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Scott et al.

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(54) **LIGHTING MODULE**

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(51) **Int. Cl.**

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F21S 8/08	(2006.01)
F21V 13/04	(2006.01)
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F21V 29/78	(2015.01)
F21V 29/83	(2015.01)
F21V 5/00	(2015.01)
F21V 7/00	(2006.01)
F21Y 101/02	(2006.01)
F21Y 105/00	(2006.01)

(52) **U.S. Cl.**
CPC ***F21V 29/2293*** (2013.01); ***F21S 8/086*** (2013.01); ***F21V 13/04*** (2013.01); ***F21V 29/74*** (2015.01); ***F21V 29/763*** (2015.01); ***F21V 29/78*** (2015.01); ***F21V 29/83*** (2015.01); *F21V 5/00* (2013.01); *F21V 7/00* (2013.01); *F21Y 2101/02* (2013.01); *F21Y 2105/001* (2013.01)

(58) **Field of Classification Search**
CPC F21S 8/086; F21V 29/78; F21V 29/745; F21V 29/70
USPC 362/294, 373, 431, 249.02
See application file for complete search history.

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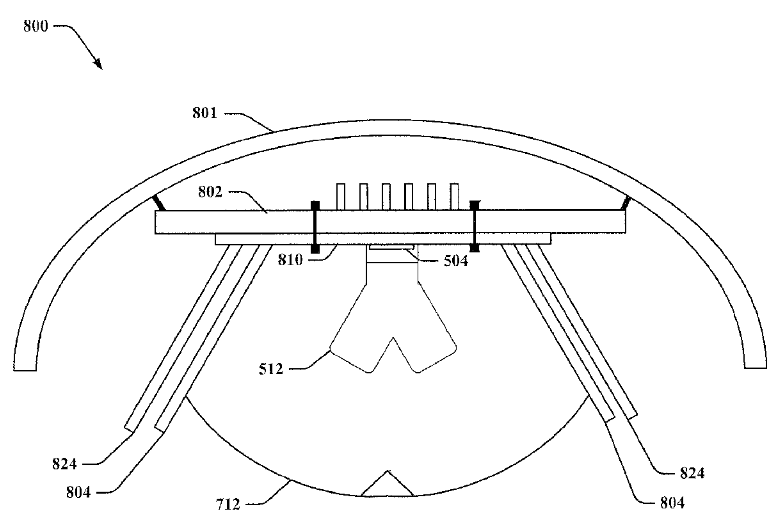
(57) **ABSTRACT**

A street light may include a pole and a head attached to the pole. The head may include a lighting module. The lighting module may include a light-emitting device configured to emit light, a thermal interface configured to conduct heat away from the light-emitting device, an optical element configured to transmit the emitted light in a light distribution pattern on an area located a distance away from the lighting module, and a reflective surface configured to redirect a portion of the light transmitted by the optical element.

