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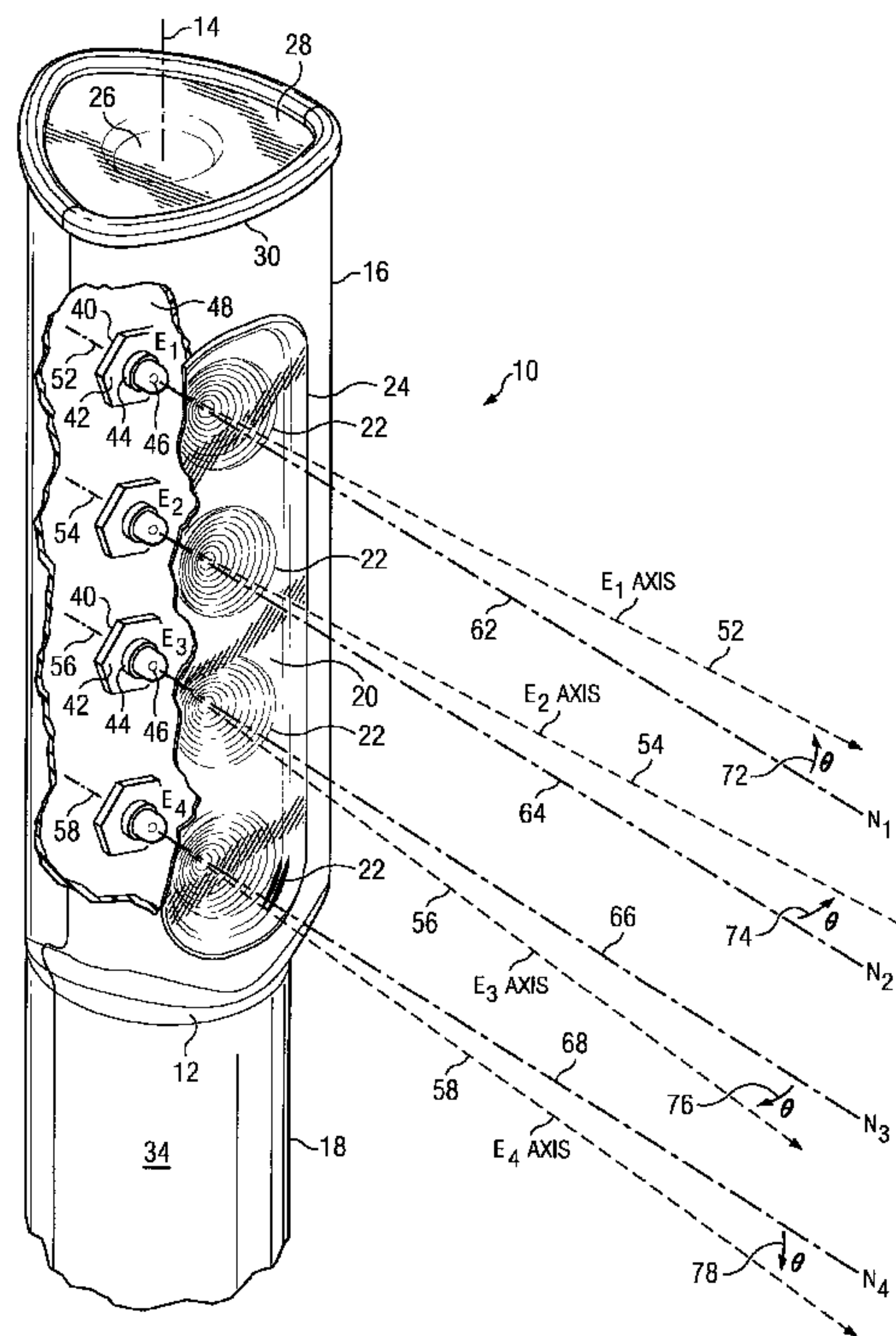
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(54) Titre : ENSEMBLES DE MODULES D'ECLAIRAGE ET METHODE APPLICABLE A UN DISPOSITIF D'ECLAIRAGE
COMPACT

(54) Title: LIGHTING MODULE ASSEMBLY AND METHOD FOR A COMPACT LIGHTING DEVICE



(57) Abrégé/Abstract:

A plurality of compact light emitting assemblies is mounted on a frame configured as a heat sink that provides a structural platform and a thermal management component. The frame further ensures proper alignment of the light emitting devices to aim the individual light emitting assemblies in a direction that provides a predetermined overlap of the individual light beams resulting in a uniform, high brightness pattern on a target surface. The source of current connected to the light emitting devices may also be mounted on the frame. The compact light emitting module thus provided is readily adaptable to a variety of compact, high performance lighting product configurations.

1 **A LIGHTING MODULE ASSEMBLY AND METHOD**
2 **FOR A COMPACT LIGHTING DEVICE**

3
4 **ABSTRACT OF THE DISCLOSURE**

5
6 A plurality of compact light emitting assemblies is mounted on a frame configured as a heat
7 sink that provides a structural platform and a thermal management component. The frame further
8 ensures proper alignment of the light emitting devices to aim the individual light emitting assemblies
9 in a direction that provides a predetermined overlap of the individual light beams resulting in a
10 uniform, high brightness pattern on a target surface. The source of current connected to the light
11 emitting devices may also be mounted on the frame. The compact light emitting module thus
12 provided is readily adaptable to a variety of compact, high performance lighting product
13 configurations.

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention generally relates portable lighting apparatus and, more particularly, to optical, mechanical, and electrical features for the design, utility, and performance of portable task lighting and flash light apparatus using very small light emitting devices.

2. Description of the Prior Art:

Lighting devices can be grouped into two basic applications: illumination devices and signaling devices. Illumination devices enable one to see into darkened areas. Signaling devices are designed to be seen, to convey information, in both darkened and well-lit areas. Widely available varieties of portable lighting apparatus, which may combine both the illumination type and the signaling type, employ a variety of lighting technologies in products such as task lamps and flashlights. Each new development in technology is followed by products that attempt to take advantage of the technology to improve performance or provide a lower cost product. For example, incandescent bulb technology in small and/or portable lighting products is being challenged by compact fluorescent lamp (CFL) bulbs, often in association with electronic ballast circuits. Other types of incandescent bulbs such as halogen lamps have become standard in a number of ordinary applications. High intensity discharge (HID) and other arc lighting technologies are finding ready markets in automotive and high brightness flood lighting, spot lighting, and signaling applications.

More recently, solid state or semiconductor devices such as light emitting diodes are finding use as compact and efficient light sources in a wide variety of applications. These applications include high intensity personal lighting, traffic and other types of signal lighting, automotive tail lamps, bicycle lighting, task lighting, flashlights, etc., to name a few examples. This technology is relatively new, however, and conventional products heretofore have suffered from a number of deficiencies. For example, current products utilizing light emitting diodes as light sources tend to

1 be highly specialized and suited to only a single use, thus limiting their versatility as lighting devices
2 or instruments for more ordinary uses. Further, such specialized devices tend to be expensive
3 because of the relatively low production volumes associated with specialized applications.
4

5 Moreover, there exist certain lighting applications for which conventional light sources are
6 unsatisfactory because of limitations in brightness, operating life, durability, power requirements,
7 excessive physical size, poor energy efficiency, and the like. Newer light sources such as
8 semiconductor light emitting diodes are very small, very durable, use relatively little power, have
9 long lifetimes, and emit very bright light relative to the electrical power input. While some presently
10 available products employ these semiconductor light sources, their full potential is frequently not
11 realized. This may occur because of deficiencies in optical components and drive circuits, or
12 interface components having particular combinations of structure and function are not available.
13 Another factor may be that improvements in the design and configuration of multiple, small, high
14 intensity light sources for maximum illumination efficiency and convenience of use have not been
15 forthcoming.
16

17 An advance in the state of the art could be realized if such small, high intensity and high
18 efficiency light emitting devices could be adapted to more general and more versatile lighting
19 applications such as flood lighting or spot lighting. Such advances could occur if improvements in
20 the components, circuits, and product architecture are developed and provided.
21

22 For example, in the field of lighting devices used by security personnel, there is a need for
23 high intensity illumination in a battery powered, hand-held instrument that is very rugged, efficient
24 in the use of power, and that provides a beam of light designed to illuminate dark regions of or
25 indistinct objects within an area being patrolled or investigated. Many circumstances require a bright,
26 well-shaped flood light beam for illuminating relatively large areas. Other situations require a more
27 directed beam of light, to spotlight particular areas or objects. Ideally, both modes of illumination
28 would be combined in a single instrument.
29

SUMMARY OF THE INVENTION

Accordingly, in one aspect of the present invention, there is provided a combination task lamp and flash light, comprising first and second elongated shells forming an elongated, tubular housing having a longitudinal axis, a first section at a first end for containing a plurality of light emitting device (LED) light sources and a second section at a second end for containing a power supply; the first section of the combination including a first directed array of LED/lens assemblies for providing flood light illumination and a second directed light array of at least one LED/lens assembly for providing spot light illumination.

In another aspect of the invention, there is provided a lens for a light emitting device (LED) comprising a combination of an aspherical reflecting surface and a spherical refracting surface. The aspherical reflecting surface has a focal point and a central axis of symmetry – i.e., an optical axis – for reflecting light rays emitted from a compact light source located approximately at the focal point in a forward direction and the reflected light rays are emitted approximately within a predetermined angle with respect to the optical axis. The spherical refracting surface is disposed in the path of the reflected light rays, centered on and normal to the central axis, concave in the forward direction of the reflected light rays and joins the aspherical reflecting surface at a boundary equidistant from the optical axis. The spherical refracting surface includes a plurality of N concentric annular surfaces, each annular surface having a cross section convex in the forward direction and disposed substantially at uniform radial intervals between the optical axis and the junction with the aspherical reflecting surface.

In another aspect of the present invention, there is provided a circuit for illuminating multiple light emitting devices, comprising a current selector circuit connected across a positive terminal and a negative terminal of a DC supply for selecting operating current from the DC supply to each of a first array and a second array of the multiple light emitting devices (LEDs); a switching regulator circuit connected across an output of the current selector circuit for respectively regulating first and second constant drive currents to the first array of LEDs and to the second array of LEDs; a first

1 array of LEDs coupled between a first output of the switching regulator circuit and a common current
2 sense device; and a second array of LEDs coupled between the first output of the switching regulator
3 circuit and the common current sense device; wherein a voltage signal generated by the common
4 current sense device is coupled to a sense input of the switching regulator circuit for regulating the
5 constant drive currents supplied to the first and second arrays of LEDs.

6
7 In another aspect of the invention, there is provided a light emitting module comprising a
8 frame configured as a heat sink having first and second opposite sides and a forward axis normal to
9 the first side thereof. Each one of an array of a plurality N of light emitting assemblies (LEAs)
10 connected to a source of current is mounted on the first side of the frame configured as a heat sink
11 such that the central axis of light emission of each LEA is disposed at a non-zero first predetermined
12 angle relative to the forward axis. The frame may include a printed circuit embodying an electric
13 circuit coupled to the array of light emitting assemblies.

14
15 In yet another aspect of the present invention, there is provided an electric circuit comprising
16 an electric circuit having an output and a single pole, single throw (SPST) switch having normally
17 open (NO) first and second contacts and a latching mechanism operable by an actuating member.
18 The switch is connected in the electric circuit for activating at least a conducting path in the electric
19 circuit wherein the switch is sequentially operable in first, second, and third states corresponding
20 respectively to latched engagement, momentary disengagement, and latched disengagement of the
21 first and second contacts in the switch. The first state provides activation of the electric circuit in an
22 OFF condition, the second state provides momentary activation of the electric circuit in an ON
23 condition, and the third state provides latched activation of the electric circuit in an ON condition.

