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(57) Abstract: A lighting system can comprise an array of domed light emitting diodes covering a surface area of a substrate and two optics for processing emitted light. The first optic can comprise an inner surface facing the array and an exterior surface facing away from the array. The second optic can comprise grooves extending away from the array. The inner surface of the first optic can form a cavity that is large relative to the array. For example, the cavity can have a volume exceeding the volume of a cube, where each side of the cube has the surface area of the array.



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LED-BASED LUMINAIRE

FIELD OF THE TECHNOLOGY

The field of the technology relates generally to illumination systems and more specifically to an illumination system that includes an array of light emitting diodes (“LEDs”) and at least two optics that process light emitted by the array of light emitting diodes, as may be useful for exterior lighting.

BACKGROUND

Light emitting diodes are useful for indoor and outdoor illumination, as well as other applications. Many such applications would benefit from an improved technology for managing light produced by a light emitting diode, such as forming an illumination distribution matched or tailored to application parameters.

For example, consider lighting an area with an array of light emitting diodes pointing downward, towards the ground. With many conventional light emitting diodes, the resulting illumination pattern would be relatively concentrated on the ground. However, efficiently spreading the light to provide a larger illumination area would be beneficial for many applications.

Need for improved light management is apparent. Need exists for a robust apparatus to manage light emitted by one or more light emitting diodes. Need further exists for an economical apparatus to manage light emitted by an array of light emitting diodes. Need further exists for a technology that can efficiently manage light emitted by one or more light emitting diodes, resulting in energy conservation. Need further exists for an optical device that can transform light emanating from a two-dimensional array of light emitting diodes into a desired distribution, for example redirecting light that is concentrated in one area so that the illuminated area is expanded. A capability addressing one or more such needs, or some other related deficiency in the art, would support cost effective deployment of light emitting diodes in lighting and other applications.

SUMMARY

An apparatus can process light emitted by one or more light emitting diodes to form a desired illumination distribution, for example converting light that is concentrated in one direction into a spread of light conducive to illuminating a relatively large area.

5 In one aspect of the present technology, a lighting system can comprise one or more light emitting diodes and two optics oriented to process emitted light. A first optic can comprise a cavity facing the light emitting diodes for subjecting emitted light to a first level of processing. A second optic can subject emitted light to a second level of processing. The second optic can comprise grooves extending lengthwise along an
10 optical axis of the lighting system.

 In another aspect of the present technology, a lighting system can comprise an array of light emitting diodes and an optic positioned to process light emitted by the light emitting diodes. The array can be distributed across a surface area, for example on a substrate. The optic can comprise a cavity that faces the array of light emitting diodes
15 and receives light from the light emitting diodes. The optic can further comprise an outer surface that faces away from the array of light emitting diodes and that emits the received light. The cavity can be large relative to the array of light emitting diodes. For example, the cavity can have a volume exceeding the volume of a cube, where each face of the cube has a surface area equal to the surface area of the array. The optic can be utilized in
20 the lighting system either with or without a secondary optic.

 The foregoing discussion of managing light is for illustrative purposes only. Various aspects of the present technology may be more clearly understood and appreciated from a review of the following detailed description of the disclosed embodiments and by reference to the drawings and the claims that follow. Moreover,
25 other aspects, systems, methods, features, advantages, and objects of the present technology will become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such aspects, systems, methods, features, advantages, and objects are to be included within this description, are to be within the scope of the present technology, and are to be protected by the
30 accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1A, 1B, 1C, and 1D, collectively Figure 1, are side-, back-, top-, and bottom-view illustrations of a lighting system according to certain exemplary embodiments of the present technology.

5 Figures 2A and 2B, collectively Figure 2, are exploded or assembly illustrations, in two perspective views, of a lighting system according to certain exemplary embodiments of the present technology.

10 Figure 3 is partial cutaway illustration of a lighting system, taken along a mounting bracket of the lighting system, according to certain exemplary embodiments of the present technology.

Figure 4 is a cross sectional illustration of a lighting system, taken perpendicular to the mounting bracket of the lighting system, according to certain exemplary embodiments of the present technology.

15 Figure 5A is a perspective view of a primary optic for managing light emitted by an array of light emitting diodes in a lighting system, wherein the optic is depicted as opaque to promote visualization of certain surface features, according to certain exemplary embodiments of the present technology.

Figure 5B is an illustration of a light emitting diode module for a lighting system according to certain exemplary embodiments of the present technology.

20 Figure 6 is a cross sectional illustration of a primary optic and an associated array of light emitting diodes in a lighting system according to certain exemplary embodiments of the present technology.

25 Figure 7 is a cross sectional illustration of a primary optic and associated path traces of rays in a lighting system according to certain exemplary embodiments of the present technology.

Figure 8 is a perspective view of a secondary optic for managing light emitted by an array of light emitting diodes in a lighting system, wherein the optic is depicted as opaque to promote visualization of certain surface features, according to certain exemplary embodiments of the present technology.

Figure 9 is a cross sectional illustration of a portion of a secondary optic and associated path traces of rays in a lighting system according to certain exemplary embodiments of the present technology.

Figures 10A, 10B, and 10C, collectively Figure 10, are simulated illuminance iso-footcandle plots for a lighting system meeting a 4000 lumen specification according to certain exemplary embodiments of the present technology.

Figure 11 is a simulated illuminance iso-footcandle plot for a lighting system meeting a 2500 lumen specification according to certain exemplary embodiments of the present technology.

Many aspects of the technology can be better understood with reference to the above drawings. The elements and features shown in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of exemplary embodiments of the present technology. Moreover, certain dimensions may be exaggerated to help visually convey such principles. In the drawings, reference numerals designate like or corresponding, but not necessarily identical, elements throughout the several views.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

A light generator can emit light. In certain embodiments, the light generator can be or comprise one or more light emitting diodes, such as an array of light emitting diodes. The light generator can emit light that presents a circular or elliptical illumination distribution on an illuminated surface. With an appropriately configured optical system, the light generator can be deployed in applications where an expanded illumination distribution is desired, for example to light a larger area. Thus, the optical system can process light emitted by the light generator to provide a larger illumination distribution on the surface, such as substantially increasing the diameter of a circular illuminance iso-footcandle line or magnifying an elliptical pattern.

In certain embodiments, such an optical system can receive light from an array of light emitting diodes, where each light emitting diode has an associated dome. The array can extend in two dimensions on a substrate, thereby covering a surface area of the substrate with a footprint. (The term “footprint,” as used herein, refers to the surface

space occupied by something, including interstitial spaces where a group of things are occupying surface space.) The array can be coupled to an optic comprising a cavity that receives light from the domes and an outer surface that emits the received light. For example, the domes can protrude into or be disposed in the cavity of the optic. The
5 cavity can be sized to accommodate the array.

In certain embodiments, the cavity can have a volume that is large relative to the array. For example, suppose each face of a cube had a surface area equal to the footprint of the array. In certain embodiments, the cavity's volume can exceed the volume of such a cube. In certain embodiments, the cavity can be sufficiently large so that such a cube
10 could fit inside the cavity. In certain embodiments, the cavity can be sized such that at least one edge of such a cube could fit in the cavity. In certain embodiments, at least one dimension of the array could fit in the cavity.

In certain embodiments, the optic having the cavity is a primary optic and is coupled to a secondary optic. Thus, the array of light emitting diodes can be coupled to
15 an optical system comprising a primary optic and a secondary optic. In certain embodiments, the secondary optic comprises a pattern of grooves that extend along an optical axis. Light emitted from the primary optic can encounter the secondary optic and be expanded to spread the light and provide a broadened pattern of light as may be useful to illuminate a large area, among other applications.

20 Technology for managing light emitted by an array of light emitting diodes or will now be described more fully with reference to Figures 1-11, which describe representative embodiments of the present technology. Figures 1-9 describe features and elements of a representative lighting system, while Figure 10 describes representative light output characteristics for the system. Figure 11 describes representative light output
25 characteristics for another system having a lower lumen specification.

The present technology can be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the technology to those having ordinary skill in the art. Furthermore, all
30 "examples" or "exemplary embodiments" given herein are intended to be non-limiting and among others supported by representations of the present technology.

