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**Casper et al.**

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- (54) **HIGH INTENSITY LED ILLUMINATION DEVICE WITH AUTOMATED SENSOR-BASED CONTROL**
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- H05B 37/02** (2006.01)
- F21V 5/00** (2015.01)
- F21V 15/01** (2006.01)
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- F21V 29/00** (2015.01)
- F21V 3/00** (2015.01)
- F21V 23/00** (2015.01)
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- CPC ..... **F21V 5/007** (2013.01); **F21V 15/011** (2013.01); **F21V 23/02** (2013.01); **F21V 29/2206** (2013.01); **H05B 33/0845** (2013.01); **H05B 33/0857** (2013.01); **H05B 37/0218** (2013.01); **F21V 3/00** (2013.01); **F21V 5/04** (2013.01); **F21V 21/30** (2013.01); **F21V 23/004** (2013.01); **F21V 29/507** (2013.01); **F21W 2101/02** (2013.01); **F21W 2131/105** (2013.01); **F21W 2131/406** (2013.01); **F21Y 2105/001** (2013.01); **G02B 27/30** (2013.01)
- (58) **Field of Classification Search**
- USPC ..... 315/149–153
- See application file for complete search history.

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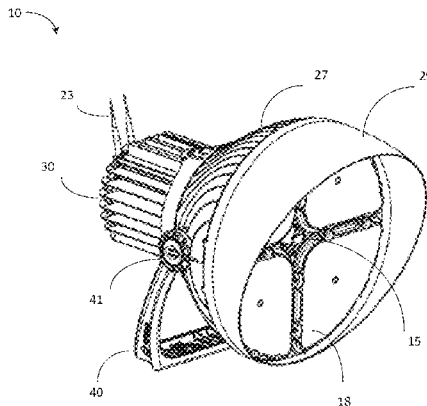
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(57) **ABSTRACT**  
A light fixture includes a light emitting diode (LED) structure, a housing with one or more sensors, and control circuitry that is configured to receive data from the sensor and automatically alter characteristics of light emitted by the LEDs in the fixture in response to the received data.

**47 Claims, 12 Drawing Sheets**



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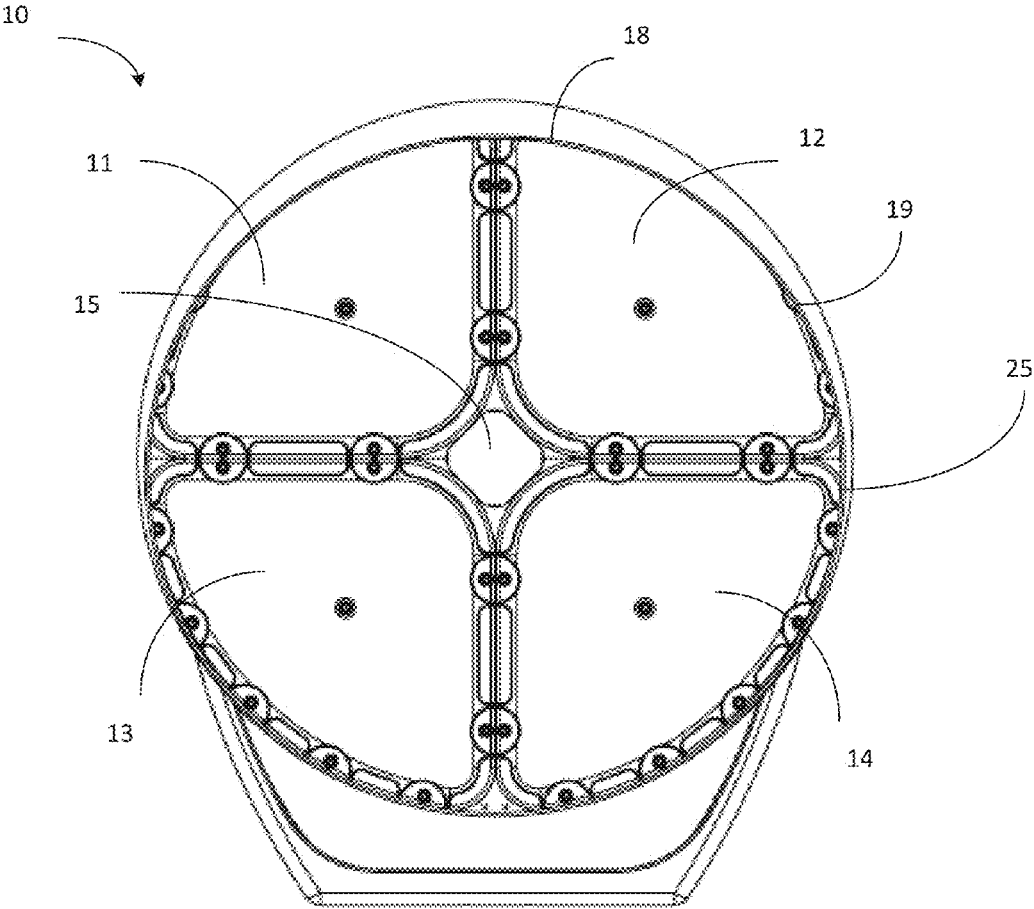