24
25 In yet another aspect of the present invention, there is provided a method of operating a single
26 pole, single throw (SPST) switch in three distinct states in an electric circuit. The method comprises
27 the steps of providing in an electric circuit having at least an output a SPST normally open (NO)
28 switch for activating at least a conducting path in the electric circuit, the switch having first and
29 second contacts and a latching mechanism operated by an actuating member; providing a first state

1 wherein the latching mechanism is activated, the first and second contacts are engaged, and the
2 electric circuit is in an OFF condition; providing a second, momentary state by exerting a first force
3 upon the actuating member of the SPST switch, sufficient to disengage but not latch the first and
4 second contacts, thereby causing the electric circuit to enter a temporary ON condition during the
5 second state, wherein release of the first force upon the actuating member causes restoration of the
6 first state; and providing a third state by exerting a second force greater than the first force upon the
7 actuating member of the SPST switch, wherein the latching mechanism is activated and the first and
8 second contacts are disengaged, causing the electric circuit to remain in an ON condition. A repeated
9 exertion of the second force upon the actuating member of the SPST switch causes engagement of
10 the first and second contacts, causing in turn the electric circuit to enter the OFF condition.
11

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing aspects and other objects of the invention disclosed herein will be understood from the following detailed description read with reference to the accompanying drawings of one embodiment of the invention. Structures appearing in more than one figure and bearing the same reference number are to be construed as the same structure.

Figure 1 illustrates one embodiment of a perspective view of a combination task lamp and flash light according to the present invention that provides both flood and spot light illumination;

Figure 2 illustrates a perspective view of the embodiment of Figure 1 showing a preferred configuration of light emitting assemblies and the directionality of their respective emissions of light;

Figure 3 illustrates a plan view of a flood light pattern on a flat target surface at a nominal distance from the embodiment of Figure 1, showing the overlapping of beams of light from individual emitters;

Figure 4A illustrates a cross section profile of a solid body lens for use with each light emitting device in the embodiment of Figure 1;

Figure 4B illustrates an enlarged cross section of a portion of Figure 4A to show detail thereof;

Figure 4C illustrates a cross section profile of the solid body lens of Figure 4A in assembly with a light emitting device assembly;

Figure 5 illustrates a block diagram of an electrical circuit for use in the embodiment of Figure 1 for powering and controlling the light outputs thereof;

1 Figure 6A illustrates a first portion of a schematic diagram of the electrical circuit of Figure
2 5;

3
4 Figure 6B illustrates a second portion of the schematic diagram of the electrical circuit of
5 Figure 5;

6
7 Figure 7 illustrates an exploded view of major parts and assemblies of the embodiment of
8 Figure 1;

9
10 Figure 8A illustrates a perspective view of a rearward side of a light emitting module of the
11 embodiment of Figure 1;

12
13 Figure 8B illustrates a perspective view of the forward side of the light emitting module
14 illustrated in Figure 8A;

15
16 Figure 8C illustrates a perspective view of a basic module portion of the light emitting
17 module appearing in Figure 8B; and

18
19 Figure 8D illustrates a side cross section view of the light emitting module of the
20 embodiment of Figure 8A and 8B.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Figure 1, there is illustrated one embodiment of a perspective view of a portable, combination task lamp and flash light (also referred to herein as a portable lighting device 10 or “PLD 10,” that provides both flood and spot light illumination, and is constructed according to the present invention. The PLD 10 includes an elongated tubular housing 12 defined along a longitudinal axis 14, having a first section 16 at a first end for containing a plurality of light emitting assemblies or light sources 22, and further having a second section 18 at a second end for containing a power supply (See Figure 7). Visible through a clear side lens 24 in Figure 1 is a bezel 20 that locates the forward surfaces of four light sources 22 substantially in a row. The side lens 24 is an internal component of the housing 12 as will be further described with Figure 7. The row of four light sources 22 may be denoted as a first directed array of light sources 22. Any number of individual light sources 22 may be arranged in a variety of configurations to form a directed array. In the present illustrative embodiment, the configuration of four light sources 22 disposed in a row is selected to illustrate the principles of the invention in a specific product application.

In general, each of the light sources 22 may be a combination of a light emitting device (LED) and a lens assembly. The combination of an LED and a lens assembly may further be denoted as a light emitting assembly (LEA) or as a lens/LED assembly. An LED may be a semiconductor light emitting diode or it may be a light emitting device employing a different technology to produce light. A lens assembly may be a single, solid body of optical material having one or more predetermined optically responsive surface configurations or it may be constructed as a combination of separate, predetermined optical elements assembled into a single unit. In the illustrated embodiment, the lens is a solid body element having a plurality of predetermined surface configurations that is designed for use with certain types of light emitting diodes.

Continuing with Figure 1, a clear top lens 28 of a second directed light array 26 is disposed in the end of the first section 16 of the elongated housing 12. Although the clear top lens 28 indicates that a single light source is shown in the illustrative embodiment, it is possible that several

1 individual light sources may be used to construct the second directed light array 26. The second
2 directed light array 26 visible through the clear top lens 28 may be configured as a spot light beam
3 or as a flood light beam. Typically, with a PLD 10 having a first directed light array 22 configured
4 to provide a flood light beam, the second directed light array 26 may be advantageously configured
5 as a spot light beam. As will become apparent, when using very small or compact light sources, the
6 type of light beam provided is largely dependent upon the lens assembly provided for the light
7 source. Generally, the light source for the second directed light array 26 may be aligned such that its
8 optical axis is coincident with or aligned parallel with the longitudinal axis 14. In other applications,
9 the alignment of the second directed array 26 may be disposed at an angle (fixed or adjustable)
10 relative to the longitudinal axis. In such cases, the optical axis of the second directed light array 26
11 would be aligned at a non-zero angle with respect to the longitudinal axis.
12

13 At the end of the first section 16 of the elongated housing 12 a lens frame 30 disposed over
14 the second directed light array of lens 26 is provided to protect the clear top lens 28. The lens frame
15 30 may be formed as part of the elongated housing 12 or implemented as a separate component. It
16 will be observed that the lens frame 30 has a three-sided, tubular shape, i.e., a substantially triangular
17 shape wherein the three sides bulge slightly outward as with a convex surface. This triangular shape
18 mimics the shape of the cross section of the elongated housing 12 in the first section 16. In the
19 illustrated embodiment, the triangular cross section of the first section 16 may be configured to
20 merge with a substantially round or oval cross section of the second section 18. The triangular shape
21 is provided so that when the PLD 10 is placed on a horizontal surface, the PLD 10 naturally assumes
22 an orientation so that the flood light beam from the first directed light array is projected upward at
23 an angle from the horizontal. This is a useful feature when both hands must be free to work.
24

25 At the opposite end of the elongated housing 12, the second section 18 may be configured
26 to contain a power supply such as a battery pack. The external portions of the second section 18 may
27 be formed as a handle or with other features to provide a comfortable or a non-slippery gripping
28 surface. A removable end cap 32 may be provided for access to the interior of the second section 18
29 of the elongated housing 12 such as to replace a battery. In other applications the cap 32 may include

1 a connector for a line cord (not shown in Figure 1) to supply external power to a power supply
2 converter or battery charger contained within the second section 18, for example.

3
4 Referring to Figure 2, there is illustrated a perspective view of the embodiment of Figure 1
5 showing a preferred configuration of light emitting assemblies and the directionality of their
6 respective emissions of light. As will be described further with Figures 4A, 4B, and 4C infra, each
7 of the light sources 22 is an assembly of a light emitting assembly (including a light emitter or light
8 emitting device) and a lens assembly. In Figure 2, each of the light sources 22 is shown aligned with
9 respect to an associated light emitter (designated as E1, E2, E3, and E4) along an optical axis thereof.
10 The light emitting assembly including the light emitter and the lens assembly share the same optical
11 axis. In the example illustrated in Figure 2, the optical axis (designated by a dashed line) of the light
12 emitter of each light source 22 is disposed at an angle θ with respect to a normal reference line
13 (designated as N1, N2, N3, and N4) at the location of each light source 22. It is known to persons
14 skilled in the art that a "normal" reference line is oriented perpendicular to a plane surface, in this
15 case to the plane surface 48 on which the focal point of the individual light emitter is located. The
16 angle θ will be described in further detail herein below.

17
18 Each of the light emitters E1, E2, E3, and E4 are shown mounted on the plane surface 48 in
19 the interior of the elongated housing 12. The light sources 22, associated with each of the light
20 emitters are not fully illustrated so that the relationship of the light emitters E1, E2, E3, and E4 and
21 the elongated housing 12 may be more clearly illustrated. In the illustrated embodiment, a light
22 emitter may be a light emitting diode having an active element (See also Figure 4C) mounted inside
23 a hemispherical dome 40 on a base 42. The base 42 may be attached to a substrate 44, such as a
24 printed circuit board. The substrate 44 may be a laminated structure that includes a bottom layer (not
25 shown) of thermally conductive material such as aluminum. The aluminum layer provides an integral
26 heat sink for the light source emitter assembly for low power applications and a suitable conductive
27 bonding surface for higher power applications where more heat must be dissipated via an external
28 heat sink in contact with the substrate 44. In the illustrated example, the plane surface 48 is
29 preferably configured as such external heat sink for conducting heat away from the light emitting

1 assembly and dissipating it into the surroundings. A thermal compound of the type well known in
 2 the art may be placed in the interface between the substrate 44 and the plane surface 48.

3
 4 As described previously, an optical axis is defined for each of the light sources 22. In the
 5 illustrated embodiment, the optical axes are defined at an angle θ with respect to the normal line
 6 defined for each of the light sources 22. The same angle θ is used in this particular embodiment for
 7 all four of the light emitting assemblies for reasons which will be described. Thus, the optical axis
 8 52 for the E1 emitter is shown by the dashed line labeled "E1 Axis" and bearing reference number
 9 52. Optical axis 52 is defined to be oriented vertically upward relative to the normal line 62 (N1),
 10 from the perspective of the PLD 10, at the angle indicated by the symbol θ . Similarly, optical axis
 11 54 (the E2 axis) is defined to be oriented horizontally leftward relative to the normal line 64 (N2),
 12 from the perspective of the PLD 10, at the angle indicated by the symbol θ . Similarly, optical axis
 13 56 (the E3 axis) is defined to be oriented horizontally rightward relative to the normal line 66 (N3),
 14 from the perspective of the PLD 10, at the angle indicated by the symbol θ . Likewise, optical axis
 15 58 (the E4 axis) is defined to be oriented vertically downward relative to the normal line 68 (N4),
 16 from the perspective of the PLD 10, at the angle indicated by the symbol θ . Thus, each of the light
 17 sources 22 is oriented or aimed at the angle θ relative to a normal reference line perpendicular to the
 18 plane surface 48 at the location of the particular light source 22.

19
 20 Moreover, in an array of N light emitting assemblies supported on a common planar base
 21 having a normal forward axis, the individual optical axes of the light emitting assemblies will be
 22 disposed such that they diverge from a reference line parallel to the forward axis by the angle θ .
 23 Further, the individual planes containing the reference line and the optical axis of each light emitting
 24 assembly are disposed at substantially equal angles from each other, in the manner of spokes of a
 25 wheel when viewed from a point on the forward axis looking back toward the origin of the forward
 26 axis. This arrangement of the optical axes of the individual light emitting assemblies is shown in
 27 Figure 2 for an array of N = 4 emitters arranged in a straight line on a flat common planar base. As
 28 will be described, the orientation of the optical axes of this array at the angle θ of approximately 5
 29 degrees (5°), wherein each light emitting assembly provides a beam of light having a beam width

1 angle of approximately 40 degrees (40°), a composite beam pattern of high brightness and uniformity
2 of cross section is provided.