Figures 1 and 2 will now be discussed. Figure 1 illustrates side, back, top, and bottom views of an exemplary lighting system 100 in accordance with certain embodiments of the present technology. Figure 2 illustrates, in two perspective views, the lighting system 100 in an exemplary exploded or assembly form in accordance with
5 certain embodiments of the present technology. In the illustrated embodiment, the lighting system 100 can be characterized as an exterior luminaire or an outdoor luminaire.

As illustrated, the lighting system 100 comprises a housing 1 that includes a bracket 130 for mounting to a wall or other site. Fasteners 7 attach an arm cover bracket 3 to the underside of the housing 1, as part of the mounting bracket 130. Heat sink fins
10 76 carry heat associated with internal electronics away from the lighting system 100.

A photocell 8 provides automatic cut-on at dusk and cutoff at dawn. A socket 12 connects the photocell 8 to the lighting system 100. When the lighting system 100 is deployed indoors, the photocell 8 may be bypassed or eliminated.

The lighting system 100 comprises a light emitting diode module 10 that produces
15 light as will be discussed in further detail below. A primary optic 150, which will also be discussed in further detail below, processes the light produced by the light emitting diode module 10. A secondary optic 125, also discussed below, subjects the light to a second level of processing.

Fasteners 2 attach the light emitting diode module 10 and the primary optic 150 to
20 the housing 1. The secondary optic 125 mounts to the housing 1 via a circular bracket 4, thereby positioning the secondary optic 125 in an opening or aperture 220 of the housing.

A bracket 13 and associated fasteners 5 mount a light emitting diode driver 6 to the housing 1. The light emitting diode driver 6 transforms line power to a form suitable for powering the light emitting diode module 10. A grounding contact 14 mounts to the
25 housing 1 via a fastener 16 and an associated lock washer 15.

Referring now to Figure 3, this figure illustrates in cutaway an exemplary embodiment of the lighting system 100 in accordance with certain embodiments of the present technology.

In the exemplary embodiment shown in Figure 3, the primary optic 150 projects
30 or extends through the circular bracket 4, thereby positioning the primary optic 150 and the secondary optic 125 to collaboratively spread light emitted from the light emitting

diode module 10. As will be discussed in further detail below, the light emitting diode module 10 comprises an array 300 of light emitting diodes.

In the illustrated embodiment, the primary optic 150, the secondary optic 125, and the light emitting diode module 10 have a common optical axis 350. The optical axis 350
5 may be associated with a distribution of emitted light and/or associated with physical structure or mechanical features.

The term “optical axis,” as used herein, generally refers to a reference line along which there is some degree of rotational or other symmetry in an optical system, or a reference line defining a path along which light propagates through a system or after
10 exiting a system. Such reference lines are often imaginary or intangible lines.

In certain embodiments, the primary optic 150 has an optical axis that is laterally offset from or tilted with respect to the optical axis of the secondary optic 125. Moreover, the light emitting diode module 10 may have an optical axis that is laterally offset from or tilted with respect to the optical axis of the primary optic 150, and may
15 further be offset or tilted relative to the optical axis of the secondary optic 125. In certain embodiments, the primary optic 150, the secondary optic 125, and the light emitting diode module 10 may have optical axes that are all laterally offset from one another or tilted relative to one another.

In certain embodiments, the light emitting diode module 10 may be of a form that
20 lacks a composite optical axis along which there is rotational symmetry. In certain embodiments, the primary optic 150 may be of a form that lacks an optical axis along which there is rotational symmetry. In certain embodiments, the secondary optic 125 may be of a form that lacks an optical axis along which there is rotational symmetry.

In certain embodiments, the lighting system 100 incorporates the primary optic
25 150 without the secondary optic 125. In certain embodiments, the lighting system 100 incorporates the secondary optic 125 without the primary optic 150. Additionally, the various components and features disclosed herein may be utilized as standalone elements or integrated together to form modules or subsystems utilized in some other appropriate system or application.

30 The present disclosure and teaching is sufficiently rich and detailed to enable one of ordinary skill in the art to make and use a wide variety of optic embodiments by

combining various features illustrated in the figures and described in text in accordance with principles of the present technology. Moreover, one of ordinary skill will be able to apply the present teaching readily to adapt the various disclosed features according to application parameters and preferences.

5 Referring now to Figure 4, this figure illustrates in cross section an exemplary embodiment of the lighting system 100 in accordance with certain embodiments of the present technology. Figure 4 further illustrates exemplary rays 400 emitted by one of the light emitting diodes 401 in the light emitting diode module 10 and processed by the primary optic 150 and the secondary optic 125. The primary optic 150 and the secondary
10 optic 125 collaboratively direct the rays 400 into a wider distribution, thereby spreading the emission pattern to facilitate expanding the area illuminated by the lighting system 100.

Referring now to Figure 5A, this figure illustrates in perspective view an exemplary embodiment of the primary optic 150 for managing light emitted by an array
15 300 of light emitting diodes 401 in the lighting system 100, wherein the optic 150 is depicted as opaque to promote visualization of certain surface features, in accordance with certain embodiments of the present technology. In an exemplary embodiment, the illustrated primary optic 150 can be an element of the lighting system 100 illustrated in Figures 1, 2, 3, and 4 and discussed above, and will be discussed in such representative
20 context, without limitation.

The primary optic 150 comprises an inner profile 500 and an outer profile 550 that can be defined by the intersection of a reference plane with the primary optic 150. In the illustrated embodiment, the inner profile 500 is formed at the intersection between the interior surface 505 and a reference plane in which the optical axis 350 of the primary
25 optic 150 lies. In the illustrated embodiment, the interior surface 505 of the primary optic 150 is refractive. However, other embodiments of the interior surface 505 may utilize forms of light manipulation other than refraction, including without limitation reflection.

Similarly, the outer profile 550 is formed at the intersection between the exterior surface 510 and the reference plane containing the optical axis 350 of the primary optic
30 150. In the illustrated embodiment, the exterior surface 510 of the primary optic 150 is

refractive. However, other embodiments of the exterior surface 550 may utilize forms of light manipulation other than refraction, including without limitation reflection

As will be appreciated by those of ordinary skill having benefit of this disclosure, a “reference plane” can be thought of as an imaginary or intangible plane providing a useful aid in describing, characterizing, or visualizing something. Although illustrated in a particular position, reference planes can ordinarily be positioned in other locations that may or may not be arbitrary.

In the illustrated embodiment, the primary optic 150 comprises a combination of optically active features and optically inactive or mechanical features. The recess 575 receives the light emitting diode module 10, and the light emitting diode module 10 may be seated in the recess 575. Channels 503 facilitate passage of electrical leads. Holes 507 facilitate fastener-based mounting as discussed above with reference to Figures 1 and 2.

In certain exemplary embodiments, the primary optic 150 is a unitary optical element that comprises molded plastic material that is transparent. The primary optic 150 may comprise poly-methyl-methacrylate (“PMMA”), polycarbonate, or an appropriate acrylic, to mention a few representative material options without limitation. In certain exemplary embodiments, the primary optic 150 can be formed of optical grade silicone and may be pliable and/or elastic, for example.

In certain exemplary embodiments, the primary optic 150 is a seamless unitary optical element. In certain exemplary embodiments, the primary optic 150 is formed of multiple transparent optical elements bonded, fused, glued, or otherwise joined together to form a unitary optical element that is void of air gaps yet made of multiple elements.

Referring now to Figure 5B, this figure illustrates an exemplary embodiment of the light emitting diode module 10 for the lighting system 100 in accordance with certain embodiments of the present technology. In an exemplary embodiment, the illustrated light emitting diode module 10 can be an element of the lighting system 100 illustrated in Figures 1, 2, 3, and 4 and discussed above, and will be discussed in such representative context, without limitation.

In the illustrated embodiment of the light emitting diode module 10, light emitting diodes 401 are organized in an array 300 mounted to a substrate 555. In this case, the

array 300 is a two-dimensional array. In various embodiments, a two-dimensional arrangement can be utilized that forms a pattern that is circular, square, rectangular, triangular, pentagon, honeycomb, or some other appropriate geometric form. In certain embodiments, a six-around-one pattern of light emitting diodes 401 can be utilized. In
5 certain embodiments, a line of light emitting diodes 401 forming a one-dimensional array can be utilized.

