherwise. Thus, for example, reference to a composition containing "a layer" includes of two or more layers. As used in this specification and the appended claims, the term "or" is generally employed in its sense including "and/or" unless the content clearly dictates otherwise.

Unless otherwise indicated, all numbers expressing quantities, measurement of properties and so forth used in the specification and claims are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification and claims are approximations that can vary depending upon the desired properties sought to be obtained by those skilled in the art utilizing the teachings of the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard deviations found in their respective testing measurements.

The term "LED" is used herein to refer to a diode that emits light, whether visible, ultraviolet, or infrared. It includes incoherent encased or encapsulated semiconductor devices marketed as "LEDs", whether of the conventional or super radiant variety. If the LED emits non-visible light such as ultraviolet light, and in some cases where it emits visible light, it can be packaged to include a phosphor (or it may illuminate a remotely disposed phosphor) to convert short wavelength light to longer wavelength visible light, in some cases yielding a device that emits white light. An "LED die" is an LED in its most basic form, i.e., in the form of an individual component or chip made by semiconductor processing procedures. For example, the LED die is ordinarily formed from a combination of one or more Group III elements and of one or more Group V elements (III-V semiconductor). Examples of suitable III-V semiconductor materials include nitrides, such as gallium nitride, and phosphides, such as indium gallium phosphide. Other types of III-V materials can be used also, as might inorganic materials from other groups of the periodic table. The component or chip can include electrical contacts suitable for application of power to energize the device. Examples include wire bonding, tape automated bonding (TAB), or flip-chip bonding. The individual layers and other functional elements of the component or chip are typically formed on the wafer scale, and the finished wafer can then be diced into individual piece parts to yield a multiplicity of LED dies. The LED die may be configured for surface mount, chip-on-board, or other known mounting configurations. Some packaged LEDs are made by forming a polymer encapsulant formed over an LED die and an associated reflector cup. The LED die has a quasi-Lambertian emission pattern and much of the light generated within the LED die is trapped due to total internal reflection at the die surface or emitted out of the polymer encapsulant directly above the LED die.

FIGS. 1, 3, and **5** depict LEDs schematically, and the reader will understand that any of the above-described types of LEDs are contemplated. Elements in these figures are not necessarily shown to scale and may be closer or further away from one another than is shown in these figures. While each figure shown is an individual structured surface element, it is understood that more than one structured surface elements can be present on a web or film to form a array of structured surface elements, which can then be sub-divided into smaller units, or used as an array, as described below. In addition, one or more layers of material (including air) may be present between the LED and the structured surface element. In some embodiments, the structured surface element is disposed within an encapsulant forming a packaged LED. In further embodiments, the LED is embedded within the structured surface element. In other embodiments, the structured surface elements be formed in a film that is extends over the LEDs as a distinct layer.

In backlight design, it is desirable to receive light from multiple compact sources and to spread out the light across a surface area (e.g., a LCD backlight illuminated directly with CCFL tubes or LEDs. The basic luminaire includes a cavity in which light propagates and reflects and eventually is extracted toward the viewer. Long light paths within the cavity are often desirable to permit adequate spreading such that uniformity is achieved.

One method to extend light paths is to confine light to a polymer lightguide, which may suffer loss if the polymer is absorptive. Alternatively, one can emit light directly within a hollow cavity bounded by a partially transmitting sheet and a fully reflective sheet. In the latter case, the light sources are normally chosen to emit the majority of light into angles close to the plane of the cavity so that light can spread freely with few reflections.

FIG. 1 is a perspective view of an illustrative optical assembly. The optical assembly **100** includes a light emitting diode (LED) **110** having a light emission axis C_L extending along a z-axis, an optional reflective layer **120** situated adjacent the LED **110**, and a structured surface element **130** is disposed over the LED **110** and optional reflective layer **120**. The structured surface element **130** preferably has an associated reference point **131** disposed along or substantially aligned with the light emission axis C_L. The structured surface element **130** has at least two, three or at least four linear prismatic structures **133** arranged (or extending) radially with respect to the reference point **131**. In many embodiments, the prism structures **133** emanate or originate at the reference point **131**.

FIG. 1 shows a structured surface element **130** having twelve linear prismatic structures **133** arranged radially with respect to the reference point **131**. Since each prismatic structure **133** has two prismatic facets or sides that intersect to form an extended apex **132**, the structured surface of element **130** has 24 such prismatic facets or sides. In many embodiments, each prismatic structure has an apex angle of 90 degrees. The structured surface element **130** can have any useful number of linear prismatic structures **133** arranged radially with respect to the reference point **131**. In many embodiments, the structured surface element **130** has any useful number of linear prismatic structures **133** arranged symmetrically with respect to the reference point **131** or to a line or plane containing the reference point **131**. In **FIG. 1**, each linear prismatic structure **133** has a prism apex **132** and these apices substantially intersect at the reference point **131**. The apices may have any useful apex angle between 10 degrees and 170 degrees, or between 70 degrees and 110 degrees, or about 90 degrees.

The prismatic structures **133** include a reference plane **134** and a substantially linear prism apex **132**. The reference plane **134** is perpendicular to the light emission axis C_L. As shown in **FIG. 1**, the reference place **134** can be parallel or substantially parallel to the linear apices **132**. In some embodiments, the reference plane **134** is parallel or substantially parallel to the linear apices **132** and the optional reflective layer **120**. When the reference plane **134** is parallel or substantially parallel to the linear apices **132**, this structured surface **130** can be termed a "flat-spine" diverting element. This flat-spine diverting element can have any useful thickness (along the z-axis) and may be disposed on the reflective layer **120** or the substrate layer **115**. The LED **110** can be separate from, or embedded within this flat-spine diverting element.