19 Claims, 10 Drawing Sheets



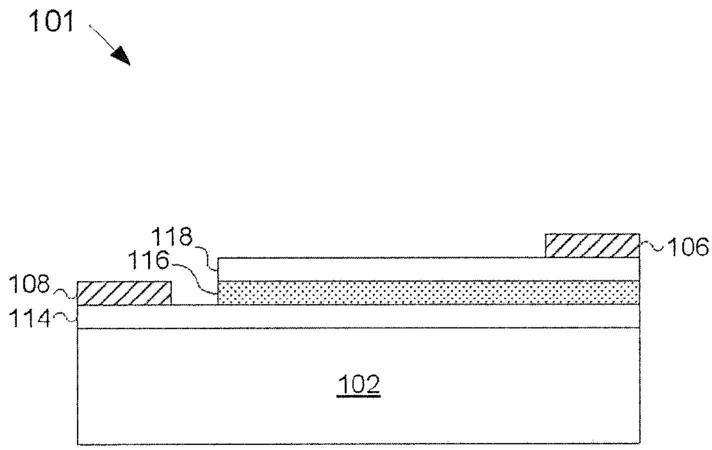


FIG. 1

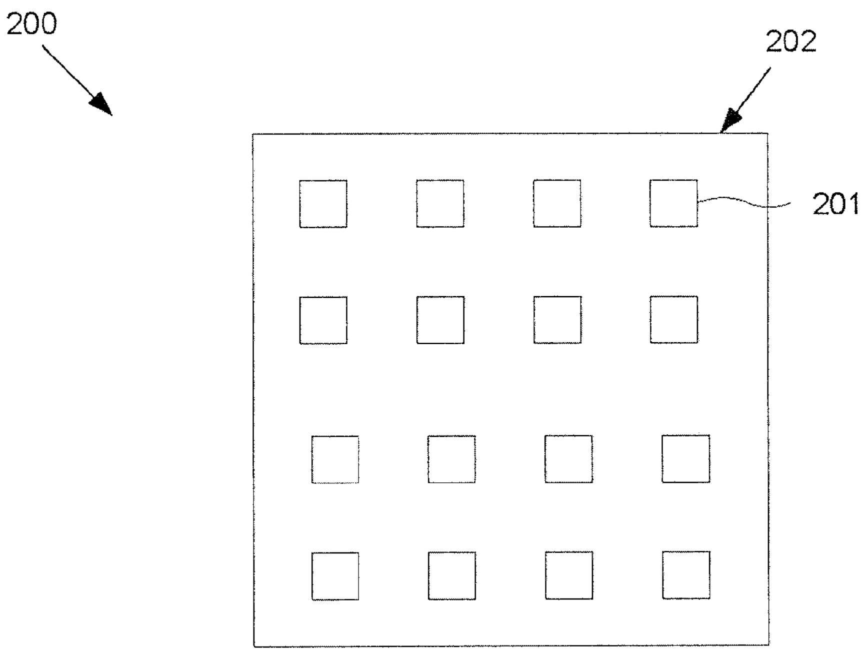


FIG. 2

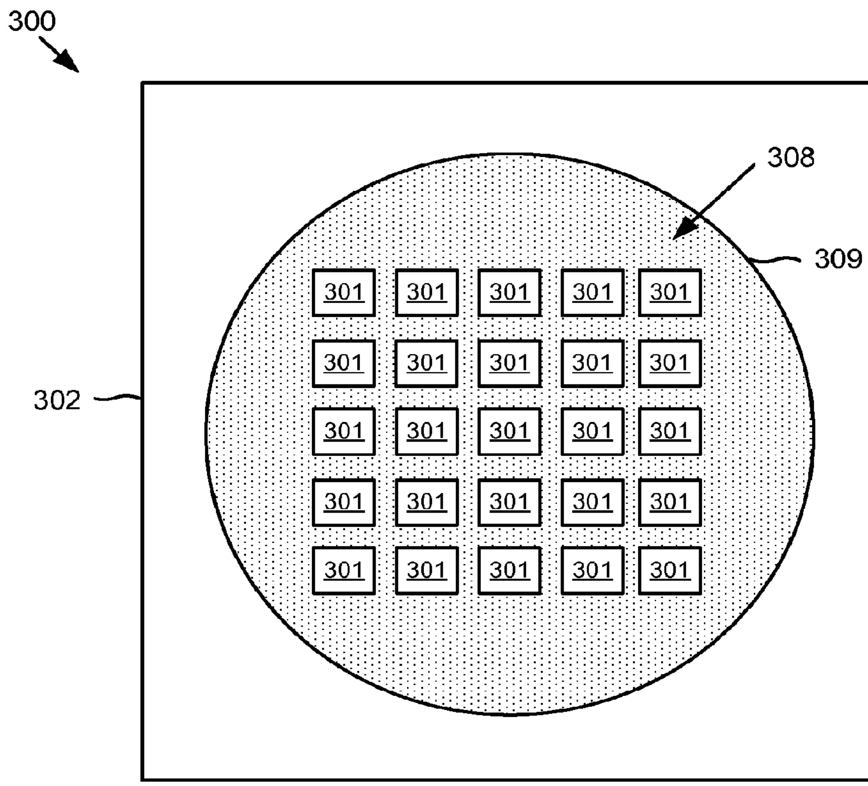


FIG. 3A

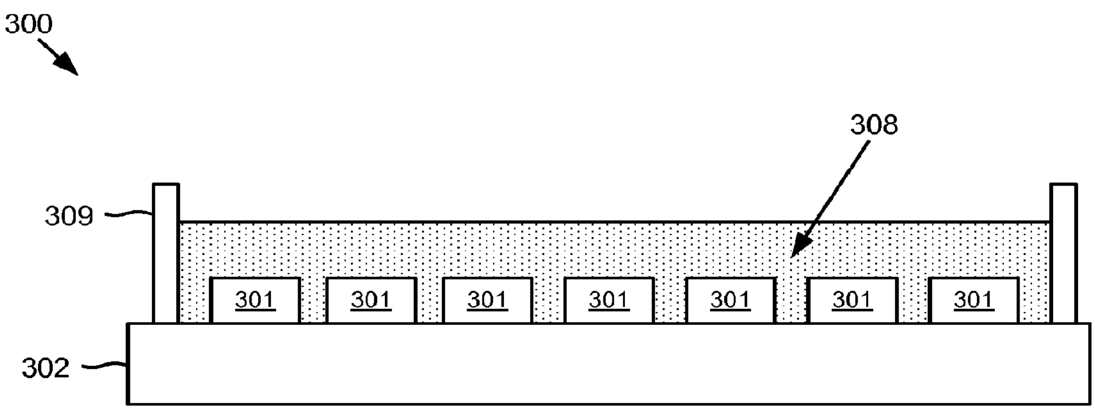


FIG. 3B

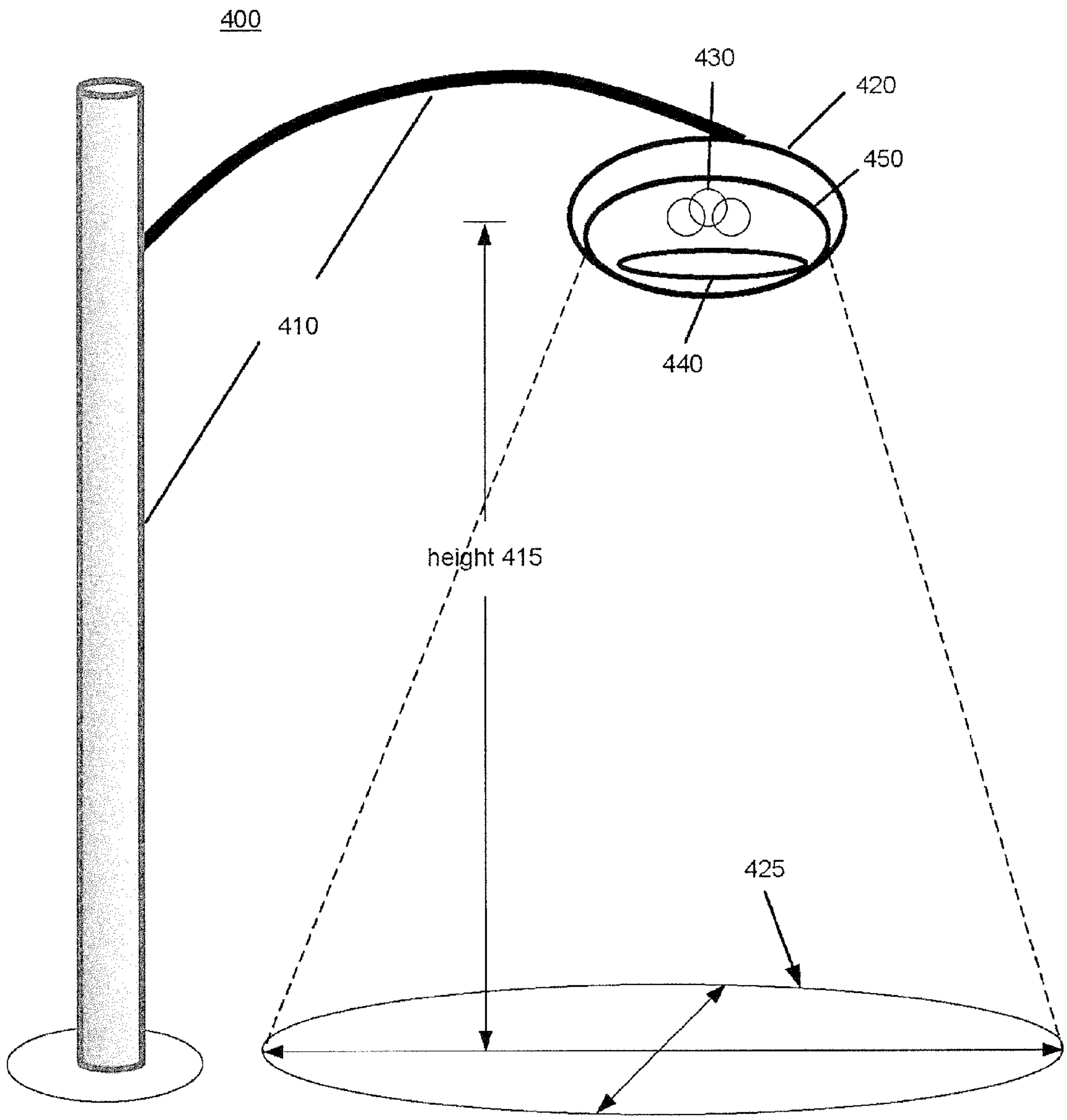


FIG. 4

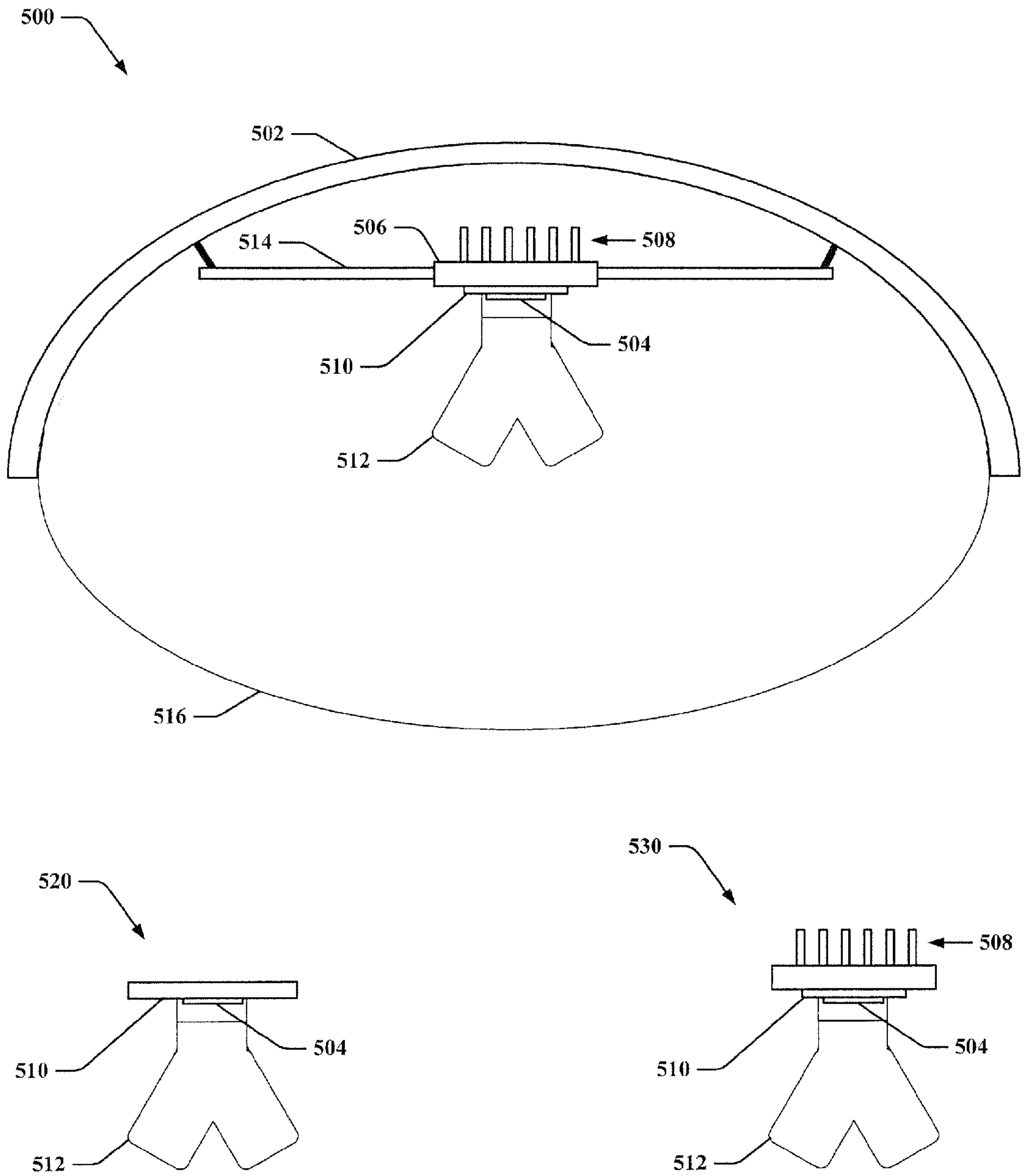

500
502
506
508
514
504
510
512
516
520
510
504
512
530
508
510
504
512

FIG. 5

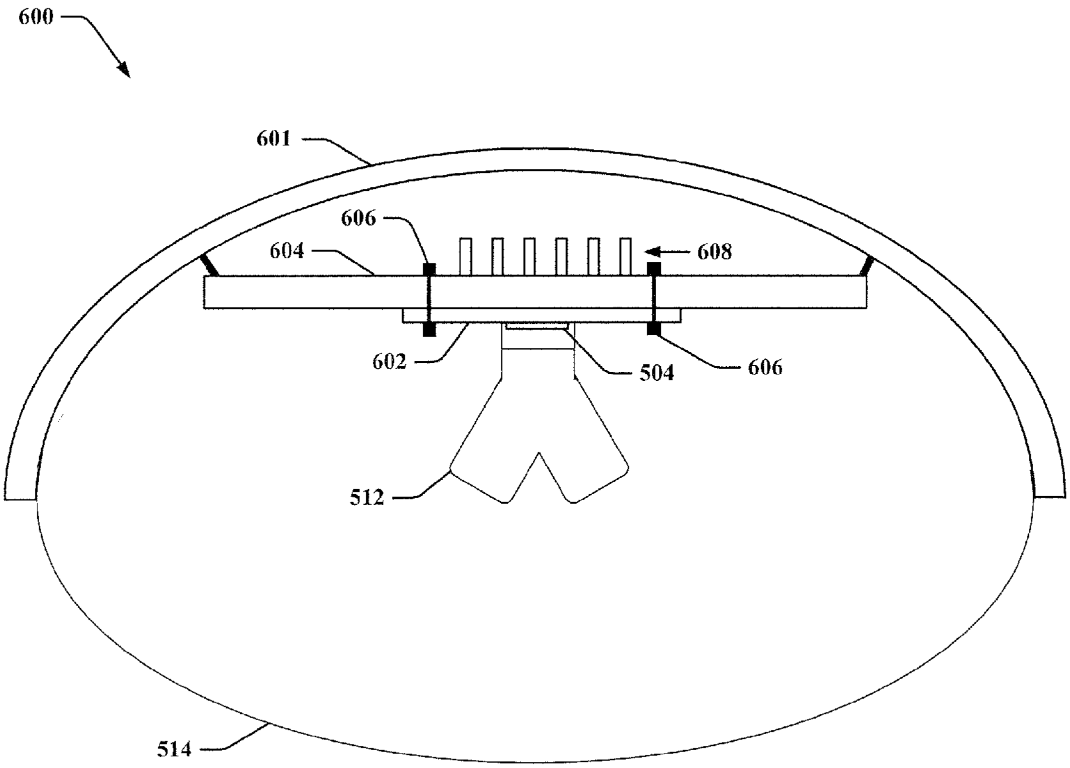


FIG. 6

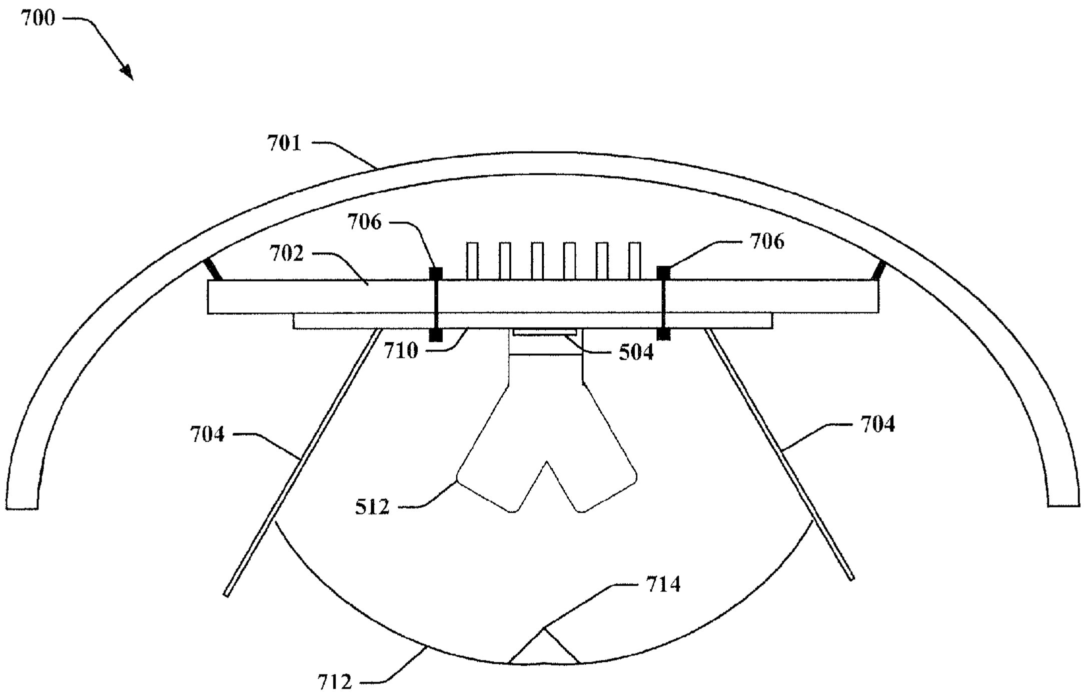


FIG. 7

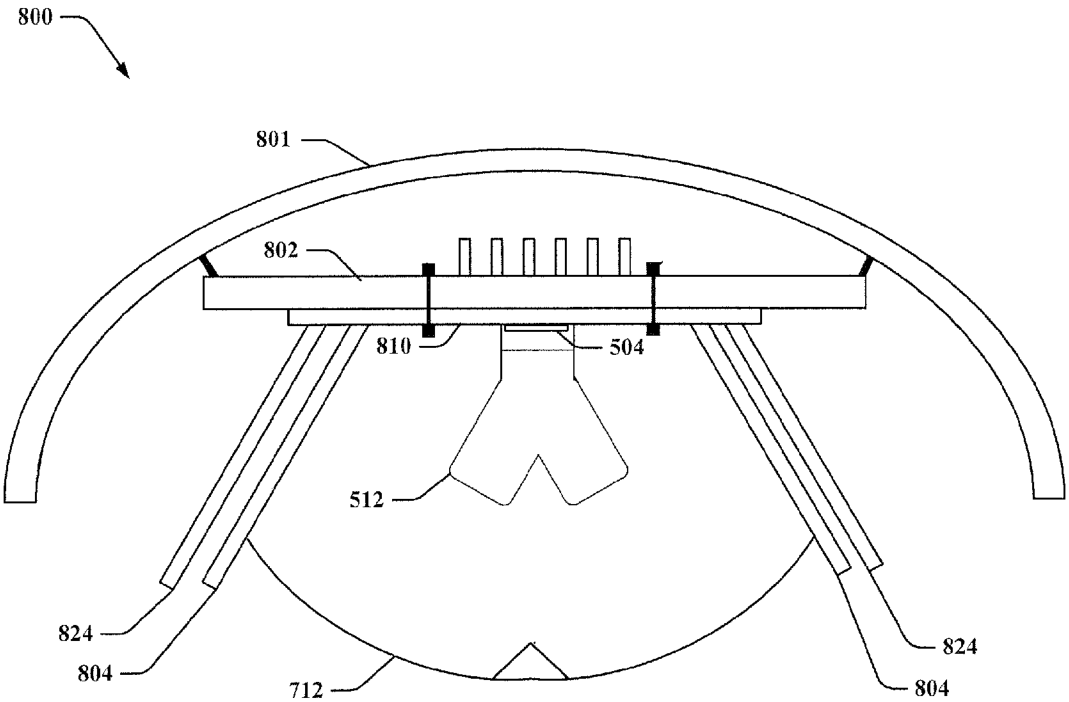


FIG. 8

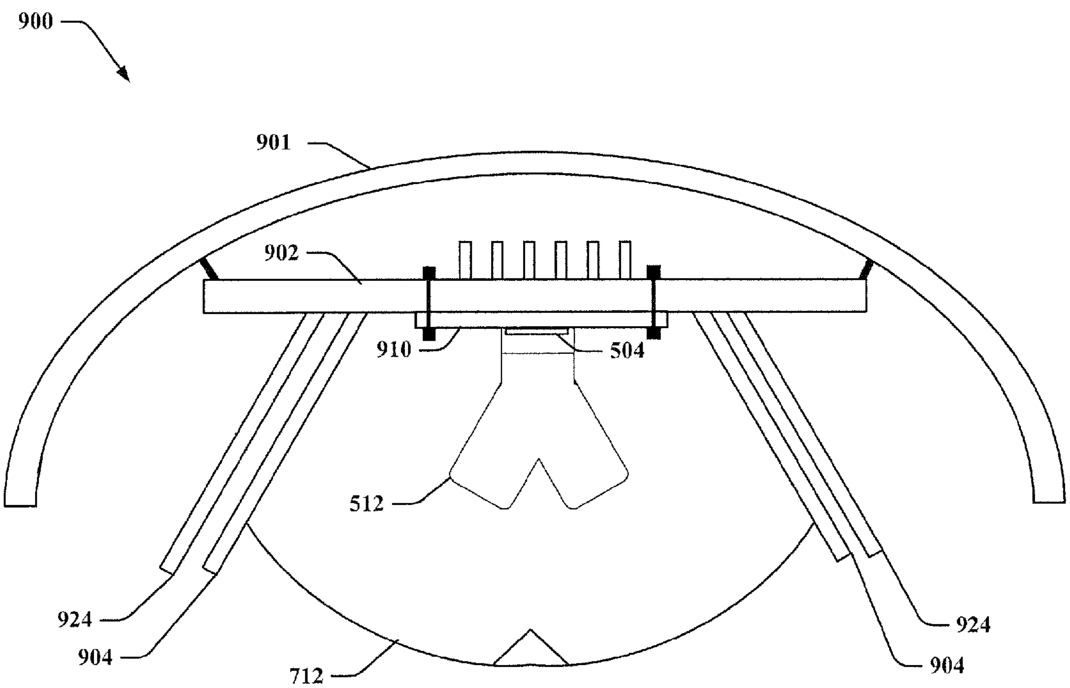


FIG. 9

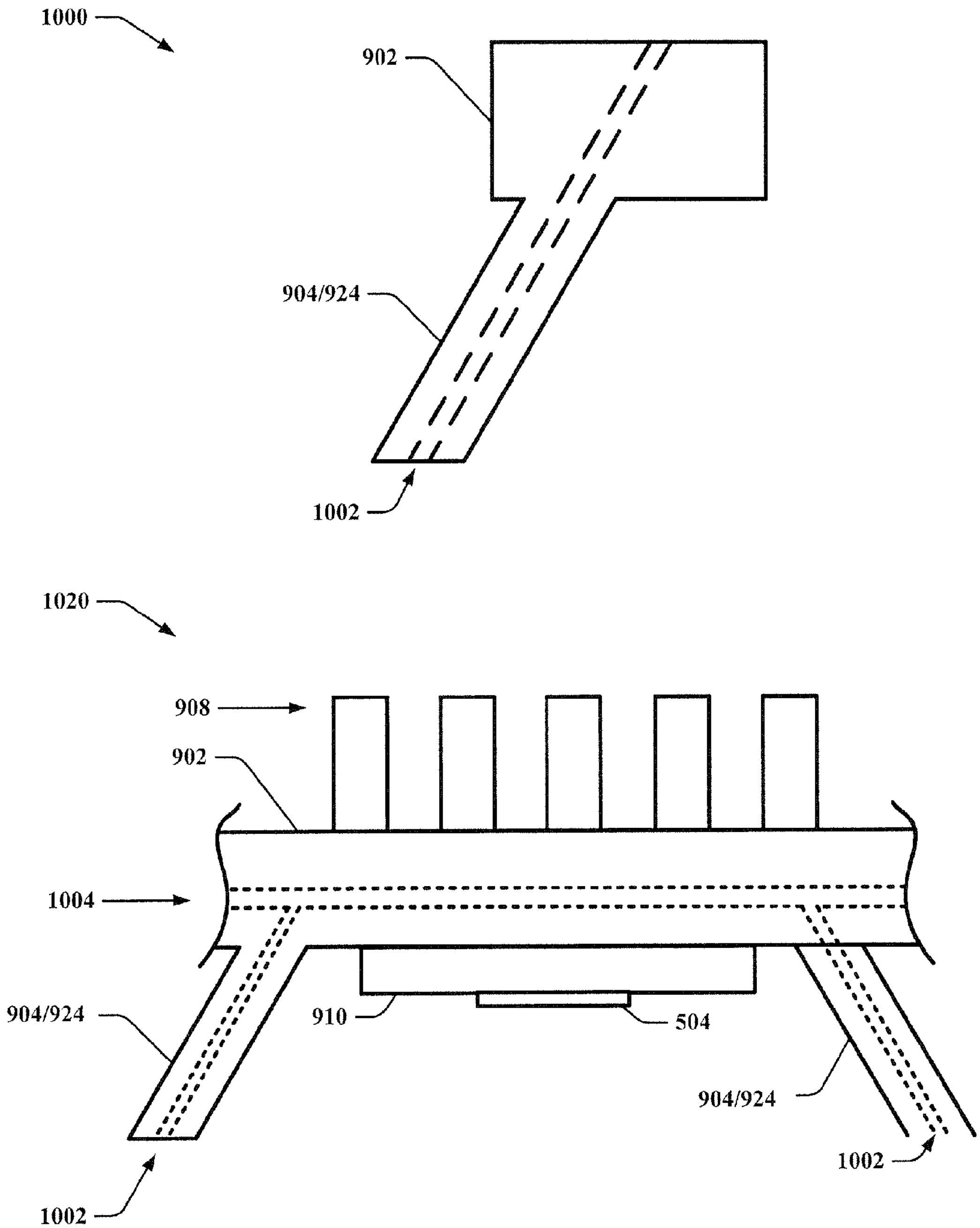

1000
902
904/924
1002
1020
908
902
1004
904/924
910
504
904/924
1002
1002

FIG. 10

LIGHTING MODULE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit and right of priority under 35 U.S.C. 119 to Provisional U.S. Patent Application No. 61/624,221, which was filed on Apr. 13, 2012.

BACKGROUND

The present disclosure relates to light sources and, more particularly, to a lighting module.

A light-emitting device, such as a light-emitting diode (LED), is an attractive candidate for replacing conventional light sources such as incandescent, halogen and fluorescent lights. LEDs have substantially higher light conversion efficiencies than incandescent and halogen lights and longer lifetimes than these types of conventional light sources. Some types of LEDs have higher conversion efficiencies than fluorescent light sources. LEDs require lower voltages than fluorescent lights and contain no mercury or other dangerous materials. Some light-emitting devices have been used to replace high-intensity discharge (HID) lights to provide high levels of light over large areas that require greater energy efficiency or light intensity. Such areas include roadways, parking lots, pathways, large public areas, and other outdoor applications.

SUMMARY