As illustrated, the array 300 of light emitting diodes 401 covers a footprint 585 of the substrate 555. The footprint 585 has a surface area. In the case of a rectangular array, surface area of the footprint 585 could be computed as length of the array multiplied by
10 width of the array, for example.

In various embodiments, the substrate 555 can be ceramic, plastic, resin, or some other electrically compatible material. The substrate 555 can comprise a circuit board, for example. In the illustrated embodiment, the substrate 555 is flat, but may be curved or have some other appropriate geometry.

15 In accordance with the illustrated embodiment, each light emitting diode 401 can comprise a light emitting diode package that includes a chip-level substrate and an active area that converts electrical energy into light. The active area can comprise an optoelectronic semiconductor structure or feature and/or an aperture. A dome 590 covers and protects the active area. As illustrated, the array 300 of light emitting diodes 401
20 comprises a corresponding array of domes 590, and the array 300 can be characterized as an array of domed light emitting diodes.

The dome 590 may comprise optical quality silicone, or some other appropriate material known in the art, that encapsulates the active area and transmits light. Thus, the dome 590 can provide environmental protection to the light emitting diode's
25 semiconductor materials and emit the light that the light emitting diode 401 generates. In many embodiments, the dome 590 emits Lambertian light. Accordingly, the dome 590 may radiate light at highly diverse angles, for example providing a light distribution pattern that can be characterized, modeled, or approximated as Lambertian. In certain embodiments, multiple light emitting diode elements are covered by a single dome.

30 Referring now to Figure 6, this figure illustrates in cross section an exemplary embodiment of the primary optic 150 and associated array 300 of light emitting diodes

401 in a lighting system 100 in accordance with certain embodiments of the present technology. Figure 6 more specifically illustrates an exemplary configuration in which the light emitting diode module 10 is mounted to the primary optic 150. The figure further illustrates representative rays 400 that are incident on and refracted first by the
5 interior surface 505 of the primary optic 150 and second by the exterior surface 510 of the primary optic 150, which have respective profiles 500, 550 as discussed above.

In the illustrated configuration, the domes 590 of the light emitting diodes 401 project towards or into a cavity 610 of the primary optic 150. One or more of the domes 590 may extend or protrude, partially or fully, into the cavity 610, for example. In certain
10 embodiments, the array 300 is disposed entirely in the cavity 610 of the primary optic 150. In certain embodiments, the array 300 is outside the cavity 610 of the primary optic 150.

As illustrated, the cavity 610 contains a gas such as air. However, in certain embodiments, the cavity 610 may be filled with a liquid, grease, or gel. For example, in
15 certain embodiments, a matching gel or fluid may reduce or substantially eliminate refraction at the interior surface 505 of the primary optic 150 and at the exterior surfaces of the domes 590.

In the illustrated embodiment, the interior surface 505 of the primary optic 150 has an inner profile 500 that redirects horizontally oriented rays 400 downward and
20 redirects other rays 400 towards horizontal. The inner profile 500 comprises a flared peripheral region 675 that provides a refractive interface for bending horizontal rays downward and that may be characterized as slanted. A sidewall region 680 of the inner profile 500 is substantially linear and bends incident rays 400 towards horizontal. The sidewall region 680 meets with the flared peripheral region 675 in a corner 650, which is
25 a rounded corner in the illustrated embodiment. The inner profile 500 further comprises a bowl-shaped region 690 through which the optical axis 350 passes. The bowl-shaped region 690 meets with the sidewall region 680 in another corner 600, which is also a rounded corner in the illustrated embodiment.

As illustrated, the interior surface 505 provides a cavity 610 having a depth 611
30 and width 605. The depth 611 can be dimensioned from the top of the bowl-shaped region 690 to the closest face of the substrate 555. The width 605 can be dimensioned

between the corners 600. As illustrated, the array 300 has a dimension 615 across the page (and further as a two-dimensional array has another, perpendicular dimension that is not visible in the view of Figure 6). The dimension 615 will be referred to in this description below as the width 615 to promote readership, without suggesting that the
5 opposing dimension of the array 300 is bigger or smaller.

In certain exemplary embodiments, dimensions of the cavity 610 can correlate with dimensions or footprint 585 or surface area of the array 300. For example, in certain embodiments, the width 605 of the cavity 610 is within approximately 20 percent of the width 615 of the array 300. In certain embodiments, the width 605 of the cavity 610 is
10 approximately equal to the width 615 of the array 300. In certain embodiments, the width 605 of the cavity 610 is greater than the width 615 of the array 300.

In certain embodiments, the depth 611 of the cavity 610 is within approximately 20 percent of the width 615 of the array 300. In certain embodiments, the depth 611 of the cavity 610 is approximately equal to the width 615 of the array 300. In certain
15 embodiments, the depth 611 of the cavity 610 is greater than the width 615 of the array 300.

In certain embodiments, the cavity 610 is large enough such that a cube can fit inside the cavity 610, where each face of the cube has the surface area of the footprint 585 of the array 300 of light emitting diodes 401. In certain embodiments, the cavity 610
20 has a volume that is at least as large as the volume of such a cube. In certain embodiments, the bowl-shaped region 690 of the primary optic 150 is at least as large as the footprint 585 of the array.

Referring now to Figure 7, this figure illustrates in cross section an exemplary embodiment of the primary optic 150 and associated path traces of rays 400 in the
25 lighting system 100 in accordance with certain embodiments of the present technology. More specifically, Figure 7 illustrates how the interior surface 505 and the exterior surface 510 of the primary optic 150 spread light rays 400 to broaden the area illuminated by the lighting system 100.

Referring now to Figure 8, this figure illustrates in perspective view an exemplary
30 embodiment of the secondary optic 125 for managing light emitted by an array 300 of light emitting diodes 401 in a lighting system 100, wherein the optic 125 is depicted as

opaque to promote visualization of certain surface features in accordance with certain embodiments of the present technology. In an exemplary embodiment, the illustrated secondary optic 125 can be an element of the lighting system 100 illustrated in Figures 1, 2, 3, and 4 and discussed above, and will be discussed in such representative context,
5 without limitation.

The illustrated secondary optic 125 has two open ends, one facing the housing 1 and one opposite. On the inside, grooves 800 extend between the two ends. In various embodiments, such grooves 800 can be refractive or reflective and may comprise fluting or prismatic surfaces.

10 As illustrated, the outer surface 850 of the secondary optic 125 is smooth. In certain exemplary embodiments, the secondary optic 125 is a unitary optical element that comprises molded plastic material that is transparent. The secondary optic 125 may comprise PMMA, polycarbonate, or an appropriate acrylic, to mention a few representative material options without limitation. In certain exemplary embodiments,
15 the secondary optic 125 can be formed of glass.

Referring now to Figure 9, this figure illustrates in cross section a portion of an exemplary embodiment of the secondary optic 125 and associated path traces of rays 400 in the lighting system 100 in accordance with certain embodiments of the present technology. More specifically, Figure 9 illustrates an exemplary embodiment of surface
20 features of the secondary optic 125 manipulating light rays 400. As illustrated the grooves 800 in combination with the smooth outer surface 850 increase axial spread of the rays 400 utilizing refraction.

Referring now to Figures 10A, 10B, and 10C, these figures illustrate exemplary simulated illuminance iso-footcandle plots 1000, 1025, and 1050 for a lighting system
25 100 meeting a 4000 lumen specification in accordance with certain embodiments of the present technology.

The plot 1000 of Figure 10A illustrates simulated performance with the lighting system 100 mounted fifteen feet above the illuminated surface. The plot 1025 of Figure 10B illustrates simulated performance with the lighting system 100 mounted twenty feet
30 above the illuminated surface. The plot 1050 of Figure 10C illustrates simulated performance with the lighting system 100 mounted twenty-five feet above the illuminated

surface. The illuminated surface might be the ground, a parking lot, a grassy field, concrete, or a floor, to mention a few representative examples without limitation.

Referring now to Figure 11, this figure illustrates an exemplary simulated illuminance iso-footcandle plot 1100 for a lighting system meeting a 2500 lumen
5 specification in accordance with certain embodiments of the present technology. Relative to the lighting system 100 discussed above, the simulated lighting system represented in Figure 11 may have fewer light emitting diodes and thus output less light. The plot 1100 illustrates simulated performance with the lighting system mounted fifteen feet above the illuminated surface.