FIG. 2 is a calculated light flux leakage plot of the optical assembly shown in **FIG. 1**. This plot shows how the number of linear prism structures affects the light flux leakage of the flat-spine diverting element. This flat-spine diverting element can be formed of acrylic having a refractive index of about 1.5 to 1.8, and light can be emitted from a circular lambertian source of zero thickness embedded in the acrylic 0.98 mm from the top of the structured surface of the diverting element and 0.02 mm from the planar reflective bottom surface. The calculated flux emitted through the prismatic surface can be plotted verses the source dimension for flat-spine diverting elements having six, eight, twelve, and twenty-four sides (i.e., three, four, six, and twelve linear prism structures respectively radiating from the reference point), and a Fresnel disk (i.e., simple flat surface with no prism structures). This flat-spine diverting element causes light to march out from the LED light source at the light emitting axis C_L via total internal reflection by successive first and second reflections from adjacent first and second prismatic facets of the flat-spine diverting element. Thus, a bright center point is eliminated or mitigated as light exits the diverting element at a perimeter of the flat-spine diverting element.

The optional reflective layer **120** can be provided on a substrate **115**. The reflective layer **120** directs at least some light emitted from the LED **110** back into the structured surface element **130**. The reflective layer **120** can be specular or diffuse and formed of any useful material. The substrate **115** can be formed of any useful material. In some embodiments, the substrate **115** is formed of a metal, ceramic, or polymer. Conductors may be provided on different layers for carrying electrical current to and from the LED **110**. For example, conductors may be provided on the substrate **115**. The conductors may take the form of metallic traces, for example formed from copper.

LED light is emitted from the LED **110** over a wide range of angles. The structured surface element **130** described herein diverts and emits this LED light at the periphery of the diverting element. Light may be extracted from the periphery into air or into another optical body, or light may be extracted from the prismatic structures **133** by striking the first or second adjacent facets of such structures at angles that fail total internal reflection. The optical assembly may include features to scatter light, such as with a diffusely reflecting reflector **120**, or scattering particles within the prism medium, or surface roughness on the prism surfaces. This LED assembly can be described as a light confinement LED assembly.

If the apices have an upward slope, relative to the reference surface, toward the periphery and away from the reference point **131**, then the propagation angles of light are increasingly parallel to the reference plane **134** and or generally perpendicular to the light emission axis C_L (along the z-axis). Such LED assemblies can be described as side-emitting LED assemblies.

The structured surface element **130** can be formed of any useful material. In many embodiments, the structured surface element **130** is a polymeric material, transparent to the light emitted by the LED **110**. In some embodiments, the structured surface element **130** is formed from a polycarbonate, polyester, polyurethane, polyacrylate, and the like.

FIG. 3 is a perspective view of another illustrative optical assembly. The optical assembly **200** includes a light emitting diode (LED) **210** having a light emission axis C_L extending along a z-axis, an optional reflective layer **220** situated adjacent the LED **210**, and a structured surface element **230** disposed over the LED **210** and optional reflective layer **220**. In many embodiments, the structured surface element **230** has a reference point **231** disposed along or substantially aligned with the light emission axis C_L. The structured surface element **230** has at least two, three, or at least four linear prism structures **233** arranged (or extending) radially with respect to the reference point **231**. In many embodiments, the prism structures **233** emanate or originate at the reference point **231**.

FIG. 3 shows a structured surface element **230** having twelve linear prismatic structures **233** arranged radially with respect to the reference point **231**. Since each prismatic structure **233** has two prismatic facets or sides that intersect to form an extended apex **232**, the structured surface of element **230** has 24 such prismatic facets or sides. The structured surface element **230** can have any useful number of linear prismatic structures **233** arranged radially with respect to the reference point **231**. In many embodiments, the structured surface element **230** has any useful number of linear prismatic structures **233** arranged symmetrically with respect to the reference point **231** or a line or plane containing reference point **231**. In many embodiments, each linear prismatic structure **233** has a prism apex **232** and these apices substantially intersect at the reference point **231**.

The prismatic structures **233** include a reference plane **234** and a substantially linear apex **232**. As shown in **FIG. 3**, the reference plane **234** is non-parallel or substantially non-parallel with the linear apices **232**. In some embodiments, the reference plane **234** is parallel or substantially parallel with the optional reflective layer **220**. In the illustrated embodiment, the linear apices **232** form a linear incline slope with respect to the reference plane **234** and are in a conical arrangement with respect to the light emission axis C_L. This structured surface element **230** can be termed a "sloped-spine" diverting element. This sloped-spine diverting element can have any useful thickness (along the z-axis) and may be disposed on the reflective layer **220** or the substrate layer **215**. The LED **210** can be separate from, or embedded within this sloped-spine diverting element. The slope of the apices 232 relative to reference plane 234 can be selected according to the desired light emission pattern from the optical assembly. In many cases the slope will be adjusted to enhance or maximize side-emission, i.e., light emitted in directions that are substantially parallel to the x-y plane or substantially perpendicular to the light emission axis of the LED, and likewise the slope can be adjusted to diminish or minimize light emitted parallel to the light emission axis. Also, as explained further below in connection with curved prismatic structures, the slope can change continuously over the length of each prismatic structure. Preferably, the slope is in a range from 2 to 80 degrees, or 5 to 30 degrees, or about 15 degrees.