FIG. 1

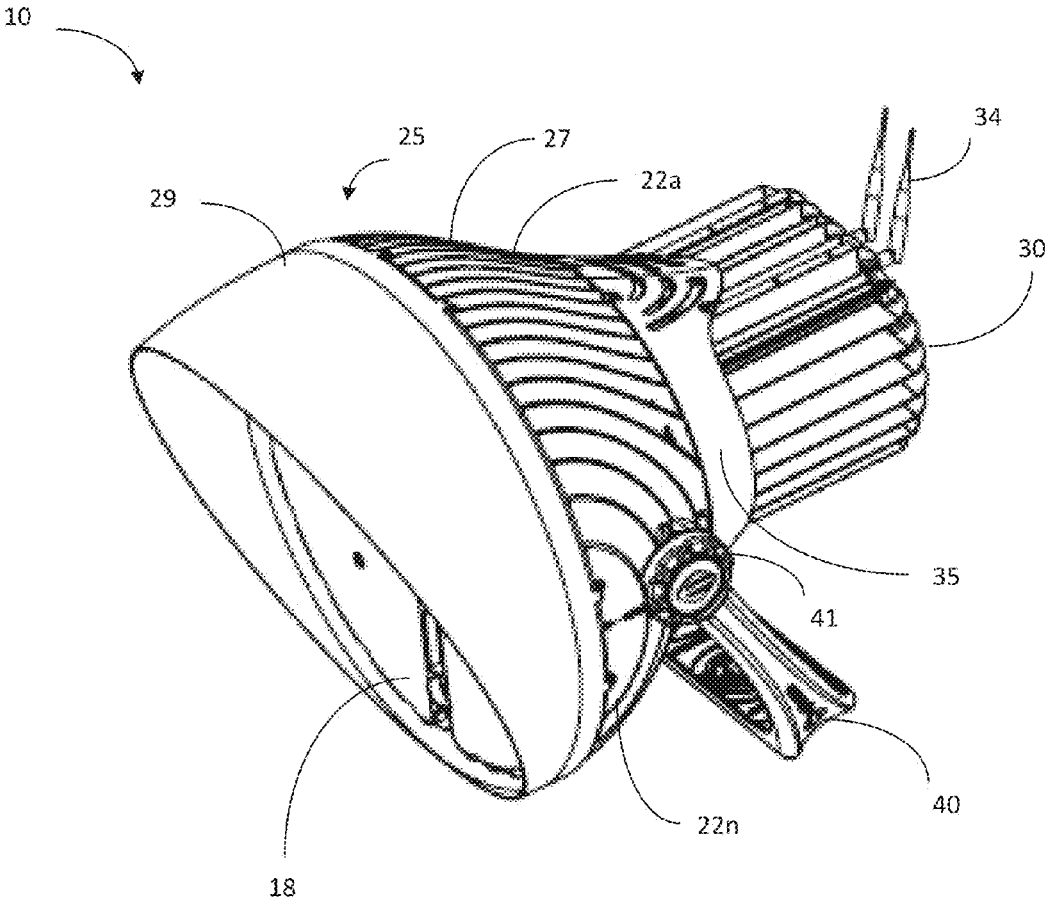


FIG. 2

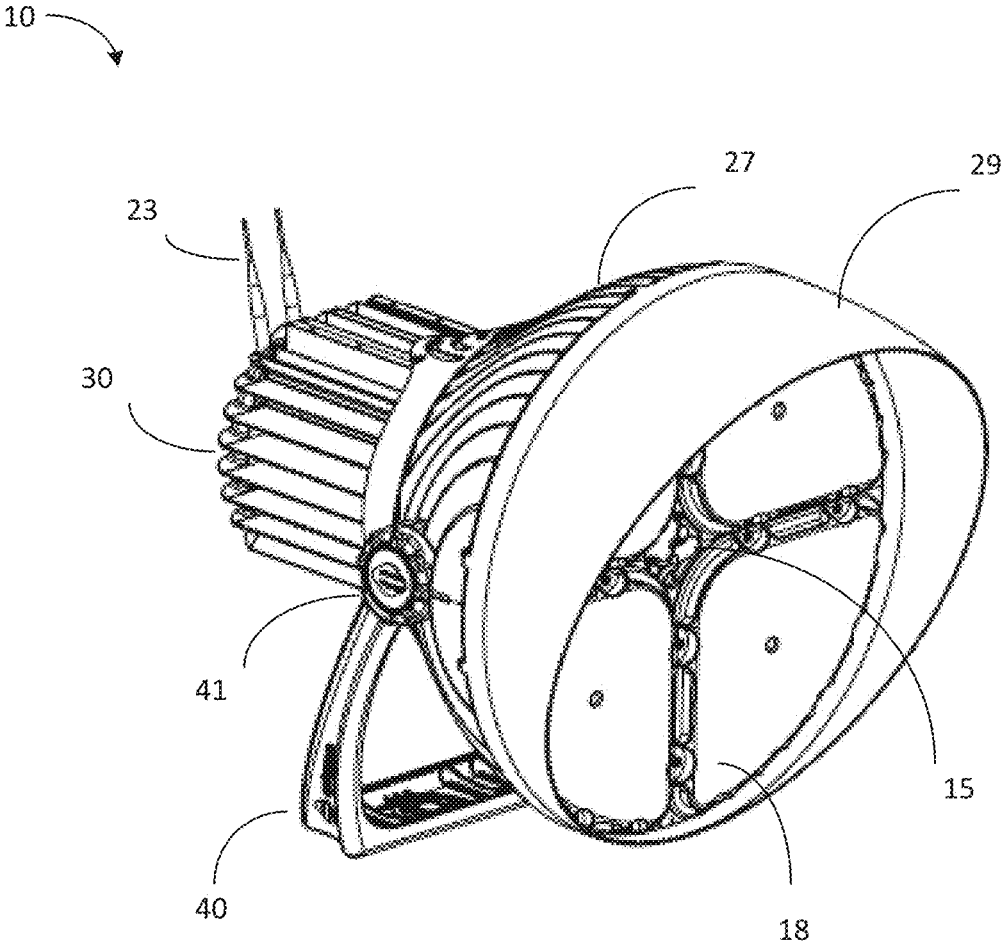


FIG. 3

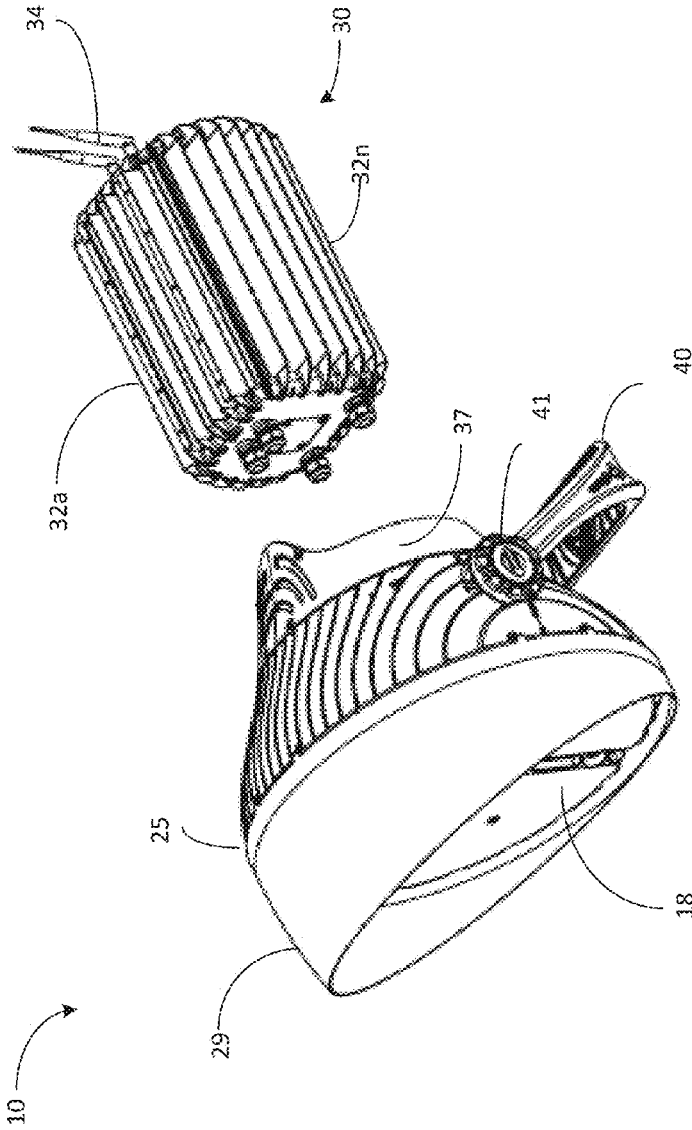


FIG. 4

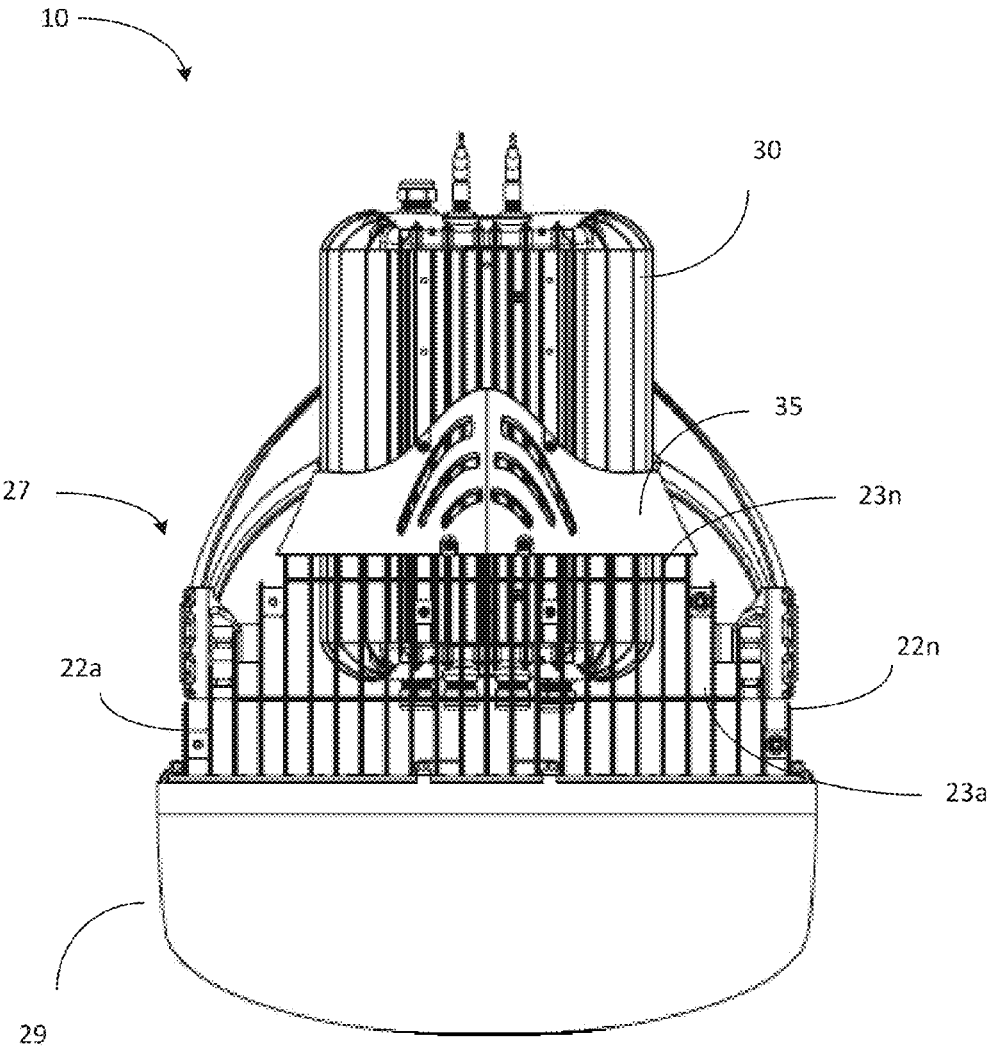


FIG. 5

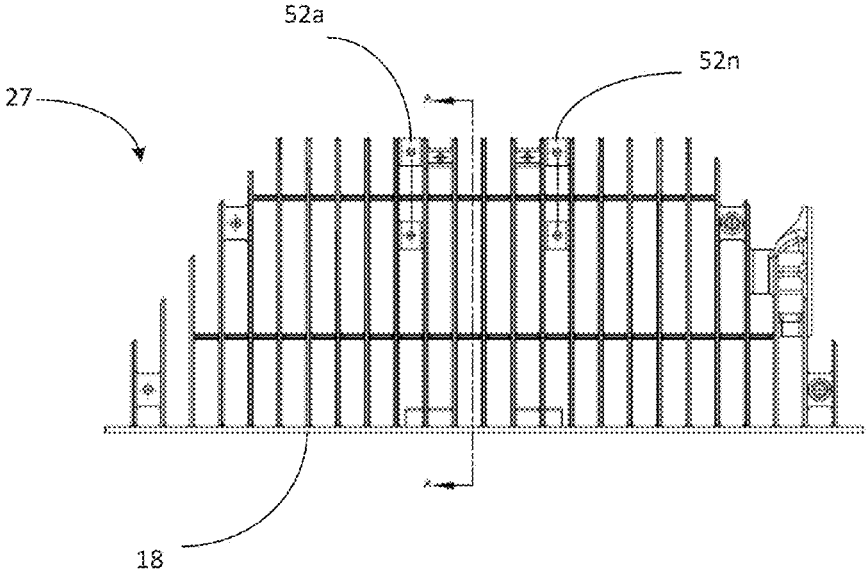


FIG. 6A

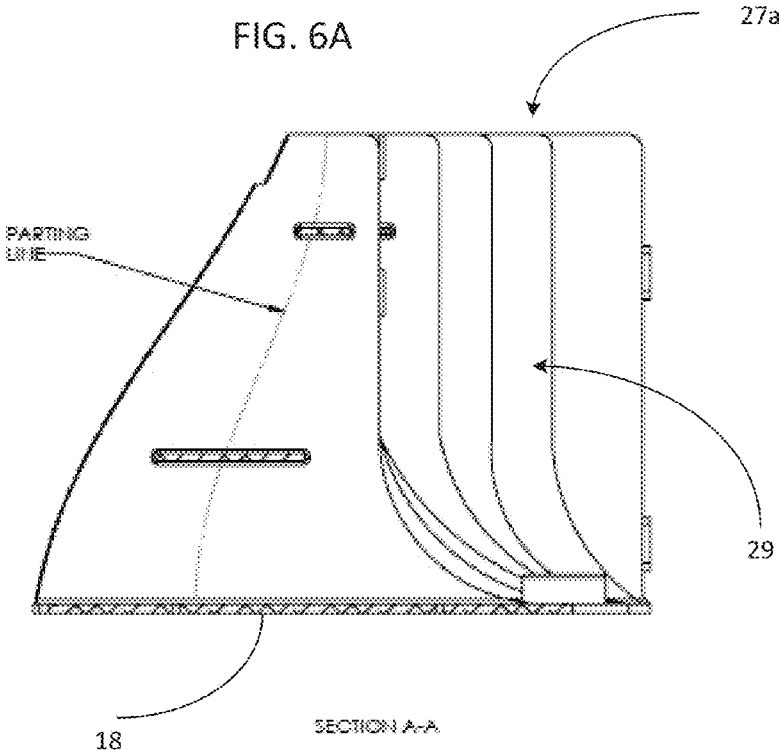


FIG. 6B



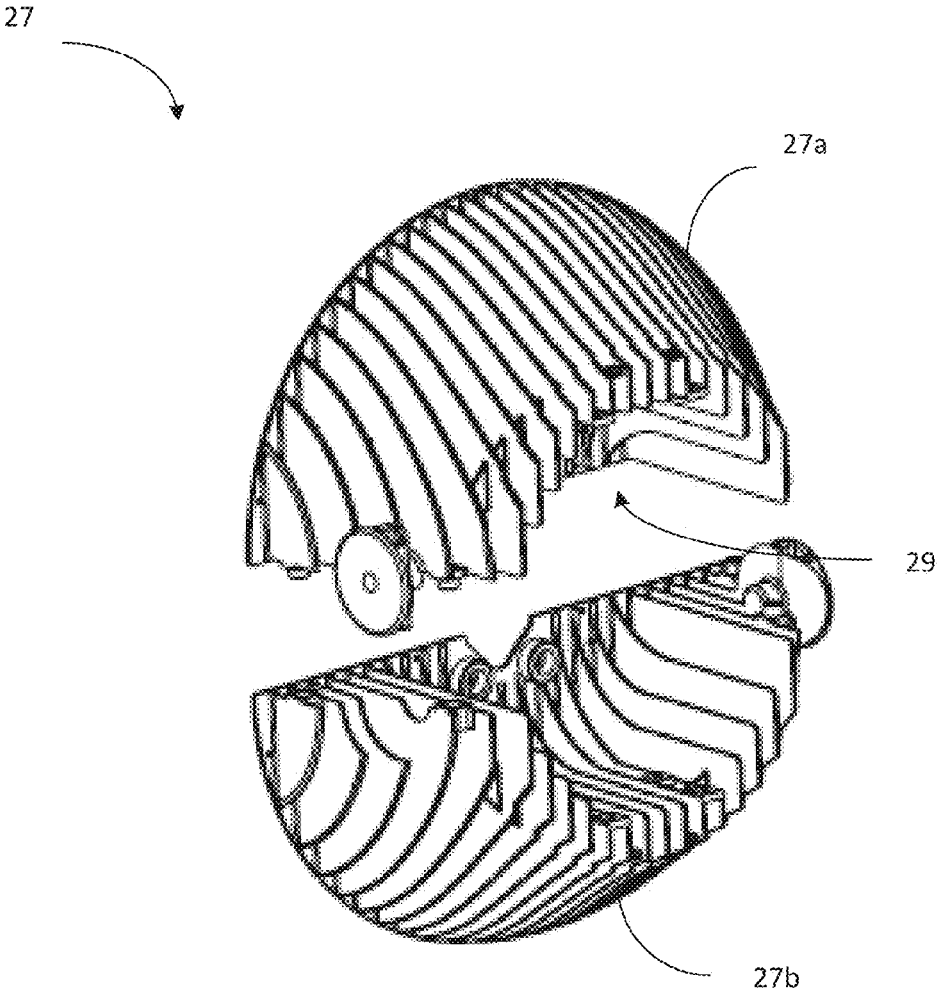


FIG. 7

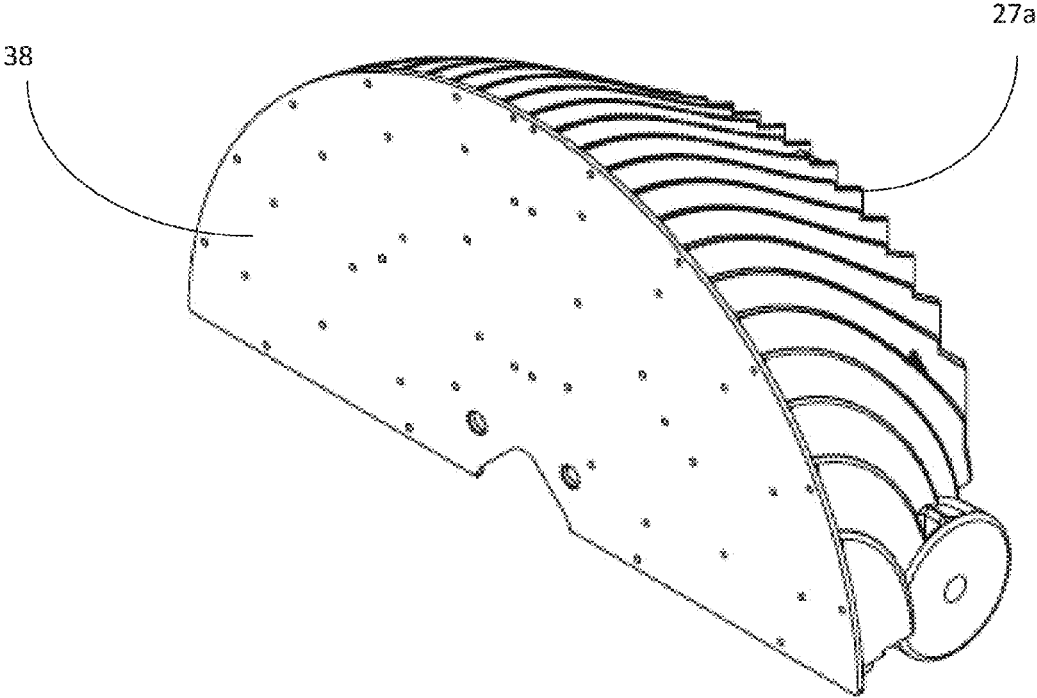


FIG. 8

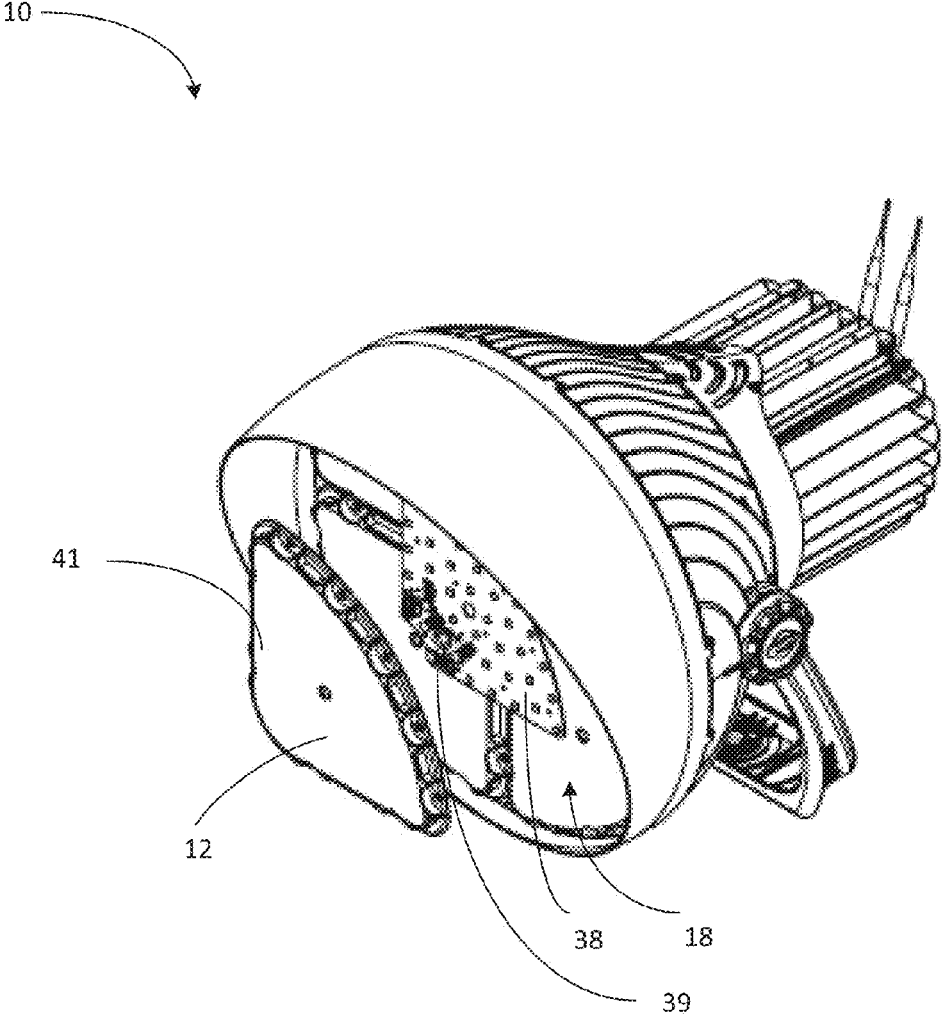


FIG. 9

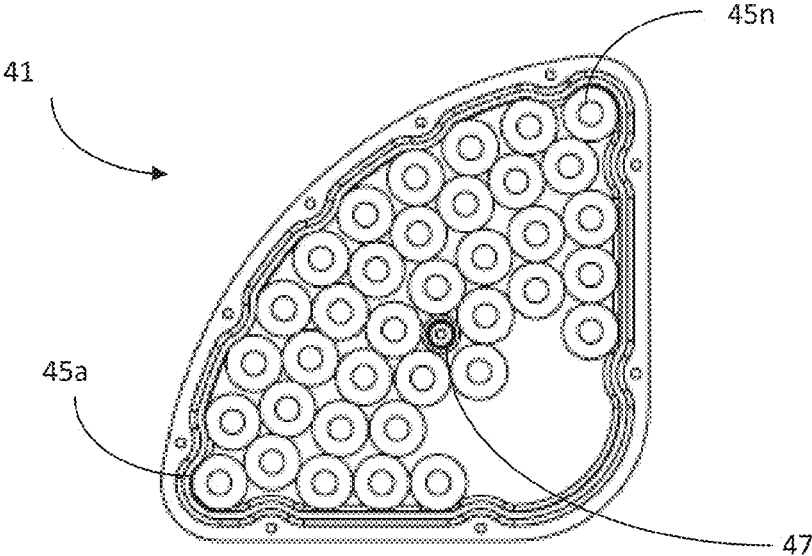


FIG. 10A

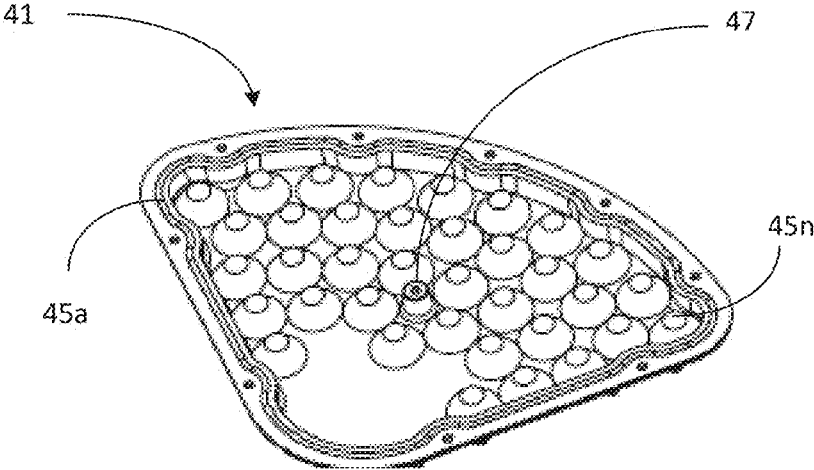


FIG. 10B

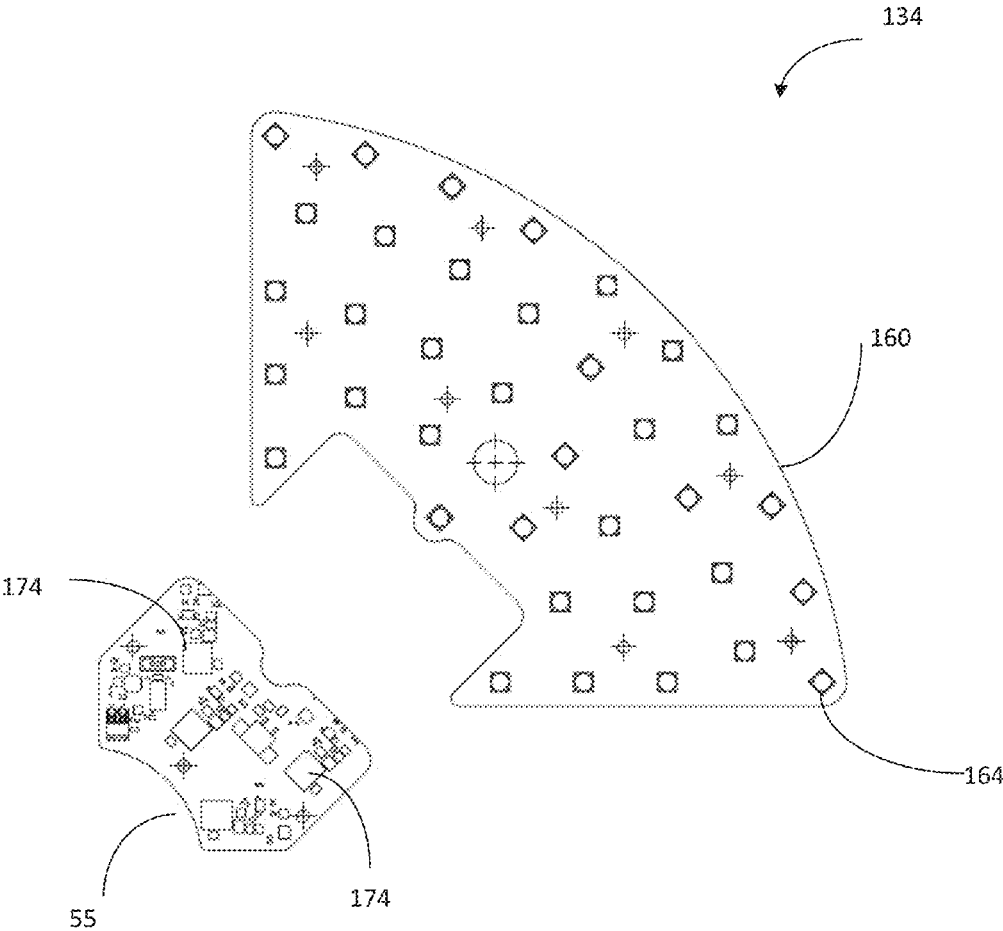


FIG. 11

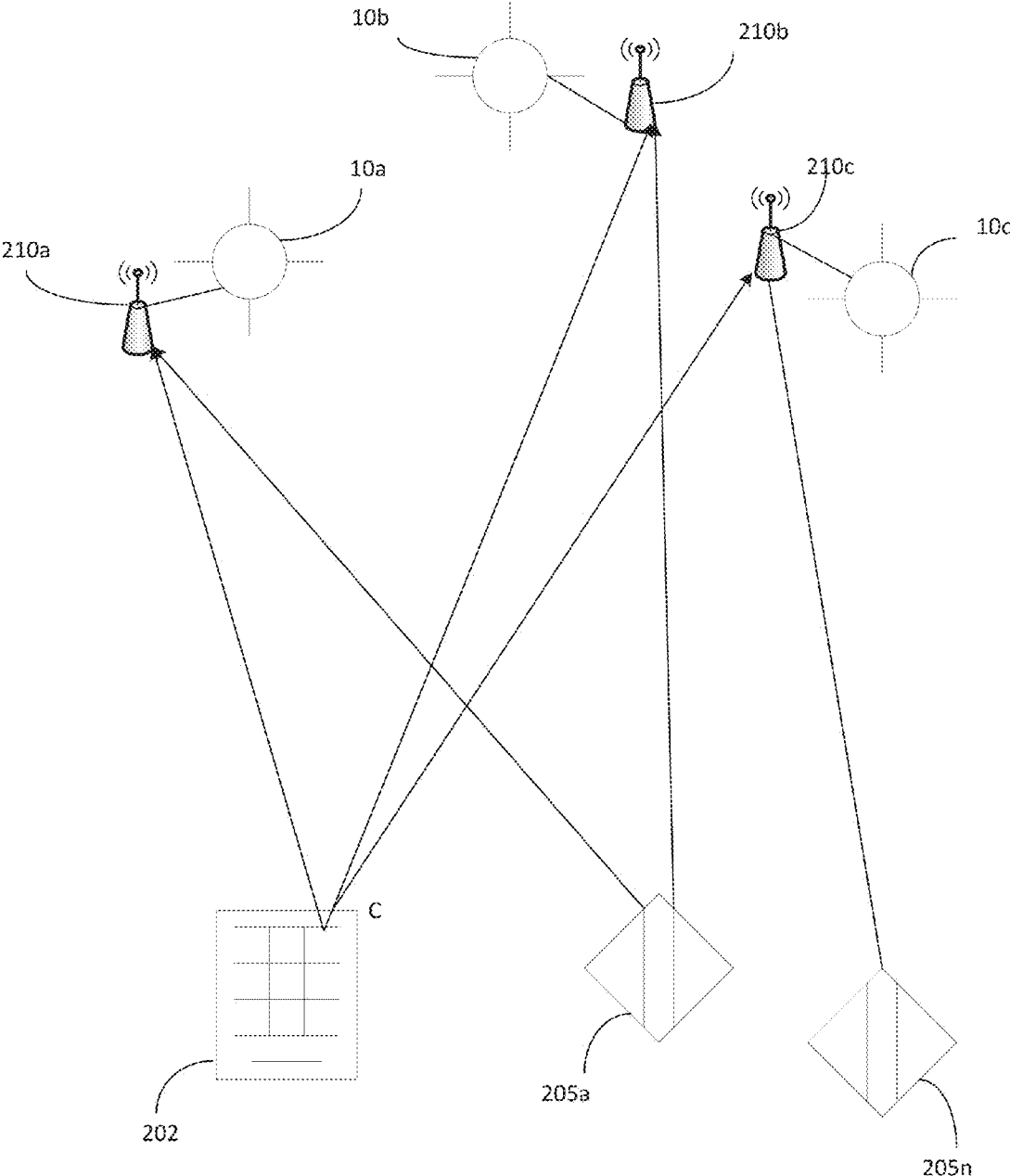


FIG. 12

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**HIGH INTENSITY LED ILLUMINATION  
DEVICE WITH AUTOMATED  
SENSOR-BASED CONTROL**

RELATED APPLICATIONS AND CLAIM OF  
PRIORITY

This patent document claims priority to U.S. Provisional Patent Application No. 61/917,030, filed Dec. 17, 2013, the disclosure of which is fully incorporated into this document by reference.

The patent document is related to U.S. patent application Ser. No. 14/573,521, U.S. patent application Ser. No. 14/573,553, U.S. patent application Ser. No. 14/573,584 and U.S. patent application Ser. No. 14/573,668, each filed Dec. 17, 2014. The disclosures of each related application are fully incorporated into this document by reference.

BACKGROUND

Entertainment facilities such as stadiums, arenas and concert halls seek ways to offer unique experiences with lighting and special effects. However, the current methods of providing such effects through lighting have been limited because of the manual operation required to change colors, intensities and positions associated with overhead light fixtures. Many facilities desire the maintenance of certain characteristics of light, such as intensity or color temperature. However, previous attempts to satisfy this desire have not been successful.

This document describes new illumination devices that are directed to solving the issues described above, and/or other problems.

SUMMARY

A light fixture includes a light emitting diode (LED) structure, a housing with one or more sensors, and control circuitry that is configured to receive data from the sensor and automatically alter characteristics of light emitted by the LEDs in the fixture in response to the received data. Optionally, the light fixture may include an opening that receives and secures the LED structure, a body portion that provides a heat sink for the LED structure, and/or a power supply that is secured to an area of the body portion that is distal from the LED structure. The sensor (which may be a single sensor or multiple sensors) will be configured to sense a characteristic of light in a vicinity of the LED structure. Optionally, the sensor may be housed in a sensor compartment, and the light fixture may include a reflecting structure that is positioned to reflect light emitted by the LEDs toward the sensor. The control card may contain control circuitry that is configured to receive data from the sensor and automatically alter a characteristic of light emitted by one or more of the LEDs in response to the received data.