3
4 It should be appreciated that the optical axes of opposing pairs of light emitting assemblies
5 in such an array diverge by twice the angle θ , which in the illustrated embodiment is $2 \times 5^\circ = 10^\circ$.
6 During the development of the present invention, it was discovered that the relationship between the
7 amount of divergence between two light emitting assemblies in an array (here 10°) and the beam
8 width angle of the individual light emitting assemblies in the array (here 40°) turns out to be an
9 optimum relationship for producing a high brightness, high uniformity composite beam cross section.
10 The relationship may be stated as the ratio of the divergence angle to the beam width angle. In this
11 example it is one to four, or a "one quarter beam width" index or figure of merit. Thus, for a given
12 beam width from a light emitting assembly having a substantially point source light emitter and a
13 lens assembly configured to produce the given beam width, the optimum amount of divergence
14 between two such light emitting assemblies or pairs of such light emitting assemblies turns out to
15 be one quarter of the beam width of the individual light emitting assemblies. This index is very
16 useful in devising arrays of light emitting assemblies to provide a particular composite beam of light
17 or illumination pattern from the array, as will become more apparent in the detailed description
18 which follows.

19
20 Continuing with the description of Figure 2, when the plane surface 48 is a flat surface, all
21 four of the normal lines at each of the light source positions are parallel to each other. In the
22 illustrated embodiment, the light sources are disposed in a row because of the space limitations of
23 the elongated tubular housing 12. However, in an embodiment that allowed the four light sources
24 to be clustered close together on a flat plane surface in a rectangular array, for example at the four
25 corners of a square, the normal lines may be closer together and, in fact, a single normal line placed
26 at the center of the array could serve as the reference for all four of the light sources. In such an
27 embodiment, the light sources would still be advantageously oriented with their optical axes
28 diverging from the common normal line by the angle θ . Further, each of the four light sources would
29 also be divergent in a direction that is at right angles from the direction of divergence of each of its

1 neighboring light source. Thus, the optical axes - and the respective light beams - of the four light
2 sources are aimed in a manner that mimics the four compass directions N, W, S, and E, or, the four
3 spokes of a wheel wherein the spokes are 90° apart.

4
5 The same aiming arrangement is provided in the illustrated embodiment of Figure 2, where
6 the four light sources 22 are arranged in a row. That is, the optical axes of the light sources 22
7 diverge in the compass directions N, W, S, and E, when viewed from the position of the longitudinal
8 axis 14, even though the light sources 22 are arranged in a single row and are somewhat more widely
9 spaced. In either of the described embodiments, as illustrated in Figure 2 or in the preceding
10 paragraph, from the perspective of the PLD 10, the beam from light source E1 diverges northward,
11 E2 diverges westward, E3 diverges southward, and E4 diverges eastward. Thus, the respective beam
12 cross sections, as the composite beam is projected on a flat wall surface, will include some overlap.
13 This characteristic will be shown in Figure 3 to be described.

14
15 In the illustrative embodiment, the angle θ is a non-zero angle typically less than
16 approximately ten degrees (10°). In the preferred embodiment, θ is approximately 5° . This amount
17 of divergence provides an enhanced flood light pattern when projected on a plane surface at a
18 distance of three to four meters, as shown in Figure 3, to be described. Experimentation has shown
19 that the angle θ is dependent on the design of the lens assembly, particularly the factors of the lens
20 assembly that affect the angle β of the beam width. The beam width angle β is the angle between
21 the sides of a cone that defines the locus of the light rays emitted from a light source located at the
22 apex of the cone. Further, as described herein above, the beam width angle β , the optical axis
23 divergence angle θ , and the properties and positions of the aspherical surfaces of the lens assembly
24 may be adjusted according to the one quarter beam width index to produce the brightest, most
25 uniform flood light pattern at a distance of three to four meters in the illustrative embodiment. The
26 relationships of these parameters will become clearer in the description which follows.

27
28 In some embodiments, the plane surface 48 shown in Figure 2 may be curved to provide a
29 particular orientation of the light emitting assemblies mounted thereon. Thus, with the focal points

1 of the light emitting assemblies coincident with the plane surface 48, bending the plane surface to
2 provide a predetermined curvature orients the optical axes of the individual light emitting assemblies to
3 conform to other beam configurations. In such cases the forward axes may be defined at the location
4 of each of the light emitting assemblies. Further, the optical axes of the individual light emitting
5 assemblies may be oriented at non-zero or zero angles with respect to the reference forward axis at
6 a particular location on the plane surface 48. In yet other embodiments the curvature or departure
7 from flat of the plane surface 48 may be adjustable, either in production or by the user, to produce
8 several beam outputs adapted to different applications. In the example described above, bending the
9 plane surface 48 is by way of illustration and not intended to limit the choice of design or method
10 available to the designer. Other design configurations may of course be implemented to configure
11 the mounting surface for the light emitting assemblies with the desired curvature.
12

13 Referring to Figure 3, there is illustrated a plan view of an overall flood light pattern
14 projected on a flat target surface at a nominal distance from the embodiment of Figure 1, showing
15 the overlapping of beams of light from individual emitters to form a composite beam 80. Figure 3
16 will be best understood when viewed in combination with Figure 2. Each of the regions identified
17 in Figure 3 are distinguished by the relative amount of shading applied to the various regions. Thus,
18 light emitter E1 having an optical axis 52 provides a projected beam cross section or pattern 82.
19 Similarly, light emitter E2 having an optical axis 54 provides a projected beam cross section or
20 pattern 84. Similarly, light emitter E3 having an optical axis 56 provides a projected beam cross
21 section or pattern 86. Likewise, light emitter E4 having an optical axis 58 provides a projected beam
22 cross section or pattern 88.
23

24 Continuing with Figure 3, the result of combining the respective patterns 82, 84, 86, and 88
25 produces the overlap region 90 in the center portion of the composite beam 80, where all four of the
26 beams overlap. In this central region 90, the pattern resembles a square with rounded sides that bulge
27 outward, roughly approximating a round region. Three of the beam cross sections from light emitters
28 overlap in the four regions identified with the reference number 92. Two of the beam cross sections
29 from light emitters overlap in the four regions identified with the reference number 94. The four

1 regions identified with the reference number 96 results from the light emitted by a single light
2 emitter. One characteristic about the composite beam pattern 80 produced by all four light beams is
3 that it is approximately round and provides a brightness that is substantially uniform at all angles
4 around the center of the pattern and varies uniformly with distance from the center. Such a pattern
5 balances the light outputs to maximize the utility in a flood lighting application.
6

7 The degree of overlap in the projected composite beam pattern 80 of Figure 3 may be
8 adjusted by variations in the angle of the respective optical axes of the individual light emitters. For
9 lighting instruments intended for illumination at certain distances or within a specified range of
10 distances, the optical axis angles of the light emitters may be adjusted accordingly. In the preferred
11 embodiment illustrated and described herein, the angle of the optical axes relative to the reference
12 normal is approximately 5° to provide the pattern illustrated in Figure 3 on a target approximately
13 3 to 4 meters away. In the illustrated embodiment, the optical axes are disposed at a fixed angle
14 because the individual light emitters are mounted on a single heat dissipating frame (heat sink) to
15 be described in detail herein below with Figure 8C. In other embodiments the angles of the optical
16 axes may be configured to be adjustable to increase the versatility of the PLD 10. Further, the
17 symmetry of the overall pattern is readily apparent in Figure 3; however, the symmetry is dependent
18 on the uniformity of the alignment of the respective optical axes as will be appreciated by those
19 skilled in the art.
20

21 Referring to Figure 4A, there is illustrated a cross section profile of a solid body lens
22 assembly 100 for use with each light emitting device of the first directed array of LEDs 22 in the
23 embodiment of Figure 1. The lens assembly 100 may be molded or cast from a clear, optical grade
24 material having an index of refraction n within the range $n = \sqrt{2}$ to 2.00, and preferably within the
25 range of $n = 1.45$ to 1.60. Thermoplastic materials such as polycarbonate (PC), polymerized methyl
26 methacrylate (PMMA, or "acrylic"), or polyethylene terephthalate (PET) are generally suitable. In
27 the preferred embodiment, polycarbonate (PC) is selected for its stability within the temperature
28 range of -60° F to $+270^\circ\text{ F}$, as compared to acrylic having an upper temperature limit of
29 approximately 160° F (PMMA Grade 8). While both PC and acrylic have a refractive index $n = 1.49$,

1 acrylic has slightly better light transmission (92 % vs. 89%) and better resistance to ultraviolet (*uv*)
 2 radiation, the higher temperature limit of PC is determinative in this application wherein the lens
 3 units are fairly close to the heat sink surfaces within the elongated housing 12.

4
 5 Many variables affect the selection of material for the lens and the production of the lens.
 6 These factors include (a) the purity of the material, which must have the clarity of pure water (“water
 7 clear”); (b) the density of the material vs. the computer model of it; (c) the dimensions and tolerances
 8 of the lens; (d) the response of the material to temperature changes and nearby heat sources; (e) the
 9 method of manufacture; and (g) the produceability of details of the lens surface in a cost effective
 10 die and process. An additional consideration is the material selected for the over lens components
 11 (24, 28 in Figure 1) which is also polycarbonate. Important factors in the selection of the material
 12 for the over lens 24, 28 are light transmission ability, refractive index n , and the distance between
 13 the lens assembly 104 and the over lens 24 or 28.

14
 15 The lens assembly 100, or, simply, lens 100, is shown in cross section in Figure 4A as
 16 aligned along its centerline or optical axis 102. The lens 100, when implemented as a molded or cast
 17 solid body unit, is bounded by several surfaces, all concentric about or centered on the optical axis
 18 102. Further, as shown in the figure, the lens 100 is oriented to the right, defined as the forward
 19 direction 104 of the emission of light from the lens 100. When an active light emitting device is
 20 located at a focal point 106 of the lens 100, the emitted light is reflected and refracted in the lens to
 21 direct it in the forward direction 104 and disperse the light uniformly within a cone-shaped beam
 22 along the optical axis 102. The cone-shaped beam is said to have a beam width defined by the beam
 23 angle β . In the preferred embodiment, the beam angle β is approximately 40° . Although such lenses
 24 are frequently known as “collimating lenses,” this term is only accurate if the light rays forming the
 25 beam emerge from the lens substantially in parallel. In the lens 100, the light rays emerge from the
 26 lens 100 in angles relative to the optical axis varying from zero to approximately $20^\circ \pm 5^\circ$. This
 27 angle is often called the “half angle” of the beam, denoted herein by the Greek letter α . The beam
 28 angle denoted by β is thus equivalent to two times the half angle α . The beam emitted from the lens
 29 100 will be further described with Figure 4C.

Continuing with Figure 4A, the optical properties of the lens 100 are determined by five kinds of surfaces, all of which are located at the physical boundaries of the lens 100. The first surface to be described is an aspherical reflecting surface 108 having a focal point 106 on the optical axis 102. The aspherical reflecting surface 108 reflects light rays emitted from a light emitting source located approximately at the focal point 106 in the forward direction and comprises substantially all of the outer boundary of the lens 100. The reflecting surface 108, having a curved profile defined by an aspherical polynomial, provides total internal reflection of light rays emitted from the light emitting source located at or near the focal point 106 that exceed a so-called "critical angle" to be defined herein below. The polynomial may generally be of the form of a parabola or other generalized polynomial and may readily be defined by persons skilled in the art using optical design software available for the purpose. For example, in the illustrated embodiment, the curve of the aspherical reflecting surface 108 is of the general form

$$y = a + b_1x + b_2x^2 + b_3x^3.$$

As will be understood by persons skilled in the art, the coefficients of the independent variable x in the above equation may be chosen based on the particular surface profile desired.