FIG. 4 is a calculated light flux leakage plot of the optical assembly shown in **FIG. 3**. This plot shows how the number of linear prism structures affects the light flux leakage of the sloped-spine diverting element. This sloped-spine diverting element can be formed of acrylic (described above), and light can be emitted from a circular lambertian source embedded in the acrylic 0.98 mm from the top of the surface of the sloped-spine diverting element and 0.02 mm from the planar reflective bottom surface. For purposes of **FIG. 4**, the slope of the apices **232** was set to approximately 15 degrees. The calculated flux emitted through the prismatic surface is plotted verses the source dimension for this sloped-spine diverting elements having six, eight, twelve, and twenty-four sides, i.e., three, four, six, and twelve prismatic structures **233**. This sloped-spine diverting element causes light to march out from the LED light source at the light emitting axis C_L via total internal reflection by successive first and second reflections from adjacent first and second prismatic facets of the sloped-spine diverting element. Thus, a bright center point is eliminated or mitigated as light exits the diverting element at a perimeter of the diverting element.

FIG. 5 is a perspective view of another illustrative optical assembly. The optical assembly **300** includes a light emitting diode (LED) **310** having a light emission axis C_L extending along a z-axis, an optional reflective layer **320** situated adjacent the LED **310**, and a structured surface element **330** disposed over the LED **310** and optional reflective layer **320**. In many embodiments, the structured surface element **330** has a reference point **331** disposed along or substantially aligned with the light emission axis C_L. The structured surface element **330** has at least two, three or at least four prism structures **333** arranged (or extending) radially with respect to the reference point **331**. In many embodiments, the prism structures **333** emanate or originate at the reference point **331**.

FIG. 5 shows a structured surface element **330** having twelve prismatic structures **333** arranged radially with respect to the reference point **331**. Since each prismatic structure **333** has two prismatic facets or sides that intersect to form an extended curved apex **332**, the structured surface of element 330 has 24 such prismatic facets or sides. The structured surface element **330** can have any useful number of prismatic structures **333** arranged radially with respect to the reference point **331**. In many embodiments, the element **330** has any useful number of prismatic structures **333** arranged symmetrically with respect to the reference point **331** or a line or plane containing reference point **331**. In many embodiments, each prismatic structure **333** has a prism apex **332** and these apices substantially intersect at the reference point **331**.

The prismatic structures **333** include a reference plane **334** and a curved apex **332**. As shown in **FIG. 5**, the reference plane **334** is non-parallel or substantially non-parallel with the apices **332**. In some embodiments, the reference plane **334** is parallel or substantially parallel with the optional reflective layer **320**. In the illustrated embodiment, the apices **332** form a curved slope with respect to the reference plane **334** and are inclined in a funnel arrangement relative to the light emitting axis C_L. This illustrated structured surface element **330** can be termed a "curved-spine" diverting element. This curved-spine diverting element can have any useful thickness (along the z-axis) and may be disposed on the reflective layer **320** or the substrate layer **315**. The LED **310** can be separate from, or embedded within this curved-spine diverting element.

FIG. 6 is a calculated light flux leakage plot of the optical assembly shown in **FIG. 5**. This plot shows how the number of curved prism structures affects the light flux leakage of the structured surface element. This structured surface element can be formed of acrylic (described above), and light can be emitted from a circular lambertian source embedded in the acrylic 0.98 mm from the top of the surface of the optical element and 0.02 mm from the planar reflective bottom surface. For purposes of **FIG. 6**, the curve of the prism apices **332** was approximately an elliptic shape of revolution where the semimajor and semiminor axes were 1mm and 0.7mm respectively and the axis of revolution was approximately 0.1mm in from the origin. The calculated flux emitted through the prismatic surface is plotted verses the source dimension for curved-spine diverting elements having six, eight, twelve, and twenty-four sides, i.e., three, four, six, and twelve prismatic structures **333**. This curved-spine diverting element causes light to march out from the LED light source at the light emitting axis C_L via total internal reflection by successive first and second reflections from adjacent first and second prismatic facets of the curved-spine diverting element. Thus, a bright center point is eliminated or mitigated as light exits the diverting element at a perimeter of the diverting element.

FIG. 7 is a perspective view of a further illustrative structured surface element **430**. The structured surface element **430** has a reference point **431** disposed along or substantially aligned with a light emission axis C_L. The structured surface element **430** includes a funnel-shaped recess **435** disposed at the reference point **431** and along the light emitting axis C_L (along a z-axis). The funnel shaped recess **435** can be utilized in any of the embodiments described herein. In many embodiments, the funnel shaped recess **435** has a rotationally symmetric shape about the light emitting axis C_L.

The structured surface element has at least two, three, or at least four linear prism structures or sides **433** each having a prism apex **432** and a first end proximate the reference point **431**. In the illustrated embodiment, the first ends of the prism apices are spaced apart from the reference point **431**. The structured surface element **430** prism structures **433** are arranged symmetrically with respect to the reference point **431** or a line or plane containing reference point **431**. In many embodiments, the prism structures **433** emanate or originate at the reference point **431** if extended into the funnel-shaped recess **435**. **FIG. 7** shows an optical element **430** having twelve linear prism structures **433** extending from the funnel-shaped recess **435**.

The recess or funnel-shaped recess **435** can have a rotationally symmetric shape about the light emitting axis C_L and/or reference point **431** and be disposed above and in registration with the LED (as described above). LED emitted light is totally internally reflected at the funnel shaped recess **435** surface and directed away from the light emitting axis C_L. The recess or funnel-shaped recess **435** includes a cusp at the reference point **431**. In many embodiments, the recess or funnel-shaped recess **435** is formed within the upper surface of the structured surface element **430**. The recess or funnel-shaped recess **435** curve can be calculated and revolved about the light emitting axis C_L to form the funnel shape that confines substantially all LED emitted light to the structured surface element **430**. In many embodiments, the funnel-shaped recess **435** has a rotationally symmetric shape about the light emitting axis C_L.