For example, if the sensor includes a light intensity sensor, the control circuitry may be programmed so that when the control circuitry receives data from the light intensity sensor indicating that light intensity is above a threshold, the control circuitry will automatically reduce the brightness of a group of the LEDs by decreasing a width of voltage pulses applied to the group of LEDs or increasing spacing between voltage pulses applied to the group of LEDs to maintain the ambient light level within the desired range. When the control circuitry receives data from the light sensor indicating that the light intensity is below a threshold, the control circuitry may automatically increase the brightness of a group of the LEDs by increasing a width of voltage pulses applied to the group of

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LEDs or decreasing spacing between voltage pulses applied to the group of LEDs to maintain the ambient light level within the desired range.

If the sensor includes a color temperature sensor, and if the LEDs of the light fixture include a first group of LEDs that exhibit a first color temperature and a second group of LEDs that exhibit a second color temperature, then the control circuitry may be programmed so that when the control circuitry receives data from the sensor indicating that detected color temperature has moved above or below a threshold, the control circuitry will generate commands to control drive currents delivered to the first group of LEDs and the second group of LEDs so that the light emitted by the light fixture will exhibit a color temperature that is within the threshold. The commands also may include commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the sensor will not substantially change when the drive currents change in response to the commands. The commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the sensor will not substantially change when the drive currents change may include commands to: (i) automatically reduce the brightness of one of the group of LEDs by decreasing a width of voltage pulses applied to that group of LEDs or increasing spacing between voltage pulses applied to that group of LEDs; and (ii) automatically increase the brightness of the other group of LEDs by increasing a width of voltage pulses applied to that group of LEDs or decreasing spacing between voltage pulses applied to that group of LEDs.

As another example, if the sensor includes a  $D_{uv}$  sensor, and if the plurality of LEDs include a first group of LEDs that exhibit a first color temperature and a second group of LEDs that exhibit a second color temperature, then the control circuitry may be programmed so that when the control circuitry receives data from the sensor indicating that detected  $D_{uv}$  has moved above or below a threshold, the control circuitry will generate commands to control drive currents delivered to the first group of LEDs and the second group of LEDs so that the light emitted by the light fixture will exhibit a  $D_{uv}$  that is within the threshold. The commands also may include commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the sensor will not substantially change when the drive currents change in response to the commands. The commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the sensor will not substantially change when the drive currents change may include commands to: (i) automatically reduce the brightness of one of the group of LEDs by decreasing a width of voltage pulses applied to that group of LEDs or increasing spacing between voltage pulses applied to that group of LEDs; and (2) automatically increase the brightness of the other group of LEDs by increasing a width of voltage pulses applied to that group of LEDs or decreasing spacing between voltage pulses applied to that group of LEDs.