10 Technology for managing light emitted from one or more light emitting diodes or other appropriate sources has been described. From the description, it will be appreciated that an embodiment of the present technology overcomes the limitations of the prior art. Those skilled in the art will appreciate that the present technology is not limited to any specifically discussed application or implementation and that the embodiments described
15 herein are illustrative and not restrictive. From the description of the exemplary embodiments, equivalents of the elements shown therein will suggest themselves to those skilled in the art, and ways of constructing other embodiments of the present technology will appear to practitioners of the art. Therefore, the scope of the present technology is to be limited only by the claims that follow.

CLAIMS

What is claimed is:

1. A lighting fixture comprising:
 - a housing comprising an opening configured to face an area to be illuminated;
 - 5 a first optic attached to the housing and comprising an interior surface defining a cavity and an exterior surface oriented to face the area to be illuminated;
 - a two-dimensional array of light emitting diodes mounted adjacent or in the cavity and oriented to emit light into the cavity; and
 - a second optic comprising:
 - 10 a first end circumscribing the first optic;
 - a second end opposite the first end; and
 - refractive grooves extending between the first end and the second end.
2. The lighting fixture of Claim 1, wherein the second optic further
15 comprises:
 - an interior surface facing the first optic and comprising the refractive grooves; and
 - an exterior surface that is substantially smooth opposite the interior surface.
- 20 3. The lighting fixture of Claim 1, wherein the second end of the second optic is open, so that light emitted from the first optic includes first rays that are incident on the second optic and second rays that are oriented to illuminate the area while missing the second optic.
- 25 4. The lighting fixture of Claim 1, wherein the interior surface of the first optic is rotationally symmetric and comprises:
 - a flared peripheral region;
 - a bowl-shaped region; and
 - 30 a substantially flat sidewall disposed between the flared peripheral region and the bowl-shaped region.

5. The lighting fixture of Claim 1, wherein the interior surface comprises a sidewall and a bowl-shaped region that meet in a corner.

6. The lighting fixture of Claim 1, wherein the interior surface of the first
5 lens has a cross sectional profile comprising an abrupt change in direction disposed between a sidewall and a bottom surface region.

7. A lighting system, for providing illumination along an axis, comprising:
a housing comprising an aperture through which the axis passes;
a substrate mounted at a position adjacent to or in the aperture;
an array of light emitting diodes mounted to the substrate and organized about the
5 axis to emit light along the axis, the array of light emitting diodes comprising an array of
domes;
a first optic comprising:
an interior surface forming a cavity; and
an exterior surface opposite the interior surface, wherein the first optic is
10 mounted adjacent the array of light emitting diodes with the axis passing through the first
optic, wherein at least portions of the domes are disposed in the cavity; and
a second optic comprising:
a first end oriented towards the housing and comprising a first aperture;
a second end comprising a second aperture; and
15 a pattern of grooves extending between the first aperture and the second
aperture, wherein the axis passes through the first aperture and the second aperture.
8. The lighting system of Claim 7, wherein the interior surface of the first
optic and the exterior surface of the first optic are rotationally symmetrical about the axis.
20
9. The lighting system of Claim 7, wherein the second optic is rotationally
symmetrical about the axis.
10. The lighting system of Claim 7, wherein, the first optic has a profile
25 defined by a cross section of the first optic taken in a plane that incorporates the axis, the
profile comprising a substantially linear region that meets with a curved region to form a
corner.

11. The lighting system of Claim 7, wherein the interior surface comprises:
a slanted region disposed peripherally with respect to the array of light emitting
diodes;

5 a sidewall region disposed about the axis; and
a bowl-shaped region through which the axis passes.

12. The lighting system of Claim 7, wherein the array of light emitting diodes
extends a first distance across the substrate, and

10 wherein, in cross section, the cavity is sized to accommodate a square having
sides of length equal to the first distance.

13. A lighting system comprising:
a housing;
a planar substrate disposed in the housing;
an array of domed light emitting diodes attached to the planar substrate to cover
5 an area of the planar substrate;
an optic comprising an interior refractive surface oriented for receiving light from
the array of domed light emitting diodes and an exterior refractive surface oriented for
emitting the received light,
wherein the interior refractive surface forms a cavity into which the array of
10 domed light emitting diodes projects, and
wherein the cavity has a volume that is greater than a cube having sides of surface
area equal to the covered area of the planar substrate.

14. The lighting system of Claim 13, wherein the cavity is large enough so
15 that the cube could fit in the cavity.

15. The lighting system of Claim 14, wherein the interior surface comprises:
a sidewall, that is substantially flat in cross section, circumscribing an axis of the
lighting system; and
20 a bowl-shaped region through which the axis passes.

16. The lighting system of Claim 15, wherein the bowl-shaped region and the
substantially flat sidewall meet in a corner.

25 17. The lighting system of Claim 16, wherein the corner is rounded, and
wherein the interior surface further comprises a flared peripheral region.

18. The lighting system of Claim 13, wherein the lighting system further
comprises:
30 an optical axis, and
a second optic comprising grooves extending along the optical axis.

19. The lighting system of Claim 13, wherein the cavity comprises a rounded corner disposed to receive light from the array.

- 5 20. The lighting system of Claim 13, wherein the array of domed light emitting diodes comprises at least seven light emitting diodes, each having a respective dome.

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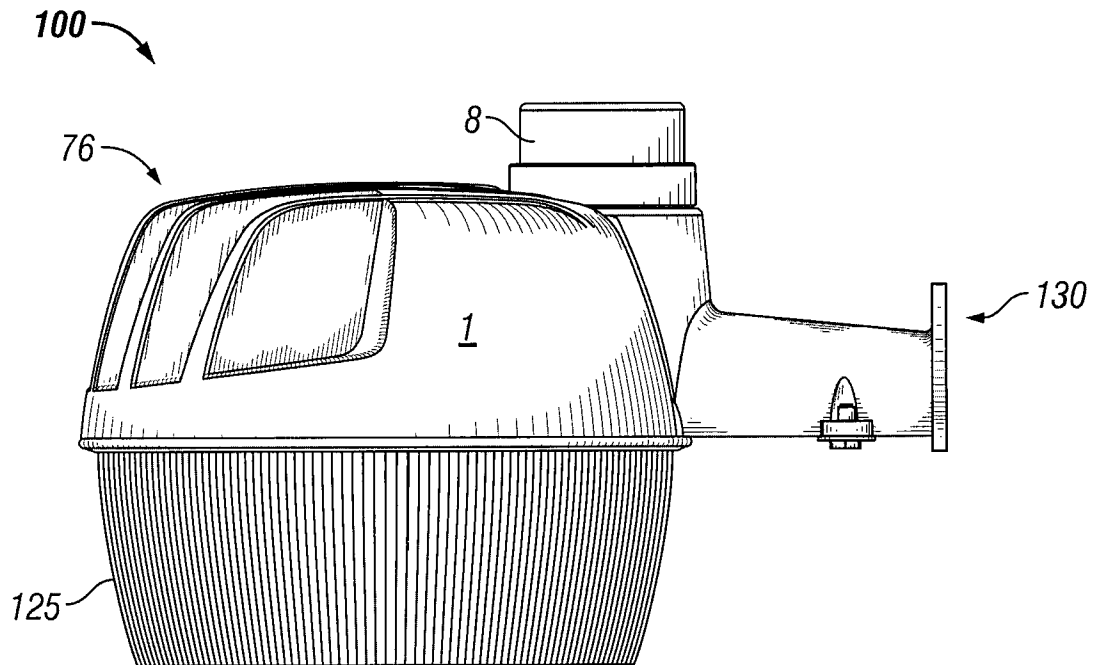