In one aspect of the present disclosure, A lighting module includes a light-emitting device configured to emit light, a thermal interface configured to conduct heat away from the light-emitting device, an optical element configured to transmit the emitted light in a light distribution pattern on an area located a distance away from the lighting module, and a reflective surface configured to redirect a portion of the light transmitted by the optical element.

It is understood that other aspects of apparatuses and methods will become readily apparent to those skilled in the art from the following detailed description, wherein various aspects of apparatuses and methods are shown and described by way of illustration. As will be realized, these aspects may be implemented in other and different forms and its several details are capable of modification in various other respects. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE FIGURES

Various aspects of apparatuses and methods will now be presented in the detailed description by way of example, and not by way of limitation, with reference to the accompanying drawings, wherein:

FIG. **1** is a cross-sectional illustration of an example light-emitting device.

FIG. **2** is a plan-view illustration of the example light-emitting device.

FIG. **3**A is a top-view illustration of an example white-light light-emitting device.

FIG. **3**B is a side-view illustration of the example white-light light-emitting device illustrated in FIG. **3**A.

FIG. **4** is an illustration of exemplary light-emitting devices in a street light.

FIG. **5** is a cross-sectional illustration of a first example head of a lighting system.

FIG. **6** is a cross-sectional illustration of a second example head of a lighting system.

FIG. **7** is a cross-sectional illustration of a third example head of a lighting system.

FIG. **8** is a cross-sectional illustration of a fourth example head of a lighting system.

