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(54) **LIGHTING DEVICE WITH TRANSPARENT SUBSTRATE, HEAT SINK AND LED ARRAY FOR UNIFORM ILLUMINATION REGARDLESS OF NUMBER OF FUNCTIONAL LEDS**

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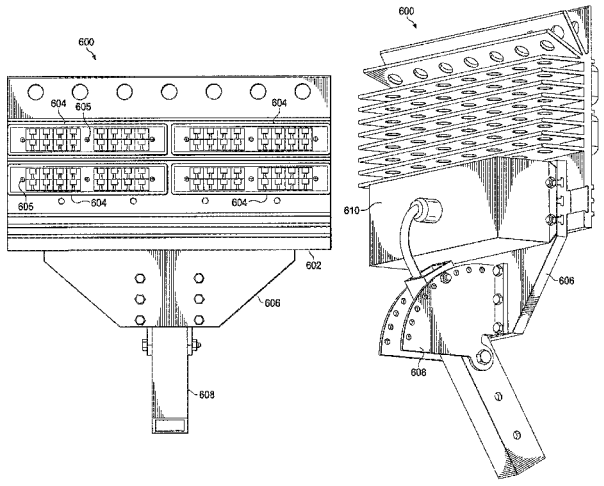
(57) **ABSTRACT**

A lighting device includes a heat sink having fins on a first side and a mounting surface of a second side opposite the first side, a substrate attached to the mounting surface, a number of LEDs attached to the substrate, and a single transparent substrate with a number of optical elements, each optical element overlying an associated one of the LEDs. The device configured to direct light from the LEDs towards an area in a manner that does not create hot spots or result in dead spots on the area regardless of whether all of the LEDs of the plurality of LEDs or some of the LEDs of the plurality of LEDs are functional.

30 Claims, 13 Drawing Sheets



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(58) **Field of Classification Search**

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See application file for complete search history.

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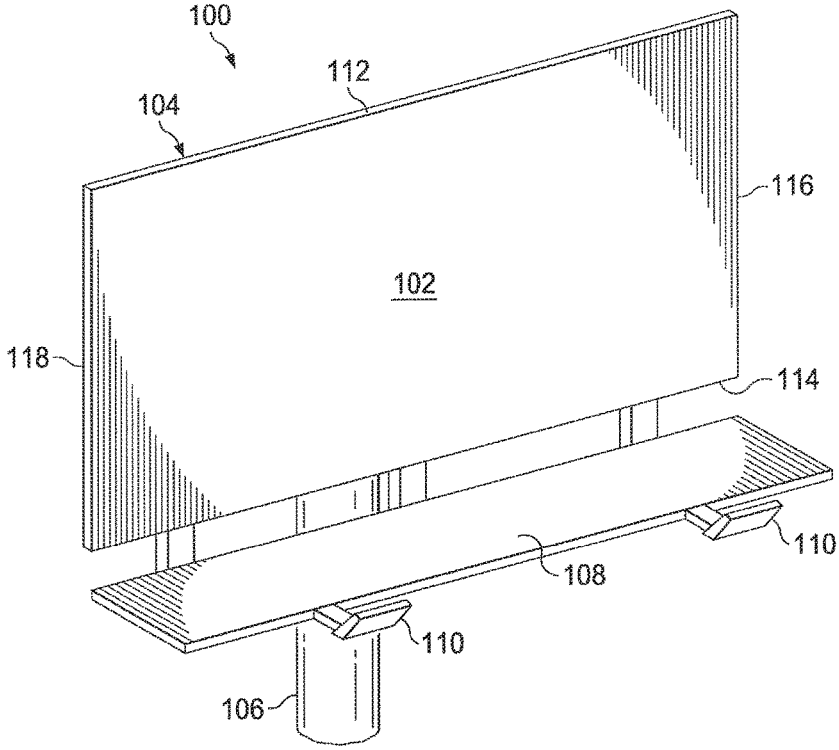