FIG. 1A

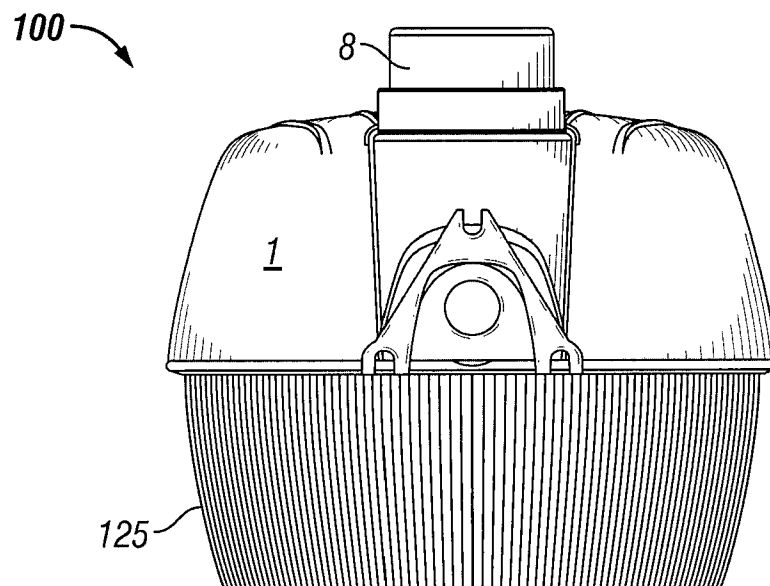


FIG. 1B

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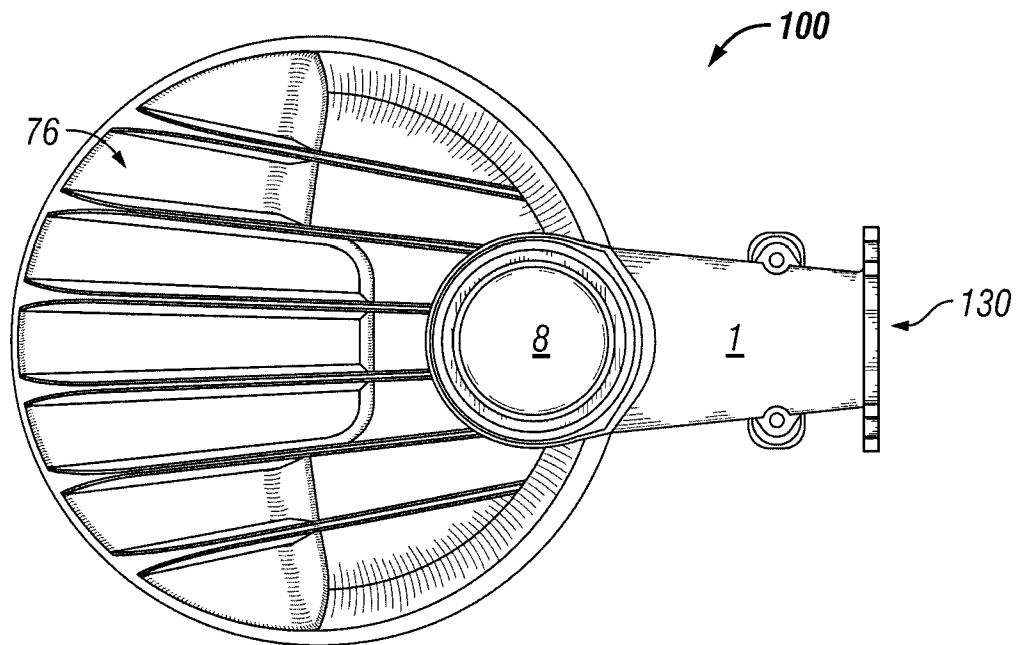


FIG. 1C

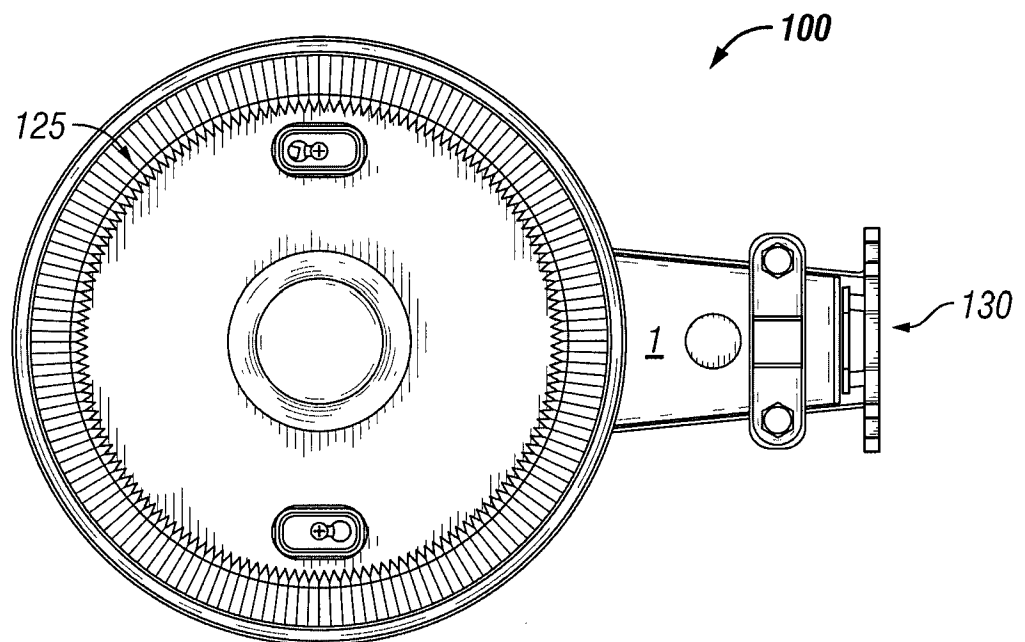


FIG. 1D

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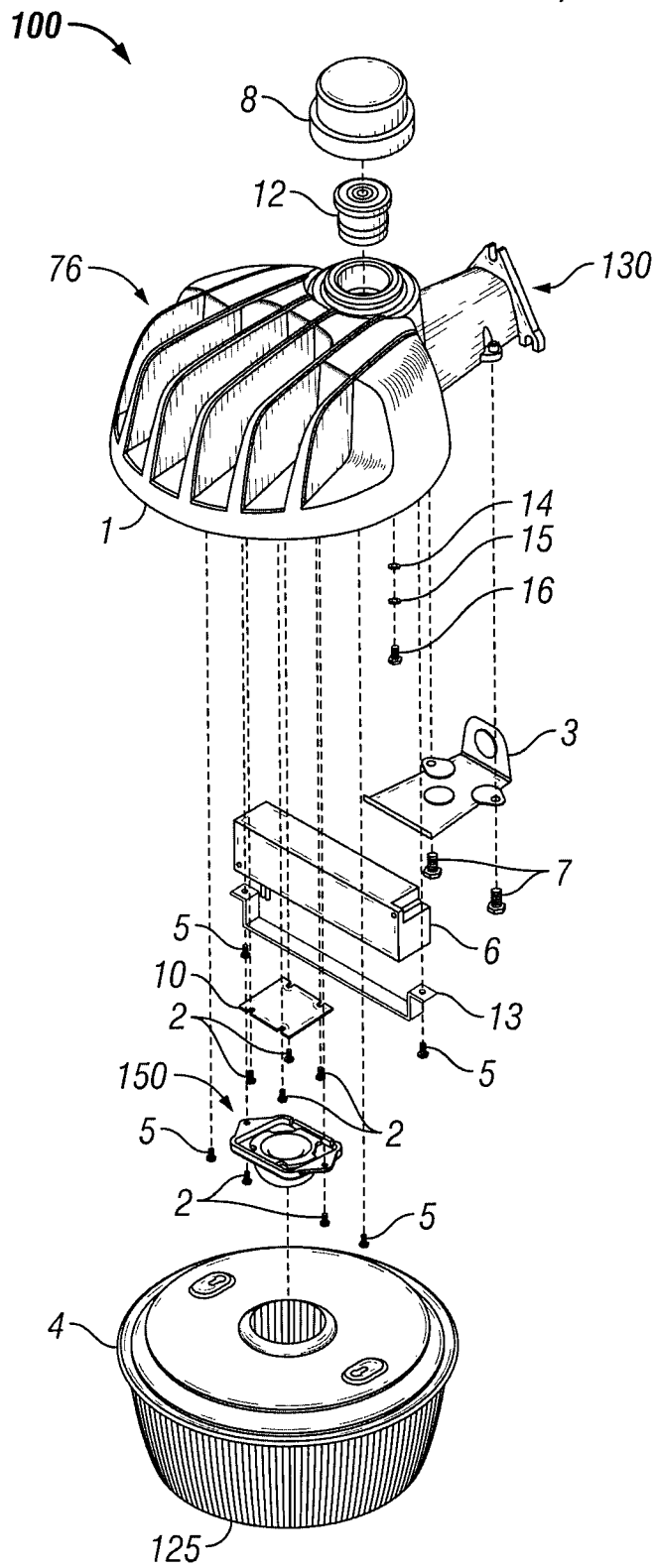