A second boundary of the lens 100 may be defined by a spherical refracting surface 110 disposed in the path of light rays emitted from the source, centered on and normal to the optical axis and positioned there along so that the light rays emerging from the lens 100 within a predetermined angle – the aforementioned half angle α – with respect to the optical axis 102. The spherical refracting surface 110 is concave in the forward direction. The radius of the surface 110 in the illustrative embodiment is 17.0 mm relative to a point forward of the surface 110 along the optical axis 102 and its outer perimeter intersects the outer perimeter of the aspherical reflecting surface 108 at a radius of 9.36 mm from the optical axis in the illustrated embodiment. The outer perimeter of the surface 110 is defined at a distance of 11.65 mm forward of the plane normal to the optical axis at the rear-most boundary edge 114 of the lens 100. The spherical refracting surface 110 may further include a plurality of N concentric, ring-like annular surfaces 120, each annular surface having a cross section that is convex in the forward direction and disposed substantially at uniform radial intervals between the optical axis and the intersection with the aspherical reflecting surface. The

purpose of the N concentric annular rings 120 is to provide correction for corona that appears just outside the principle beam pattern illustrated in Figure 3. This “Gaussian” correction minimizes the corona and improves the uniformity of the distribution of light within the composite beam cross section provided by the PLD 10. The number and dimensions of the annular rings 120 are determined empirically for a given application. The cross section of each of the annular rings 120 may be substantially hemispherical. In the illustrated embodiment, centered along the optical axis and within the smallest diameter annular ring, a fragment of a hemispherical surface 122 may be provided to adjust the beam pattern falling on a distant object. At least $N = 3$ annular surfaces have been found to be a suitable number, with $N = 7$ to be preferable, as shown in Figure 3, for the target distances of three to four meters.

A third boundary of the lens 100 may be defined by a hollow cylindrical surface 112 having a longitudinal axis coincident with the optical axis 102, disposed within the aspherical reflecting surface 108, and extending in the forward direction 102 from a plane normal to and intersecting the optical axis 102 approximately at the rear-most boundary edge 114 of the lens 100. The cylindrical surface 112 also defines a hollow interior space 130 that extends to a distance 116 of approximately 5.15 mm from the plane normal to the rear-most boundary edge 114. As will be described herein below, the boundary edge 114 serves as a seat against which a light emitting assembly makes contact with the lens 100. Further, the distance 116 is defined by the circumferential point around the radius of the cylindrical surface 112 that also lies on the surface of a reference cone having the same diameter at that point as the cylindrical surface 112 and an apex at the focal point 106. It is along this circumferential point that an aspherical refracting surface 118 (to be described) intersects the cylindrical surface 112. This distance of this circumferential line of intersection (between the cylindrical 112 and aspherical refracting 118 surfaces) from the normal plane 114 is determined by a “critical angle” (shown in Figure 4C) defined as one-half of the included angle (i.e., the beam width angle β) of the reference cone.

The critical angle α , in the context of the present discussion, refers to the included angle of light emission from a light source located at the focal point 106 within which the emitted light would

1 not be reflected by the aspherical reflecting surface 108. The critical angle α is equivalent to the half
2 angle of the beam of light that emerges from the lens 100, and corresponds to an optimum beam
3 cross section that, when merged with identical beams from a specified number of like light emitting
4 sources arranged in a closely-spaced array, provides the brightest, most uniformly illuminated pattern
5 of projected light. The critical angle α for producing a high-brightness, uniform projected beam is
6 an empirically determined function of the number of light emitters and the characteristics of the lens
7 elements used for the emitters. Generally, high brightness is achieved with multiple light emitting
8 devices arranged to project overlapping individual beams of light on the target surface. The critical
9 angle α can be thought of as an angle of disposition that defines the beam cross sections of the
10 individual lenses for the light emitting devices, and may be different for each lens when the number
11 of light emitting devices used in a particular array is different. The number of light emitting devices
12 used in a particular array depends on various factors such as product packaging, available power,
13 heat dissipation, the target distance, manufacturing costs, etc.

14
15 A fourth boundary of the lens 100 may be defined by an aspherical refracting surface 118
16 disposed in the path of light rays emitted from the source and centered on and normal to the optical
17 axis. Further, the surface 118 is positioned along the optical axis 102 so that light rays emerging
18 from the light source located at the focal point 106 and within the critical angle α with respect to
19 the optical axis 102 are properly directed by the spherical refracting surface 110 to emerge from the
20 lens 100 within the required half angle to produce the desired beam width angle β . In the illustrated
21 embodiment the aspherical refracting surface 118 is a parabola concave in the forward direction and
22 its outer perimeter intersects the outer perimeter of the cylindrical surface 112 at a boundary
23 equidistant from the optical axis and at an appropriate linear distance along the optical axis 102 that
24 is defined by the critical angle α .

25
26 It should be appreciated that the combination of the four kinds of concentric surfaces 108,
27 110, 112, and 118 described herein above - all surfaces of revolution about the optical axis 102 -
28 form and define the outer surface, i.e., the physical boundaries, of the lens 100. It will also be
29 apparent that the four lens surfaces are maintained in a fixed relationship with each other in all

1 copies of the lens 100 because of the solid body construction of the lens 100. This construction
2 provides ruggedness, repeatability, and is amenable to the use of simple manufacture and assembly
3 processes as will be appreciated by persons skilled in the art. Other features of the lens 100 include
4 a circumferential ridge 124 surrounding the perimeter 128 of the lens 100. The ridge 124 includes
5 a forward face 126 for use as a mounting surface. The mounting of the lens 100 will be further
6 described with Figure 8B. The hollow space 130 within the cylindrical surface 112 provides space
7 for certain structural elements of the light emitting device to be described herein below.

8
9 The fifth kind of surface at the boundaries of the lens 100 is the compound surface profile
10 resulting from the combination of the spherical refracting surface 110 and the series of annular rings
11 120 as shown in Figures 4A and 4B.

12
13 Referring to Figure 4B, there is illustrated an enlarged cross section of a portion of Figure
14 4A to show details thereof. A portion of the spherical refracting surface 110 is shown, having
15 superimposed thereon the partially hemispherical cross section of three adjacent annular ring
16 surfaces 120. The illustration in Figure 4B clearly shows the radial separation between adjacent
17 annular ring surfaces 120. In the illustrated embodiment, the spherical refracting surface 110 has a
18 radius of 17.0 mm relative to a point along the optical axis 102 forward of the lens 100. Each annular
19 ring 120, spaced at 1.338 mm intervals, has a cross section radius of 1.60 mm. The flat portion of
20 the spherical refracting surface 110 between each annular ring 120 is approximately 0.25 mm.

21
22 Referring to Figure 4C, there is illustrated a cross section profile of the solid body lens 100
23 of Figure 4A in combination with a light emitting device assembly 139 (which may also be called
24 LED assembly 139 or LED unit 139). The light emitting device assembly 139 includes the light
25 emitting device 140, the base 142, the hemispherical shell 144, and the substrate 146 as will be
26 described. The combination of the solid body lens 100 and the LED assembly 139 will be called the
27 lens/LED assembly 155 herein below. In the description which follows, a plurality of the lens/LED
28 assemblies 155 will appear in some figures being described, but not separately identified in the
29 figures with the reference number 155 to avoid confusion with the structures being described and

1 their relationship with each other. Structures shown in Figure 4C having the same reference numbers
2 used in Figures 4A and 4B are identical. Figure 4C thus includes a light emitting device 140 (shown
3 in phantom) mounted on a base 142. The light emitting device 140 is enclosed within a transparent
4 hemispherical shell 144 mounted on the base 142 such that the center of the hemispherical shell is
5 coincident with the emitting point of the light emitting device 140. The base 142 is in turn mounted
6 on a substrate 146. The base 142 and the hemispherical shell 144 are typically integral parts of the
7 semiconductor package containing the light emitting device 140 (in this case a light emitting diode).
8 The substrate 146 may be a printed circuit board. In the illustrative embodiment the substrate 146
9 is a laminated structure of a printed circuit and an aluminum base layer that acts as a heat sink. One
10 suitable LED assembly 139 is a Luxeon® type LXHL-PW01 white, Lambertian emitter available
11 from the Lumileds Lighting, Inc., San Jose, CA, USA. This emitter is also available as an assembly
12 (including the emitter, base, substrate, and hemispherical shell) as a Luxeon® type LXHL-MW1D
13 “Star Base” with the white, Lambertian emitter. The “Star Base” configuration corresponds to the
14 LED assembly 139 described herein. In alternative embodiments, the LED 140 in the LED assembly
15 139 may be an incandescent light emitting bulb, a gas discharge light emitting unit, an arc discharge
16 light emitting unit, a halogen light emitting bulb, a fluorescent light emitting unit, an organic light
17 emitting unit or a light emitting unit that emits light through any physical mechanism when initiated
18 or driven by an electrical power source.

19
20 The light emitting device assembly 139 or LED unit 139 is typically available as a
21 preassembled LED unit 139 from the manufacturer, assembled at the factory in planar arrays on a
22 single printed circuit substrate for shipment to the customer. The customer need only separate or
23 ‘break off’ a small section of the planar array, for example, a strip of four LED units 139, for
24 assembly into products that employ an LED unit 139. In other applications, individual LED units 139
25 may be separated for installation in a product. An example of the latter is the illustrated embodiment
26 (See, for example, Figure 8D infra) wherein each LED unit 139 in an array of a plurality of LED
27 units 139 is installed in a recessed area having a different angular orientation than the other LED
28 units 139 in the array.

1 Returning to the description of the lens/LED assembly 155 of Figure 4C, when assembled
 2 together with the lens 100, the transparent hemispherical shell 144 fits within the inside diameter of
 3 the cylindrical surface 112. The base 142 of the light emitting device 140 is placed against the rear-
 4 most edge 114 of the lens 100. This places the light emitting device (LED) 140 approximately at the
 5 focal point 106 of the aspherical reflecting surface 108, in the correct position for light emitted from
 6 the LED 140 to be formed by the lens 100 into the beam of light having the characteristics previously
 7 described. It will be appreciated that the transparent hemispherical shell 144, since its center is
 8 coincident with the point of emission of the light from the LED 140, passes the emitted light
 9 substantially without reflection or refraction into the space 130 bounded by the cylindrical surface
 10 112 and the aspherical refracting surface 118. Light emitted within the critical angle α passes through
 11 the aspherical refracting surface 118. Light emitted outside the critical angle α passes through the
 12 cylindrical surface 112 or is reflected toward the aspherical refracting surface 118. The critical angle
 13 is shown in Figure 4C as the angle α between the optical axis 102 and the dashed lines 148 and 150.
 14 In the preferred embodiment, the critical angle α , which is equivalent to the half angle of the beam
 15 width, is $20^\circ \pm 5^\circ$, and the beam width β is equal to twice the critical angle α or $40^\circ \pm 10^\circ$. Light
 16 passing through the cylindrical surface 112 will thus be reflected by the aspherical reflecting surface
 17 108 before being refracted by the spherical refracting surface 110 as it exits the lens 100. The dashed
 18 boundary lines 152 and 154 define the nominal boundary of the beam of light emitted by the lens
 19 100. The boundary lines 152 and 154 of the light beam are parallel to the lines 148 and 150
 20 illustrating the critical angle α .

21
 22 To summarize several of the features of the optical system of the illustrative embodiment of
 23 the present invention, a unitary lens and light emitting device combination (lens/LED assembly 155)
 24 is provided that produces a highly uniform beam of light, corrected for distortions and gaps in
 25 illumination, throughout a full beam width angle β in the range of $40^\circ \pm 10^\circ$. This lens/LED
 26 combination or light source unit is illustrated herein to demonstrate its use in arrays of such light
 27 source units to provide optimum flood illumination from a portable, hand held task lamp product.
 28 The unitary lens may be formed as a solid body plastic lens which incorporates all of the necessary
 29 optical surfaces in a single piece unit, including the pattern-correcting spherical refracting surface,

1 concave in the forward direction of illumination, that smooths out intensity variations in the overall
 2 illumination pattern. The light source unit provided by this lens/LED combination may be used
 3 singly or arranged in many different arrays formed of a plurality of such light source units for use
 4 in a wide variety of applications.