FIG. 8 is a perspective view of a further illustrative structured surface element **530**. The structured surface element **530** includes a plurality of linear prism structures or sides **533** extending from the reference point **531**. The reference point **531** can be disposed along the light emitting axis C_L extending along a z-axis. The structured surface element **530** has at least two, three, or at least four linear prismatic structures **533** arranged (or extending) radially with respect to the reference point **531**. The structured surface element **530** prism structures **533** are arranged symmetrically with respect to the reference point **531** or a line or plane containing reference point **531**. In many embodiments, the prism structures **533** emanate or originate at the reference point **531**. **FIG. 8** shows a structured surface element **530** having eight linear prism structures **533** arranged radially with respect to the reference point **531**. In many embodiments, each linear prismatic structure **533** has a prism apex **532** and these apices substantially intersect at the reference point **531**.

FIG. 9 is a schematic sectional view of another structured surface element **630**. The structured surface element **630** has a reference point **631** disposed along or substantially aligned with a light emission axis C_L. The structured surface element **630** includes a funnel-shaped recess **635** disposed about an outer perimeter **633**. While a flat-spine diverting element is shown in **FIG. 9**, this outer funnel shaped recess **635** can be utilized in any of the embodiments described herein. In many embodiments, the funnel shaped recess **635** has a rotationally symmetric shape about the light emitting axis C_L.

The structured surface element **630** has at least two, three, or at least four linear prism structures or sides each having a prism apex **632** and a first end proximate the reference point **631**. The structured surface element **630** prism structures are arranged (or extend) radially with respect to the reference point **631**. The structured surface element **630** can have any useful number of linear prismatic structures arranged radially with respect to the reference point **631**, as described above.

The recess or funnel-shaped recess **635** can have a rotationally symmetric shape about the light emitting axis C_L and/or reference point **631**. LED emitted light is totally internally reflected at the funnel shaped recess **635** surface and directed away from the light emitting axis C_L. In many embodiments, the recess or funnel-shaped recess **635** is formed within the upper surface of the structured surface element **630** and extends upwardly and away from the outer perimeter **633** (as shown). The recess or funnel-shaped recess **635** curve can be calculated and revolved about the light emitting axis C_L to form the funnel shape that confines substantially all LED emitted light to the structured surface element **630**. In many embodiments, the funnel-shaped recess **635** has a rotationally symmetric shape about the light emitting axis C_L.

FIG. 10 is a schematic perspective view of an LED light source useful in any of the embodiments disclosed herein. This light source is an LED die. This LED die can include one or more electrical contact pads, e.g., in the center of the LED die (not shown). A light emitting axis C_L is shown extending through the center of the LED die.

FIG. 11 is a schematic sectional view of an alternative LED light source useful in any of the embodiments disclosed herein. This LED light source includes an encapsulant that surrounds the LED die, reflective cup, and wire bond. Such LED sources are commercially available from a number of manufacturers. A light emitting axis C_L is shown extending through the center of the LED die and encapsulant.

In some embodiments, multiple structured surface elements can be combined to form arrays of structured surface elements. An array of LEDs can be combined with the array of structured surface elements, where each structured surface element has a plurality of prismatic structures arranged radially with respect to a reference point. Preferably, the reference point for each structured surface element is substantially aligned with a light emission axis of a corresponding LED. In some embodiments, the LEDs can be disposed adjacent a reflective layer. If the LEDs each include an LED die disposed within an encapsulant, the structured surface elements can be formed individually on each of the encapsulants. Alternatively, the structured surface elements can be formed in a continuous optical film that extends over some or all of the LEDs in the array.

The optical assemblies and arrays described herein can be utilized in a variety of flat illumination, display, or backlight applications where an optical display element is disposed above the structured surface element for emitting the light.

The optical assemblies and arrays described herein can be formed by any useful method. In some embodiments, these optical assemblies and arrays are molded. In some embodiments, these optical assemblies and arrays are formed on a web or film of any length.

The present invention should not be considered limited to the particular examples described herein, but rather should be understood to cover all aspects of the invention as fairly set out in the attached claims. Various modifications, equivalent processes, as well as numerous structures to which the present invention can be applicable will be readily apparent to those of skill in the art to which the present invention is directed upon review of the instant specification.

WHAT IS CLAIMED IS:

1. An optical assembly, comprising:

a light emitting diode (LED) having a light emission axis; and

a structured surface comprising a plurality of prismatic structures arranged radially with respect to a reference point, the structured surface disposed relative to the LED such that the reference point is substantially aligned with the light emission axis.

2. The optical assembly of claim 1, wherein each of the prismatic structures has a substantially linear prism apex.

3. The optical assembly of claim 2, wherein each prism apex is parallel to a reference plane, the reference plane being perpendicular to the light emission axis.

4. The optical assembly of claim 2, wherein the prism apices are inclined in a conical arrangement relative to the light emission axis.

5. The optical assembly of claim 1, wherein each of the prismatic structures has a curved prism apex.

6. The optical assembly of claim 5, wherein the prism apices are inclined in a funnel arrangement relative to the light emission axis.

7. The optical assembly of claim 1, wherein each of the prismatic structures has a prism apex, and the prism apices substantially intersect at the reference point.

8. The optical assembly of claim 1, wherein each of the prismatic structures has a prism apex having a first end proximate the reference point, the first ends of the prism apices being spaced apart from the reference point.

9. The optical assembly of claim 8, wherein the diverting element also includes a funnel-shaped recess at the reference point, the first ends of the prism apices being arranged around the recess.