FIG. **9** is a cross-sectional illustration of a fifth example head of a lighting system.

FIG. **10** shows cross-sectional illustrations of portions of an exemplary lighting module.

DETAILED DESCRIPTION

Various aspects of the disclosure will be described more fully hereinafter with reference to the accompanying drawings. This disclosure may, however, be embodied in many different forms by those skilled in the art and should not be construed as limited to any specific structure or function presented herein. Rather, these aspects are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. Based on the teachings herein, one skilled in the art should appreciate that the scope of the disclosure is intended to cover any aspect of this disclosure, whether implemented independently of or combined with any other aspect of the disclosure. For example, an apparatus may be implemented or a method may be practiced using any number of the aspects set forth herein. In addition, the scope of the disclosure is intended to cover such an apparatus or method which is practiced using other structure and/or functionality in addition to or instead of other aspects of this disclosure. It should be understood that any aspect of the disclosure disclosed herein may be embodied by one or more elements of a claim.

Disclosed is an apparatus that may be used for retrofitting a conventional lighting system, such as a street light. In one example, a street light may have a head including a light source comprising one or more light-emitting devices, an optical element, and one or more reflectors configured to reflect light emitted by the one or more light-emitting devices to the optical element to produce a light distribution pattern from the head. The one or more light-emitting devices may produce Lambertia light, such that an observer perceives a constant brightness across the