FIG. 1A

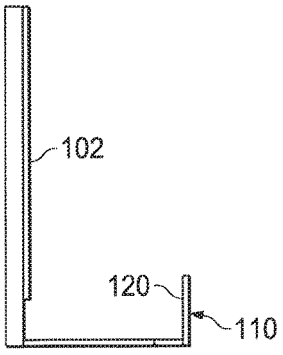

FIG. 1B

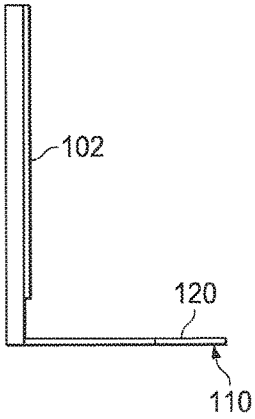

FIG. 1C

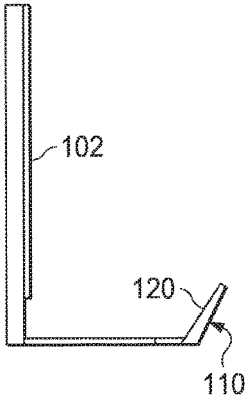

FIG. 1D

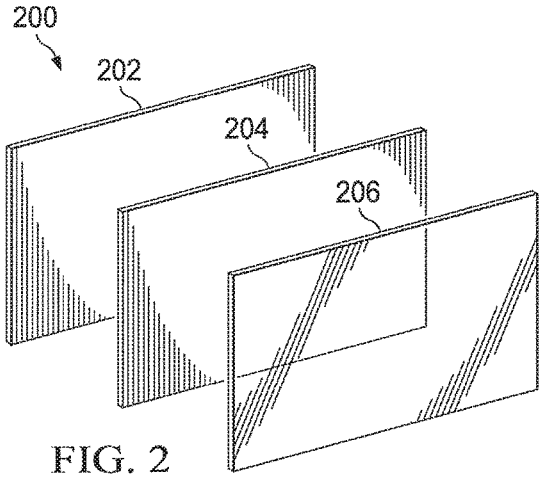

FIG. 2

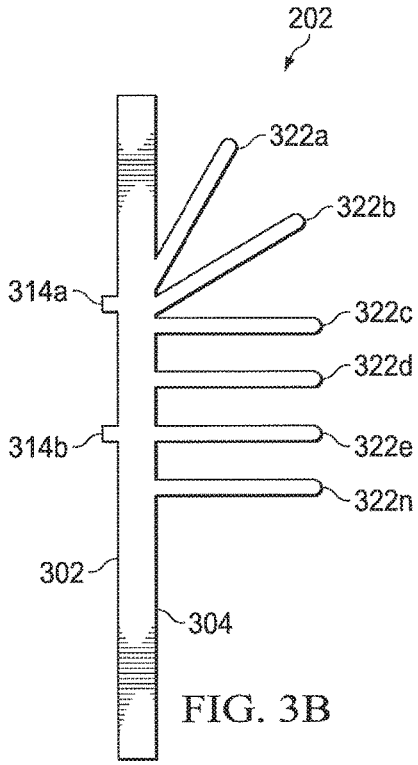

FIG. 3B

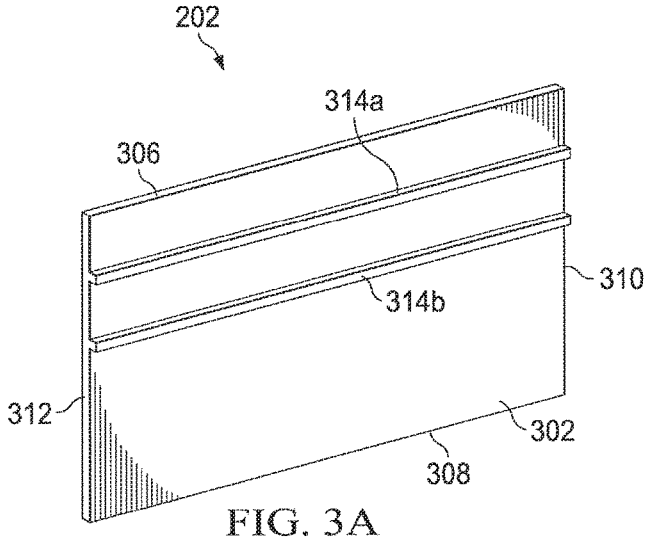

FIG. 3A

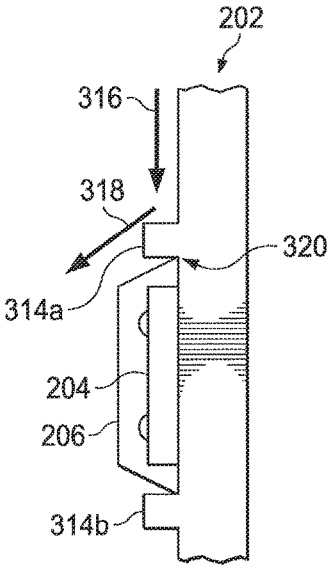

FIG. 3C

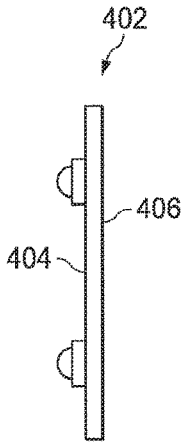

FIG. 4B

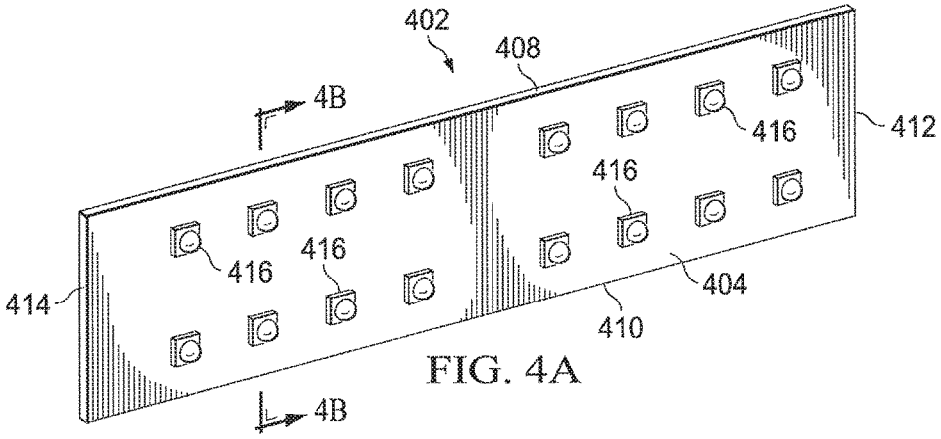

FIG. 4A

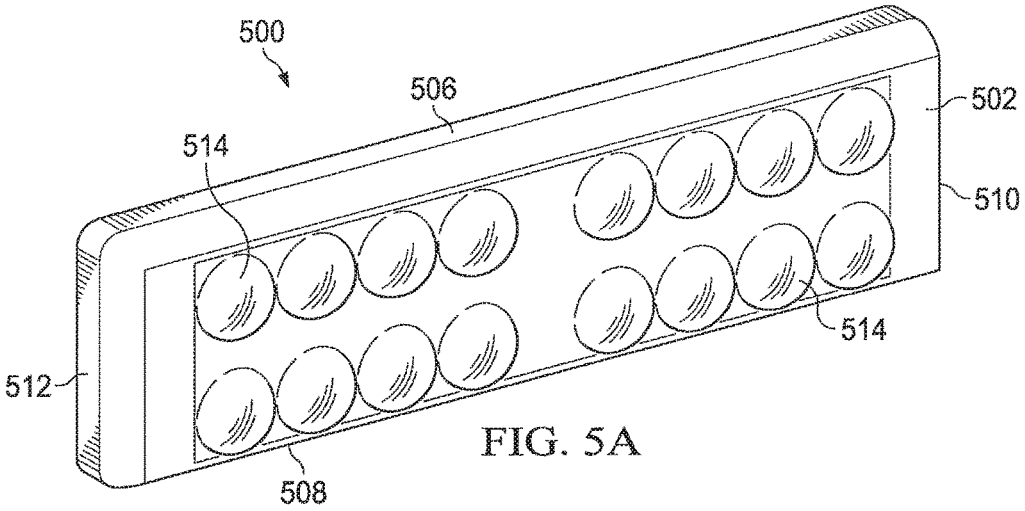

FIG. 5A

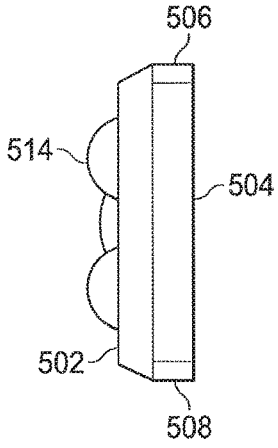

FIG. 5B

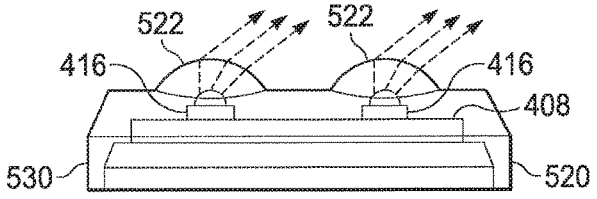

FIG. 5C

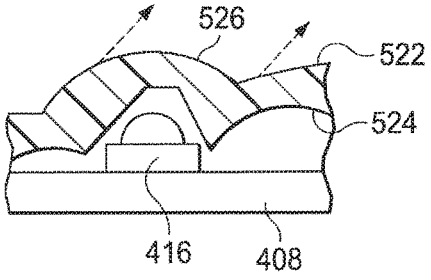

FIG. 5D

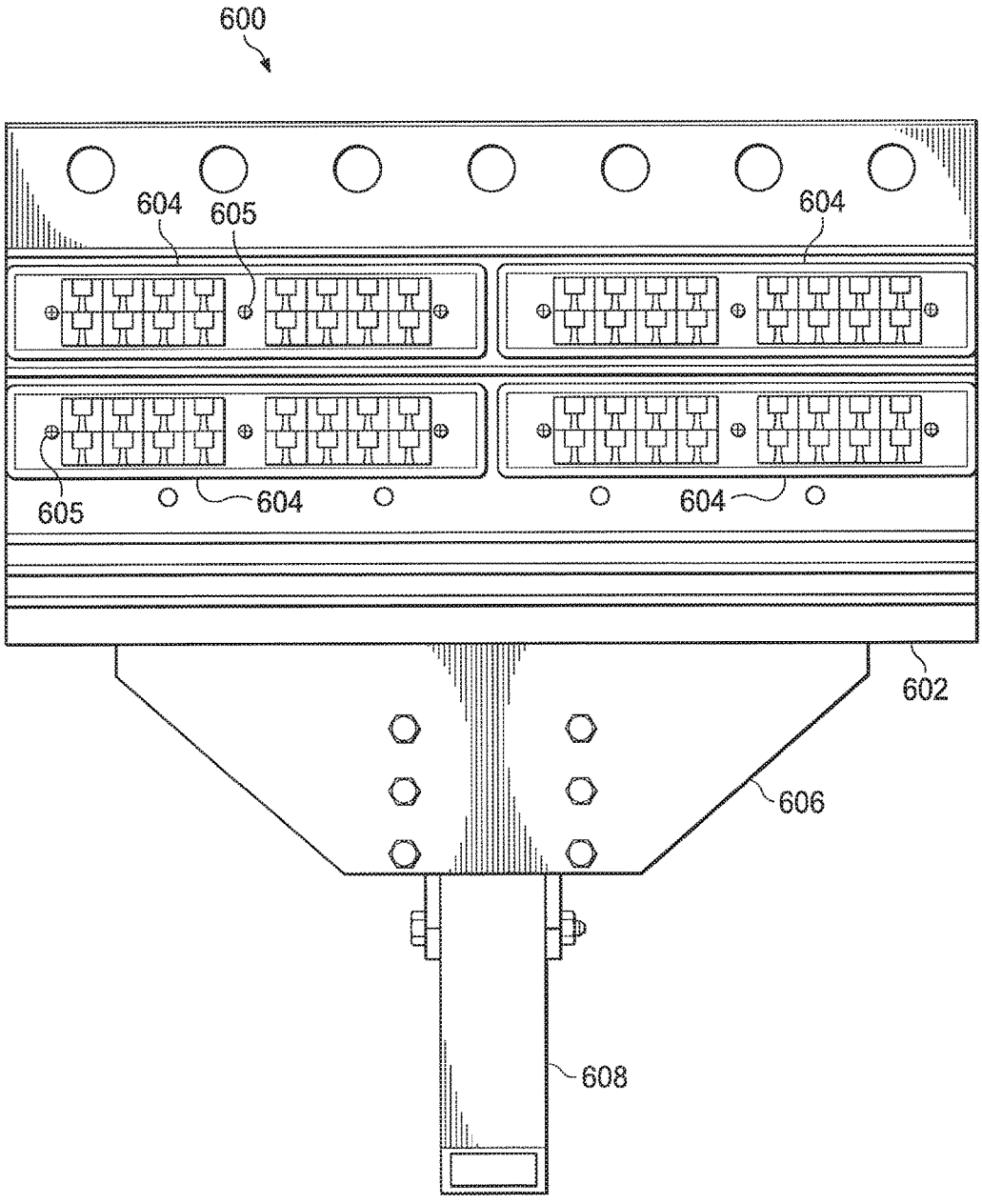

FIG. 6A

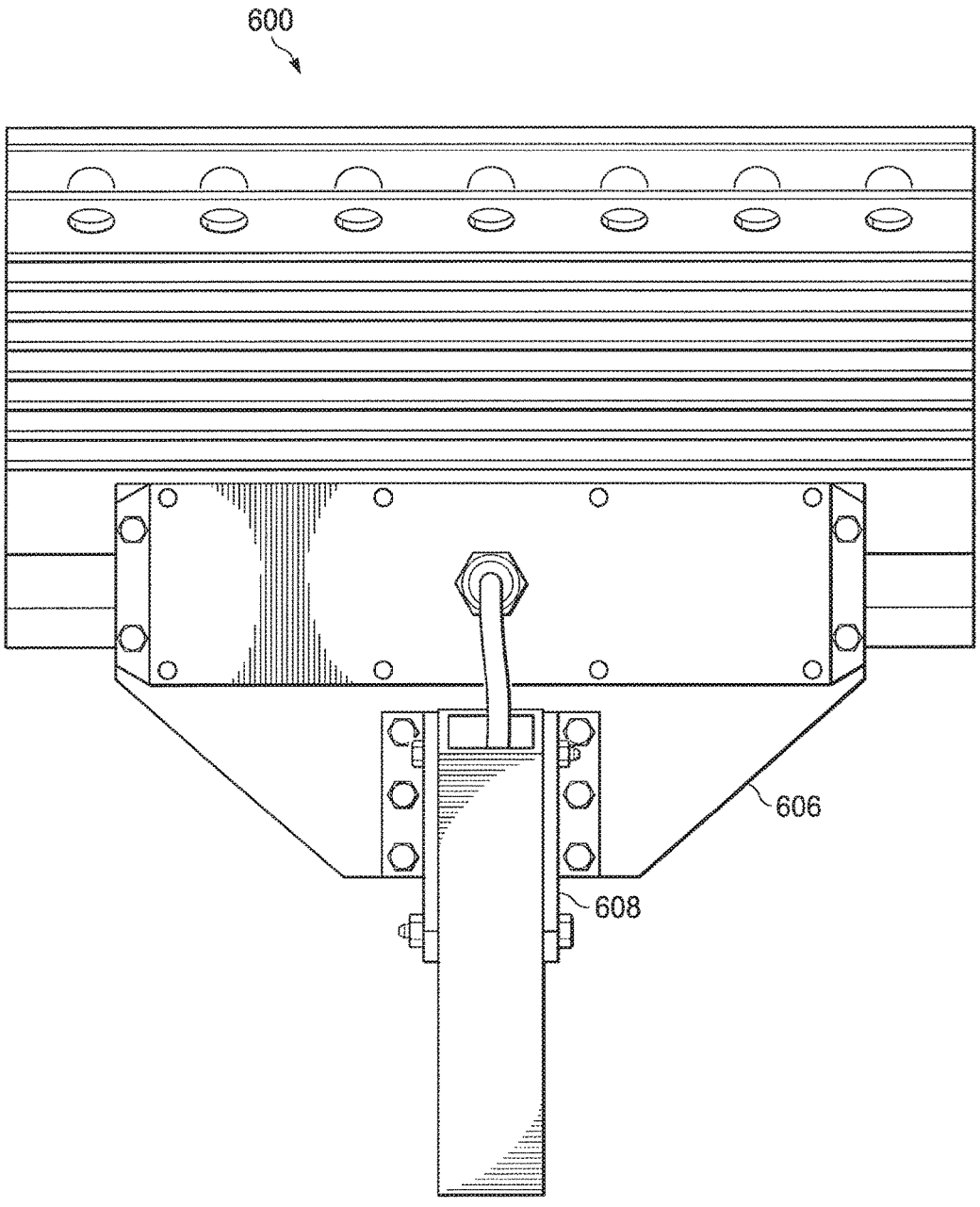

FIG. 6B

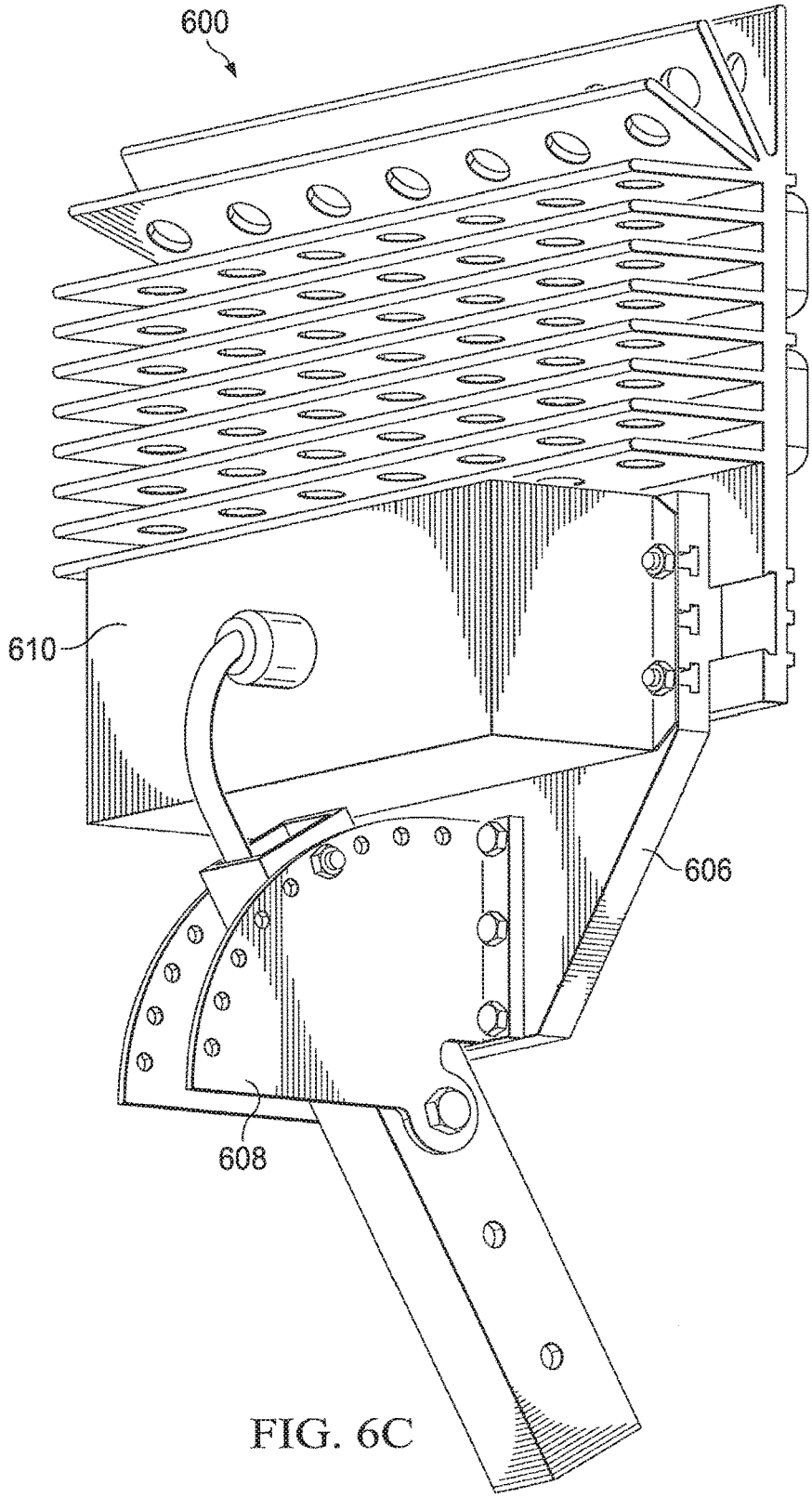

FIG. 6C

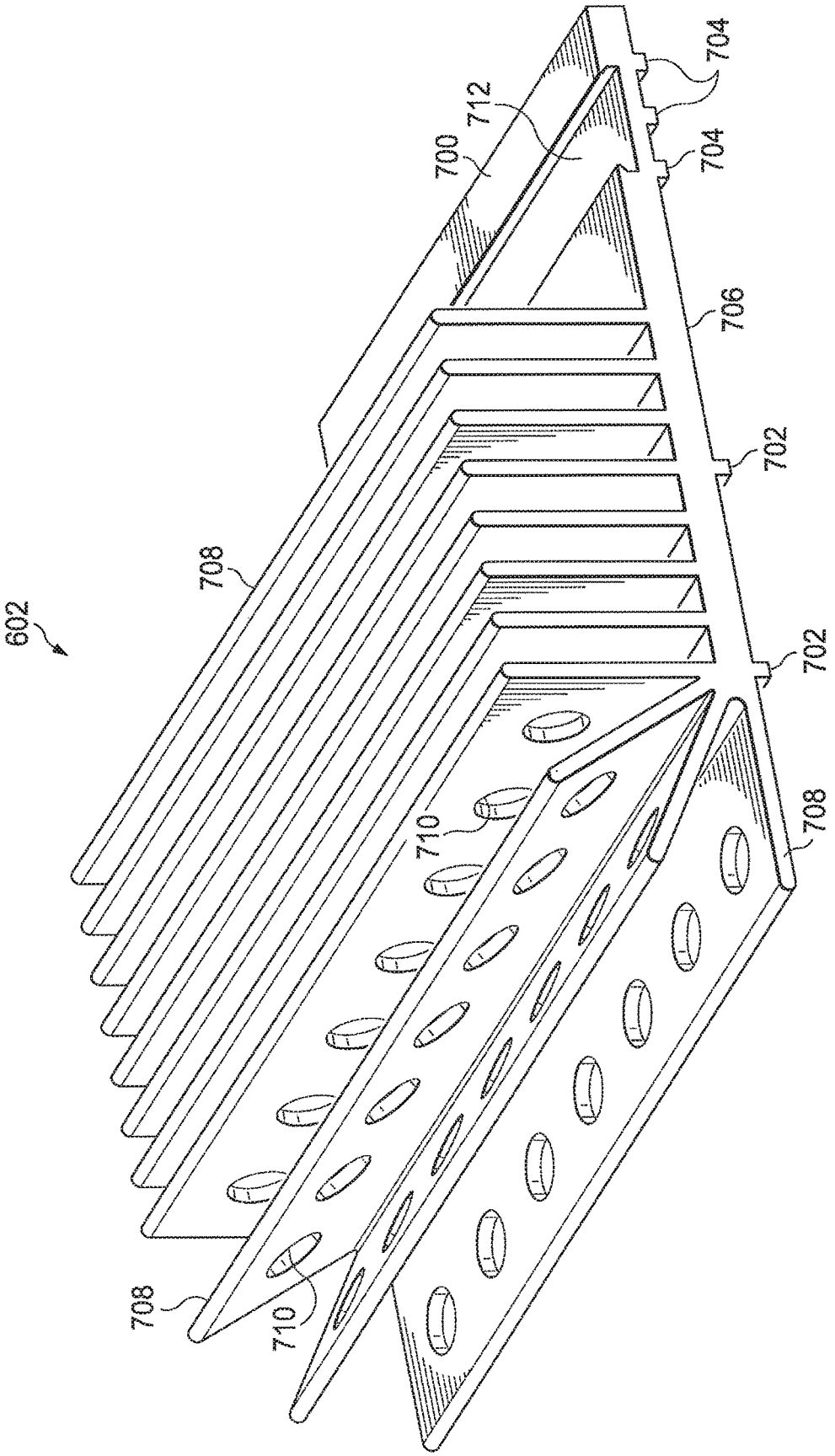

FIG. 7A

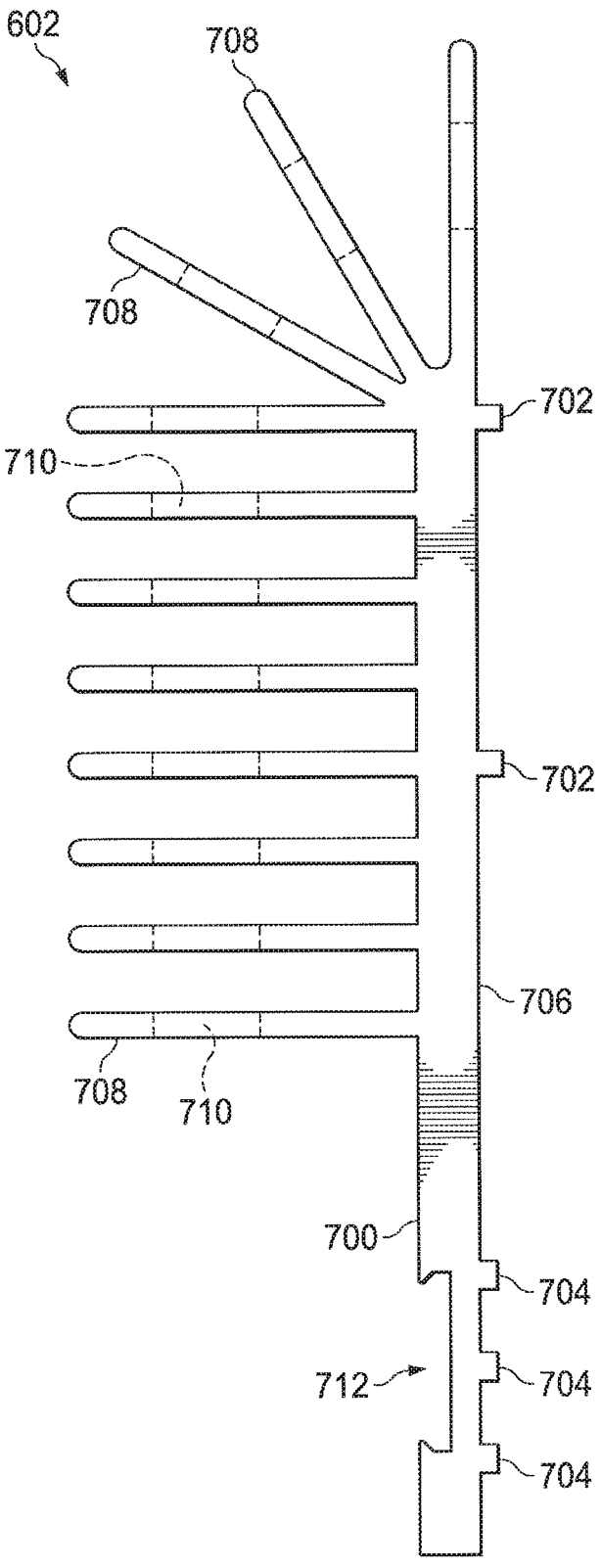

FIG. 7B

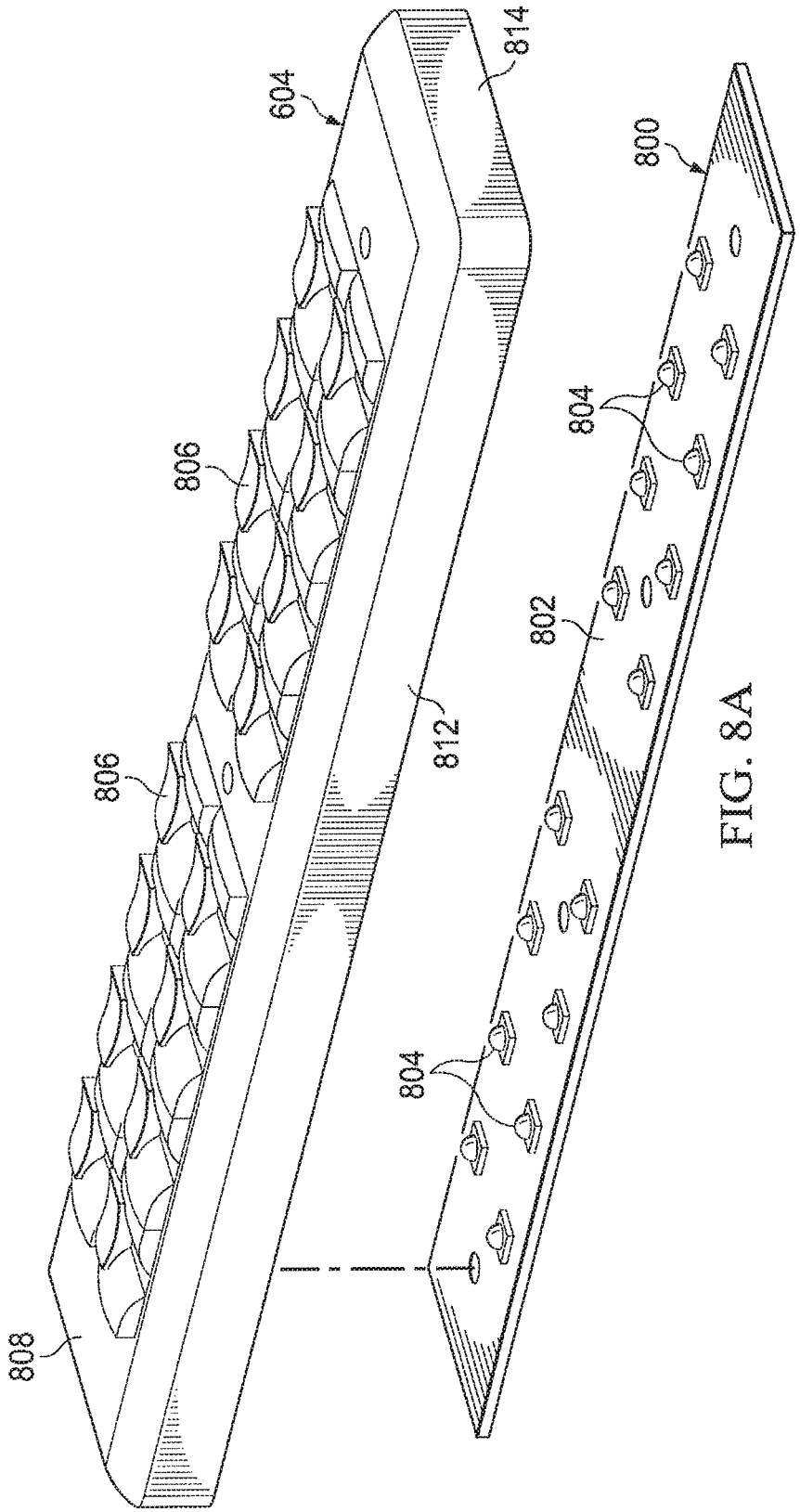

FIG. 8A

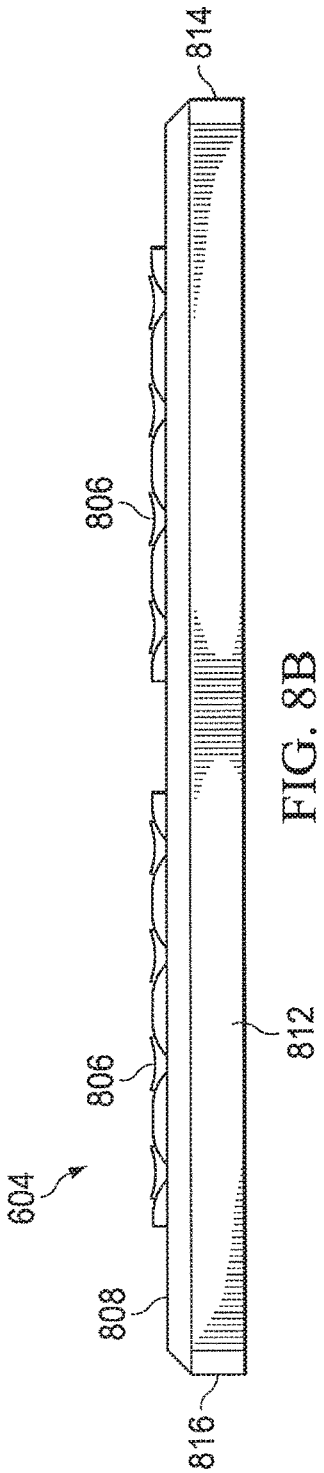

FIG. 8B

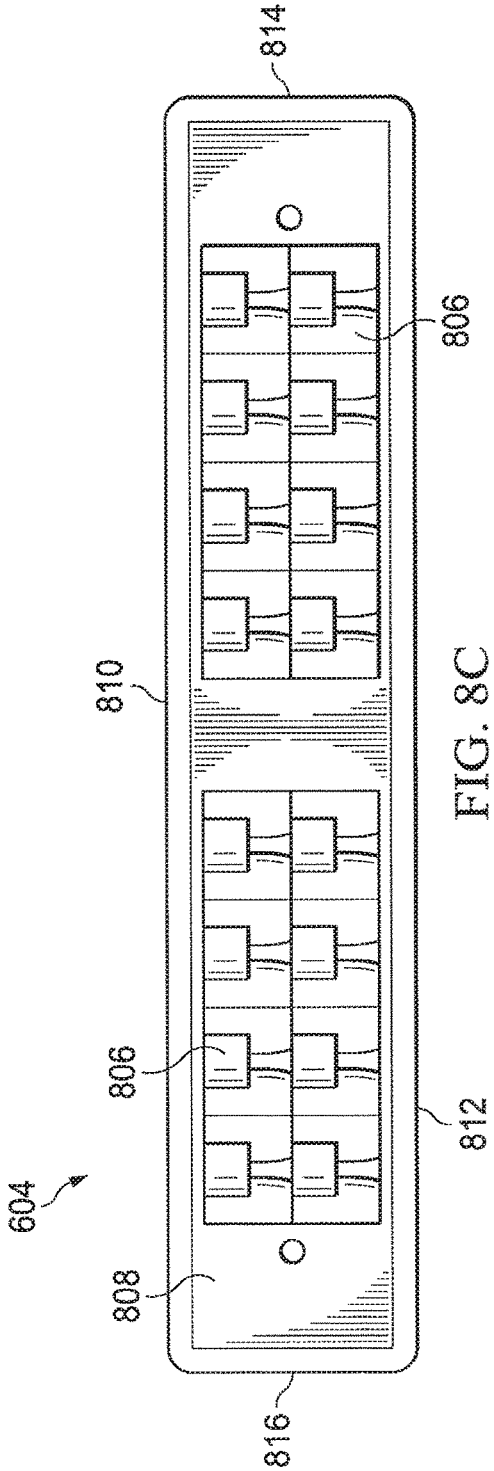

FIG. 8C

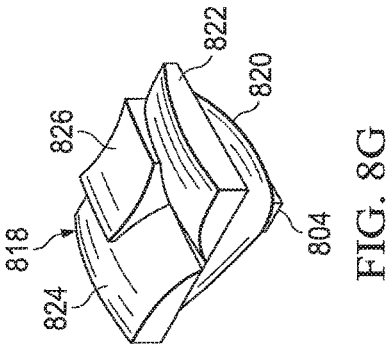

FIG. 8G

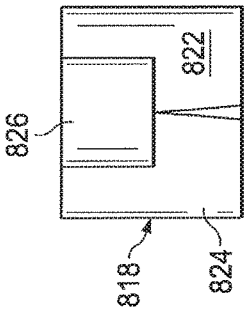

FIG. 8F

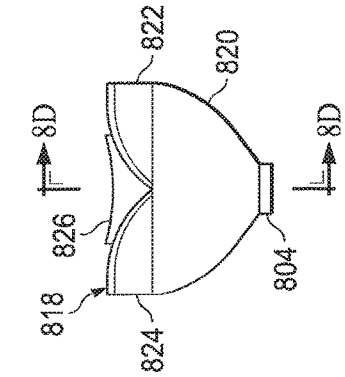

FIG. 8E

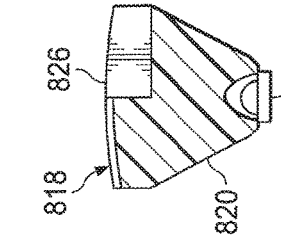

FIG. 8D