Optionally, the light fixture also may include an ambient air temperature sensor. If so, then the control circuitry may be programmed so that when the control circuitry receives data from the ambient air temperature sensor indicating that ambient air temperature is above a threshold, the control circuitry will automatically alter a characteristic of light emitted by one or more of the LEDs in response to the received ambient air temperature.

In some embodiments, the opening of the light fixture may be circular. The LED structure may be positioned and shaped to form a ring structure in the opening around a central area,

and the sensor may be contained in a sensor compartment positioned in a central area of the opening.

Optionally, the light fixture also may include a power sensor that is configured to measure voltage across a group of the LEDs; and the control circuitry may be programmed so that, when it receives data from the power sensor indicating that the voltage across the group of LEDs has changed by at least a threshold amount, it causes current delivered to the group of LEDs to change to maintain light emitted by the remaining LEDs in the group at a desired illuminance level.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a front view of an example of one embodiment of the illumination devices disclosed in this document.

FIG. 2 illustrates a perspective view from a first side of the device of FIG. 1.

FIG. 3 illustrates a perspective view from a second side of the device of FIG. 1.

FIG. 4 illustrates a perspective view of the device of FIG. 1 with the power supply detached from the unit.

FIG. 5 illustrates a top view of the device of FIG. 1, and shows an embodiment of the housing's fins that provide a heat sink effect.

FIGS. 6A and 6B illustrate an example of a heat sink body portion.

FIG. 7 illustrates an embodiment of a clamshell-type housing for a body portion of the device of FIG. 1.

FIG. 8 illustrates how a body portion of the device of FIG. 1 may receive a portion of a light emitting diode (LED) array structure.

FIG. 9 illustrates an embodiment of the device with an expanded view of an LED module.

FIGS. 10A and 10B illustrate a lens cover for an LED module.

FIG. 11 illustrates an example of an LED array on a substrate, with a control card.

FIG. 12 illustrates an example of a lighting system and control devices for such a system.

#### DETAILED DESCRIPTION

As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. As used in this document, the term "comprising" means "including, but not limited to."

When used in this document, the terms "upper" and "lower," as well as "vertical" and "horizontal," are not intended to have absolute orientations but are instead intended to describe relative positions of various components with respect to each other. For example, a first component may be an "upper" component and a second component may be a "lower" component when a light fixture is oriented in a first direction. The relative orientations of the components may be reversed, or the components may be on the same plane, if the orientation of a light fixture that contains the components is changed. The claims are intended to include all orientations of a device containing such components.