5
 6 Referring to Figure 5, there is illustrated a block diagram of an electrical circuit 160 for use
 7 in the embodiment of Figure 1 for powering and controlling the light outputs thereof. The purpose
 8 of the circuit is to drive two different arrays of LEDs, the first array and the second array, each at a
 9 constant brightness, from a single drive circuit. Driving each of the arrays at a constant brightness
 10 from the single drive circuit requires providing a constant current to the respective arrays, which may
 11 require different current levels to provide the specified brightness for the particular illumination
 12 pattern. The current levels are independently regulated for each array of LEDs by the electrical
 13 circuit. Further, the array of LEDs to be utilized is selected by operation of switches in the circuit
 14 by the user. The first array in the illustrated embodiment includes a plurality of LEDs and provides
 15 a flood light illumination. The second array in the embodiment example includes at least one LED
 16 and provides a spotlight illumination. The basic circuit includes a DC supply voltage 162, a current
 17 selector circuit 172, a switching regulator circuit 182, and first 192 and second 202 arrays of light
 18 emitting devices (LEDs). Optional circuits, which will be described separately, include a strobe
 19 circuit 240, a dimming circuit 260, and a low battery indicator 270.

20
 21 The DC power supply 162 includes a positive terminal 164 and a negative terminal 166. The
 22 positive terminal 164 is connected to a positive supply voltage bus 168, which may also be called
 23 a supply bus 168 herein. The negative terminal 166 is connected to a negative supply voltage bus
 24 170, which may also be called a common bus 170 herein. In the illustrative embodiment, three
 25 rechargeable, 1.2 Volt, "D" cell, nickel-metal-hydride (NiMH) cells are utilized to provide the DC
 26 power supply for the PLD 10. The current selector circuit 172 includes an input terminal 174, a
 27 common terminal 176, and an output terminal 178. The input terminal 174 is connected to the supply
 28 bus 168 and the common terminal 176 is connected to the common bus 170. The switching regulator
 29 circuit 182 includes an input terminal 184, a common terminal 186, and an output terminal 188. The

1 input terminal 182 is connected to the output terminal 178 of the current selector circuit 172 through
 2 a node 180. The common terminal 186 of the switching regulator circuit 182 is connected to the
 3 common bus 170.

4
 5 Continuing with Figure 5, the first array of LEDs 192 includes a positive terminal 194 and
 6 a negative terminal 196. The positive terminal 194 is connected to the output terminal 188 of the
 7 switching regulator 182 through a node 190. The negative terminal 196 of the first array of LEDs
 8 192 is connected through a node 198 and a series current sense resistor 200 to the common bus 170.
 9 The second array of LEDs 202 includes a positive terminal 204 and a negative terminal 206. The
 10 positive terminal 204 is connected to the output terminal 188 of the switching regulator 182 through
 11 the node 190. The negative terminal 206 of the second array of LEDs 202 is connected through the
 12 node 198 and the series current sense resistor 200 to the common bus 170. The current sense resistor
 13 200 may also be called a common current sense resistor 200. The sense resistor 200 may also be
 14 called a common current sense device 200 herein because, in some embodiments, the resistor may
 15 be replaced by other elements such as an active circuit.

16
 17 Working backwards through the basic circuit just assembled, a few other details will be
 18 described. The second array of LEDs 202 includes an input terminal 208, which is connected through
 19 a series resistor 216 to a drive output 218 of the current selector circuit 172. The signal coupled from
 20 the drive output 218 is a control signal to be described infra. The first array of LEDs 192 also
 21 includes an output terminal 210, which is connected through a node 212 to a sense input 214 of the
 22 switching regulator circuit 182. The current selector circuit 172 includes a first control terminal 220
 23 and a second control terminal 230. Connected between the first control terminal 220 and the
 24 common bus 170 is a first SPST switch 222. Connected between the second control terminal 230 and
 25 the common bus 170 is a second SPST switch 232.

26
 27 The first 222 and second 232 switches respectively provide ON/OFF control of the first 192
 28 and second 202 arrays of LEDs. Both switches 222 and 232 may preferably be single pole, single
 29 throw (SPST), normally open (N.O.) switches. In Figure 5 (and also in Figure 6A), the symbols for

1 the first 222 (SW1) and second 232 (SW2) are N.O. switches shown with their contacts in the closed
2 position. This is correct as will become apparent in the description to follow. In the preferred
3 embodiment, the first and second switches 222 and 232 are actuated with a push ON, push OFF
4 switching action. The actuator is preferably operated by a push button. However, in other
5 embodiments a lever, rocking button, rotating collar, or any type of actuator having a back-and-forth
6 travel or a repeating rotational travel may be employed. Still other embodiments may employ touch-
7 sensitive or proximity sensitive switch mechanisms requiring no moving parts. Switches having no
8 moving parts or latching mechanisms may require a programming feature to provide the required
9 action described herein as will be apparent to persons skilled in the art. As will become apparent in
10 the description for Figure 6A to follow, the first 222 and second 232 switches are operated in a non-
11 obvious manner that provides three operating states for each SPST, N.O. switch: OFF, momentary
12 ON, and ON.
13

14 Continuing with Figure 5, a strobe circuit 240, which may be provided as an optional circuit
15 to operate the first and second LED arrays of the PLD 10 in a continuous or strobed (flashing) mode,
16 includes a positive terminal 242 connected to the supply bus 168, and a negative terminal 244
17 connected to the common bus 170. A switch terminal 246 on the strobe circuit 240 is coupled to the
18 common bus 170 through a strobe switch 248 (also called SW3). The strobe switch 248 is preferably
19 a SPST switch having normally closed (N.C.) contacts, and provides ON/OFF control to the strobe
20 circuit 240. An output terminal 250 of the strobe circuit 240 is connected via a line 252 to an input
21 terminal 254 of the current selector circuit 172. The strobe circuit 240 includes an oscillator which
22 supplies a gating signal via the line 252 to control the current selector circuit 172 when activated by
23 the strobe switch 248.
24

25 A dimming circuit 260 may be provided as an option to control the brightness of the first 192
26 or second 202 array of LEDs. It is available primarily as a power saving feature but may also be
27 useful when the high brightness available from either of the LED arrays 192, 202 is not needed. An
28 example would be when the target area to be illuminated by the PLD 10 is closer than three to four
29 meters. The dimming circuit 260 includes a first terminal 262 and a second terminal 264. The first

terminal 262 is connected to the node 212. As will be described herein below, node 212 is a connection point to the current sense circuit for the first 192 and second 202 arrays of LEDs. The second terminal 264 of the dimming circuit 260 is connected through a SPST switch 266 having N.O. contacts to the node 180. The switch 266 (also called (SW4) may be a push ON, push OFF switch for activating or deactivating the dimming circuit.

A low battery indicator circuit 270 having a positive terminal 272 and a negative terminal 274, respectively connected to the supply bus at node 180 and to the common bus 170, may be included in the illustrated embodiment of the PLD 10. The DC supply voltage 162 in the illustrated embodiment of the PLD 10 is provided by a battery pack. As will be described, the low battery indicator circuit 270 senses the voltage available at the node 180 and provides a visual indicator when the terminal voltage of the battery pack drops to a predetermined threshold.

Referring to Figure 6A, there is illustrated a first portion of a schematic diagram of the electrical circuit of Figure 5. Some of the structural features of Figure 6A, previously described in Figure 5 and identical therewith, bear the same reference numbers. Other structures in Figure 6A having a counterpart in Figure 5 will be so identified. For example, the positive supply bus 300 in Figure 6A is the counterpart of supply bus 168 in Figure 5, and the common bus 302 is the counterpart of the common bus 170 in Figure 5. Several key structures of figure 6A having counterparts in Figure 5 will include the counterpart reference number in parentheses, as 300 (168), 302 (170), and so on.

Continuing with Figure 6A, a battery 310 (162) is connected to the circuit 160, its positive terminal connected through a resettable fuse 308 to the node 300 (168) and its negative terminal connected to the node 302 (170). The node 300(168) provides the connection to the positive supply voltage bus 300(168), also known as the supply bus 300(168). The node 302(170) provides the connection to the negative supply voltage bus 302(170), also known as the common bus 302(170). A capacitor 312 connected between the nodes 300 and 302 absorbs transients and noise from the supply 300 (168) and common 302 (170) buses. A quad NAND gate 314 (also called U1), which

1 may be a type 74AC00SC integrated circuit, is coupled with a P-channel FET transistor 316 (also
 2 called Q1), which together function as the current selector 172 of figure 5. The P-channel FET 316
 3 may be rated at 4.5 Amperes, 20 volts in the illustrated embodiment.
 4

5 The quad NAND gate 314 is connected in the electrical circuit 160 as follows. As a
 6 preliminary condition, the FET 316 is connected in the supply bus 300(168) between the nodes 300
 7 (168) and 304 (180) as follows. The drain terminal of the FET 316 is connected to the positive
 8 terminal of the battery 310 (162) via the node 300 (168). The source terminal of the FET is
 9 connected to the load side of the FET 316 at a node 304 (180). The gate terminal of FET 316 is
 10 connected to the respective anodes of first 318 and second 320 steering diodes. The cathodes of the
 11 first 318 and second 320 steering diodes are connected to output pins 3 and 11 of the first 314A and
 12 second 314B NAND gates in the quad NAND gate 314 (U1) . The positive supply or Vcc terminal
 13 14 of the quad NAND gate 314 is connected to the supply bus at node 300(168). The negative supply
 14 or Vss terminal of the quad NAND gate 314 (U1) is connected to the common bus at node 302(170).
 15

16 Pins 2 (of the first NAND gate 314A (U1A)) and 13 (of the second NAND gate 314B (U1B))
 17 are connected together at a node 254. Node 254 is connected to a node 250. Node 250 is connected
 18 to the supply bus 300 (168) through a pull up resistor 374, and also to the output pin 3 of a gated
 19 oscillator 364 (integrated circuit U4). The gated oscillator 364 is part of an optional strobe circuit
 20 to be described. Without the strobe circuit in place, the node 250 is tied to the positive supply voltage
 21 at node 300 (168) through the pull up resistor 374. The pull up resistor is provided to maintain pins
 22 2 and 13 of the first 314A and second 314B NAND gates at a logic HIGH, unless the pins 2 and 13
 23 are required to be driven LOW by the action of a signal applied to the node 254 to provide an
 24 auxiliary control function. Such an auxiliary control function may include a strobe function or any
 25 other function that requires interruption of current to the illumination drive circuitry that may be
 26 included in a particular embodiment. The interruption to the drive circuitry may be timed, as for
 27 providing a strobe function, or untimed, to provide a temporary OFF condition under manual control,
 28 for example. The operation of a strobe circuit, identified by reference number 240 in Figure 5, will
 29 be described later to illustrate the control effect of signals present at node 254.

Continuing with Figure 6A, the inputs 9 and 10 (tied together) of the third NAND gate 314C (U1C), shown configured to operate as an inverter, are coupled to the output pin 11 of the second NAND gate 314B (U1B). This arrangement provides a separate, second drive signal to control the operation of the second array 202 of LEDs. The second array 202 of LEDs is enabled to operate when selected by pressing the second ON/OFF switch 232, causing the output of the second NAND gate to go LOW and the output pin 8 of the third NAND gate 314C (U1C) to go HIGH. A HIGH output from the third NAND gate 314C (U1C) will cause a second N-channel FET 360 (Q3) to conduct, thereby causing the second array 202 of LEDs to illuminate, as will be described. As this occurs, and as will be described, the first array 192 of LEDs will not be activated even though it has been enabled by pressing the first switch 222.