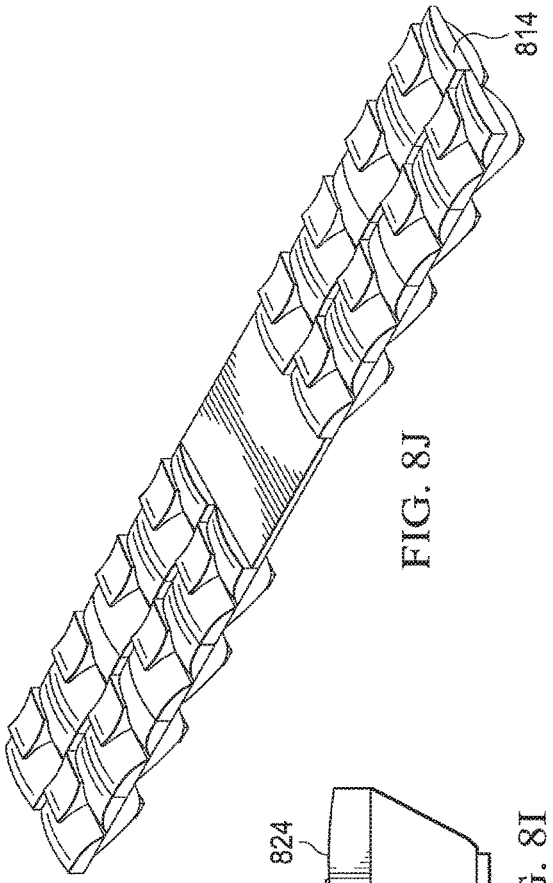

FIG. 8J

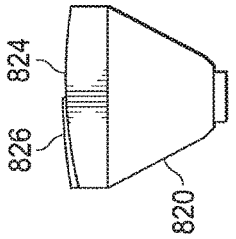

FIG. 8I

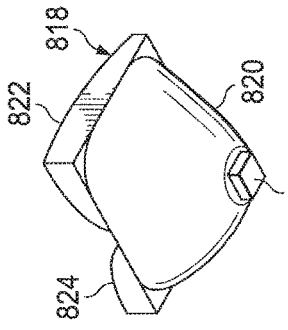

FIG. 8H

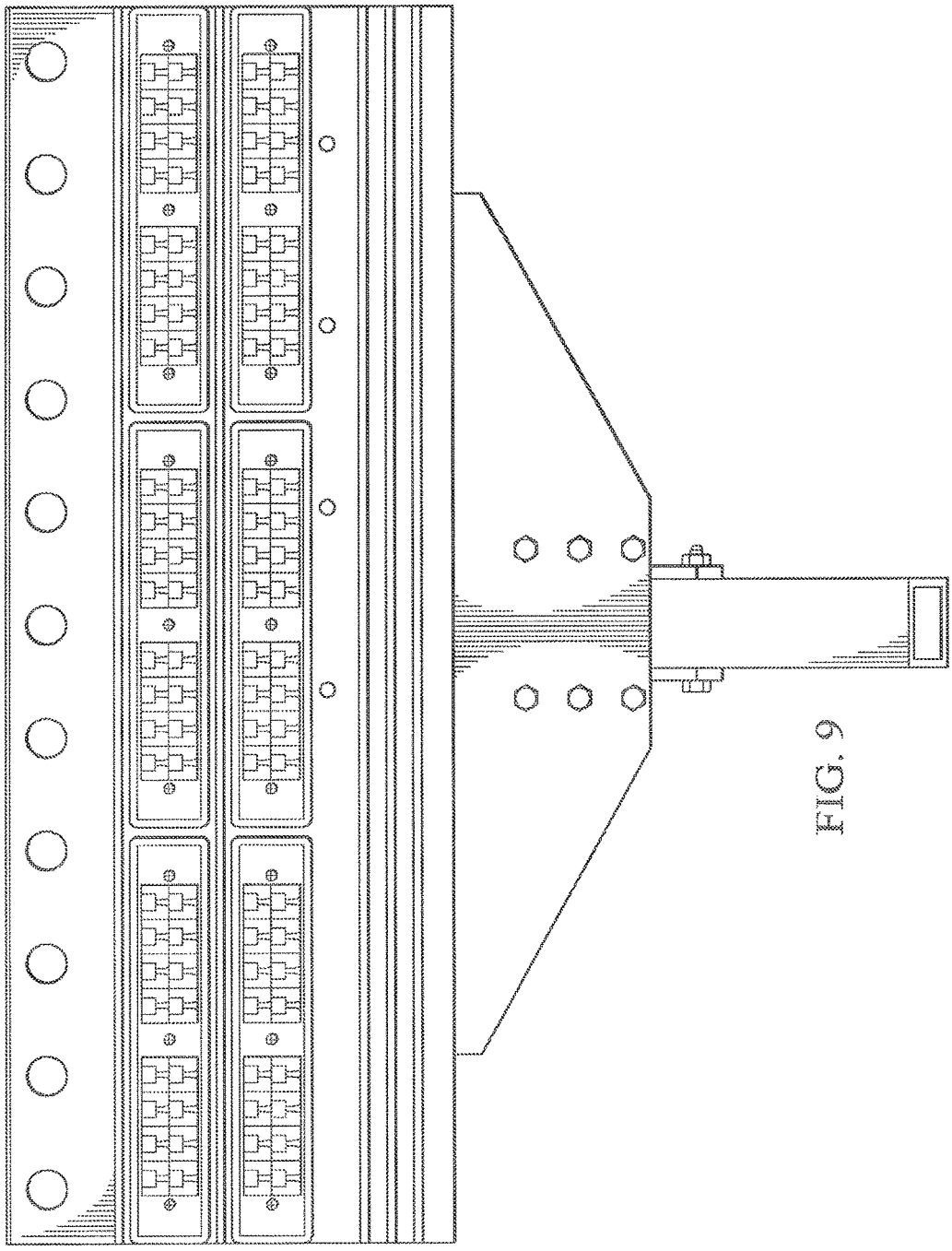

FIG. 9

LIGHTING DEVICE WITH TRANSPARENT SUBSTRATE, HEAT SINK AND LED ARRAY FOR UNIFORM ILLUMINATION REGARDLESS OF NUMBER OF FUNCTIONAL LEDS

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a continuation of U.S. patent application Ser. No. 15/627,089, filed Jun. 19, 2017, which is a continuation of U.S. patent application Ser. No. 15/429,320, filed Feb. 10, 2017, which is a continuation of U.S. patent application Ser. No. 15/216,562, filed Jul. 21, 2016, which is a divisional of U.S. patent application Ser. No. 14/968,520, filed Dec. 14, 2015, which is a division of U.S. patent application Ser. No. 14/706,634, filed May 7, 2015, which is a continuation of U.S. patent application Ser. No. 14/630,500, filed Feb. 24, 2015, which is a continuation of U.S. patent application Ser. No. 13/836,517, filed Mar. 15, 2013, which claims the benefit of U.S. Provisional Application No. 61/677,346, filed on Jul. 30, 2012, which applications are all hereby incorporated herein by reference.

The following patents and applications are related:

- U.S. patent application Ser. No. 61/677,340, filed Jul. 20, 2012 (now expired)
- U.S. patent application Ser. No. 61/677,346, filed Jul. 30, 2012 (now expired)
- U.S. patent application Ser. No. 61/677,352, filed Jul. 30, 2012 (now expired)
- U.S. patent application Ser. No. 13/836,517, filed Mar. 15, 2013 (now U.S. Pat. No. 8,974,077)
- U.S. patent application Ser. No. 13/836,612, filed Mar. 15, 2013 (now U.S. Pat. No. 8,870,410)
- U.S. patent application Ser. No. 13/836,710, filed Mar. 15, 2013 (now U.S. Pat. No. 9,062,873)
- U.S. patent application Ser. No. 14/137,306, filed Dec. 30, 2013 (now U.S. Pat. No. 8,985,806)
- U.S. patent application Ser. No. 14/137,343, filed Dec. 20, 2013 (now U.S. Pat. No. 8,870,413)
- U.S. patent application Ser. No. 14/137,380, filed Dec. 20, 2013 (now U.S. Pat. No. 9,068,738)
- U.S. patent application Ser. No. 14/630,500, filed Feb. 24, 2015 (now U.S. Pat. No. 9,812,043)
- U.S. patent application Ser. No. 14/635,907, filed Mar. 2, 2015 (now U.S. Pat. No. 9,234,642)
- U.S. patent application Ser. No. 14/706,634, filed May 7, 2015 (now U.S. Pat. No. 9,212,803)
- U.S. patent application Ser. No. 14/968,520, filed Dec. 14, 2015 (now U.S. Pat. No. 9,589,488)
- U.S. patent application Ser. No. 14/992,680, filed Jan. 11, 2016 (now U.S. Pat. No. 9,349,307)