FIG. 1 illustrates a front view of an example of one embodiment of the illumination devices disclosed in this document. FIG. 2 illustrates a perspective view from one side of the device of FIG. 1, while FIG. 3 illustrates a perspective view from the opposite side of the device of FIG. 1. The illumination device 10 includes a housing 25 that encases various

components of a light fixture. The housing 25 includes an opening in which a set of light emitting diode (LED) modules 11-14 are secured to form a multi-module LED structure 18. The LED modules 11-14 are positioned to emit light away from the fixture. Each LED module includes a frame that holds a set of LEDs arranged in an array or other configuration, and in various embodiments the set of LEDs may be of a number that is sufficient to provide a high intensity LED device.

The opening also provides a sensor compartment 15 in which one or more sensors may be installed to detect information about the environment exterior to the device. The sensors included in the sensor compartment may include sensors that are configured to ambient temperature, or properties of light such as color rendering index (CRI),  $D_{uv}$ , color temperature (CCT), intensity or other properties of light in the ambient area in front of the LED modules 11-14. Optionally, the sensor compartment 15 may be fully enclosed in a housing to protect the sensors from rain and dust, or at least some of the compartment may include an opening to ambient air. Optionally, some or all of the sensors may be positioned in the LED modules instead of or in addition to the sensor compartment.

Optionally, the fixture may include one or more reflectors 19, such as mirrors or other reflective substrates, positioned and angled to reflect some of the light emitted by the LED modules toward the sensor compartment 15. The reflectors 19 are reflective structures that may be attached to the housing 25, the shroud 29 (described below), any of the LED modules 11-14, or any other suitable component of the fixtures. In this way, the sensor(s) may be positioned at or near the same plane as the LEDs, rather than substantially above the plane.

The opening of the housing 25 may be circular as shown, with the sensor housing 15 positioned at the center of the circle and the LED modules 11-14 positioned around the central open section to form a ring-shaped overall LED structure, although other shapes and configurations are possible. The LED modules 11-14 may include four modules, each of which is positioned in a quadrant of the circle as shown. Alternatively, any other number of LED modules, such as one, two, three, five or more LED modules, may be positioned within the opening in any configuration.

The device's housing 25 includes a body portion 27 and an optional shroud portion 29. The body portion 27 serves as a heat sink that dissipates heat that is generated by the LED modules. The body/heat sink 27 may be formed of aluminum and/or other metal, plastic or other material, and it may include any number of fins 22a . . . 22n on the exterior to increase its surface area that will contact a surrounding cooling medium (typically, air). Thus, the body portion 27 may have a bowl shape (i.e., semi-hemispherical) as shown, the LED structure 18 may fit within the opening of the bowl, and heat from the LED modules 11-14 may be drawn away from the LED structure and dissipated via the fins 22a . . . 22n on the exterior of the bowl.

The body 27 may be formed as a single piece, or it may be formed of two pieces that fit together as in a clamshell-type structure as shown. In a clamshell design, a portion of the interior wall of the clamshell near its opening may include a groove, ridge, or other supporting structure that is configured to receive and secure the LED structure in the opening when the clamshell is closed. In addition, the fins 22a . . . 22n may be curved or arced as shown, with the base of each fin's curve/arc positioned proximate the opening/LED modules, and the apex of each fin's curve/arc positioned distal from the opening/LED modules to further help draw heat away from the LED modules.



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Typically, any openings of the housing **25** will be sealed with a weatherproofing material such as rubber or silicone. In addition, the housing may include a shroud **29** that extends from the body **27** and beyond the LED modules. The shroud may be semi-circular in shape when the multi-module LED structure is circular, and it may be angled or shaped to shield an upper portion of the light assembly from rain while directing, focusing and/or reflecting light so that the light is concentrated in a desired direction (e.g., downward). In this way, the housing **25** may provide a dust-resistant and water-resistant housing that protects electronic components of the illumination device. This may be sufficient to meet the standards required to provide a National Electrical Manufacturers Association (NEMA) type 1 or type 2 enclosure. For outdoor installations, the housing may be sealed to provide a NEMA type 3 enclosure.

While the LED structure is positioned at one side of the body **27**, the opposing side of the body may include a power supply **30**. The power supply **30** may include a battery, solar panel, or circuitry to receive power from an external and/or other internal source. As shown, the external housing of the power supply **30** also may include fins to help dissipate heat from the power supply. The fins of the power supply may have a longest dimension that extends away from the LED structure (i.e., perpendicular to the widest dimension of the LED structure) to help with heat dissipation. Power wiring may be positioned within the body **27** to convey energy from the power supply **30** to the LED array modules **11-14**. The power supply **30** may extend from the rear of the housing as shown, or it may be placed into the housing so that it is flush or substantially flush with the rear of the housing **25**, or it may be configured to extend to some point between being flush with the housing **25** and the extended position of the configuration shown in FIG. 2.

The housing may be attached to a support structure **40**, such as a base or mounting yoke, optionally by one or more connectors **41**. As shown, the connectors **41** may include axles about which the housing and/or support structure may be rotated to enable the light assembly to be positioned to direct light at a desired angle.

FIG. 3 helps to illustrate components of the lighting device that can, in some embodiments, have self-cooling effects through its use of a sensor opening **15** in the front of the bowl (which is otherwise covered by the LED structure). When the LED modules operate, heat generated by the LEDs will rise and dissipate through the heat sink, creating a negative pressure that may draw cool ambient air into the housing via an opening that is positioned proximate to (i.e., at, near or around) the sensor compartment **15**. This chimney effect helps keep the LED modules and other components cool during operation. FIG. 3 also illustrates that the shroud **29** may have a variable width so that an upper portion positioned at the top of the LED structure **18** is wider than a lower portion positioned at the bottom and/or along the sides of the LED structure. This helps to reduce the amount of light wasted to the atmosphere by reflecting and redirecting stray light downward to the intended illumination surface.

As shown in FIG. 4, the power supply **30** may be detachable from the lighting device's housing **25** so that it can be replaced and/or removed for maintenance without the need to remove the entire device from an installed location, or so that it can be remotely mounted to reduce weight. In addition, the power supply may include a power supply housing made of a set of fins **32a . . . 32n** that are positioned lengthwise along an axis that extends away from the LED array when the power supply is installed in the device. The fins of the power supply housing thus provide an additional heat sink that draws heat

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away from the power supply during operation. The power supply housing and/or a portion of the lighting unit housing **25** may include one or more antennae, transceivers or other communication devices **34** that can receive control signals from an external source. For example, the illumination device may include a wireless receiver and an antenna that is configured to receive control signals via a wireless communication protocol. Optionally, a portion of the lighting unit housing **25** or shroud **29** may be equipped with an attached laser pointer that can be used to identify a distal point in an environment to which the lighting device directs its light. The laser pointer can thus help with installation and alignment of the device to a desired focal point.

FIG. 5 illustrates a top view of the device **10** and shows one embodiment of how the heat sink may help to keep the LED structure cool. In some embodiments the housing may be substantially or fully enclosed to provide a dome that receives the LED structure. In other embodiments, such as that shown in FIG. 5, the body portion **27** of the housing may be open so that the fins **22a . . . 22n** are positioned to extend away from the shroud **29** at an angle that is substantially perpendicular to the axis of the widest dimension (i.e., supporting panels) of the LED structure and shroud's opening.

The fins **22a . . . 22n** may be positioned substantially vertically (i.e., lengthwise from a top portion of the LED array structure and shroud **29** to a bottom portion of the same). Optionally, one or more lateral supports **23a . . . 23n** may be interconnected with the fins to provide support to the housing. The lateral supports **23a . . . 23n** may be positioned substantially parallel to the axis of the widest dimension of the LED structure as shown, or they may be curved to extend away from the LED structure, or they may be formed of any suitable shape and placed in any position. Each support may connect two or more of the fins. In this embodiment shown in FIG. 5, the fins and optional supports **23a . . . 23n** form the body portion **27** as a grate, and hot air may rise through the spaces that exist between the fins and supports of the grate. In addition, precipitation may freely fall through the openings of the grate. In addition, any small debris (such dust or bird droppings) that is caught in the grate may be washed away when precipitation next occurs.

FIG. 4 shows that a thermal insulating structure **37** may be positioned in the body and may receive the power supply so that the power supply is secured to the body but thermally separated from the body. The thermal insulating structure **37** may be a structure that provides a barrier or wall, a plate, a ring that separates the fins of the body from those of the power supply, or any other suitable configuration. The thermal insulating structure may be made of any suitable insulating material, such as a ceramic material. FIG. 5 also shows that the insulating structure may have a central opening so that the power supply **30** may be received into the body **27** via a receptacle **35**. The receptacle **35** may have inner dimensions that are at least as large as those of the power supply's housing. The receptacle and/or any portions of the body **27** may removably secure the power supply **30** in place by friction and/or by one or more connectors such as clips, hooks, bolts or other connecting structures. For example, as shown in FIG. 6A, the body **27** may have a number of anchors **52a . . . 52n** that receive and secure one or more connectors of the power supply. Returning to FIG. 5, the power supply **30** may include one or more plugs, wires or other connectors so that the supply can deliver power to the LED structure. Note that the power supply **30** is optional and need not be part of the lighting device. The lighting device can be connected to an external power source by one or more wires, plugs, busses or other conductors.

The illustration of FIG. 6A also illustrates a cross section A-A. FIG. 6B shows a side view of this cross section in a top half 27a of the body, with the uppermost portion of the body portion illustrated to the right in FIG. 6B, and the lower section of the body portion illustrated to the left in FIG. 6B. As illustrated in FIG. 6B, the fins of the cross-section sweep away from the LED structure 18, and form a cavity 29 within the body to provide a heat sink. The rightmost portion 27a may be connected to a lower body portion as illustrated in FIG. 7. The fins and connecting structures of the body portion 27 are made of a durable yet lightweight material, such as aluminum, an aluminum alloy such as A380 or ADC12, or other materials.

FIG. 7 illustrates that the housing 27 may be formed of two or more molded sections 27a, 27b that fit together as a clamshell-type structure. Each section 27a, 27b may include one or more pins, receptacles, clips, or other receiving structures that help align and/or secure the sections together when positioned in place and connected to the shroud and/or power supply receptacle (shown in other Figures). The two sections 27a, 27b form a cavity 29 within the body when connected. FIG. 8 illustrates that each housing section 27a may form part of the opening in which the LED structure resides. Each LED module of the LED structure may include one or more conducting substrates 38 that serve to hold the LEDs in place and provide the primary cooling path to the LEDs. The substrates may be made of any support material (such as fiberglass or aluminum) with conductive elements (such as traces, bars or wires) placed thereon or therein to direct power to the LEDs. FIG. 8 also illustrates an embodiment in which two LED modules form the LED structure, and each LED module is configured in a half-circle configuration. Thus, with a circular opening, the LED modules may be semi-circular in shape so that two, three, four or more of them together form a circle that fits within the opening.

FIG. 9 illustrates an embodiment of the device, with an expanded view of one of the LED array modules 12 of the LED structure 18. As shown, the module 12 includes a conductive substrate 38 on which a number of LEDs 39 are positioned. The LEDs 39 may be arranged in one or more rows, matrices, or other arrangements with corresponding components supported in place and/or spaced apart by supports. For example, the LEDs may form matrices of  $n \times n$  LEDs, such as  $4 \times 4$  or  $8 \times 8$  matrices. Alternatively, as shown in FIG. 9, the LEDs in each module 12 may be positioned in curved rows so that when all modules are positioned within the opening, the LED structure 18 comprises concentric rings of LEDs. The grouping of LEDs for the purpose of power supply and control may or may not conform to the arrangement of the LEDs in rings, clusters, matrices or other groupings. The substrate 38 may include a portion that is a printed circuit board. Driver circuitry on the circuit board may deliver current to the LEDs, and the LED array modules may include multi-wire connectors with prongs and/or receptacles for connecting to external conductors and/or signal wires, or other LED array modules. A lens cover 41 may be positioned over the substrate 38 to protect the substrate 38 and LEDs 39 from the ambient elements, as well as to focus and/or direct light emitted by the LEDs 39.