The operation of the current selector 172 in Figure 6A proceeds as follows. The first NAND gate 314A (U1A) and the second NAND gate 314B (U1B), are respectively operated by the first 222 and second 232 ON/OFF switches (SW1 and SW2) to gate ON or OFF the FET 316 that is coupled in series with the positive DC supply voltage on the supply bus 300(168). The outputs of the first 314A and second 314B NAND gates are connected via the respective steering diodes 318 and 320 to the gate of the FET 316. If the output of either the first 314A or second 314B NAND gate is a logic LOW, the FET 316 is enabled to conduct current, thus supplying operating current to the switching regulator circuit 182. As an initial condition, the input pin 2 of NAND gate 314A and pin 13 of NAND gate 314B, which are tied together at node 254, are held HIGH by the action of resistor 374 and the respective inputs, pins 1 and 12 of the NAND gates 314A and 314B are held LOW by the action of the first 222 and second 232 ON/OFF switches. (An exception to this condition, to be described infra, occurs when a strobe circuit 240 is included in the circuit and has been activated.) From this initial condition, the output pin 3 of the first NAND gate 314A switches LOW when the first ON/OFF switch 222 is pressed, opening its contacts and causing a HIGH signal at input pin 1 of U1A by the action of resistor 322. Similarly, the output pin 11 of the second NAND gate 314B switches LOW when the second ON/OFF switch 232 is pressed, opening its contacts and causing a HIGH signal at input pin 12 of U1B by the action of resistor 324. In this way, operating current for

1 either of the first 192 or second 202 LED arrays is supplied to the switching regulator 182 by causing
2 the FET 316 to conduct.

3
4 The foregoing operation of the first 222 and second 232 ON/OFF switches demonstrates the
5 unusual use of the SPST, N.O., push-ON, push-OFF switches having first and second contacts to
6 provide three operating states. The usual application of this type of switch is a first state in which
7 the contacts are disengaged, thus disconnecting the circuit path in which the switch is used, and a
8 second state in which the contacts are engaged, thus connecting the circuit path in which the switch
9 is used. However, in the present invention, each of these SPST switches is sequentially operable in
10 the first, second, and third states corresponding respectively to latched engagement of the contacts
11 of the switch, momentary disengagement of the contacts of the switch, and latched disengagement
12 of the first and second contacts of the switch. In this sequence, the first state (contacts engaged)
13 operates to place the electric circuit in an OFF condition, the second state (contacts disengaged but
14 not latched) provides activation of the electric circuit in a momentary ON condition, and the third
15 state (contacts disengaged and latched) provides activation of the electric circuit in a latched ON
16 condition. The first state corresponds to non-operation of the switch. Pressing the push button of the
17 switch with less pressure than necessary to cause it to latch moves the contacts from a closed
18 (engaged) condition to a momentarily open (disengaged) condition, which is the second state.
19 Pressing the push button of the switch with sufficient pressure to cause it to latch moves the contacts
20 from a closed (engaged) condition past a detent in the switch mechanism to a latched open
21 (disengaged) condition, which is the third state. As noted previously, when the contacts are
22 disengaged, the current selector circuit is turned ON to supply current to the first or second array of
23 LEDs depending upon which of the two ON/OFF switches was pressed. Conversely, when the
24 contacts are engaged, the FET 316 is turned OFF, inhibiting the current supply to the first or second
25 array of LEDs.

26
27 Before describing the operation of the switching regulator circuit 182, some characteristics
28 of the first 192 and second 202 LED arrays need to be described. In the illustrated embodiment,
29 semiconductor light emitting diodes are selected for the light emitting devices of the PLD 10. For

1 the first array 192, four each white, 1 watt, Lambertian emitter, Luxeon® type LXHL-PW01 (or type
2 LXHL - MW1D “Star Base” as described herein above), available from Lumileds Lighting, Inc., San
3 Jose, CA is suitable. Typical values for the forward current and voltage in the 1 watt device are 0.35
4 Amperes and 3.42 Volts respectively, corresponding to a typical light output of 25 lumens (25 lm).
5 For the second array 202, one each white, 3 watt, Lambertian emitter, a Luxeon® III type LXHL-
6 PW09 (or type LXHL-LW3C “Star Base”), also available from Lumileds Lighting is suitable.
7 Typical values for the forward current and voltage in the 3 watt device are 1.0 Amperes and 3.70
8 Volts respectively, corresponding to a typical light output of 80 Lumens (80 lm). Thus, the operating
9 current for the first array 192 is approximately 0.35 Amperes and the forward voltage drop is
10 approximately 4 X 3.42 Volts or 13.68 Volts, resulting in an approximate power utilization of the
11 array of 4.8 watts. Similarly, the operating current for the second array is approximately 1.0 Amperes
12 and the forward voltage drop is approximately 3.70 Volts, resulting in an approximate power
13 utilization of 3.70 watts.

14
15 The foregoing figures for operating currents and power levels in the illustrated embodiment
16 are typical values that conform approximately with the manufacturer’s published specifications. In
17 the illustrative embodiment, the second array may be operated at slightly higher current, for example,
18 1.10 to 1.40 Amperes, to obtain power utilization in the four to five watt range to provide greater
19 light output for the spot light array. In one exemplary unit, the current for operating the first array
20 192 is approximately 0.36 Amperes as regulated by the current selector circuit 172 including the
21 quad NAND gate 314. Further, the current for operating the second 202 array is approximately 1.30
22 Amperes as regulated by the control circuit 330. Keeping these current and voltage drop values in
23 mind will inform the description of the switching regulator. Persons skilled in the art will readily
24 understand that a wide variety of lens/LED combinations (of numbers of light emitting sources and
25 arrays of light emitting sources) and operating power levels are possible using the principles
26 described herein. An important feature of the switching regulator described herein is that it drives
27 two disparate loads with constant currents from a single drive circuit.

1 The first array 192 of LEDs is enabled whenever current is supplied to the switching
2 regulator 182. This may occur upon the pressing of either the first 222 or the second 232 ON/OFF
3 switch because either condition results in a LOW applied to the gate of the FET 316 in the current
4 selector circuit 172. In the illustrated embodiment, the first array 192 of LEDs has more LEDs in
5 series across the output of the switching regulator than the second array 202 of LEDs. The electrical
6 circuit 160 is arranged so that the first array 192 of LEDs will be activated by the output of the
7 switching regulator circuit 182 unless the second array 202 of LEDs is activated. This result occurs
8 because the voltage drop across the fewer devices in the second array 202 of LEDs is less than the
9 voltage drop across the greater number of devices in the first array 192. If the second array 202 is
10 activated there will be insufficient voltage from the constant current switching regulator circuit 182
11 to activate the first array 192 of LEDs and the LEDs of the first array 192 will be in an OFF
12 condition. To look at it another way, when the second array 202 of LEDs is activated, it shunts
13 current away from the first array 192 of LEDs. The PLD 10 as described herein takes advantage of
14 this configuration as follows. The circuit of the current selector 172 includes a third NAND gate
15 314C (U1C) that responds to the operation of the second switch 232 by causing a LOW signal to be
16 present at the output pin 11 of the second NAND gate 314B (U1B). As a result, the output of the
17 third NAND gate 314C goes HIGH to enable the second array 202 of LEDs.

18
19 Referring to Figure 6B, there is illustrated a second portion of the schematic diagram of the
20 electrical circuit 160 of Figure 5. Figure 6B includes the switching regulator circuit 182, the first
21 array 192 of LEDs and the second array 202 of LEDs. Some of the structural features of Figure 6B,
22 previously described in Figure 5 and identical therewith, bear the same reference numbers. As with
23 figure 6A, several of the structures in Figure 6B having a counterpart in Figure 5 will be so
24 identified. The switching regulator circuit 182 of the illustrated embodiment is provided by a step-up
25 flyback converter architecture that includes an integrated control circuit 330 (U2) having a positive
26 Vcc terminal pin 1 coupled to the supply bus at node 184 and a ground terminal pin 2 (node 182)
27 connected to the common bus 302 (170).

1 An inductor 342, 6.8 microHenry (uHy) in the illustrated embodiment, is connected in series
 2 between the node 184 and a node 336. A 3 Ampere, 100 volt, fast switching diode 344, is connected
 3 between the node 336 and a node 306. The inductor 342 and the switching diode 344 are connected
 4 in series with the voltage supply bus 178 at the output of the current selector 172. A 47 microFarad
 5 (uF), 25 volt filter capacitor 348 is connected between the node 306 (188) and the common bus at
 6 node 302 (170), effectively the output terminals of the switching regulator 182. Capacitor 348 is used
 7 if it is desired to drive the first 192 or second 202 arrays of LEDs with a DC voltage. However, the
 8 circuit may be operated without the capacitor 348. Without capacitor 348, the switching regulator
 9 provides a pulsed drive to the arrays 192, 202 of LEDs. The duty cycle at maximum available voltage
 10 is approximately 50%; the duty cycle when operating at minimum voltage is approximately 90%,
 11 at the operating frequency of approximately 100 Khz.

12
 13 Connected between the node 336 and the common bus node 302 (170) is a first switching
 14 transistor, N-channel FET 334 (Q2), rated at 14 Amperes, 50 volts. The drain terminal of the FET
 15 334 is connected to the node 336 and the source terminal of the FET 334 is connected to the common
 16 bus 302 (170) through a very small-valued (0.0075 Ohms in the present embodiment) series resistor
 17 340. The source terminal of the FET 334 is also connected to pin 4 (a current sense terminal) of the
 18 integrated control circuit 330. The gate terminal of the FET is connected to pin 6 (the drive voltage
 19 output terminal) of the integrated control circuit 334. Pin 5 (a voltage feedback terminal) of the
 20 integrated control circuit 334 will be described later. The integrated control circuit 334 may be, for
 21 example, a "regulated, voltage mode converter," type ZXSC400 available from Zetex Inc.,
 22 Hauppauge, NY 11788. The ZXSC400 provides a programmable constant current output for driving
 23 an array of LEDs such as one or more light emitting diodes. In embodiments of the PLD 10 using
 24 other types of LEDs, the switching regulator circuit 182 may be changed to match or adapt to the
 25 particular characteristics of the LEDs.

26
 27 The switching regulator 182 in the embodiment illustrated herein operates as follows. When
 28 power is first applied to the control circuit 330, the drive signal at the output pin 6 appears at the gate
 29 of the first FET 334, turning the FET 334 ON . Current ramps up through the inductor 342, the FET

334, and the series resistor 340, charging the inductor 342 until the voltage across the resistor 340 reaches 30 millivolts (mV). At that point, the FET is biased OFF and the flyback action of the inductor 342 dumps the energy stored in its magnetic field as a current through the fast switching diode 344, charging the filter capacitor 348 to the peak value of the voltage available at the node 306 (188). This voltage is available to drive the first 192 and second 202 arrays of LEDs according to whether the first 222 or the second 232 ON/OFF switch is activated. Meanwhile, the circuitry within the control circuit 330 and connected to the feedback pin 5 monitors the voltage present at pin 5. Whenever the voltage at pin 5 exceeds 300 mV, the FET 334 will be gated OFF for approximately 2.0 microseconds (2.0 usec). After this time period expires, and the voltage at pin 5 falls below the 300 mV value, the FET 334 will be gated ON again. This sequence is repeated, which stabilizes the voltage at pin 5 of the control circuit 330 at the 300 mV level and the current delivered to the first 192 or second 202 array of LEDs is maintained at a constant level determined by the value of the inductor 342 and the resistor values selected for the current sensing network comprising the resistors 354 and 356.

The first 192 and the second 202 arrays of LEDs, along with the current sensing network will now be described before completing the description of the operation of the switching regulator circuit 182 when performing its current regulating functions. The first array 192 of LEDs in the illustrative embodiment is a series circuit connected between a node 190 and the common bus at the node 302 (170). The series circuit includes a string 350 of four light emitting diodes of like characteristics connected to be forward biased between the node 190 and a node 352. The anodes of the string 350 of the light emitting diodes are all oriented toward the node 190 and the cathodes are oriented toward the node 352. A lead or terminal 194 connects the anode of the uppermost light emitting diode to the node 190. A current sense resistor 354 is connected between the node 352 and through a terminal 196 to a node 198. A common current sense resistor 356 is connected between the node 198 and the common bus at node 302. A third sense resistor 358 is connected between the node 352 and the node 210 to the node 212. The node 212 is connected to the feedback pin 5 of the control circuit 330 via the node 214.