10. The optical assembly of claim 1, further comprising:
a reflective layer positioned to receive at least some LED light reflected by the a structured surface.

11. The optical assembly of claim 1, wherein the LED includes an LED die disposed within an encapsulant, and wherein the structured surface is disposed on the encapsulant.

12. The optical assembly of claim 11, wherein the structured surface is formed in an outer surface of the encapsulant.

13. The optical assembly of claim 11, wherein the structured surface is formed in a diverting element and is disposed on the encapsulant.

14. The optical assembly of claim 1, wherein the prismatic structures divert at least some light from the LED by total internal reflection.

15. The optical assembly of claim 1, wherein a given prismatic structure diverts at least some light from the LED by successive first and second reflections from adjacent first and second prismatic facets respectively.

16. The optical assembly of claim 1, wherein the structured surface includes a funnel-shaped recess having a rotationally symmetric shape about the light emission axis.

17. An array of optical assemblies according to claim 1.

18. The array of claim 17, further comprising:
a reflective layer disposed adjacent the LEDs.

19. The array of claim 17, wherein the diverting elements are formed on an optical film that extends over at least some of the LEDs.

20. A backlight comprising the optical assembly of claim 1.

21. A backlight comprising the array of claim 17.

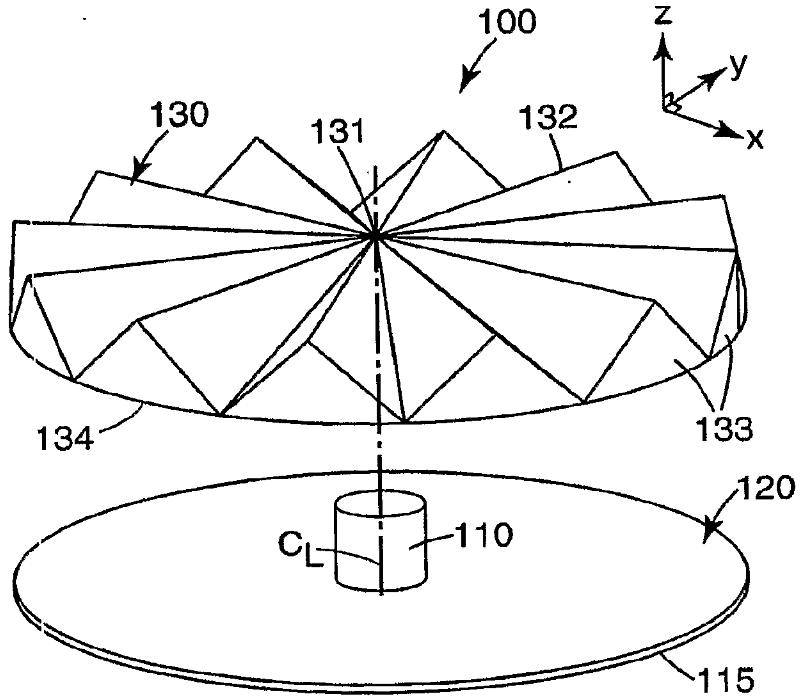
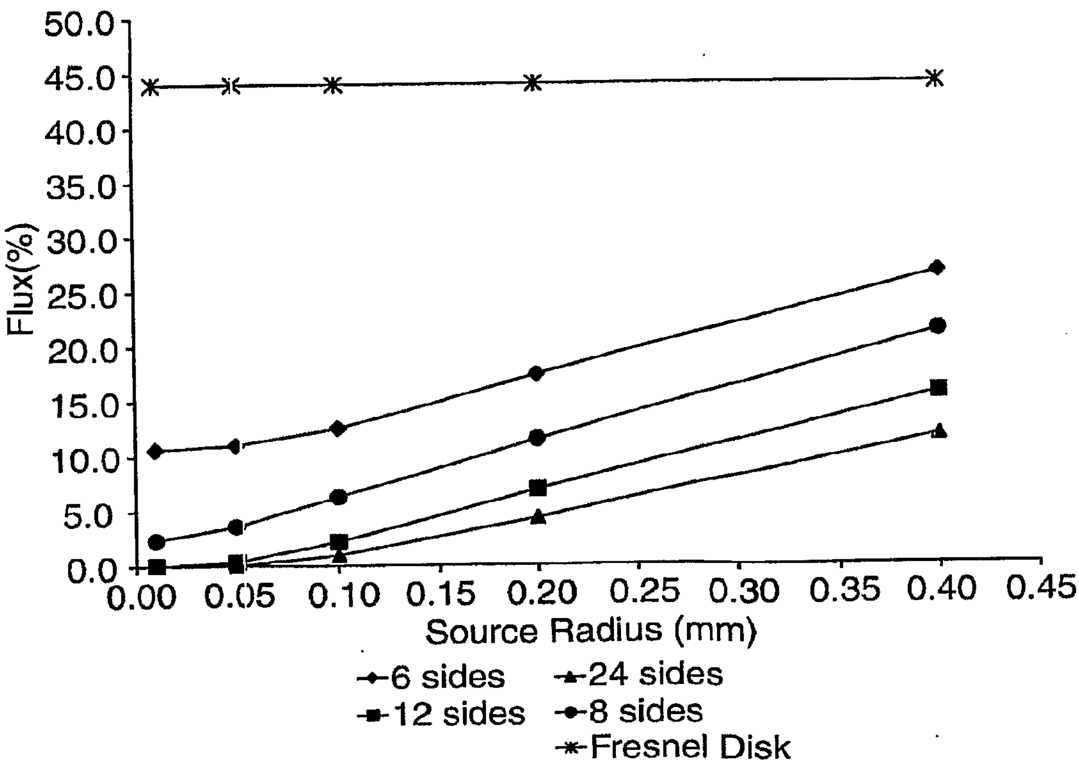