FIGS. 10A and 10B illustrate an underside of an embodiment of a lens cover 41. As shown, the lens cover 41 includes a set of lenses 45a . . . 45n, each of which is positioned to fit over an LED that has been placed on the substrate. The LEDs, and thus the lenses, may form an array. Optionally, more than one LED may share a lens. The spacing of LEDs (and thus the lenses) with respect to each other may vary based on the size of the LEDs. As shown in FIG. 10B, each lens 45a . . . 45n may

be dome-shaped, with the apex of each dome being flat or concave to receive light from the corresponding LED, and the larger part of each dome being positioned on the outer side the cover to direct the light. The standoff and slope of each dome may vary depending on the desired beam angle that is to be achieved by the lighting device. For example, a lighting system may be provided with domes of at least six different shapes to correspond to various beam limiting (collimating) standards. Alternatively, the LEDs may be domeless and/or equipped with other lens structures.

FIGS. 10A and 10B illustrate an optional area of the lens cover 41 on which no lenses appear. This may be the case of a portion of the lens cover 41 covers an area of the substrate that contains no LEDs, or in areas where no lenses are desired to be positioned over the LEDs. For example, the substrate may include a printed circuit board that provides control functions. If so, then the lens cover 41 will not need to include lenses in that area, and it may instead simply be a solid cover over those portions of the substrate. Alternatively, one or more LEDs may be equipped with no domes over the LEDs so that the beam is not limited, or one or more LEDs may be equipped with a channel 47 that serves as a collimator to focus the beam of light from its associated LED. In addition, LEDs are normally manufactured with a primary lens. In some embodiments, the dome lenses 45a . . . 45n may be added as secondary lens structures over the LEDs' primary lenses. In other embodiments, LEDs with no primary lens may be used, in which case the dome lenses 45a . . . 45n may serve as the only lens for one or more of the LEDs. When dome lenses 45a . . . 45n are used, they may be spaced apart from each other, adjacent to each other as shown in FIGS. 10A and 10B, configured so that their bases slightly overlap, or in any combination of such positioning options. In situations where the bases overlap, a small amount of overlap may be selected to help reduce glare from the LED assembly during operation. The amount of overlap may be any suitable amount, such as approximately 2% of the base area of each dome, approximately 3% of the base area of each dome, approximately 5% of the base area of each dome, approximate 7% of the base area of each dome, approximately 10% of the base area of each dome, any range between the percentages listed above, or other percentages.

FIG. 11 illustrates an example of a portion of an LED module 134. The LED module includes any number of LEDs 164. The LEDs may be arranged in rows, matrices, or other arrangements with corresponding components supported in place and/or spaced apart to form modules of any number of LEDs. The LEDs may be arranged and mounted on a circuit board 160. Driver circuitry on the circuit board 160 may deliver current to the LEDs, and the LED array modules may include multi-wire connectors with prongs and/or receptacles for connecting to external conductors and/or signal wires, or other LED modules.

One or more circuit control cards 55 may be positioned under, adjacent to or otherwise near the LED modules to provide power to the LEDs. The LEDs to which power is supplied may be selectively controlled by control circuitry such as that described below in this document. The control card may include a supporting substrate made of a material such as fiberglass, and a non-transitory computable-readable memory for storing programming instructions and/or monitored data and/or operational history data, one or more processors, a field programmable gate array (FPGA), application specific integrated circuit (ASIC) or other integrated circuit structures, and a received for receiving control signals from

an external transmitter. The LED module **134** and control card **55** may be placed within an opening of one end of the housing body.

The circuitry of the control card **55** and or the LED module **134** may operate to maintain a constant current draw across the LEDs and automatically adjust the intensity of the emitted light in response to feedback collected by the sensors. For example, each LED module **134** may be arranged so that groups of LEDs are electrically connected in series. Each group may be served by a programmable system on a chip (SoC) **174** which serves to receive a command from telemetry and send duty cycle information to multiple strings of LEDs.

Under ordinary operation, the system may include one or more power supplies, each of which applies a default direct current (DC) voltage (e.g., 36 volts or 48 volts) to an LED group, and each LED in any given group may have a constant voltage drop across it. Each string of LEDs may comprise a set of LEDs connected in series, so that the string maintains the circuit if one bulb should fail. The system may include sensors that monitor current and/or voltage drop across each series, or across individual LEDs in a series. If the values monitored by these sensors change, it may indicate that one or more LEDs in a string has failed. For example, if string includes five bulbs connected in parallel, each of which is rated at 2 amps (A) each, an applied current of 10 A will be divided equally across each bulb. If one bulb fails, the hardware may maintain the circuit, and the voltage drop across the string may occur, thus changing the intensity of light output by the device.

To protect against this, if any of the sensors detects that the voltage across a string has dropped by more than a threshold amount (indicating that a bulb has failed), the control card may generate a command to adjust the drive current across that string to compensate for the lost bulb. The control card may do this by any suitable means, such as by adjusting a variable resistor that is connected in the power delivery circuit, or by causing a variable transformer to reduce the voltage, or by implementing a command on a programmable system on a chip. The system may also selectively control the remaining LEDs using pulse width modulation, as will be described in more detail below. These methods can help to maintain the overall light output by the group of LEDs at a constant intensity, and the detected light at a desired illuminance level, even if one or more LEDs in a series may fail.

Alternatively, the sensors may include light intensity sensors, CRI sensors, CCT sensors,  $D_{uv}$  sensors, and/or ambient air temperature sensors. The control card may be programmed to receive data from the sensors and selectively control the LEDs to maintain a desired light output when it determines that measured light intensity, CRI, CCT,  $D_{uv}$ , or ambient air temperature exceeds or falls below a threshold. The threshold may be a value, or it may be a range of values with an upper and lower value. Optionally, the threshold may be a time-sensitive threshold, such as a threshold amount of change within a certain period of time or a sustained measurement above or below a threshold over a certain period of time.

In an option where the control card controls the LEDs by pulse width modulation (PWM), an oscillating output from the processor repeatedly turns the LEDs on and off by applying a pulsed voltage. Each pulse is of a constant voltage level, and the control circuitry varies the width of each pulse and/or the space between each pulse. When a pulse is active, the LEDs may be turned on, and when the pulses are inactive the LEDs may be turned off. If the duty cycle of the “on” state is 50%, then the LEDs may be on during 50% of the overall cycle of the control pulses. The pulses are delivered rapidly so

that the human eye does not detect a strobing effect—at least 24 pulses per second. The control card may dim the lights by reducing the duty cycle—and effectively extending the time period between each “on” pulse—so that the LEDs are off more than they are on. Alternatively, the control card may increase the brightness of the LEDs by increasing the duty cycle.

The control card may receive data from the sensors and apply that data to a rule set to determine whether to increase, decrease, or maintain the intensity of the LEDs. For example, if an ambient air temperature sensor detects that the temperature in the vicinity of the LED array module exceeds a threshold, the control card may cause the LEDs to dim by reducing the voltage output of each transformer and/or reducing the duty cycle of the LEDs in the module. If a light sensor detects that an ambient light level is above a desired range, the control circuitry may automatically reduce the brightness of a group of the LEDs by decreasing a width of voltage pulses applied to the group of LEDs or increasing spacing between voltage pulses applied to the group of LEDs to maintain the ambient light level within the desired range. If the light sensor detects that the ambient light level is above (or below) a desired threshold, the control circuitry may automatically reduce (or increase) increase the brightness a group of the LEDs by reducing (or increasing) a width of voltage pulses applied to the group of LEDs, or by increasing (or decreasing) spacing between voltage pulses applied to the group of LEDs to maintain the ambient light level within a desired range.

Optionally, any LED module may include several LED strings or groups of different colors. For example, a module may include a red (R) LED series, a green (G) LED series, a blue (B) LED series, and a white (W) LED series. If so, the color of light emitted by the unit may be selectably controlled by the control card in response to external commands as described below.

In addition or alternatively, some, all, or portions of the LED modules may include white LEDs of different color temperatures so that they can be selectively driven at different levels to produce variable temperature white light from the same fixture. In addition, any LED module may include various strings or groups, all of which emit white light, but which collectively exhibit a variety of color temperatures. For example, various LED lamps may have strings or other sets of LEDs that exhibit color temperatures ranging from about 2700K to about 6500K, from about 4000K to about 6500K, in a range around 5000K, or other CCT ranges and combinations. In these situations, the control card may automatically alter the drive currents delivered to particular sets of LEDs in order to maintain a desired CCT output by the device.

For example, an illumination device may have a first set of LEDs having a CCT of 4000K and second set of LEDs having a CCT of 6500K. The light fixture control card may include programming to maintain the light emitted by the device at a threshold level or threshold range. When the sensor detects that the emitted light exceeds or falls below the threshold, the control card may implement a process that applies an algorithm, reference a lookup table, or use other suitable methods to determine what drive currents to apply to each of the groups of LEDs to achieve the desired CCT. For example, if the desired output is a CCT of 5000K, the system may drive the 4000K LEDs at a current of 1250 ma and the 6500K LEDs at a drive current of about 900 ma. The same process or a similar process may be applied when the sensor measures  $D_{uv}$ . The algorithms and lookup table amounts may be set so that the system does not substantially change the illuminance level measured by light intensity sensors in the sensor compartment when the drive current changes are implemented.

The programming on the control card may be programmed in any suitable format, such as in a field programmable gate array (FPGA), or as computer-readable instructions stored in a computer-readable memory device and configured to be read and implemented by a processor of the control card.

FIG. 12 illustrates that any number of lighting devices **10a**, **10b**, **10c** such as those disclosed in this document may be positioned in an environment, such as a wall, ceiling, mast, tower or other supporting structure in a stadium, arena, concert hall, outdoor amphitheater or other location. Each illumination device may include or be connected to a device controller **210(a)**, **210(b)**, **210(c)** that includes wiring and circuitry to supply power and/or control signals to one or more lights. A device controller may be an external device, or an integral device that includes various components of an illumination device's control card. Each device controller **210(a)**, **210(b)**, **210(c)** may include a receiver that receives wireless signals from one or more transmitters. The transmitters may be included in, for example, one or more user interface devices **202**.

Each interface device **202** may include selectable user inputs, programming, a processor or circuitry, and a transmitter for transmitting command signals to the various illumination devices. For example, the user inputs may include inputs to turn certain lights in a certain zone of an environment on or off, in which case the interface device will generate and send signals with encoded data that instruct the zone's lights to turn on and off. The user inputs also may include brightness level adjustments for one or more zones and/or lights, or scenes that are designed to set various lighting devices at various brightness levels. Each user input command will cause the user interface device to send a signal that includes data indicating which illumination devices should be operated by the signal. When a control device detects a signal that is intended for its illumination device, it will cause its illumination device to execute the command that corresponds to the control signal. The system may do this by adjusting the light intensity using PWM, as described elsewhere in this document.