FIG. 2A

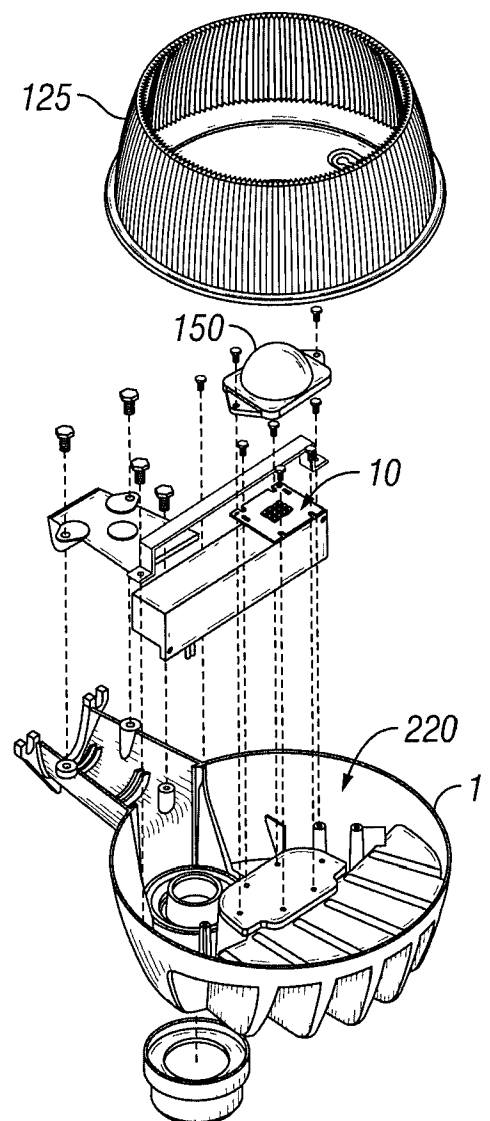
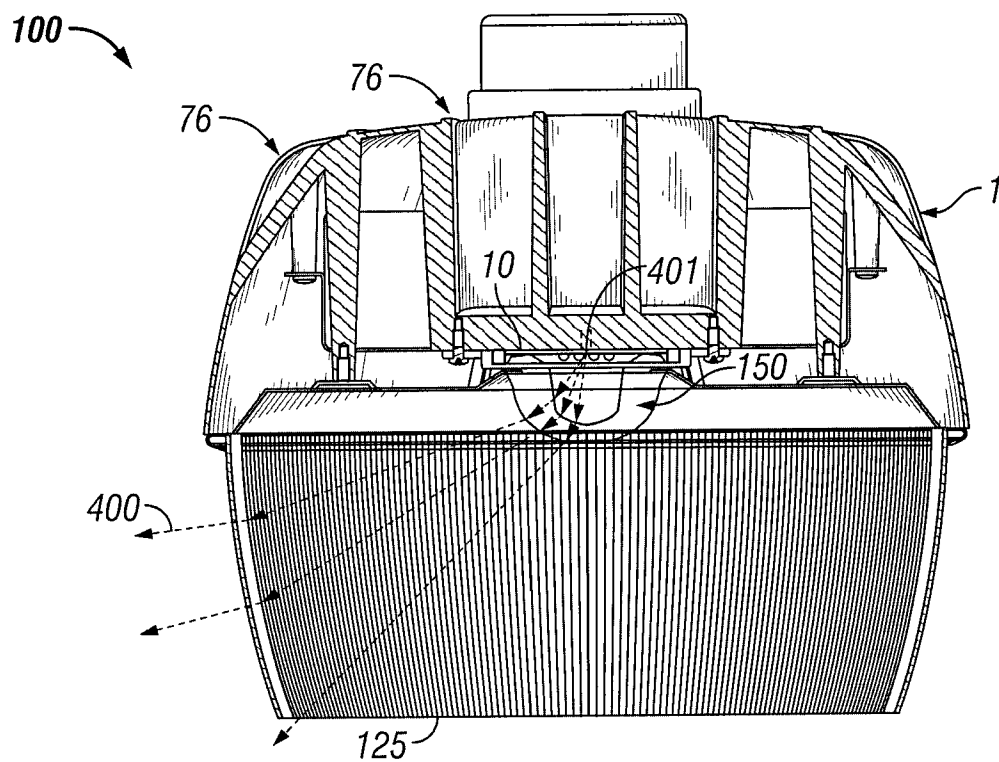
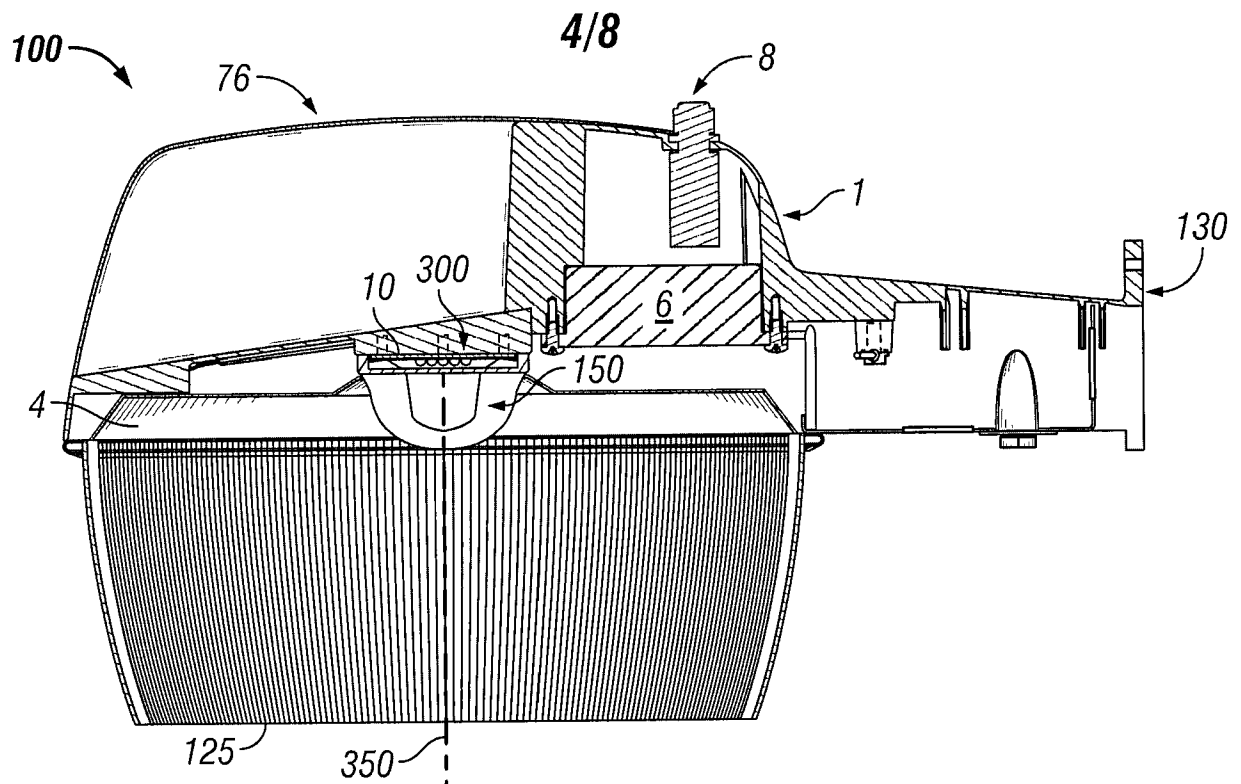