- U.S. patent application Ser. No. 15/162,278, filed May 23, 2016 (now U.S. Pat. No. 9,734,737)
- U.S. patent application Ser. No. 15/208,483, filed Jul. 12, 2016 (now U.S. Pat. No. 9,514,663)
- U.S. patent application Ser. No. 15/208,521, filed Jul. 12, 2016 (now U.S. Pat. No. 9,524,661)
- U.S. patent application Ser. No. 15/216,562, filed Jul. 21, 2016 (now U.S. Pat. No. 9,659,511)
- U.S. patent application Ser. No. 15/216,595, filed Jul. 21, 2016 (now U.S. Pat. No. 9,542,870)
- U.S. patent application Ser. No. 15/413,277, filed Jan. 23, 2017 (now U.S. Pat. No. 9,734,738)
- U.S. patent application Ser. No. 15/413,306, filed Jan. 23, 2017 (now U.S. Pat. No. 9,732,932)

- U.S. patent application Ser. No. 15/429,320, filed Feb. 10, 2017 (now U.S. Pat. No. 9,685,102)
- U.S. patent application Ser. No. 15/627,089, filed Jun. 19, 2017 (co-pending)
- U.S. patent application Ser. No. 15/676,823, filed Aug. 14, 2017 (now U.S. Pat. No. 9,947,248)
- U.S. patent application Ser. No. 15/939,565, filed Mar. 29, 2018 (co-pending)
- U.S. patent application Ser. No. 15/969,392, filed May 2, 2018 (co-pending)

TECHNICAL FIELD

The following disclosure relates to lighting systems and, more particularly, to lighting systems using light emitting diodes to externally illuminate signs.