one or more light-emitting devices. The light produced by the light-emitting devices may be used to illuminate a reflector. The reflector may be used to transform the Lambertia light to collimated light and direct the collimated light towards the optical element. The optical element may be configured to produce the light distribution pattern from the collimated light.

By way of example, “street light” may refer to any lighting system that provides any illumination to a street, road, walkway, tunnel, park, outdoor facility, parking lot, or the like. A “pole” may refer to any structure for supporting a lighting system, such as a light post, hi-bay support, wall mounting, suspended hanging fixture, support frame, ceiling mount, or the like. A “thermal management system” may comprise at least a heat sink, heat spreader, heat fin, heat pipe, thermal interface material, active air movement devices, or the like.

An example of a light-emitting device is an LED. An LED is a semiconductor material impregnated, or doped, with impurities. These impurities add “electrons” and “holes” to the semiconductor, which can move in the material relatively freely. Depending on the kind of impurity, a doped region of the semiconductor can have predominantly electrons or holes, referred to as an n-type or p-type semiconductor region, respectively. In LED applications, the semiconductor includes an n-type semiconductor region and a p-type semiconductor region. A reverse electric field is created at the junction between the two regions, which causes the electrons and holes to move away from the junction and towards an active region. When a forward voltage sufficient to overcome the reverse electric field is applied across the p-n junction, electrons and holes are forced into the active region and combine. When electrons combine with holes, they fall to lower energy levels and release energy in the form of light.