FIG. 2B



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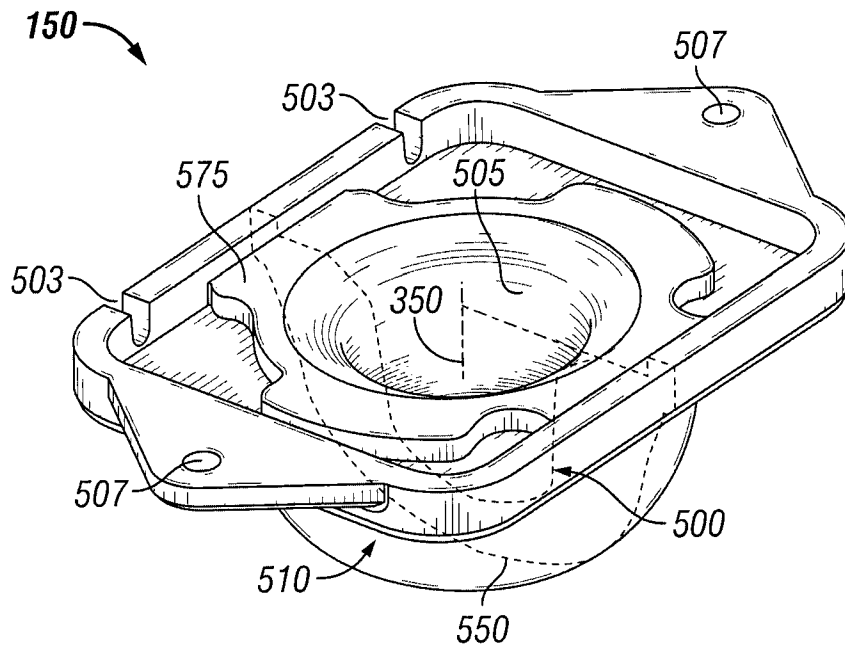


FIG. 5A

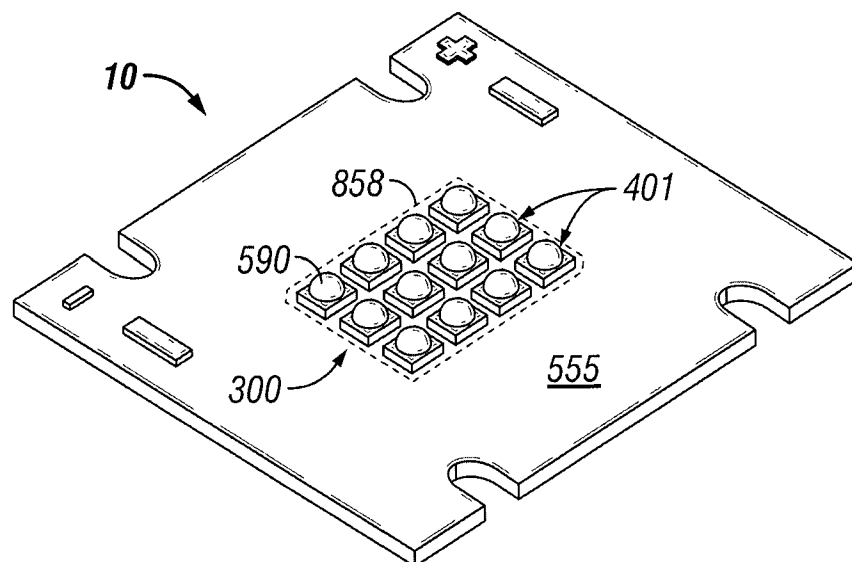


FIG. 5B

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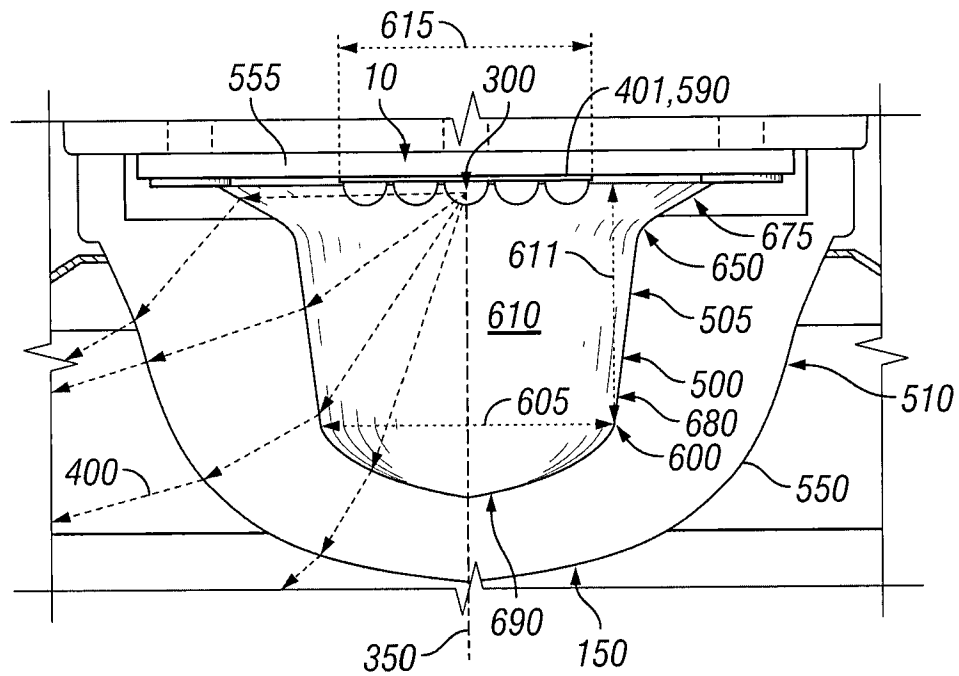