SUMMARY

The present invention, in one aspect thereof, comprises a back panel for use in a light emitting diode (LED) lighting assembly. An extruded substrate formed of a thermally conductive material is provided, the substrate having a plurality of fins extending from a first side of the substrate, each of the fins having a substantially rectangular shape oriented so that a longitudinal axis of the fin is substantially parallel to a longitudinal axis of the substrate. At least some of the fins include a hole formed through the fin to enable heated air to rise through the fins. A plurality of LEDs are mounted on a second side of the substrate, and oriented in a longitudinal orientation with the fins oriented parallel to the bottom edge of a surface to be illuminated, such that heat rises perpendicular to the surface of the fin.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding, reference is now made to the following description taken in conjunction with the accompanying drawings in which:

FIG. **1**A illustrates one embodiment of a billboard that may be externally lighted by one or more lighting assemblies;

FIGS. **1**B-**1**D illustrate embodiments of angular positions of the lighting assembly of FIG. **1** relative to the billboard;

FIG. **2** illustrates one embodiment of a lighting assembly that may be used to light the billboard of FIG. **1**;

FIGS. **3**A and **3**B illustrate one embodiment of a back panel that may be used in the lighting assembly of FIG. **2**;

FIG. **3**C illustrates one embodiment of the back panel of FIGS. **3**A and **3**B with a light panel and an optics panel that may also be used in the lighting assembly of FIG. **2**;

FIGS. **4**A and **4**B illustrate one embodiment of a light panel that may be used with the lighting assembly of FIG. **2**;

FIGS. **5**A, **5**B, **5**C and **5**D illustrate one embodiment of an optics panel that may be used with the lighting assembly of FIG. **2**;

FIGS. **6**A-**6**C illustrate a more detailed embodiment of the lighting assembly of FIG. **2**;

FIGS. **7**A and **7**B illustrate an embodiment of a back panel that may be used with the lighting assembly of FIGS. **6**A-**6**C;

FIG. **8**A illustrates an embodiment of an LED assembly and an optics panel that may be used with the lighting assembly of FIG. **6**;

FIGS. **8**B-**8**J illustrates embodiments of the optics panel of FIG. **8**A and optical elements that may be used to form part of the optics panel; and

FIG. **9** illustrates a more detailed embodiment of the lighting assembly of FIG. **2**.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Billboards, such as those commonly used for advertising in cities and along roads, often have a picture and/or text that must be externally illuminated to be visible in low-light conditions. As technology has advanced and introduced new lighting devices such as the light emitting diode (LED), such advances have been applied to billboards. However, current lighting designs have limitations and improvements are needed. Although billboards are used herein for purposes of example, it is understood that the present disclosure may be applied to lighting for any type of sign that is externally illuminated.

Referring to FIG. **1**A, one embodiment of a billboard **100** is illustrated. The billboard **100** includes a surface **102** onto which a picture and/or text may be painted, mounted, or otherwise affixed. The surface **102** may be any size, such as a commonly used size having a width of forty-eight feet wide and a height of fourteen feet. The surface **102** may be provided by placing a backing material on a frame **104** made of steel and/or other materials. The frame **104** may be mounted on one or more support poles **106**, which may be considered part of the frame **104** or separate from the frame **104**. The billboard **100** may include a walkway or other support structure **108** that enables the surface **102** to be more easily accessed.

One or more lighting assemblies **110** may be coupled to the walkway **108** (e.g., to a safety rail or to the walkway itself) and/or to another structural member of the billboard **100** to illuminate some or all of the surface **102** in low light conditions. The lighting assembly **110** may be mounted at or near a top edge **112** of the billboard **100**, a bottom edge **114** of the billboard **100**, a right edge **116** of the billboard **100**, and/or a bottom edge **118** of the billboard **100**. The lighting assembly **110** may be centered (e.g., located in approximately the center of the billboard **100**) or off center as illustrated in FIG. **1**A.

With additional reference to FIGS. **1**B-**1**D, a surface **120** of the lighting assembly **110** may be parallel with respect to the surface **102** of the billboard **100** (FIG. **1**B), may be perpendicular with respect to the surface **102** (FIG. **1**C), or may be angled with respect to the surface **102** (FIG. **1**D). It is understood that the lighting assembly **110** may be placed in many different orientations and locations relative to the billboard **100** and to one another, and the illustrated positions are only for purposes of example. Furthermore, it is understood that references to "top," "bottom," "left," and "right" are used in the present disclosure for purposes of description and do not necessarily denote a fixed position. For example, the billboard **100** may be turned on end, and the referenced "top," "bottom," "left," and "right" edges may still be readily identifiable although the "top" edge would be the "left" edge or the "right" edge.

One problem with current lighting technology is that it can be difficult to direct light only onto the surface **102** and even more difficult to do so evenly. This may be due partly to the placement of the lighting assembly **110**, as shown in FIGS. **1**B-**1**D. As the lighting assembly **110** is off center relative to the surface **102**, light emitted from the lighting assembly **110** may not evenly strike the surface **102**. One problem with uneven illumination is that certain parts of the surface **102** may be more brightly illuminated than other parts. This creates "hot spots" that may be undesirable. Attempting to evenly illuminate the surface **102** may cause light to be directed past the edges **112**, **114**, **116**, and **118** as attempts are made to balance out hot spots in particular areas. However, light that does not strike the surface **102** is wasted and may create problems (e.g., light pollution), as well as waste illumination that could be used for the surface **102**.

In addition to the difficulties of evenly illuminating the surface **102**, the use of LEDs in an exterior lighting environment involves issues such as heat dissipation and protecting the LEDs against environmental conditions such as moisture. The presence of moving mechanical features such as fans that may be used to provide increased airflow for cooling may create additional reliability problems. Due to the difficulty and expense of replacing and/or repairing the lighting assembly **110** in combination with the desire to provide consistent lighting while minimizing downtime, such issues should be addressed in a manner that enhances reliability and uptime.

Referring to FIG. **2**, one embodiment of a lighting assembly **200** is illustrated. The lighting assembly **200** provides a more detailed embodiment of the lighting assembly **110** of FIG. **1**. The lighting assembly **200** includes a back panel **202**, a light panel **204** (e.g., a printed circuit board (PCB)) having a plurality of LEDs (not shown) mounted thereon, and an optics panel **206**. As will be described below in more detailed examples, light from the LEDs of the light panel **204** may be directed by the optics panel **206** to illuminate the surface **102** of the billboard **100** of FIG. **1**. The back panel **202** may be configured to serve as a supporting substrate for the light panel **204** and optics panel **206**, as well as to dissipate heat produced by the LEDs.

It is understood that any of the back panel **202**, light panel **204**, and optics panel **206** may actually be two or more physical substrates rather than a single panel as illustrated in FIG. **2**. Furthermore, it is understood that there may be additional panels positioned behind the back panel **202**, in front of the optics panel **206**, and/or between the back panel **202** and light panel **204** and/or between the light panel **204** and optics panel **206**.

Referring to FIGS. **3**A-**3**C, one embodiment of the back panel **202** is illustrated with a front surface **302** and a back surface **304**. The back panel **202** includes a top edge **306**, a bottom edge **308**, a right edge **310**, and a left edge **312**. The panel **202** may be formed of one or more thermally conductive materials (e.g., aluminum) and/or other materials.

The front surface **302** provides a mounting surface for the light panel **204**. In some embodiments, the front surface **302** of the panel **202** may include one or more protrusions **314***a* and **314***b* that are substantially parallel to the top edge **306**. The protrusions **314***a* and **314***b* may be configured to protect the light panel **204** from moisture. Although only two protrusions **314***a* and **314***b* are illustrated, it is understood that a single protrusion may be provided or three or more protrusions may be provided. Furthermore, such protrusions may vary in length, shape (e.g., may have angled or curved surfaces), orientation, and/or location on the front surface **302**.

Referring specifically to FIG. **3**C, a light panel **204** and an optical panel **206** may be mounted under the protrusion **314***a* (FIG. **3**C). Moisture running down the front surface **302** in the direction of arrow **316** may strike the protrusion **314***a* and be directed away from the light panel **204** and optical panel **206** as shown by arrow **318**. Although not shown,

moisture may also be directed length down the protrusion **314***a*. Accordingly, protrusion **314***a* may serve as a gutter and aid in directing moisture away from a joint **320** where the optical panel **206** abuts the front surface **302**. This may be beneficial even when a moisture resistant compound is used to seal the joint **320**. In embodiments where there are multiple light panels **204** arranged vertically on the front surface **302**, there may be a protrusion positioned above each light panel **204**. For example, the protrusion **314***a* may be positioned directly above one light panel **204** and the protrusion **314***b* may be positioned directly above another light panel **204**.

Referring specifically to FIG. **3**B, the back surface **304** may be configured to increase heat dissipation. For example, the back surface **304** may be configured with a heat sink provided by fins **322***a*-**322**N, where N denotes a total number of fins. The fins **322***a*-**322**N increase the surface area of the back surface **304**, thereby providing for additional heat dissipation to the surrounding air. The fins **322***a*-**322**N may be formed as part of the panel **202** or may be otherwise coupled to the panel **202** (e.g., may be part of a discrete heat sink that is coupled to the back surface **304**). Some or all of the fins **322***a*-**322**N may be angled, as shown by fins **322***a* and **322***b*. In some embodiments, holes (not shown) may be provided in some or all of the fins **322***a*-**322**N to aid in air circulation. In such embodiments, the holes may cause a chimney effect in which heated air rises through the holes and is replaced by cooler air. This may be particularly effective in environments where natural air movement is limited.

Referring to FIGS. **4**A and **4**B, one embodiment of a single PCB **402** of the light panel **204** is illustrated. In the present example, the light panel **204** may include multiple PCBs **402**, although it is understood that any number of PCBs may be used based on design issues such as the amount of illumination needed, the amount of illumination provided by a single PCB **402**, the size of the surface **102** of the billboard **100**, and/or other factors. As shown in the present embodiment with a substantially rectangular cross-section, the PCB **402** includes a front surface **404**, a back surface **406**, a top edge **408**, a bottom edge **410**, a right edge **412**, and a left edge **414**.

The PCB **402** may include one or more strings of LEDs **416**, with multiple LEDs **416** in a string. For example, a string may include eight LEDs **416** and each PCB **402** may include two strings for a total of sixteen LEDs **416**. In this configuration, a light panel **204** having eight PCBs **402** would include ninety-six LEDs **416**. It is understood that although the PCBs **402** are shown as being substantially identical, they may be different in terms of size, shape, and other factors for a single light panel **204**.

In the present example, the LEDs **416** are surface mounted, but it is understood that the LEDs **416** may be coupled to the panel **204** using through hole or another coupling process. The surface mounted configuration may ensure that a maximum surface area of each LED **416** is in contact with the PCB **402**, which is in turn in contact with the back panel **202** responsible for heat dissipation. Each string of LEDs may receive a constant current with the current divided evenly among the LEDs **416**.

Referring to FIGS. **5**A, **5**B, **5**C and **5**D, one embodiment of a single lens panel **500** of the optics panel **206** is illustrated. In the present example, the optics panel **206** may include multiple lens panels **500**, although it is understood that any number of lens panels may be used based on design issues such as the number, arrangement, and orientation of the LEDs **416**, the size of the surface **102**, and/or other factors. As shown in the present embodiment with a substantially rectangular cross-section that is configured for use with the PCB **402** of FIG. **4**, a single lens panel **500** includes a front surface **502**, a back surface **504**, a top side **506**, a bottom side **508**, a right side **510**, and a left side **512**. The sides **506**, **508**, **510**, and **512** may form a cavity into which the PCB **402** may fit, thereby providing protection for the PCB **402** from environmental conditions such as moisture.