100
z
y
x
130
131
132
134
133
120
CL
110
115

Fig. 1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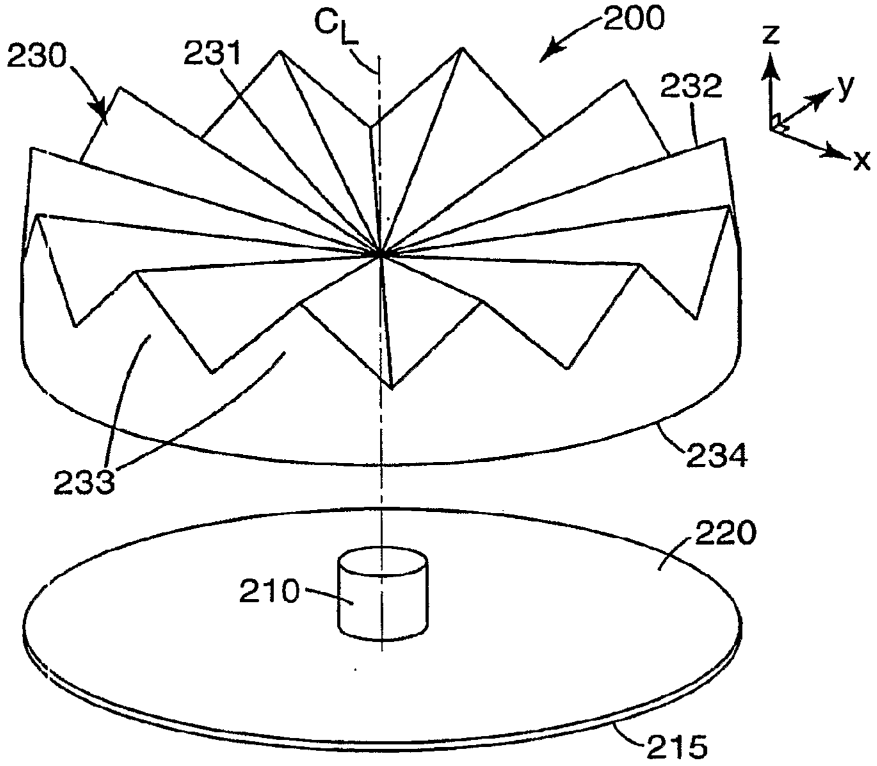
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Flux(%)
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45
Source Radius (mm)
6 sides
24 sides
12 sides
8 sides
Fresnel Disk

Fig. 2



CL
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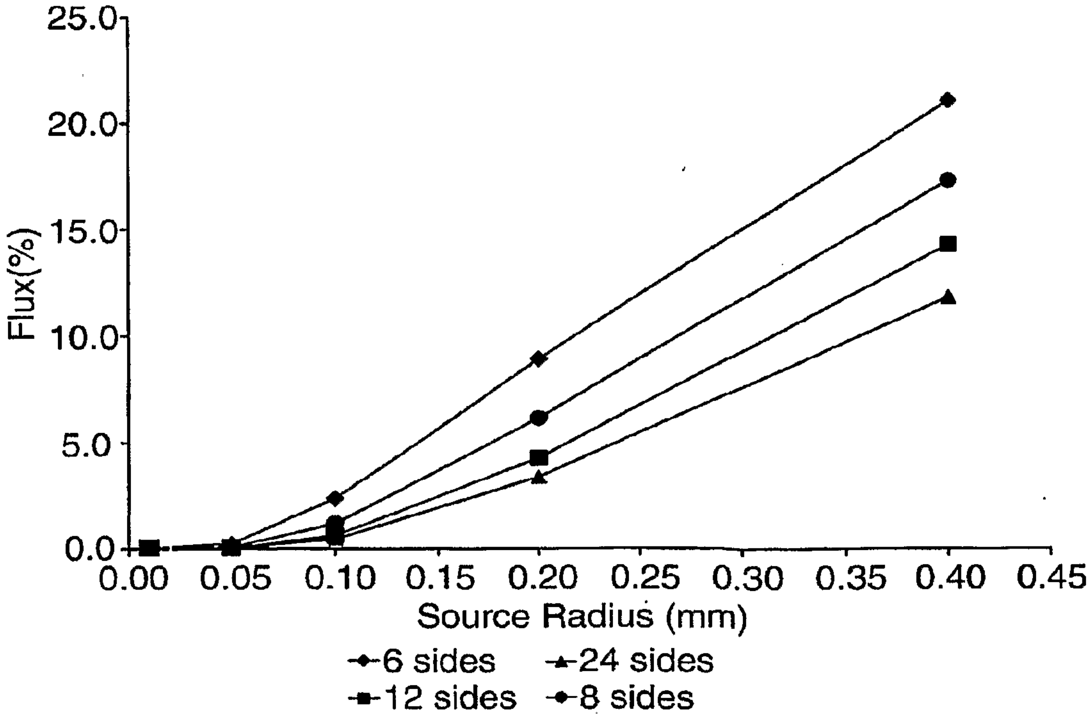
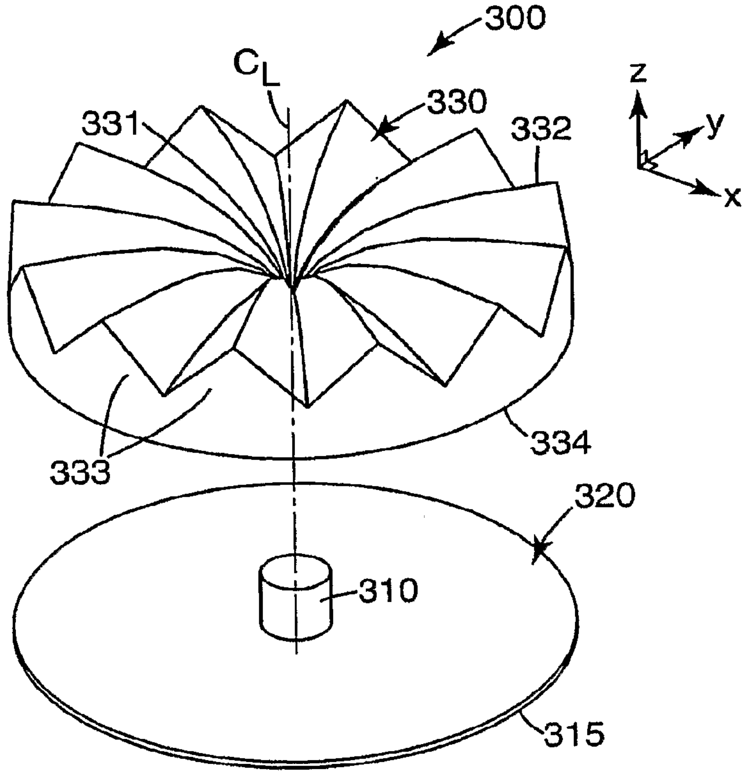
230
231
232
z
y
x
233
234
220
210
215