1 The feedback voltage at pin 5 is developed as follows. The resistor 356 is a common current
 2 sense resistor, developing a voltage drop proportional to the currents in both the first 192 and the
 3 second 202 arrays of LEDs. A second sense resistor 354, in series with the first 192 array of LEDs
 4 and the common sense resistor 356, provides a voltage at the node 352, which is sensed at pin 5
 5 through a resistor 358 and the nodes 210 and 212. Pin 5 of the control circuit 330 is high impedance
 6 point in the circuit; thus, resistor 358 has little effect on the current sensing during normal operation.

7
 8 The dimming circuit 260 may be provided as an option to control the brightness of the first
 9 192 or second 202 array of LEDs for saving power or limiting brightness of output illumination of
 10 the PLD 10. The dimming circuit 260 includes a first terminal 262 and a second terminal 264. The
 11 first terminal 262 is connected to the node 212. The second terminal 264 of the dimming circuit 260
 12 is connected through a SPST switch 266 having N.O. contacts to the node 180. The switch 266 (also
 13 called (SW4) may be a push ON, push OFF switch for activating or deactivating the dimming circuit.
 14 In operation, under normal operating conditions without dimming the light output, the feedback
 15 voltage at pin 5 of the control circuit 330 is approximately 300 millivolts. Closing the contacts of
 16 the dimming switch 262 drives a current through the resistor 264, thus increasing the voltage drop
 17 across the resistor 358. this action increases the feedback voltage applied to pin 5 of the control
 18 circuit 330 sufficiently to reduce the current drive to the respective first 192 or second 202 LED array
 19 to cause the brightness level to decrease by approximately 50%.

20
 21 The strobe circuit 240 of Figure 5, shown in greater detail in Figure 6A, provides for
 22 operating the first 192 or second 202 arrays of LEDs in an alternating ON and OFF mode – i.e.,
 23 flashing – at a fixed duty cycle and frequency. The timing provided is approximately 0.25 seconds
 24 ON and 1.0 second OFF. The heart of the strobe circuit 240 is a 555 timer circuit 364 operated as
 25 a gated oscillator. The timer circuit 364 is an 8-pin integrated circuit that includes a Vcc terminal 242
 26 (pin 8, which is tied to pin 4) connected to the supply bus 300 (168) and a Vss terminal 244 (pin 1)
 27 connected to the common bus 302 (170). Pin 2 is connected through resistor 368 and resistor 374
 28 to the supply bus 300 (168). The junction of the resistors 368 and 374 is a node 250 that is connected
 29 to pin 3 of the timing circuit 364. Pin 6 of the timing circuit 364 is connected to a node 246. Node

1 246 is connected through a resistor 366 to the cathode of a signal diode 376. The anode of the diode
 2 376 is connected to the node 250. Node 246 is further connected to the common bus 302 (170) via
 3 a SPST, normally closed (N.C.) switch 248 (also called SW3 in Figure 6A). Pin 5 of the timing
 4 circuit 364 is connected to the common bus 302 (170) via a capacitor 372 acting as a noise filter. As
 5 previously described, the node 250 is connected to the node 254, which is the signal input for
 6 controlling the current selector 172 in either a continuous or strobe mode.

7
 8 The strobe circuit 240 operates as follows. When the strobe switch 248 (SW3), having N.C.
 9 contacts is in a released state, i.e., not pressed or activated, its contacts are closed and the output pin
 10 3 of the timer circuit 364 is held HIGH by the action of the pull up resistor 374 at the node 250. This
 11 signal is applied to pins 2 and 13 of the NAND gate 314, providing the initial or quiescent condition
 12 for responding to the activation of the first 222 and second 232 ON/OFF switches during operation
 13 of the PLD 10. When the strobe switch 248 (SW3), having N.C. contacts is pressed or activated, its
 14 contacts are open, the voltage across the capacitor 370 rises until it exceeds a threshold value, and
 15 the output pin 3 of the timer circuit 364 is caused to switch to a logic LOW, removing the drive to
 16 the FET 316. At that instant, the capacitor 370 begins to discharge toward zero. When the voltage
 17 across the capacitor 370 reaches the threshold voltage at pin 2 of the timer circuit 364, the output at
 18 pin 3 of the timer circuit 364 switches back to a HIGH, causing the FET 316 to turn ON. The cycle
 19 repeats as long as the strobe switch 248 is activated. It is preferably a push ON, push OFF, latching
 20 type of switch that remains activated until it is pressed a second time after turning ON the strobe
 21 function. The timing of the cycle is set by the RC time constants of the capacitor 370 and the
 22 resistors 366 and 368. As mentioned herein above, the current selector circuit 172 is held OFF for
 23 approximately 1.0 second and ON for approximately 0.25 second when the strobe circuit is activated.
 24 This timing sequence can of course be revised by changing component values to satisfy particular
 25 preferences.

26
 27 Returning to Figure 6A, the circuit for the low battery indicator 270 of Figure 5 will now be
 28 described. The low battery indicator 270 includes a positive terminal 272 and a negative terminal
 29 274, respectively connected to the supply bus at node 304 in Figure 6B (180 in Figure 5) and to the

1 common bus 302 (170). The DC supply voltage 162 in the illustrated embodiment of the PLD 10 is
 2 provided by a battery 310 (162). In the illustrative embodiment, three rechargeable, 1.2 Volt, "D"
 3 cell, nickel-metal-hydride (NiMH) cells are utilized to provide the DC power supply for the PLD 10.
 4 The circuit for the low battery indicator 270 senses the voltage available at the node 180 and
 5 provides a visual indicator when the terminal voltage of the battery pack 310 (162) drops to a
 6 predetermined threshold. The predetermined threshold is set to approximately 3.1 Volts,
 7 corresponding to a useful output for about one hour.

8
 9 Continuing with Figure 6A, the node 272 represents the positive supply voltage connected
 10 to the output of the current selector circuit 172. The node 272 is also the monitored point in the
 11 circuit 160 for tracking the available battery voltage. The node 274 represents the negative supply
 12 terminal connected to the common bus 302 (170). The indicator circuit utilizes an op amp 380 (also
 13 called U3) connected as a comparator. Pin 7 of the op amp is connected to the node 272 and pin 4
 14 is connected to the node 274. The positive input pin 3 is connected to a node 382 and the negative
 15 input pin 2 is connected to a node 388. The output pin 6 is connected to node 382 through a resistor
 16 398 to provide some positive feedback to ensure a rapid transition when the op amp comparator
 17 switches. Pin 6 is also connected to the node 388 through a capacitor 400 to roll off the gain at higher
 18 frequencies so that the comparator is less sensitive to noise. Output pin 6 is further connected to the
 19 node 272 through a light emitting diode 402 in series with a resistor 404. The positive input pin 3
 20 tracks the DC voltage present at node 382, the center of the voltage divider formed by resistors 392
 21 and 394 connected between the nodes 272 and 274. A capacitor 396 is connected from node 382 to
 22 node 274 to stabilize the DC voltage at node 382. Also connected between the nodes 272 and 274
 23 is a series circuit formed by a resistor 386 and a zener diode 390. The junction of the resistor 386 and
 24 the zener diode 390 is node 388, which applies the zener reference voltage of 2.50 volts to the
 25 negative input pin 2 of the op amp 380. Thus, whenever the voltage at the node 382 drops below the
 26 reference voltage present at the node 388, the output of the op amp switches from HIGH to LOW,
 27 causing sufficient current to flow in the light emitting diode 402, indicating the low battery voltage
 28 condition.

1 To summarize several of the features of the electrical circuit of the illustrative embodiment
2 of the present invention, a single drive circuit is configured to drive disparate current loads of first
3 and second lighting arrays – combinations of compact light emitting devices – with the respective
4 regulated constant currents. Further, a configuration of first and second standard push ON, push
5 OFF, latching switches provides independent control of the two lighting loads wherein each switch
6 operates in three states including momentary ON, continuous ON, and OFF. The circuit is readily
7 adapted to providing continuous or pulsed drive to the lighting arrays. Also described are optional
8 circuit features that provide a dimming control, a strobe control, and a low battery indicator.
9

10 Referring to Figure 7, there is illustrated an exploded view 420 of major parts and assemblies
11 of the embodiment of Figure 1. The first 422 and second 424 elongated shells, when assembled
12 together around the contents of the PLD 10 (See Figure 1) form an elongated tubular housing 12 (See
13 Figure 1) having a longitudinal axis 14 (See Figure 1) approximately coincident with the centerline
14 406 of the battery pack 432. A combination of a plurality of alignment tabs 408 distributed along
15 each side of the second elongated shell 424 are placed to fit within complementary receptacles, such
16 as that identified by reference number 410, disposed in a plurality of corresponding locations along
17 each side of the first elongated shell 422, thus ensuring that the first 422 and second 424 shells are
18 securely and correctly aligned upon assembly. The first 422 and second 424 shells are typically
19 secured together using machine screws inserted in the locations 414 and elsewhere through surfaces
20 not visible in Figure 7. Further, resilient prongs 412 molded near the inside edges of the second
21 elongated shell 424 near the first section 16 (See Figure 1) may be configured to spring into a locking
22 relationship with corresponding ridges molded into the first elongated shell 422, to further secure
23 the first 422 and second 424 shells together prior to inserting the machine screws at the locations
24 414. The alignment tabs and resilient prongs, in combination with the use of overmold gaskets
25 applied during the manufacturing process (described two paragraphs infra), contribute to the overall
26 strength and rigidity of the elongated housing structure. Such ruggedness is expected in a lighting
27 product intended for the specific industrial markets listed below in the next paragraph.
28

1 The first 422 and second 424 elongated shells shown in Figure 7 may be preferably molded
2 or cast from thermoplastic or metallic materials. In the illustrative embodiment, a general purpose,
3 unreinforced polyetherimide resin (PEI) sold by G. E. Plastics under the brand name ULTEM®,
4 1000 series, may be used because of its heat resistance, dimensional stability, durability, very high
5 strength and resistance to chemicals. It is much lighter than aluminum or steel, and does not make
6 metallic sounds or produce sparks when contacting other objects. These are important characteristics
7 in a product intended for use in all kinds of weather and environmental conditions by security
8 personnel, service truck persons, military, police, fire, EMS, and CSI units, etc., as well as aircraft
9 and vehicle maintenance personnel.
10

11 The major components or assemblies housed within or forming part of the elongated housing
12 include an end cap 426, a side over lens 428, an illumination module or light emitting assembly 430,
13 the battery pack 432, a positive battery contact 434, and a negative battery contact 436. The end cap
14 426, molded from the same material as the elongated shells, may be threaded to permit access to the
15 battery pack 432 for replacement. The side lens 428 (See also side lens 24 in Figure 1) is a one-piece,
16 transparent covering lens that extends the housing shell over the light emitting assembly 430. The
17 side lens 428 protects the LED/lens assemblies in the flood light array and includes an extension
18 428A to protect the spot light array portions of the PLD 10. In standard applications the side lens 428
19 may be “water clear,” a term denoting a high degree of colorless optical clarity. In certain
20 applications, the side lens 428 may be colored, but preferably maintaining a high degree of optical
21 clarity and light transmission.
22

23 The side lens 428 and its extension 428A may be molded as a single piece of a suitable
24 thermoplastic such as polycarbonate (PC), which exhibits a suitable blend of toughness, optical
25 clarity, stability, etc. The side lens 428 is slightly curved in the illustrative embodiment to match the
26 slight curvature of the second housing shell 424 over the first array of LEDs in the light emitting
27 assembly 430. The side lens extension 428A may be formed as an end cap over the end of the PLD
28 10 including the spot light array. Further, the polycarbonate material satisfies a requirement that the
29 refractive index of the side lens 428 be uniform throughout the side lens 428 to minimize distortion

1 of the light beams emitted by the light emitting assemblies. An additional feature of the side lens 428
2 may be a gasket portion provided during an overmolding process that is well-known to persons
3 skilled in the art. The gasket is a band of suitable material added along the edges of the side lens 428
4 where the side lens 428 mates with corresponding edges in the first 422 and second 424 elongated
5 shells of the elongated housing. The gasket is formed in a mold similar to that used to form the side
6 lens but having a different profile for being molded during a second operation (i.e., a “second shot”)
7 before ejection of the finished part. The same technique may also be used to advantage during the
8 molding of the first 422 and second 424 elongated shells. The overmold type of gasket ensures
9 sealing against water and stability of the joint between the components of the elongated housing.
10