The lens panel **500** may include a beveled or angled top side **506** and/or bottom side **508** as illustrated in FIG. **5**B. The beveling/angling may aid in preventing moisture from reaching the PCB **402** under the lens panel **500**, as water will more readily flow from the area of the joint **320** (FIG. **3**C) due to the angled surface than if the top side **506** was relatively flat.

The lens panel **500** may include multiple optical elements **514**. A single optical element **514** may be provided for each LED **416**, a single optical element **514** may be provided for multiple LEDs **416**, and/or multiple optical elements **514** may be provided for a single LED **416**. In some embodiments, the optical elements **514** may be provided by a single multi-layer optical element system provided by the lens panel **500**.

In the present example, the optical elements **514** are configured so that the light emitted from each LED **416** is projected onto the entire surface **102** of the billboard **100**. In other words, if all other LEDs **416** were switched off except for a single LED **416**, the entire surface **102** would be illuminated at the level of illumination provided by the single LED **416**. In one embodiment, the rectangular target area of the surface **102** would be evenly illuminated by the LED **416**, while areas beyond the edges **112**, **114**, **116**, and **118** would receive no illumination at all or at least a minimal amount of illumination from the LED **416**. What is meant by "evenly" is that the illumination with a uniformity that achieves a 3:1 ratio of the average illumination to the minimum. Thus, by designing the lens in such a manner, when all LEDs are operating, the light form the collective thereof will illuminate the surface at the 3:1 ratio. When one or more LEDs fail, the overall illumination decreases, but the uniformity maintains the same uniformity. Also, as described hereinabove, the "surface" refers to the surface that is associated with a particular LED panel. It may be that an overall illuminated surface is segmented and multiple panels are provided, each associated with a particular segment.

FIG. **5**C illustrates a detail of the lens assembly. Each of the diodes **416** is mounted on the board **408** at a minimum distance. Overlying the board and LEDs **416** is transparent lens substrate **520**. This substrate **520** has a plurality of lens structures **522**, each associated with one of the LEDs **416**, such that each of the LEDs **416** has the light emitted therefrom directed outward towards the surface, each lens structure being substantially the same. The minimum distance is designed such that overlapping light from adjacent LEDs does not create interference patterns and result in dead spots on the surface. The lens structure **522** is designed to create the 3:1 uniformity and also, the lens structure is designed to "direct" the light from an edge of the surface to cover the entire surface. This is shown by the angle of the light rays in FIG. **5**C. Also, the beveled edge **530** will basically surround the PCB **402**, thus protecting it from moisture. The lens substrate **520** is secured with screws (not shown).

FIG. **5**D illustrates a detail of the lens structure **522**. This structure includes an interior surface **524** and an exterior surface **526** that shapes and directs the light in the correct

pattern. This is an acrylic material. With such a design, the lighting assembly can be disposed at an edge of the surface to illuminate the entire surface.

In some embodiments, as shown in FIG. **1**, two lighting assemblies **110** may be used. Each lighting assembly may be powered by a separate power supply (not shown), and may be configured to illuminate the entire surface **102**. In such an embodiment, if one power supply fails, the remaining lighting assembly **110** will still illuminate the entire surface **102**, although at a lesser intensity than when both lighting assemblies **110** are functioning. This provides evenly distributed illumination when both lighting assemblies **110** are functioning correctly, and continues to provide evenly distributed illumination when one lighting assembly **110** malfunctions. Accordingly, the entire surface **102** of the billboard **100** may be illuminated even when an entire lighting assembly **110** has malfunctioned and is providing no illumination at all due to the redundancy provided by configuration of the lighting assemblies **110**.

Furthermore, in some embodiments as described above, each LED **416** of a single lighting assembly **110** may be configured via the optical elements **514** to illuminate the entire surface **102**. In such embodiments, if one or more LEDs **416** or strings of LEDs fails, the remaining LEDs **416** will still illuminate the entire surface **102**, although at a lesser intensity than when the failed LEDs **416** are functioning. This provides evenly distributed illumination when all LEDs **416** are functioning correctly, and continues to provide evenly distributed illumination when one or more LEDs are malfunctioning. Accordingly, the billboard **100** may be illuminated even when multiple LEDs **416** have malfunctioned and are providing no illumination at all due to the redundancy provided by configuration of the lighting assemblies **110**.

It is understood that some embodiments may direct substantially all illumination from a lighting assembly **110** evenly across the surface **102** while some illumination is not evenly distributed. For example, substantially all LEDs **416** may be directed to each evenly illuminate the surface **102** with the exception of a relatively small number of LEDs **416**. In such cases, the illumination provided by the remaining LED or LEDs **416** may be directed to one or more portions of the surface **102**. If done properly, this may be accomplished while minimizing any noticeable unevenness in the overall illumination, even if one of the remaining LEDs **416** malfunctions. For example, the lighting assembly **110** may be configured to direct the illumination provided by one LED **416** to only the left half of the surface **102**, while directing the illumination from another LED **416** to only the right half of the surface **102**. The loss of one of these two LEDs may not noticeably impact the illumination of the surface **102**. It is understood that such variations are within the scope of this disclosure.

In embodiments where the illumination is evenly distributed across the surface **102**, it is understood that the optics panel **206** may be configured specifically for the light panel **204** and the surface **102**. For example, assuming the surface **102** is forty-eight feet wide and sixteen feet high, the lens panel **500** of FIG. **5** may be specifically designed for use with the PCB **402** of FIG. **4**. This design may be based on the particular layout of the PCB **402** (e.g., the number and arrangement of the LEDs **416**), the amount of illumination provided by the LEDs **416**, the size of the surface **102**, the distance between the lens panel **500** and the surface **102**, the angle at which the lens panel **500** is mounted relative to the surface **102** (e.g., FIGS. **1**B-**1**D), and/or other factors. Accordingly, changes in any of these factors may entail a change in the design of the lens panel **500** in order to again evenly distribute the illumination provided by each LED **416** across the entire surface **102**. It is understood that various standard configurations of the lighting assembly **110** may be developed for various billboard and/or other externally illuminated signs so that a particular configuration may be provided based on the parameters associated with a particular billboard and/or externally illuminated sign.

Referring to FIGS. **6**A-**6**C, one embodiment of a lighting assembly **600** is illustrated that provides a more detailed embodiment of the lighting assembly **200** of FIG. **2**. The lighting assembly **600** includes a back panel **602**, a light panel formed by multiple LED assemblies (denoted by reference number **800** in FIG. **8**A), and an optics panel formed by multiple lens panels **604**. Accordingly, as described previously, the light panel **204** in the current example is represented by multiple LED assemblies **800** and the optics panel **206** is represented by multiple lens panels **604**. In the present embodiment, the lighting assembly **600** includes four LED assemblies **800** and four lens panels **604**.

Although various attachment mechanisms (e.g., threaded screws, bolts, and/or other fasteners) may be used to coupled the lens panels and LED assemblies to the back panel **602**, the present embodiment uses multiple threaded fasteners **605** (e.g., screws) that extend through the lens panels and the LED assemblies and engage threaded holes in the back panel **602**.

The lighting assembly **600** is also illustrated with a mounting plate **606** that couples to the back panel **602** and to an adjustable mounting bracket **608**. The adjustable mounting bracket **608** may be used to couple the lighting assembly **600** to a portion of the billboard **100** (FIG. **1**) and/or to another support member. A power supply enclosure **610** may be coupled to the mounting plate **606** and configured contain a power supply (not shown) capable of supplying power to LEDs of the LED assemblies **800**. It is noted that separating the power supply from the back panel **602** may aid in heat dissipation by the back panel **602** as it does not have to dissipate heat from the power supply to the same extent as if the power supply was mounted directly to the back panel **602**.

The location of the power supply may also be beneficial as snow not melted by the heat produced by the LED may be melted by heat produced by the power supply. This may aid in reducing snow buildup on the LEDs.

With additional reference to FIGS. **7**A and **7**B, one embodiment of the back panel of FIG. **602** is illustrated. A front surface **700** includes multiple protrusions **702** that may be configured to protect the light panels (not shown) against moisture as previously described. The front surface **700** may include additional protrusions **704**.

A back surface **706** includes multiple fins **708** that form a heat sink to aid in the dissipation of heat from the back panel **602**. In the present example, the fins **708** are substantially rectangular in shape. In the present example, the back panel **602** is extruded and the fins **708** run parallel to the top edge with a longitudinal axis of each fin **708** being substantially parallel to a longitudinal axis of the back panel **602**. Forming the fins **708** in a vertical manner is possible, but may increase the cost of the back panel **602** due to the extrusion process. As shown, the fins **708** may be substantially perpendicular to the back surface **706**, and/or may be angled. In the present example, the fins **708** are angled such that near the top of the back panel **702**, the fins **708** are angled towards the top.

Because the fins **708** are parallel to the top edge, heat may be trapped due to its inability to rise vertically. Accordingly,

holes **710** may be present in some or all of the fins **708** (marked but not actually visible in the side view of FIG. **7**B) to provide paths for the heat to rise vertically in spite of the orientation of the fins **708**. The holes **710** may create a chimney effect that increases air flow across the fins **708** and aids in the cooling process. In some embodiments, some or all of the fins **708** may be angled such that heat is not trapped.

The back surface **706** may also include a groove **712** that is configured to receive a tongue of the mounting plate **606** in a tongue-in-groove manner.

With additional reference to FIGS. **8**A-**8**J, embodiments of a single LED assembly **800** and a single lens panel **604** that may be used with the lighting assembly **600** are illustrated. As shown, the single LED assembly **800** and the single optics panel **604** may be configured for use together.

Referring specifically to FIG. **8**A, the LED assembly **800** includes a substrate **802** (e.g., a PCB) onto which are mounted multiple LEDs **804**. In the present example, the LED assembly **800** includes two strings of eight LEDs **804** each for a total of sixteen LEDs **804**. It is understood that this is merely an example, and there may be more or fewer LEDs **804** on the light panel **800**, and the LEDs **804** may be arranged in many different ways on the substrate **802**.

Referring also to FIGS. **8**B-**8**J, the optics panel **604** may include optical elements **806** arranged on an upper surface **808** of the optics panel **604**. The optics panel **604** may further include sides **810**, **812**, **814**, and **816** that are configured to fit around the edge of the substrate **802** of the light panel **800**. The bottom edge of each side **810**, **812**, **814**, and **816** abuts the front surface **700** of the back panel **602** and may be sealed to the front surface **700** using a moisture resistant sealant.