Fig. 3



25.0
20.0
15.0
10.0
5.0
0.0
Flux(%)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
Source Radius (mm)
6 sides
24 sides
12 sides
8 sides

Fig. 4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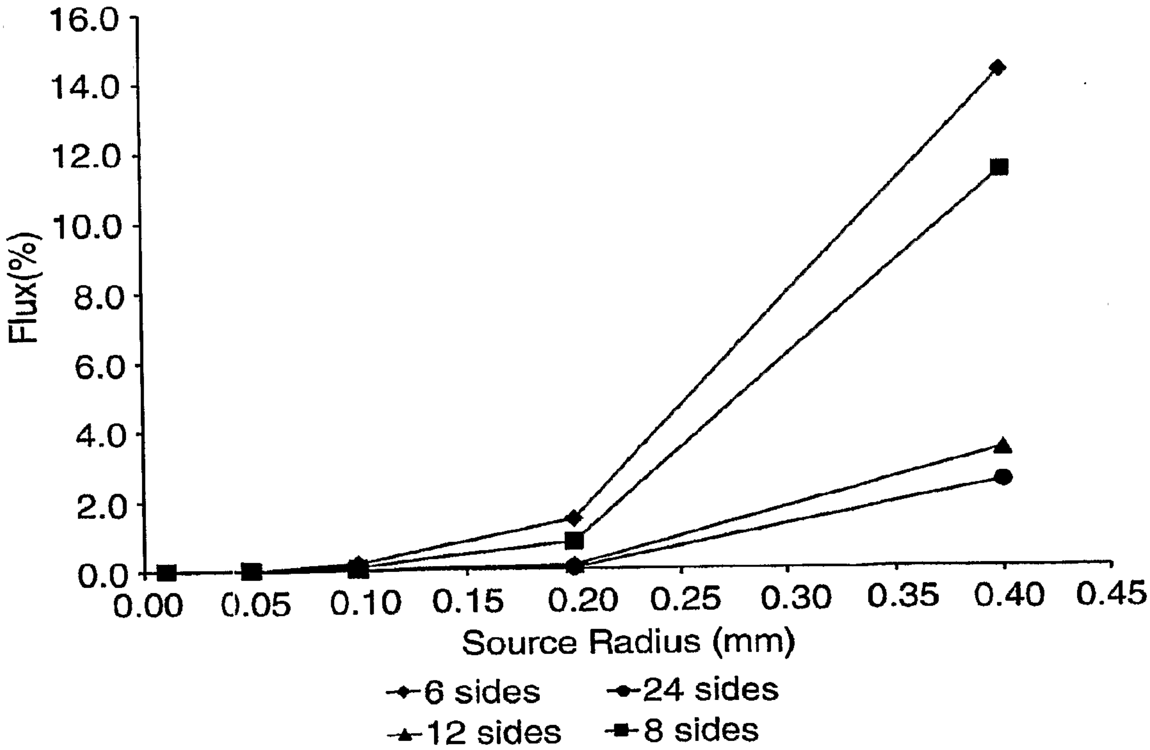
330
332
z
y
x
333
334
320
310
315

Fig. 5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8.0
6.0
4.0
2.0
0.0
Flux(%)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
Source Radius (mm)
6 sides
24 sides
12 sides
8 sides