FIG. **1** is a cross-sectional illustration of an example LED. The LED **101** includes a substrate **102**, an epitaxial-layer structure formed on the substrate **102**, and a pair of electrodes **106**, **108** on the epitaxial-layer structure. The epitaxial-layer structure comprises an active region **116** located between two oppositely-doped epitaxial regions (**114**, **118**). In this example, an n-type semiconductor region **114** is formed on the substrate **102** and a p-type semiconductor region **118** is formed on the active region **116**. In other examples, the p-type semiconductor region **118** may be formed on the substrate **102** and the n-type semiconductor region **114** may formed on the active region **116**. As those skilled in the art will readily appreciate, various concepts described throughout this disclosure may be extended to any suitable epitaxial-layer structure. Additional layers (not shown) may also be included in the epitaxial-layer structure, including buffer, nucleation, contact and current-spreading layers as well as light-extraction layers.

The electrodes **106**, **108** may be formed on the surface of the epitaxial-layer structure. The p-type semiconductor region **118** is exposed at the top surface and, therefore, the p-type electrode **106** may be readily formed on the p-type semiconductor region **118**. However, the n-type semiconductor region **114** is buried beneath the p-type semiconductor region **118** and the active region **116**. Accordingly, to form the n-type electrode **108** on the n-type semiconductor region **114**, a portion of the active region **116** and the p-type semiconductor region **118** is removed to expose the n-type semiconductor region **114**. After this portion of the epitaxial-layer structure is removed, the n-type electrode **108** may be formed.

One or more LEDs may be used to construct a light-emitting device. A light-emitting device having multiple LEDs disposed on a single substrate, as will be described in connection with FIG. **2**, is sometimes referred to as an "LED array." However, the present disclosure is not limited to LED arrays, and may be extended to any suitable LED device or other suitable light source. FIG. **2** is a top-view illustration of an example light-emitting device **200**. The light-emitting device **200** comprises multiple LEDs **201** arranged on a substrate **202**. The substrate **202** may be made from any suitable material that provides mechanical support to the LEDs **201**. Preferably, the material is thermally conductive to dissipate heat away from the LEDs **201**. The substrate **202** may includes a dielectric layer (not shown) to provide electrical insulation between the LEDs **201**. The LEDs **201** may be electrically-coupled in parallel or in series by a conductive circuit layer, wire bonding, or a combination of these or other methods on the dielectric layer (not shown).

The light-emitting device **200** may be configured to produce white light. White light may enable the LED device to act as a direct replacement for conventional light sources used today in incandescent, halogen, fluorescent, HID, and other suitable lights. There are at least two suitable ways of producing white light. One suitable way is to use individual LEDs that emit wavelengths (corresponding to certain colors, such as red, green, blue, or amber) and then mix all the colors to produce white light. Another suitable way is to use a phosphor material to convert monochromatic light emitted from a blue or ultra-violet (UV) LED to broad-spectrum white light. The present disclosure, however, may be practiced with other LED and phosphor combinations to produce different colored lights.

FIG. **3**A is a top-view illustration of an example white-light light-emitting device **300**. FIG. **3**B is a cross-sectional illustration of the example white-light light-emitting device **300** shown in FIG. **3**A. The white-light light-emitting device **300** is shown with a substrate **302**, which may be used to support multiple LEDs **301**. A phosphor material **308** may be deposited within a cavity defined by an circular-shaped boundary **309** that extends circumferentially around the upper surface of the substrate **302**. The circular-shaped boundary **309** may be formed with a suitable mold or, alternatively, formed separately from the substrate **302** and attached to the substrate **302** using an adhesive or other suitable means. The phosphor material **308** may include, by way of example, phosphor particles suspended in an epoxy, silicone, or other carrier, or may be constructed from a soluble phosphor that is dissolved in the carrier.

In another example, each LED **301** of a white-light light-emitting device **300** may have its own phosphor layer. Other configurations of LEDs **301** and other light-emitting cells may be used to create a white-light light-emitting device **300**. The present disclosure is not limited to light-emitting devices that produce only white light and may be extended to lighting-emitting devices that produce other colors of light.

Street lights may be designed to provide improved visibility and increased safety on a roadway while making efficient use of energy. A street light provides illumination in a particular light distribution pattern. The Illumination Engineering Society (IES) has established a series of lateral distribution patterns, which are designated as Types I, II, III, IV, and V. High-intensity discharge (HID) lights may be used in street lights. LEDs may replace HID lights.

FIG. **4** is an illustration of exemplary light-emitting devices in a street light **400**. The street light **400** may include a pole **410** and a head **420** attached to the pole **410**. The head **420** may include a light source that includes one or more light-emitting devices **430**, an optical element **440**, and a reflector **450** of the head **420**. The reflector **450** may be configured to reflect light emitted by the light-emitting devices **430** to the optical element **440** to produce a light distribution pattern **425**.

In some embodiments, the light emitted from the light-emitting devices **430** may be Lambertian patterned light. The Lambertian patterned light may be used to illuminate a reflector **450** and/or may be directed to optical element **440**. Optical element **440** may be used to transform the Lambertian patterned light and/or internally reflected light to produce a desired light distribution pattern **425**.

Optical element **440** may comprise one or more mirrors, lenses and other elements that may be configurable to accommodate various heights **415** of the street light **400**, light distribution patterns **425**, illumination intensities, and/or size of the light-emitting device **430**.

In certain embodiments, systems, apparatus and methods are provided to facilitate rapid and/or easy replacement of a lighting module in a street light or other lighting device. A lighting module may comprise one or more light-emitting devices **430** and an optical component that diffuses, collimates, focuses or otherwise modulates light to obtain a desired light distribution pattern **425**.

FIG. **5** is a cross-sectional illustration of a first example head **502** of a lighting system **500**. The lighting system **500** may comprise a lighting module **520**, **530** and a base plate **514**. The lighting module **520**, **530** may comprise one or more LED arrays **504**, a thermal interface **510**, a heat sink **506** and an optical element **512**. In one example, the lighting module **520**, **530** comprises each of the LED arrays **504**, the thermal interface **510**, the heat sink **506**, and the optical element **512**. In another example, the lighting module **520**, **530** comprises LED array **504**, thermal interface **510** and, optionally, optical element **512**. The thermal interface **510** may assist in dissipating heat generated by the LED array **504**. The lighting module **520**, **530** may be used in association with the heat sink **506**.

In some embodiments, the thermal interface **510** may be characterized by low thermal resistance and high electrical resistance. Thermal interface **510** may be multilayered. For example, the thermal interface **510** may include a relatively thin electrical isolation layer that is bonded to a surface of the thermal interface **510**. An electrical isolation layer may be created through an oxidation of a surface of the LED array **504** and/or the heat sink **506**. In some embodiments, electrical isolation is not desired or required and the heat sink **506** may provide a portion of an electrical circuit that includes the LED array **504**. For example, the heat sink **506** may provide a grounding connection for the lighting module **520**, **530**.