In addition, any number of external light sensors **205a-205n** may be positioned at a location or multiple locations in an environment, such as a stadium playing field, a stage in a concert hall, or a court/floor/ice rink in an area, to detect the intensity of light. The external light sensors may include transmitters that send status information and/or commands to any or all of the illumination device controllers and/or the interface device. For example, a particular illumination device controller **210c** may be programmed to detect signals from a particular sensor **205a** that is positioned in an area at which the controller's corresponding light fixture **10c** directs light. The sensor may sense light intensity in its vicinity and transmit intensity data to the device controller **210c**. The device controller **210c** may be programmed to increase the LED device's **10c** brightness if the local intensity data is less than a threshold, or it may decrease the LED device's **10c** brightness if the local intensity data is greater than a threshold. As described above, the controller may do this by increasing or decreasing the frequency of "on" signals that cycle the LEDs on and off by PWM. Alternatively, the sensor **205a** itself may include programming and electronics that cause it to send a command to the controller **210c**, such as an increase brightness command if local intensity is less than a threshold level or a decrease brightness command if local intensity is greater than a threshold level.

It is intended that the portions of this disclosure describing LED modules and control systems and methods are not limited to the embodiment of the illumination devices disclosed in this document. The LED modules, control systems and

control methods may be applied to other LED illumination structures, such as those disclosed in International Patent Application No. PCT/US2012/069442, filed Sep. 13, 2012 by Nolan et al., the disclosure of which is incorporated herein by reference in its entirety.

The features and functions described above, as well as alternatives, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements may be made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

The invention claimed is:

**1.** A light fixture comprising:

a light emitting diode (LED) structure comprising a plurality of LEDs; and

a housing comprising:

an opening that receives and secures the LED structure, a body portion that provides a heat sink for the LED structure,

a power supply that is secured to an area of the body portion that is distal from the LED structure,

a light intensity sensor that is configured to sense a characteristic of light in a vicinity of the LED structure, and

a control card containing control circuitry that is configured to receive data from the light intensity sensor and automatically alter a characteristic of light emitted by one or more of the LEDs in response to the received data;

wherein the control circuitry is programmed so that:

when the control circuitry receives data from the light intensity sensor indicating that light intensity exceeds a threshold, the control circuitry will automatically reduce brightness of a set of the LEDs by decreasing a width of voltage pulses applied to that set of LEDs or increasing spacing between voltage pulses applied to that set of LEDs to maintain ambient light level within a desired range, and

when the control circuitry receives data from the light intensity sensor indicating that the light intensity is below the threshold, the control circuitry will automatically increase brightness of a set of the LEDs by increasing a width of voltage pulses applied to that set of LEDs or decreasing spacing between voltage pulses applied to that set of LEDs to maintain the ambient light level within the desired range.

**2.** The light fixture of claim **1**, further comprising a reflecting structure that is positioned to reflect light emitted by the LEDs toward the sensor.

**3.** The light fixture of claim **1**:

the light fixture further comprises a color temperature sensor,

the plurality of LEDs include a first group of LEDs that exhibit a first color temperature and a second group of LEDs that exhibit a second color temperature; and

the control circuitry is further programmed so that when the control circuitry receives data from the color temperature sensor indicating that detected color temperature has moved above or below a threshold, the control circuitry will generate commands to control drive currents delivered to the first group of LEDs and the second group of LEDs so that the light emitted by the light fixture will exhibit a color temperature that is within the threshold.

**4.** The light fixture of claim **3**, wherein the commands also include commands to control the first group of LEDs and the

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second group of LEDs so that the illuminance level of the light detected by an illuminance sensor will not substantially change when the drive currents change in response to the commands.

5 5. The light fixture of claim 4, wherein the commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the illuminance sensor will not substantially change when the drive currents change comprise commands to:

10 automatically reduce the brightness of one of the two groups of LEDs by decreasing a width of voltage pulses applied to that group of LEDs or increasing spacing between voltage pulses applied to that group of LEDs; and

15 automatically increase the brightness of the other two groups of LEDs by increasing a width of voltage pulses applied to that group of LEDs or decreasing spacing between voltage pulses applied to that group of LEDs.

20 6. The light fixture of claim 1, wherein:

the light fixture further comprises a  $D_{uv}$  sensor, the plurality of LEDs include a first group of LEDs that exhibit a first color temperature and a second group of LEDs that exhibit a second color temperature; and the control circuitry is further programmed so that when the control circuitry receives data from the  $D_{uv}$  sensor indicating that detected  $D_{uv}$  has moved above or below a threshold, the control circuitry will generate commands to control drive currents delivered to the first group of LEDs and the second group of LEDs so that light emitted by the light fixture will exhibit a  $D_{uv}$  that is within the threshold.

7. The light fixture of claim 6, wherein the commands also include commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the  $D_{uv}$  sensor will not substantially change when the drive currents change in response to the commands.

8. The light fixture of claim 7, wherein the commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the  $D_{uv}$  sensor will not substantially change when the drive currents change comprise commands to:

45 automatically reduce the brightness of one of the groups of LEDs by decreasing a width of voltage pulses applied to that group of LEDs or increasing spacing between voltage pulses applied to that group of LEDs; and

50 automatically increase brightness of the other group of LEDs by increasing a width of voltage pulses applied to that group of LEDs or decreasing spacing between voltage pulses applied to that group of LEDs.

9. The light fixture of claim 1, wherein:

the light fixture also comprises an ambient air temperature sensor; and

55 the control circuitry is programmed so that when the control circuitry receives data from the ambient air temperature sensor indicating that ambient air temperature is above a threshold, the control circuitry will automatically alter a characteristic of light emitted by one or more of the LEDs in response to the received ambient air temperature.

10. The light fixture of claim 1, wherein:

the opening is circular;

65 the LED structure is positioned and shaped to form a ring structure in the opening around a central area; and the sensor is contained in a sensor compartment positioned in a central area of the opening.

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11. The light fixture of claim 1, further comprising:

a power sensor that is configured to measure voltage across an additional group of the LEDs; and

the control circuitry is programmed so that, when it receives data from the power sensor indicating that the voltage across the additional group of LEDs has changed by at least a threshold amount, it causes current delivered to the additional group of LEDs to change to maintain light emitted by the remaining LEDs in the additional group at a desired illuminance level.

12. A light fixture comprising:

a light emitting diode (LED) structure comprising a plurality of LEDs; and

a housing comprising:

an opening that receives and secures the LED structure, a sensor compartment containing one or more sensors, at least one of which comprises a light intensity sensor, that are configured to sense a characteristic of light in a vicinity of the LED structure,

a reflecting structure that is positioned to reflect light emitted by the LEDs toward the light intensity sensor, and

a control card containing control circuitry that is configured to receive data from the sensor and automatically alter a characteristic of light emitted by one or more of the LEDs in response to the received data,

wherein the control circuitry is programmed so that:

when the control circuitry receives data from the light intensity sensor indicating that light intensity exceeds a threshold, the control circuitry will automatically reduce brightness of a set of the LEDs by decreasing a width of voltage pulses applied to that set of LEDs or increasing spacing between voltage pulses applied to that set of LEDs to maintain the ambient light level within the desired range; and

when the control circuitry receives data from the light intensity sensor indicating that the light intensity is below the threshold, the control circuitry will automatically increase brightness of a set of the LEDs by increasing a width of voltage pulses applied to that set of LEDs or decreasing spacing between voltage pulses applied to that set of LEDs to maintain the ambient light level within the desired range.

13. The light fixture of claim 12, wherein:

the light fixture also comprises a color temperature sensor, the plurality of LEDs include a first group of LEDs that exhibit a first color temperature and a second group of LEDs that exhibit a second color temperature; and

the control circuitry is programmed so that when the control circuitry receives data from the color temperature sensor indicating that detected color temperature has moved above or below a threshold, the control circuitry will generate commands to control drive currents delivered to the first group of LEDs and the second group of LEDs so that the light emitted by the light fixture will exhibit a color temperature that is within the threshold.

14. The light fixture of claim 13, wherein the commands also include commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by an illuminance sensor will not substantially change when the drive currents change in response to the commands.

15. The light fixture of claim 14, wherein the commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the illuminance sensor will not substantially change when the drive currents change comprise commands to:

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automatically reduce brightness of one of the groups of LEDs by decreasing a width of voltage pulses applied to that group of LEDs or increasing spacing between voltage pulses applied to that group of LEDs; and automatically increase the brightness of the other group of LEDs by increasing a width of voltage pulses applied to that group of LEDs or decreasing spacing between voltage pulses applied to that group of LEDs.

**16.** The light fixture of claim **12**, wherein: the light fixture also comprises a  $D_{uv}$  sensor; the plurality of LEDs include a first group of LEDs that exhibit a first color temperature and a second group of LEDs that exhibit a second color temperature; and the control circuitry is programmed so that when the control circuitry receives data from the  $D_{uv}$  sensor indicating that detected  $D_{uv}$  has moved above or below a threshold, the control circuitry will generate commands to control drive currents delivered to the first group of LEDs and the second group of LEDs so that the light emitted by the light fixture will exhibit a  $D_{uv}$  that is within the threshold.

**17.** The light fixture of claim **16**, wherein the commands also include commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by an illuminance sensor will not substantially change when the drive currents change in response to the commands.

**18.** The light fixture of claim **17**, wherein the commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the illuminance sensor will not substantially change when the drive currents change comprise commands to:

automatically reduce the brightness of one of the groups of LEDs by decreasing a width of voltage pulses applied to that group of LEDs or increasing spacing between voltage pulses applied to that group of LEDs; and automatically increase the brightness of the other group of LEDs by increasing a width of voltage pulses applied to that group of LEDs or decreasing spacing between voltage pulses applied to that group of LEDs.

**19.** A light emitting diode (LED) structure comprising: a plurality of LEDs that include a first group of LEDs that exhibit a first color temperature and a second group of LEDs that exhibit a second color temperature; and a housing comprising:

an opening that receives and secures the LED structure, a body portion that provides a heat sink for the LED structure,

a power supply that is secured to an area of the body portion that is distal from the LED structure,

a color temperature sensor that is configured to sense a characteristic of light in a vicinity of the LED structure, and

a control card containing control circuitry that is configured to receive data from the color temperature sensor and automatically alter a characteristic of light emitted by one or more of the LEDs in response to the received data, wherein the control circuitry is programmed so that when the control circuitry receives data from the color temperature sensor indicating that detected color temperature has moved above or below a threshold, the control circuitry will generate commands to:

control drive currents delivered to the first group of LEDs and the second group of LEDs so that the light emitted by the light fixture will exhibit a color temperature that is within the threshold, and

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control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by an illuminance sensor will not substantially change when the drive currents change in response to the commands.

**20.** The light fixture of claim **19**, wherein the commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the illuminance sensor will not substantially change when the drive currents change comprise commands to:

automatically reduce brightness of one of the two groups of LEDs by decreasing a width of voltage pulses applied to that group of LEDs or increasing spacing between voltage pulses applied to that group of LEDs; and

automatically increase brightness of the other of the two groups of LEDs by increasing a width of voltage pulses applied to that group of LEDs or decreasing spacing between voltage pulses applied to that group of LEDs.

**21.** The light fixture of claim **19**: the light fixture further comprises a  $D_{uv}$  sensor, the plurality of LEDs include a first set of LEDs that exhibit a first color temperature and a second set of LEDs that exhibit a second color temperature; and

the control circuitry is further programmed so that when the control circuitry receives data from the  $D_{uv}$  sensor indicating that detected  $D_{uv}$  has moved above or below a threshold, the control circuitry will generate commands to control drive currents delivered to the first set of LEDs and the second set of LEDs so that light emitted by the light fixture will exhibit a  $D_{uv}$  that is within the threshold.