As shown in FIGS. **8**D-**8**H, a single optical element **806** may include multiple lens elements designed to distribute the illumination provided by a single LED **804** across a surface such as the surface **102** of FIG. **1**. A first lens element **820** may be positioned proximate to the LED **804**, and additional lens elements **822**, **824**, and **826** may be positioned above the lens element **820**. Multiple optical elements **806** may be combined and formed as a single optics panel **604** that is configured to operate with the LED assembly **800**.

Referring to FIG. **9**, another embodiment of a lighting assembly **900** is illustrated that provides a more detailed embodiment of the lighting assembly **200** of FIG. **2**. The lighting assembly **900** is similar to the lighting assembly **600** of FIG. **6**, but includes six LED assemblies rather than the four six LED assemblies of the lighting assembly **600**. It is understood that the lighting assembly **900** may require a larger power supply than the lighting assembly **600** (e.g., a one hundred and fifty watt power supply instead of a one hundred and twenty watt power supply).

Although the preferred embodiment has been described in detail, it should be understood that various changes, substitutions and alterations can be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A light assembly comprising:

a thermally conductive support structure configured for outdoor use, wherein the support structure protects electronic components attached to the support structure from direct contact with rainwater, wherein the support structure comprises an attachment point for securing the support structure to a weatherproof mount designed for outdoor use;

a heat sink;

a substantially planar circuit board attached to the support structure;

a plurality of LEDs attached to the circuit board, wherein the LEDs are arranged in an array configuration; and

a single transparent substrate overlying all LEDs attached to the circuit board, wherein the transparent substrate includes a plurality of convex optical elements, each convex optical element overlying an associated one or more of the LEDs;

wherein the light assembly is configured to direct light from the LEDs towards an area in a manner that does not create hot spots or result in dead spots on the area regardless of whether all of the LEDs of the plurality of LEDs or some of the LEDs of the plurality of LEDs are functional.

2. The light assembly of claim **1**, wherein the light assembly is further configured to provide illumination redundancy such that the average illumination to the area when all LEDs are functional and emitting light is no more than three times the average illumination to the area when two or fewer of the LEDs are not functional and not emitting light.

3. The light assembly of claim **1**, wherein the heat sink includes a plurality of fins extending in a direction away from the circuit board.

4. The light assembly of claim **1**, wherein a portion of the heat sink is in direct contact with the support structure.

5. The light assembly of claim **1**, wherein the heat sink is directly exposed to the outside atmosphere and is not entirely enclosed by the support structure.

6. The light assembly of claim **1**, wherein the support structure and the heat sink are portions of a single integral component.

7. The light assembly of claim **1**, wherein each convex optical element overlies a single associated LED and wherein each and every one of the plurality of LEDs has an overlying convex optical element.

8. The light assembly of claim **1**, wherein the circuit board is in physical contact with the heat sink.

9. The light assembly of claim **1**, wherein the circuit board surrounded by a portion of the support structure.

10. The light assembly of claim **1**, wherein each LED is located between the circuit board and one of the convex optical elements.

11. The light assembly of claim **1**, further comprising a reflector disposed at a surface of the support structure, wherein a portion of the reflector has surfaces that are not coplanar with a main surface of the circuit board and wherein the reflector surfaces are configured to direct light emitted by each of the LEDs towards a direction away from the main surface of the circuit board, the LEDs being attached to main surface of the circuit board.

12. The light assembly of claim **1**, wherein the light assembly is further configured to provide illumination redundancy such that failure of some of the LEDs will cause an illumination level of light emitted from the light assembly to decrease while a uniformity of the light emitted from the light assembly remains substantially the same.

13. The light assembly of claim **1**, wherein the attachment point is coupled to an adjustable mount for attaching the support structure to a stationary object.

14. The light assembly of claim **1**, wherein each of the plurality of convex optical elements is substantially identical in shape and size.

15. The light assembly of claim **1**, wherein the transparent substrate includes a first plurality of holes;

wherein the support structure includes a second plurality of holes;

wherein the light assembly further comprises a plurality of screws; and

wherein the screws attach the transparent substrate to the support structure by being fastened through the first plurality holes of the transparent substrate to the second plurality of holes in the support structure.

16. The light assembly of claim **1**, further comprising:

a second circuit board attached to the support structure;

a second plurality of LEDs attached to the second circuit board; and

a second single transparent substrate overlying all LEDs attached to the second circuit board.

17. The light assembly of claim **16**, wherein a main surface of the second circuit board being parallel to a main surface of the circuit board.

18. The light assembly of claim **1**,

wherein each of the plurality of optical elements is configured to direct light from each LED in three primary directions;

wherein each optical element includes a first portion, a second portion, and a third portion;

wherein the first portion of each optical element is configured to direct light from the associated LED in a first primary direction, the second portion of each optical element is configured to direct light from the associated LED in a second primary direction, and the third portion of each optical element is configured to direct light in a third primary direction;

wherein the first primary direction is a lateral direction, the second primary direction is also a lateral direction and the third primary direction is approximately orthogonal to the first and second lateral directions; and

wherein the light assembly is configured so that the light is directed asymmetrically in the third direction so as to illuminate a substantially rectangular area that is off-center relative to the light assembly.

19. The light assembly of claim **18**, wherein for each optical element, the second portion intersects with the first portion in a region between the first portion and the second portion, and wherein, for each optical element, the first portion and the second portion are shaped so that at least one surface normal of the first portion intersects with at least one surface normal of the second portion.

20. The light assembly of claim **18**, wherein the weatherproof mount comprises an adjustable mount that has an angle of tilt that ranges between o degrees and 45 degrees relative to a plane parallel to the first and second directions.

21. A light assembly comprising:

a thermally conductive support structure configured for outdoor use, wherein the support structure protects electronic components attached to the support structure from direct contact with rainwater, wherein the support structure comprises an attachment point for securing the support structure to a weatherproof mount designed for outdoor use;

a heat sink;

a substantially planar circuit board attached to the support structure;

a plurality of LEDs attached to the circuit board, wherein the LEDs are arranged in an array configuration, the LEDs being thermally coupled to the heat sink; and

a single transparent substrate overlying all LEDs attached to the circuit board, wherein the transparent substrate includes a plurality of convex optical elements;

wherein each convex optical element overlies an associated one of the LEDs;

wherein each of the plurality of optical elements is configured to direct light from each LED in three primary directions;

wherein each convex optical element includes a first portion, a second portion, and a third portion;

wherein the first portion of each convex optical element is configured to direct light from the associated LED in a first primary direction, the second portion of each convex optical element is configured to direct light from the associated LED in a second primary direction, and the third portion of each convex optical element is configured to direct light in a third primary direction;

wherein the first primary direction is a lateral direction, the second primary direction is also a lateral direction and the third primary direction is approximately orthogonal to the first and second lateral directions; and

wherein the light assembly is configured to direct light from the LEDs towards an area in a manner that does not create hot spots or result in dead spots on the area regardless of whether all of the LEDs of the plurality of LEDs or some of the LEDs of the plurality of LEDs are functional.

22. The light assembly of claim **21**, wherein, for each convex optical element, the second portion intersects with the first portion in a region between the first portion and the second portion, and wherein, for each convex optical element, the first portion and the second portion are shaped so that at least one surface normal of the first portion intersects with at least one surface normal of the second portion.

23. The light assembly of claim **21**, wherein the heat sink includes a plurality of fins and wherein a portion of the heat sink is in direct contact with the support structure.

24. The light assembly of claim **21**, wherein the light assembly is configured so that the light is directed asymmetrically in the third direction so as to illuminate a substantially rectangular area that is off-center relative to the light assembly.

25. The light assembly of claim **21**, further comprising:

a second substantially planar circuit board attached to the support structure, a main surface of the second circuit board being parallel to a main surface of the circuit board;

a second plurality of LEDs attached to the second circuit board; and

a second single transparent substrate overlying all LEDs attached to the second circuit board.

26. The light assembly of claim **21**, wherein the attachment point is coupled to an adjustable mount for attaching the support structure to a stationary object, wherein the adjustable mount has an angle of tilt that ranges between o degrees and 45 degrees relative to a plane parallel to the first and second directions.

27. The light assembly of claim **21**, wherein the light assembly is further configured to provide illumination redundancy such that failure of one to five of the LEDs will cause an illumination level of light emitted from the light assembly to decrease while a uniformity of the light emitted from the light assembly remains substantially the same.

28. The light assembly of claim **27**, wherein the light assembly is further configured to provide illumination redundancy such that the average illumination to the area when all LEDs are functional and emitting light is no more than three times the average illumination to the area when two or fewer of the LEDs are not emitting light.

29. A light assembly comprising:

a thermally conductive support structure configured for outdoor use, wherein the support structure protects electronic components attached to the support structure from direct contact with rainwater, wherein the support structure comprises an attachment point for securing the support structure to a weatherproof mount designed for outdoor use, and wherein the support structure serves as a heat sink;

a substantially planar circuit board attached to the support structure;

a plurality of LEDs attached to the circuit board, wherein the LEDs are arranged in an array configuration; and

a transparent substrate overlying all LEDs attached to the circuit board, wherein the transparent substrate includes a plurality of convex optical elements, each convex optical element overlying an associated one of the LEDs, wherein a surface the transparent substrate is an outermost of the light assembly;

wherein the light assembly is configured to direct light from the LEDs towards a substantially rectangular area that is off-center relative to the light assembly, the light being directed in a manner that does not create hot spots or result in dead spots on the substantially rectangular area regardless of whether all of the LEDs of the plurality of LEDs or some of the LEDs of the plurality of LEDs are functional.

30. A light assembly comprising:

a thermally conductive support structure configured for outdoor use, wherein the support structure comprises an attachment point for securing the support structure to a weatherproof mount designed for outdoor use;

a substantially planar circuit board attached to the support structure;

a plurality of LEDs attached to the circuit board, wherein the LEDs are arranged in an array configuration, wherein all of the LEDs attached to the circuit board are arranged in a single plane, and wherein the thermally conductive support structure is configured to serve as a heat sink and dissipate heat during operation of the LEDs; and

a single transparent substrate overlying all LEDs attached to the circuit board, wherein the transparent substrate includes a plurality of optical elements, each optical element overlying an associated one or more of the LEDs, wherein the optical elements are configured to redirect light from the plurality of LEDs, each optical element being substantially the same as all other optical elements, wherein each LED is associated with a single optical element and each optical element is associated with a single LED, wherein each optical element comprises a convex portion at least partially overlying the associated LED, and wherein the optical elements are part of an outer surface that forms an exposed surface of the light assembly;

wherein the light assembly is configured to direct light from the LEDs towards an area in a manner that does not create hot spots or result in dead spots on the area regardless of whether all of the LEDs of the plurality of LEDs or some of the LEDs of the plurality of LEDs are functional.

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