The lighting module **520**, **530** may be fitted into a base plate **514** mounted within the head **502**. Base plate **514** may be constructed from a metal, polymer, ceramic, a composite or other material having sufficient tensile strength to support the lighting module **520**, **530** and a relatively heavy heat sink **506**. Base plate **514** may be configured to adapt head **502** for use with the lighting module **520**, **530**, thereby replacing incandescent, fluorescent or HID lights with an array **504** of light-emitting devices. For example, the base plate **514** may be used to adapt a head **502** that is otherwise configured for use with an HID light. Base plate **514** may be adapted by, for example, providing holes, threads or other elements configured to receive one or more fasteners used to attach base plate to the head **502**. In some embodiments, the base plate **514** may comprise an adapted or original base plate **514** that is used to attach HID or another type of light to the head **502**. The base plate **514** may attach directly to the heat sink **506**, which may attach to the LED arrays **504**, thermal interface **510**, and/or optical element **512**. The heat sink **506** may comprise fins **508** to increase surface area exposed to air in order to permit rapid dissipation of heat generated by the LED array **504**. The heat sink **506** may be constructed from a low-thermal resistance material, and the heat sink **506** may have sufficient volume and density to absorb cyclic variations in heat generation.

The optical element **512** typically comprises one or more lenses, mirrors, reflectors and/or prisms that receive light from the LED array **504** and that produce one or more light distribution patterns **425** (see FIG. **4**). The optical element **512** may be mechanically adjustable to re-size and/or re-orient light distribution patterns **425** (see FIG. **4**) based on a specific application of the lighting system **500**. For example, the relative distances of certain optical components within an optical module can be adjusted with respect to one another and/or with respect to the LED array **504**. The optical element **512** may include elements that diffract, diffuse, focus, defocus, collimate, polarize, depolarize, and/or attenuate light or frequencies of light received from the LED array **504**. A lens **516** may provide further light correction and/or manipulation. In some embodiments, the lens **516** may be a transparent, optically-neutral cover that serves to protect lighting module and other components within the head **502** from environmental conditions.

FIG. **6** is a cross-sectional illustration of a second example head **601** of a lighting system **600**. The lighting system **600** may comprise a lighting module **520**, **530** (see FIG. **5**) and a base plate **604**. The lighting module **520**, **530** (see FIG. **5**) may comprise a LED array **504**, a thermal interface **602**, and/or an optical element **512**. In one example, the lighting module **520**, **530** (see FIG. **5**) comprises each of the LED array **504**, the thermal interface **602**, and the optical element **512**. The lighting module **520**, **530** (see FIG. **5**) may be removably attached to a base plate **604** that is attached to the head **502**.

In one example, the base plate **604** is constructed to operate as a heat sink and may comprise heat dissipating elements, such as one or more fins **608**. The lighting module **520**, **530** (see FIG. **5**) may be attached to the base plate **604** using fasteners **606** that, for example, couple the thermal interface **602** and the base plate **604**. Fasteners may comprise screws, bolts, pins, rivets, or other suitable fasteners. In some embodiments, threaded surfaces provided on the thermal interface **602** and the base plate **604** may be used to fasten the lighting module **520**, **530** (see FIG. **5**) to the base plate **604**.

The thermal interface **602** may be constructed as a plate of any suitable shape and with a thickness to provide sufficient mechanical strength to support lighting module. In particular, the thermal interface **602** may provide one or more fasteners and/or threaded surfaces (not shown) to engage and support the optical element **512**. The thermal interface **602** may be constructed from any suitable material that provides desired thermal and electrical conductivities.

A self-contained lighting module **520**, **530** (see FIG. **5**) comprising the LED array **504**, the thermal interface **510**, the optical element **512**, and their corresponding electrical connections may alternatively be used. For example, a failed or failing lighting module **520**, **530** (see FIG. **5**) may be replaced without removing the head **502** from the street light **400** (see FIG. **4**).

FIG. **7** is a cross-sectional illustration of a third example head **701** of a lighting system **700**. The lighting system **700** may comprise certain features and elements described in relation to FIGS. **5** and **6**. The lighting system **700** may include one or more additional reflectors **704** mounted on an outer part of the lighting module **520**, **530** (see FIG. **5**) or external to the lighting module **520**, **530** (see FIG. **5**). In certain embodiments, the reflectors **704** may be provided as an integral part of the lighting module **520**, **530** (see FIG. **5**). As shown in the example of FIG. **7**, one or more reflectors **704** may be attached to the thermal interface **710**.

In one example, the one or more reflectors **704** have a frustoconical shape that is aligned concentrically with the center of the LED array **504**. In another example, the one or more reflectors **704** may comprise a plurality of reflective segments corresponding to segments of a frustum of a cone. The one or more of reflectors **704** may comprise a generally flat, parabolic or irregularly-shaped surface. The one or more reflectors **704** may modify a light distribution pattern **425** (see FIG. **4**). The one or more reflectors **704** may operate to deflect light from a particular area of the light distribution pattern **425** (see FIG. **4**). The one or more reflectors **704** may operate to recover light that would otherwise leak from the lighting module **520**, **530** (see FIG. **5**), such as from the optical element **512** and/or the LED array **504**. The one or more reflectors **704** may operate to shade a neighboring structure from an otherwise broad light pattern. The one or more reflectors **704** may be constructed from any suitable material, including polished metals, and/or polymers, glass, ceramics or other material treated or manufactured to have a reflective surface.

In some embodiments, the one or more reflectors **704** may be adapted to provide a light absorbing surface. In some embodiments, the one or more reflectors **704** are provided as reflective areas of a frustoconical protective screen that may be clear or opaque in areas that are not reflective. A dome or flattened lens **712** may be provided to complete the protective outer shell. The lens **712** may optically transform light passing through it, or the lens **712** may conduct light with minimum diffraction and/or attenuation. The lens **712** may comprise an optical block **714** that reduces the occurrence of hotspots and other artifacts in the light distribution pattern **425** (see FIG. **4**) by dispersing a portion of the light transmitted by optical element **512**.

FIG. **8** is a cross-sectional illustration of a fourth example head **801** of a lighting system **800**. The lighting system **800** may comprise certain features and elements described in relation to FIGS. **5-7**. The lighting system **800** may comprise one or more reflectors **804**. Some of the one or more reflectors **804** may have multiple functions. For example, one or more of the reflectors **804** may serve to dissipate heat generated by the LED array **504**. One or more concentric layers of fins **824** may surround the one or more reflectors **804**. The one or more concentric layers of fins **824** may operate to dissipate heat generated by the LED array **504**. The one or more reflectors **804** may be arranged with the lens **712** in a manner that encloses the lighting module **520**, **530** (see FIG. **5**). The thermal interface **810** may be increased in volume and area in order to provide heat-sinking capacity directly to one or more lighting modules **520**, **530** (see FIG. **5**). The one or more reflectors **804** and/or one or more concentric layers of fins **824** may be thermally coupled to the thermal interface **810** and may assist in dissipating heat generated by the LED array **504**. Accordingly, the one or more reflectors **804** and the one or more concentric layers of fins **824** may be constructed from a thermally-conductive material in order to enable efficient dissipation of heat generated by the LED array **504**.

In some embodiments, the heat sink **802** may be replaced by an adaptor plate (not shown) that attaches the lighting module **520**, **530** (see FIG. **5**) to the head **801**. Accordingly, the plate **802** may primarily perform mechanical mounting services, and the one or more concentric layers of fins **824** being eliminated. In some embodiments, the plate **802** may be reduced in size to perform less heat-sinking and the one or more concentric layers of fins **824** may be reduced in size or eliminated.