**22.** The light fixture of claim **21**, wherein the commands also include commands to control the first set of LEDs and the second set of LEDs so that the illuminance level of the light detected by the  $D_{uv}$  sensor will not substantially change when the drive currents change in response to the commands.

**23.** The light fixture of claim **22**, wherein the commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the  $D_{uv}$  sensor will not substantially change when the drive currents change comprise commands to:

automatically reduce brightness of one of the two groups of LEDs by decreasing a width of voltage pulses applied to that set of LEDs or increasing spacing between voltage pulses applied to that set of LEDs; and

automatically increase brightness of the other of the two groups of LEDs by increasing a width of voltage pulses applied to that set of LEDs or decreasing spacing between voltage pulses applied to that set of LEDs.

**24.** The light fixture of claim **19**, wherein: the light fixture also comprises an ambient air temperature sensor; and

the control circuitry is programmed so that when the control circuitry receives data from the ambient air temperature sensor indicating that ambient air temperature is above a threshold, the control circuitry will automatically alter a characteristic of light emitted by one or more of the LEDs in response to the received ambient air temperature.

**25.** The light fixture of claim **19**, wherein: the opening is circular; the LED structure is positioned and shaped to form a ring structure in the opening around a central area; and the color temperature sensor is contained in a sensor compartment positioned in a central area of the opening.

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26. The light fixture of claim 19, further comprising:  
 a power sensor that is configured to measure voltage across  
 an additional group of LEDs; and  
 the control circuitry is programmed so that, when it  
 receives data from the power sensor indicating that the  
 voltage across the additional group of LEDs has  
 changed by at least a threshold amount, it causes current  
 delivered to the additional group of LEDs to change to  
 maintain light emitted by the remaining LEDs in the  
 additional group at a desired illuminance level.

27. The light fixture of claim 19, further comprising a  
 reflecting structure that is positioned to reflect light emitted  
 by the LEDs toward the color temperature sensor.

28. A light fixture comprising:

a light emitting diode (LED) structure comprising a plu-  
 rality of LEDs that include a first group of LEDs that  
 exhibit a first color temperature and a second group of  
 LEDs that exhibit a second color temperature; and

a housing comprising:

an opening that receives and secures the LED structure,  
 a body portion that provides a heat sink for the LED  
 structure,

a power supply that is secured to an area of the body  
 portion that is distal from the LED structure,

a  $D_{uv}$  sensor that is configured to sense a characteristic of  
 light in a vicinity of the LED structure, and

a control card containing control circuitry that is config-  
 ured to receive data from the sensor and automatically  
 alter a characteristic of light emitted by one or more of  
 the LEDs in response to the received data, so that  
 when the control circuitry receives data from the  $D_{uv}$   
 sensor indicating that detected  $D_{uv}$  has moved above  
 or below a threshold, the control circuitry will gener-  
 ate commands to control drive currents delivered to  
 the first group of LEDs and the second group of LEDs  
 so that light emitted by the light fixture will exhibit a  
 $D_{uv}$  that is within the threshold.

29. The light fixture of claim 28, wherein the commands  
 also include commands to control the first group of LEDs and  
 the second group of LEDs so that the illuminance level of the  
 light detected by the  $D_{uv}$  sensor will not substantially change  
 when the drive currents change in response to the commands.

30. The light fixture of claim 29, wherein the commands to  
 control the first group of LEDs and the second group of LEDs  
 so that the illuminance level of the light detected by the  $D_{uv}$   
 sensor will not substantially change when the drive currents  
 change comprise commands to:

automatically reduce brightness of one of the two groups of  
 LEDs by decreasing a width of voltage pulses applied to  
 that group of LEDs or increasing spacing between volt-  
 age pulses applied to that group of LEDs; and

automatically increase brightness of the other of the two  
 groups of LEDs by increasing a width of voltage pulses  
 applied to that group of LEDs or decreasing spacing  
 between voltage pulses applied to that group of LEDs.

31. The light fixture of claim 28, further comprising a  
 reflecting structure that is positioned to reflect light emitted  
 by the LEDs toward the  $D_{uv}$  sensor.

32. The light fixture of claim 28, wherein:

the light fixture also comprises an ambient air temperature  
 sensor; and

the control circuitry is programmed so that when the con-  
 trol circuitry receives data from the ambient air tempera-  
 ture sensor indicating that ambient air temperature is  
 above a threshold, the control circuitry will automati-

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cally alter a characteristic of light emitted by one or more  
 of the LEDs in response to the received ambient air  
 temperature.

33. The light fixture of claim 28, wherein:

the opening is circular;

the LED structure is positioned and shaped to form a ring  
 structure in the opening around a central area; and  
 the  $D_{uv}$  sensor is contained in a sensor compartment posi-  
 tioned in a central area of the opening.

34. The light fixture of claim 28, further comprising:

a power sensor that is configured to measure voltage across  
 an additional group of LEDs from the plurality of LEDs; and

the control circuitry is programmed so that, when it  
 receives data from the power sensor indicating that the  
 voltage across the additional group of LEDs has  
 changed by at least a threshold amount, it causes current  
 delivered to the additional group of LEDs to change to  
 maintain light emitted by the remaining LEDs in the  
 additional group at a desired illuminance level.

35. A light fixture comprising:

a light emitting diode (LED) structure comprising a plu-  
 rality of LEDs; and

a housing comprising:

an opening that receives and secures the LED structure,  
 a body portion that provides a heat sink for the LED  
 structure,

a power supply that is secured to an area of the body  
 portion that is distal from the LED structure,

a light characteristic sensor that is configured to sense a  
 characteristic of light in a vicinity of the LED struc-  
 ture,

an ambient air temperature sensor, and

a control card containing control circuitry that is config-  
 ured to:

receive light characteristic data from the light charac-  
 teristic sensor and automatically alter a character-  
 istic of light emitted by one or more of the LEDs in  
 response to the received light characteristic data, and

receive air temperature data from the ambient air tem-  
 perature sensor and automatically alter a character-  
 istic of light emitted by one or more of the LEDs  
 when the received air temperature data indicates  
 that ambient air temperature is above a threshold.

36. The light fixture of claim 35, further comprising a  
 reflecting structure that is positioned to reflect light emitted  
 by the LEDs toward the light characteristic sensor.

37. The light fixture of claim 35, wherein:

the opening is circular;

the LED structure is positioned and shaped to form a ring  
 structure in the opening around a central area; and  
 the light characteristic sensor is contained in a sensor com-  
 partment positioned in a central area of the opening.

38. The light fixture of claim 35, further comprising:

a power sensor that is configured to measure voltage across  
 an additional group of the LEDs; and

the control circuitry is programmed so that, when it  
 receives data from the power sensor indicating that the  
 voltage across the additional group of LEDs has  
 changed by at least a threshold amount, it causes current  
 delivered to the additional group of LEDs to change to  
 maintain light emitted by the remaining LEDs in the  
 additional group at a desired illuminance level.

39. A light fixture comprising:  
 a light emitting diode (LED) structure comprising a first group of LEDs that exhibit a first color temperature and a second group of LEDs that exhibit a second color temperature; and  
 a housing comprising:  
 an opening that receives and secures the LED structure, a sensor compartment containing one or more sensors, at least one of which comprises a  $D_{uv}$  sensor, that are configured to sense a characteristic of light in a vicinity of the LED structure,  
 a reflecting structure that is positioned to reflect light emitted by the LEDs toward the sensor, and  
 a control card containing control circuitry that is configured to receive data from the sensor and automatically alter a characteristic of light emitted by one or more of the LEDs in response to the received data,

wherein the control circuitry is also programmed so that when the control circuitry receives data from the  $D_{uv}$  sensor indicating that detected  $D_{uv}$  has moved above or below a threshold, the control circuitry will generate commands to control drive currents delivered to the first group of LEDs and the second group of LEDs so that the light emitted by the light fixture will exhibit a  $D_{uv}$  that is within the threshold.

40. The light fixture of claim 39, wherein the commands also include commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the  $D_{uv}$  sensor will not substantially change when the drive currents change in response to the commands.

41. The light fixture of claim 40, wherein the commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the  $D_{uv}$  sensor will not substantially change when the drive currents change comprise commands to:

- automatically reduce brightness of one of the groups of LEDs by decreasing a width of voltage pulses applied to that group of LEDs or increasing spacing between voltage pulses applied to that group of LEDs; and
- automatically increase brightness of the other group of LEDs by increasing a width of voltage pulses applied to that group of LEDs or decreasing spacing between voltage pulses applied to that group of LEDs.

42. A light fixture comprising:

a light emitting diode (LED) structure comprising a plurality of LEDs, wherein the plurality of LEDs include a first group of LEDs that exhibit a first color temperature and a second group of LEDs that exhibit a second color temperature; and

a housing comprising:  
 an opening that receives and secures the LED structure, a sensor compartment containing one or more sensors, at least one of which comprises a color temperature sensor, configured to sense a characteristic of light in a vicinity of the LED structure,  
 a reflecting structure that is positioned to reflect light emitted by the LEDs toward the color temperature sensor, and  
 a control card containing control circuitry that is configured to receive data from the color temperature sensor

and automatically alter a characteristic of light emitted by one or more of the LEDs in response to the received data;

wherein the control circuitry is also programmed so that when the control circuitry receives data from the color temperature sensor indicating that detected color temperature has moved above or below a threshold, the control circuitry will generate commands to control drive currents delivered to the first group of LEDs and the second group of LEDs so that the light emitted by the light fixture will exhibit a color temperature that is within the threshold.

43. The light fixture of claim 42, wherein the commands also include commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the sensor will not substantially change when the drive currents change in response to the commands.

44. The light fixture of claim 43, wherein the commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the sensor will not substantially change when the drive currents change comprise commands to:

- automatically reduce the brightness of one of the groups of LEDs by decreasing a width of voltage pulses applied to that group of LEDs or increasing spacing between voltage pulses applied to that group of LEDs; and
- automatically increase the brightness of the other group of LEDs by increasing a width of voltage pulses applied to that group of LEDs or decreasing spacing between voltage pulses applied to that group of LEDs.

45. The light fixture of claim 42, wherein:

the sensor comprises a  $D_{uv}$  sensor;  
 the plurality of LEDs include a first group of LEDs that exhibit a first color temperature and a second group of LEDs that exhibit a second color temperature; and  
 the control circuitry is programmed so that when the control circuitry receives data from the sensor indicating that detected  $D_{uv}$  has moved above or below a threshold, the control circuitry will generate commands to control drive currents delivered to the first group of LEDs and the second group of LEDs so that the light emitted by the light fixture will exhibit a  $D_{uv}$  that is within the threshold.

46. The light fixture of claim 45, wherein the commands also include commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the sensor will not substantially change when the drive currents change in response to the commands.

47. The light fixture of claim 46, wherein the commands to control the first group of LEDs and the second group of LEDs so that the illuminance level of the light detected by the sensor will not substantially change when the drive currents change comprise commands to:

- automatically reduce the brightness of one of the groups of LEDs by decreasing a width of voltage pulses applied to that group of LEDs or increasing spacing between voltage pulses applied to that group of LEDs; and
- automatically increase the brightness of the other group of LEDs by increasing a width of voltage pulses applied to that group of LEDs or decreasing spacing between voltage pulses applied to that group of LEDs.