Fig. 6

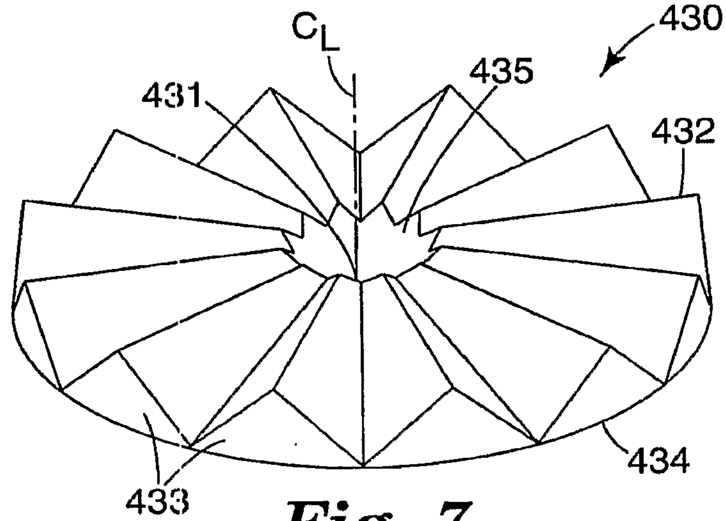

Fig. 7

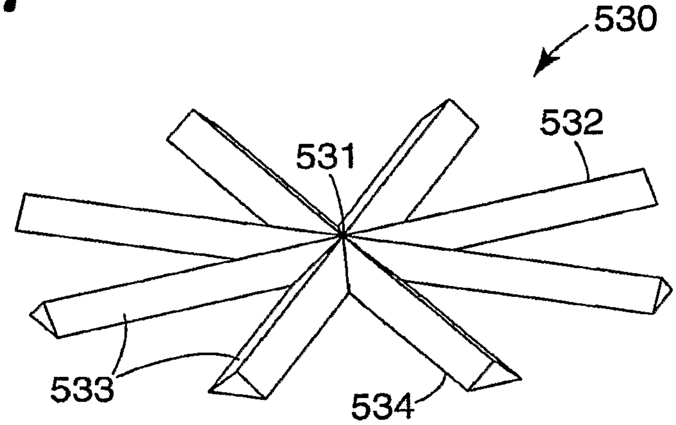

Fig. 8

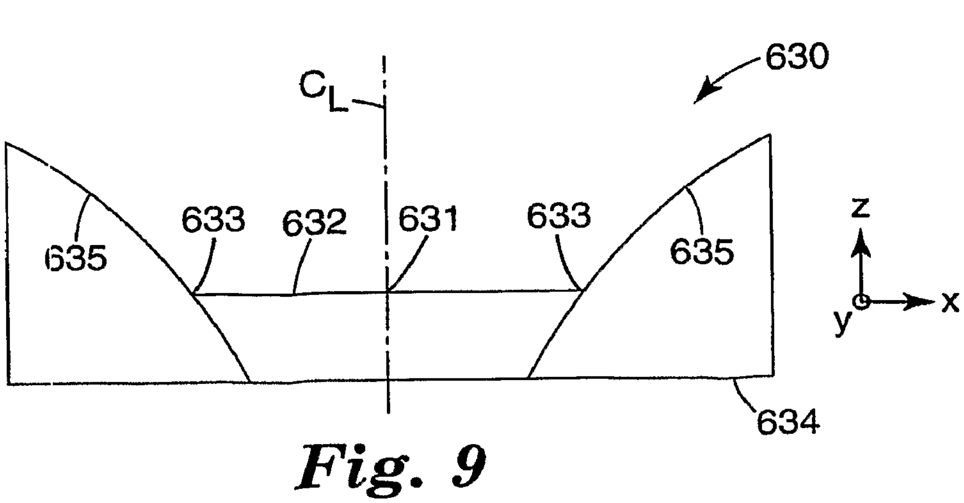

Fig. 9

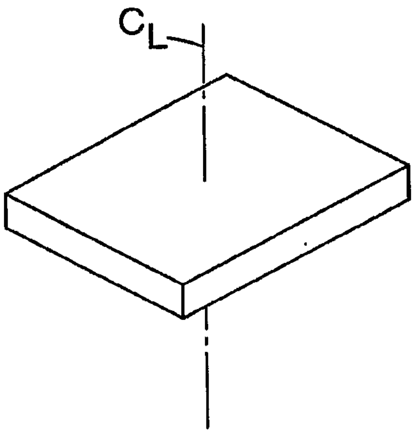

Fig. 10

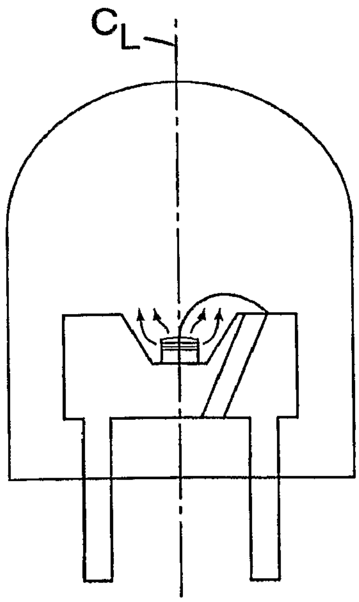

Fig. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2006/047580

A. CLASSIFICATION OF SUBJECT MATTER

H01L 33/00(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)

IPC8 H01L

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

Korean Utility models and applictions for Utility models since 1975

Japanese Utility models and application 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) "radial prismatic light diverter"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 02/052656 A1 (KONINKLIJKE PHILIPS ELECTRONICS N.V.) 4 Jul. 2002 See Figures 1, 2	1
A	JP 16-133391 A (LUMILEDS LIGHTING US LLC) 30 Apr. 2003 See Abstract; Figure 5	1
A	KR 10-2005-0096510 A (SAMSUNG ELECTRO-MECHANICS CO., LTD.) 6 Oct. 2005 See Figure 1	1
A	KR 10-2002-0080834 A (OPTONICA CO., LTD.) 26 Oct. 2002 See Figure 2	1

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

☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" 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

"X" 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

"Y" 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	Date of mailing of the international search report
20 JUNE 2007 (20.06.2007)	**20 JUNE 2007 (20.06.2007)**

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Facsimile No. 82-42-472-7140

Authorized officer

LEE, Jin Hong

Telephone No. 82-42-481-8509

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