FIG. **9** is a cross-sectional illustration of a fifth example head **901** of a lighting system **900**. The lighting system **900** generally comprises certain features and elements of the lighting system previously described in relation to FIGS. **5-8**. The lighting system **900** includes one or more reflectors **904**, provided externally to the lighting module **520**, **530** (see FIG. **5**). The one or more reflectors **904** may perform multiple functions and may include one or more layers of fins **924** concentrically aligned with the one or more reflectors **904** and the LED array **504**. The one or more concentric later of fins **924** may be attached to base plate **902** with low thermal resistance, and the one more concentric layers of fins **924** may serve as heat-sinking fins. The innermost of the one or more concentric layer of fins **904** may comprise a reflective surface that faces towards a lighting module **520**, **530** (see FIG. **5**) and may operate to selectively reflect and/or absorb light leaked or emitted by the optical element **512** and/or LED array **504**.

The one or more reflectors **904** or one or more concentric layers of fins **924** may attach to an optional lens **712** that encloses the lighting module **520**, **530** (see FIG. **5**). The thermal interface **910** may fasten the lighting module **520**, **530** (see FIG. **5**) to the base plate **902**, which performs as the principal heat sink for array **504**. Reflective elements **904** and one or more concentric layers of fins **924** may be attached to the base plate **902**, and may be constructed from a thermally-conductive material to dissipate heat generated by the LED array **504**. In some embodiments, the one or more reflectors **904**, the one or more concentric layers of fins **924**, and the base plate **902** may be constructed or cast as a single element.

FIG. **10** are cross-sectional illustrations of portions of an exemplary lighting module. In one example **1000**, the reflector/fin **904/924** may have one or more thermal chimneys formed from passage **1002**. A thermal chimney, comprising passage **1002**, is provided within the body of the reflector/fin **904/924** and extends along the length of the reflector/fin **904/924** and through the base plate **902**. As the base plate **902** and the reflector/fin **904/924** are heated, air within the passage **1002** is heated and rises (due to convection). As the heated air in the passage **1002** rises, cooler air is drawn into the passage **1002**, thereby increasing the effectiveness of the heat sink (i.e., the base plate **902** and the reflector/fin **904/924**).

In another example **1020**, a passage **1004** connects to one or more passages **1002** provided in reflectors/fins **904/924**. The one or more passages **1002** may form a heat pipe capable of efficiently transporting heat throughout the base plate **902** and the reflectors/fins **904/924**. Convection airflow through the heat pipe formed by passages **1002**, **1004** may transfer heat between the base plate **902** and the reflectors/fins **904/924**.

The one or more reflectors **804**, **904** (see FIGS. **8** and **9**) may have a reflective surface on at least one surface of the innermost reflector. The reflective surface may be located and configured to redirect a portion of the light emanating from the light-emitting array **504** or the optical element **512**. The reflective surface may redirect a portion of the light emitted from the one or more light-emitting devices **504** away from an area adjacent to the lighting module **520**, **530** (see FIG. **5**). The reflective surface may redirect a portion of the light transmitted by the optical element to modify the light distribution pattern **425** (see FIG. **4**). The reflective surface may increase or decrease light transmitted to a portion of the light distribution pattern **425** (see FIG. **4**). The reflective surface may increase, decrease, or otherwise modify the coverage area of the light distribution pattern **425** (see FIG. **4**).

The fins **804**, **824** (see FIG. **8**) and/or **904**, **924** (see FIG. **9**) may have a shape that is frustoconical, where one end has a greater diameter than the other end, and the end defined by the larger radius/diameter may mount a protective lens **712** (see FIG. **9**). The protective lens **712** (see FIG. **9**) may protect the LED array **504**, the reflective surface, and/or the optical element **512** from environmental conditions and contaminants. The end comprising the smaller radius/diameter may be attached to thermal interface **810** (see FIG. **8**). The end comprising the smaller radius/diameter may be attached to heat sink **902** (see FIG. **9**).

The various aspects of a street light are provided to enable one of ordinary skill in the art to practice the present disclosure. Various modifications to, and alternative configurations of, the street light presented throughout this disclosure will be readily apparent to those skilled in the art, and the concepts disclosed herein may be extended to other lighting applications. Thus, the claims are not intended to be limited to the various aspects of a street light presented throughout this disclosure, but are to be accorded the full scope consistent with the language of the claims. Thus, for example, lighting fixtures of any type, and for any lighting purpose, may be configured in accordance with the disclosure. All structural and functional equivalents to the elements of the various aspects of a light source described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims.

What is claimed is:

1. A lighting module, comprising:
a light-emitting device configured to emit light;
a thermal interface configured to conduct heat away from the light-emitting device;
an optical element configured to transmit the emitted light in a light distribution pattern on an area located a distance away from the lighting module;
first and second fins disposed in concentric alignment with the light-emitting device, wherein the second fin surrounds the first fin, and wherein the second fin is configured to dissipate heat generated by the light-emitting device; and
a reflective surface configured to redirect a portion of the light transmitted by the optical element, wherein the reflective surface is provided on an inner surface of the first fin.

2. The lighting module of claim 1, wherein the reflective surface is further configured to redirect a portion of the light emitted by the light-emitting device.

3. The lighting module of claim 1, wherein the portion of transmitted light redirected by the reflective surface modifies the light distribution pattern.

4. The lighting module of claim 1, wherein the reflective surface is further configured to increase an amount of light transmitted to a portion of the light distribution pattern.

5. The lighting module of claim 1, wherein the reflective surface is further configured to decrease an amount of light transmitted to a portion of the light distribution pattern.

6. The lighting module of claim 1, wherein the reflective surface is further configured to modify a coverage area of the light distribution pattern.

7. The lighting module of claim 1, wherein at least one of the first and second fins is thermally coupled to the thermal interface.

8. The lighting module of claim 7, wherein the at least one of the first and second fins is also thermally coupled to a heat sink.

9. The lighting module of claim 8, wherein the at least one of the first and second fins comprises a first passage that is configured to allow an airflow through the at least one of the first and second fins.

10. The lighting module of claim 9, wherein the first passage is connected to a second passage that is configured to allow an airflow through the thermal interface.

11. The lighting module of claim 9, wherein the first passage is connected to a third passage that is configured to allow an airflow through a heat sink.

12. The lighting module of claim 11, wherein the thermal interface is thermally coupled to the heat sink.

13. The lighting module of claim 8, wherein the first fin has a frustoconical shape, a first end corresponding to a first radius, and a second end corresponding to a second radius, and wherein the first radius is smaller than the second radius.

14. The lighting module of claim 13, further comprising a lens attached at the second end, wherein the lens is configured to protect the light-emitting device and the optical element from environmental conditions.

15. The lighting module of claim 13, wherein the first end is attached to the thermal interface.

16. The lighting module of claim 13, wherein the first end is attached to the heat sink.

17. The lighting module of claim 16, wherein the thermal interface is further configured to be removably fastened to the heat sink.

18. The lighting module of claim 16, wherein the heat sink is mounted in a head of a street light.

19. The lighting module of claim 1, wherein the light-emitting device comprises a plurality of light-emitting diodes.

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