FIG. 6

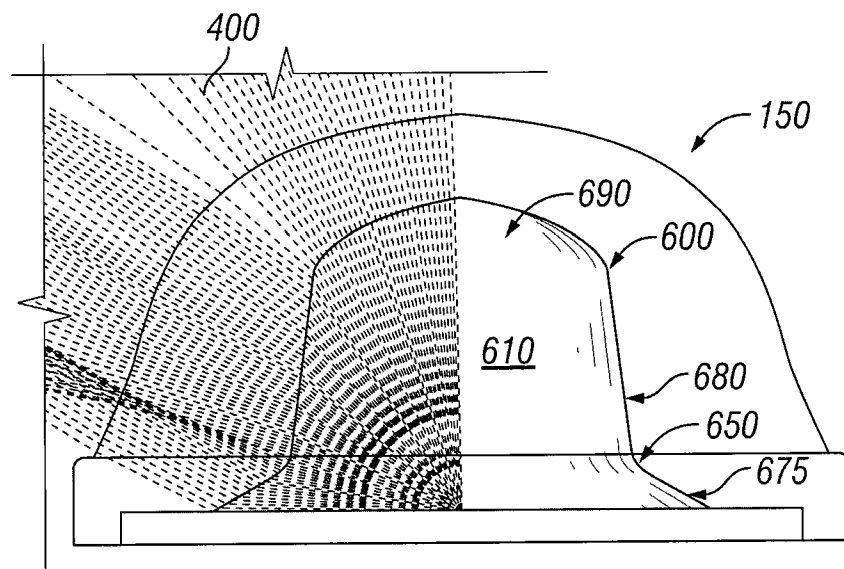


FIG. 7

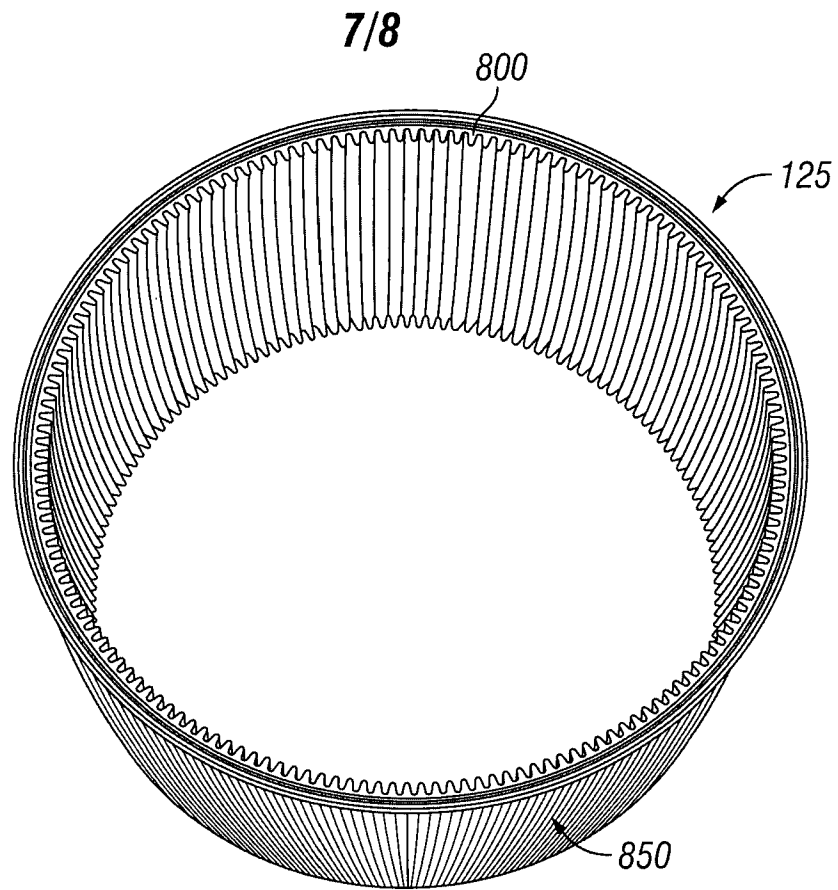


FIG. 8

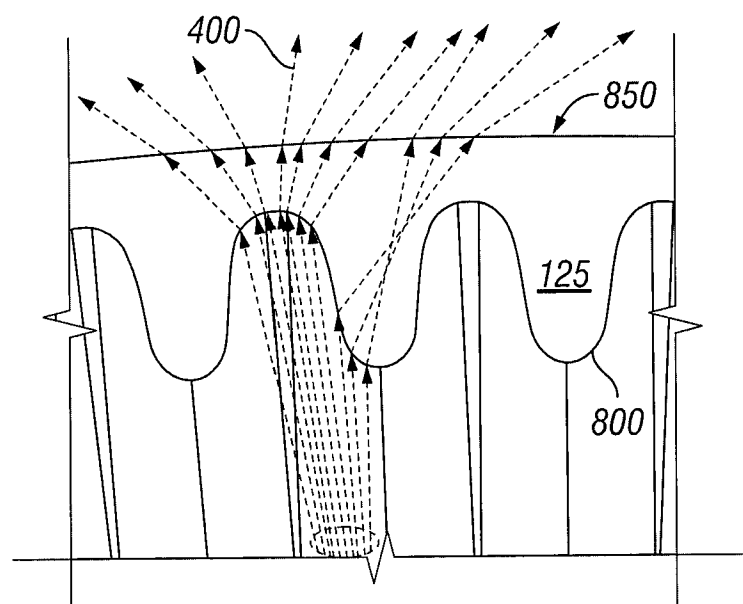
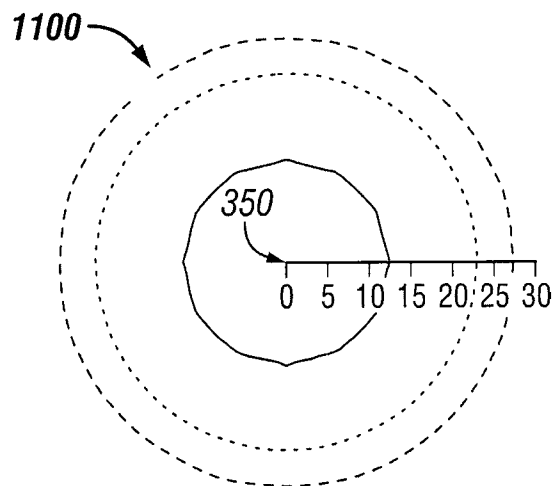
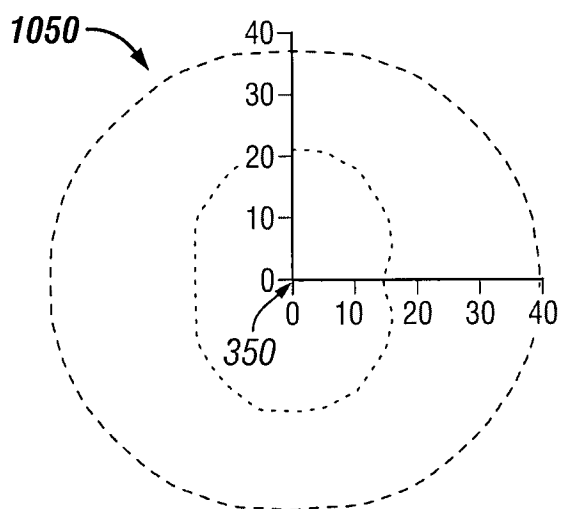
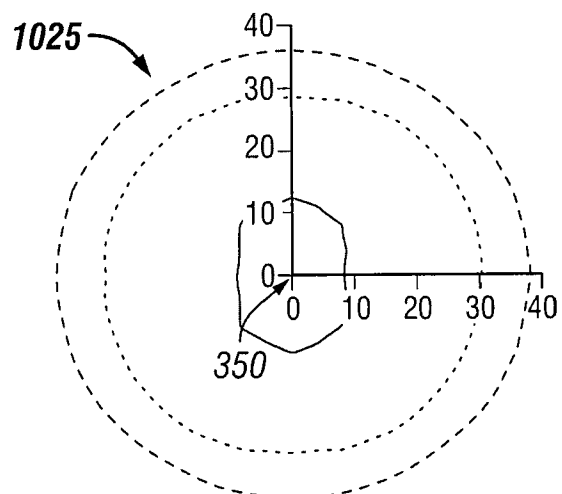
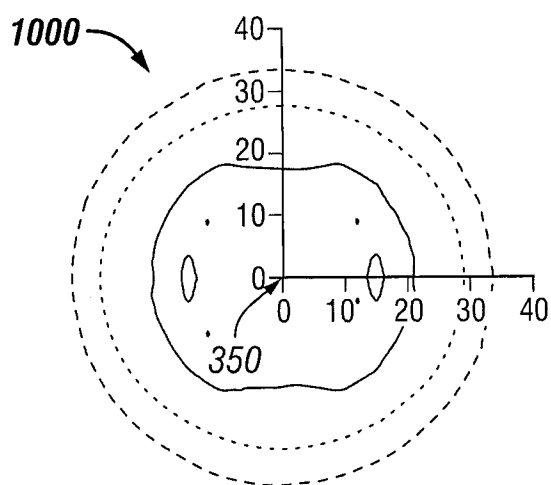


FIG. 9

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2013/072797

A. CLASSIFICATION OF SUBJECT MATTER		
<i>F21S 10/00 (2006.01)</i> <i>F21V 7/09 (2006.01)</i> <i>F21W 131/00 (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)		
F21S 10/00, 8/08, F21V 7/09, 7/04, 7/22, 5/02, 5/04, 5/08, 17/002, F21W 131/02		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, DWPI, EAPATIS, PATENTSCOPE, Information Retrieval System of FIPS		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/0039810 A1 (COOPER TECHNOLOGIES COMPANY) 18.02.2010	1-20
A	CN 102748706 A (B & M OPTICS CO., LTD.) 24.10.2012	1-20
A	US 6220722 B1 (U.S. PHILLIPS CORPORATION) 24.04.2001	1-20
A	US 2002/0051363 A1 (NSI ENTERPRISES, INC.) 02.05.2002	1-20
A	US 2008/0100773 A1 (SEONG YONG HWANG et al.) 01.05.2008	1-20
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents:	“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
“A” document defining the general state of the art which is not considered to be of particular relevance	“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
“E” earlier document but published on or after the international filing date	“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
“L” 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 member of the same patent family
“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		
Date of the actual completion of the international search	Date of mailing of the international search report	
03 March 2014 (03.03.2014)	10 April 2014 (10.04.2014)	
Name and mailing address of the ISA/ FIPS Russia, 123995, Moscow, G-59, GSP-5, Berezhkovskaya nab., 30-1	Authorized officer M. Trofimova	
Facsimile No. +7 (499) 243-33-37	Telephone No. 499-240-25-91	

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2013/072797

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Two groups of inventions have been claimed, which do not share any common inventive concept, due to the reason that they have no common or corresponding special technical features.

1st group comprises claims 1 and 7. They are united in that the second optic comprises two opposite edges and refractive grooves located between them.

2nd group comprises claim 13. Selection of the volume of internal cavity is a special technical feature of this group.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.