11 Continuing with Figure 7, the light emitting assembly 430, to be described in detail with
12 Figures 8A through 8D, includes a frame, a circuit board for the electrical circuit 160, the lens/LED
13 assemblies for the first 192 and second 202 arrays of LEDs, the first 222 and second 232 ON/OFF
14 switches, and lens bezels (to be described) in a compact, rugged, serviceable unit that is configured
15 for ease of replacement in the field. In Figure 7, the first 222 and second 232 ON/OFF switches are
16 represented by the flexible sealing bezel 502 having first and second raised portions 484 and 486
17 respectively covering the push buttons 504 and 506 of the first 222 and second 232 ON/OFF
18 switches. The first 484 and second 486 raised portions, when the light emitting assembly 430 is
19 assembled in position within the first 422 and second 424 halves of the elongated housing 420,
20 extend through the first 485 and second 487 openings in the first half 422 of the elongated housing.
21 This arrangement of the first 222 and second 232 ON/OFF switches in the elongated housing 420
22 enables holding the PLD 10 in one hand with two of the fingers of the user’s hand curled loosely
23 around the body of the PLD 10 in the location of the switches 222, 232, thus permitting easy,
24 independent operation of either switch. The positive 434 and negative 436 battery contacts are
25 preferably formed from a beryllium copper alloy well known for its properties as used in the
26 manufacture of springs and contacts that require high longevity for uses involving many flexing
27 cycles.
28

1 Referring to Figure 8A, there is illustrated a perspective view of a rearward side of a light
2 emitting module 430 for use in the embodiment of Figure 1. The light emitting module 430 is shown
3 in various views in Figures 8A, 8B and 8D. Figure 8C to be described later illustrates an internal
4 portion of the structure of the light emitting module 430. Reference numbers used in common in the
5 several views identify features in the view that appear in one or more of the other views. In Figure
6 8A, a heat sink 440 disposed in the middle portion of the light emitting module 430 serves as a frame
7 having first 452 and second 462 opposite sides for the support of the other structures that comprise
8 the light emitting module 430. In the description that follows, the terms heat sink and frame may
9 be used interchangeably, accompanied by the same reference number 440. The heat sink 440 is
10 preferably fabricated of aluminum or other suitable conductor of heat. Further, the heat sink 440 is
11 configured as a low profile platform for mounting thereon one or more arrays of light source units
12 such as the lens/LED assembly 155 (Illustrated in Figure 4C) combinations as described herein. The
13 lens/LED assemblies 155 as they appear in the light emitting module 430 are most clearly shown in
14 Figure 8C, described herein below.

15
16 Continuing with Figure 8A, the heat sink 440 preferably includes sufficient surface area for
17 dissipating the heat generated by the LEDs in the first 192 and second 202 arrays of LEDs and the
18 electrical circuit 160. In the illustrated embodiment, the heat sink 440 includes a plurality of heat
19 radiating fins 522 on the second (upward) side 462 as it appears in Figure 8A. A heat sink extension
20 470 is attached to the right-hand or first end 524 (as shown in the figure) of the light emitting module
21 430, mounted at a right angle to the first end 524 of the frame 440. The heat sink extension 470 may
22 be a separate part attached with screws or other fastener or it may be fabricated with the frame 440
23 as a single piece heat sink unit. The heat sink extension 470 is provided to dissipate heat produced
24 by the second array 202 of LEDs when producing a spotlight beam. The heat sink extension also
25 supports the second array 202 of LEDs in the light emitting module 430.

26
27 The heat sink or frame 440 shown in Figure 8A further supports the printed circuit board (PC
28 board) 442, which contains the electrical circuitry 160, adjacent the second side 462 of the heat sink
29 or frame 440. A first end (obscured by the heat sink extension 470) of the PC board 442 is attached

1 to the heat sink extension 470, preferably in a groove machined therein for the purpose or its
 2 equivalent. The second end 438 of the PC board 442 is supported by a spacer 512 that is positioned
 3 between the heat sink 440 and the PC board 442 and secured by a machine screw 478. The spacer
 4 512 is located in a recess in the second side 462 of the heat sink 440 that includes the heat radiating
 5 fins 522. The PC board 442 may be supported on the frame 440 by other methods well known to
 6 persons skilled in the art or otherwise integrated into an assembly of the frame/heat sink 440 and the
 7 one or more arrays of light source units.

8
 9 Mounted on the opposite side of the heat sink or frame 440 from the PC board 442 of the
 10 illustrative embodiment are the four lens/LED assemblies 155 (See Figure 4C) of the first array 192
 11 of LEDs. Partly visible in Figure 8A, between the heat sink 440 and a first array bezel 468 (to be
 12 described; see also the bezel 20 in Figure 1) are the outer sides of the lenses 454, 456, 458, and 460
 13 for the four lens/LED assemblies 155. The first array bezel 468 is preferably a one piece molded
 14 thermoplastic component that serves as a front panel – a mask and alignment support surrounding
 15 the light-emitting side of the lenses 454, 456, 458, and 460. The first array bezel 468 also serves as
 16 a U-shaped mounting clip (when viewed in cross section) that holds the lens /LED assemblies 155
 17 against the heat sink frame 440. Extending from both of the longer, opposite edges of the first array
 18 bezel 468 are a plurality of resilient prongs or “flex arms” – a hooked end preferably having a curled
 19 “finger” (not shown) formed in the end of each prong. Two prongs 494, 496 of the three prongs
 20 disposed on the near side of the first array bezel 468 are shown in Figure 8A. Three such prongs 494
 21 or 496 may be used on each side of the first array bezel 468. The space within the curled “fingers”
 22 of the end of each prong 494, 496 snaps over the proximate edge of corresponding recessed notches
 23 490, 492 formed in the edges of the heat sink or frame 440. When installed on the frame 440, the
 24 bezel 468 traps the individual lens/LED assemblies 155 between it and the frame 440 to secure them
 25 in position.

26
 27 Two other assemblies are shown in Figure 8A. Mounted on the heat sink extension 470 is
 28 the second LED array 202 enclosed within a cannister 472. The cannister 472 acts as a holder for the
 29 lens/LED assembly 155 of the second LED array 202, positioning a heat transferring face of a printed

1 circuit portion 474 of the lens/LED assembly 155 against the heat sink extension 470 in a correct
2 alignment. The heat transferring face of the printed circuit portion 474 is typically an aluminum plate
3 that is laminated to the surface of the printed circuit. The assembly of the cannister 472 and the
4 printed circuit portion 474 of the lens/LED assembly 155 of the second array 202 is held in place by
5 a front lens support 476 (which may also be called a second array bezel 476). The front lens support
6 476 has a lip that fits over a corresponding ridge formed in the first array bezel 468. Once the lip is
7 engaged with the ridge, the front lens support 476 may be tilted toward the heat sink extension 470
8 until a resilient prong 540 having a hooked end 546 hooks through an edge of a hole formed in the
9 heat sink extension 470, as shown in cross section in Figure 8D. Also shown in Figure 8A is the
10 forward surface of the second LED array 202. Close observers will note that the side lens 428 and
11 its extension 428A (Reference number 24 in Figures 1 and 2) are not shown in Figure 8A. In the
12 illustrated embodiment the clear side lens 24 and the clear top lens 28 are shown as a single part,
13 called the side lens 428 and its extension 428A respectively in Figure 7.
14

15 The remaining assembly of Figure 8A includes a switch bracket 480, which encloses and
16 aligns the first 222 and second 232 ON/OFF switches (See Figures 5 and 6A) in position with respect
17 to the frame 440. The switch bracket 480 may be fabricated from, e.g., 19 gauge metal
18 (approximately 0.042 in or 1.06 mm thick). A portion 488 of the second ON/OFF switch 232 is
19 visible in Figure 8A. The ON/OFF switches 222, 232 are mounted on the frame 440, the switch
20 bracket 480 is slipped over the push button actuators 504, 506 (see Figure 8D) of the switches 222,
21 232, and a flexible sealing bezel 502 (also called flexible bezel) is placed over the push button
22 actuators of the switches 222, 232. The flexible bezel 502 has raised portions 484, 486 respectively
23 for enclosing the push button actuators for the switches 222, 232. A link 482 couples the raised
24 portions 484, 486 of the flexible bezel 502 together. The link 482 helps to maintain alignment of the
25 raised portions 484, 486 upon installation within the elongated housing 420. The flexible bezel 502,
26 which may be fabricated of neoprene or similar material, is provided to seal the ON/OFF switches
27 222, 232 against intrusion of moisture, dirt, and other possible contaminants encountered during use
28 of the PLD 10. Wire leads (not shown in Figures 8A through 8D for clarity) may be provided for

1 connecting the ON/OFF switches (obscured by the flexible bezel 502) to the electrical circuitry of
2 the PC board 442.

3
4 Referring to Figure 8B, there is illustrated a perspective view of the forward side of the light
5 emitting module 430 illustrated in Figure 8A. The forward side of the light emitting module 430 is
6 the side that faces in the direction of light emission. For example, see Figure 8C, which illustrates
7 a forward axis 508 of illumination normal to the frame 440. While shown disposed in a central
8 portion of the frame 440, the forward axis 508 may be defined at the optical axis of each light
9 emitting assembly where it provides a reference for the angular orientation of the individual light
10 emitting assembly (lens/LED assembly 155). As described previously with Figure 2, and as will be
11 described further herein below, the angular orientation of the light emitting assemblies is an aspect
12 of one of the novel features of the present invention. While shown as defined for a frame 440
13 configured as a flat planar surface, where all normal reference lines are by definition parallel to each
14 other, in other embodiments having a curved frame, the normal lines are unique to the location of
15 each light emitting assembly. In such cases, the forward axis 508 would be a nominal axis defining
16 the direction of illumination but not normal to all parts of the frame.

17
18 Continuing with Figure 8B, the perspective view is similar to the view in Figure 8A except
19 that the light emitting module 430 has been rotated about its longitudinal axis 180°, thereby exposing
20 the forward, light emitting side the light emitting module 430. Each of the lenses 454, 456, 458, and
21 460 for the four lens/LED assemblies 155 of the illustrated embodiment are shown in alignment with
22 the first array bezel 468. Also shown are two of the resilient prongs 494, 496 extending from the first
23 array bezel 468 that engage two corresponding notches 490, 492 in the edges of the frame/heat sink
24 440 to secure the lens/LED assemblies 155 against the frame 440. Four other prong/latch
25 combinations are used (but not shown) to secure the first array bezel 468 to the frame 440 to entrap
26 and secure the four lens/LED assemblies 155 there between. The PC board 442 is shown disposed
27 below the frame 440, adjacent the second side 462 of the frame 440.

1 The partly obscured first ends of the heat sink or frame 440 and the PC board 442 are
 2 disposed toward the heat sink extension 470. The second end 438 of the PC board 442 is shown
 3 oriented to the left in the figure toward the first and second ON/OFF switches 504, 506 (not visible
 4 in Figure 8B, but see Figure 8D) and enclosed within the corresponding raised portions 484, 486 of
 5 the flexible bezel 502. Wire leads (not shown) for connecting the switches 504, 506 to the PC board
 6 442 are typically routed alongside the bodies of the switches 504, 506. The switch bracket 480 is
 7 shown extending from beneath the flexible bezel 502 and upward along each side of the first array
 8 bezel 468. The front lens support 476 and the forward surface of the lens 26 of the second LED array
 9 202 are shown attached to the right-hand end of the light emitting module 430 in Figure 8B.

10
 11 Referring to Figure 8C, there is illustrated a perspective view of a basic module 500 of the
 12 light emitting module 430 appearing in Figure 8B. In fact, reduced to the minimum essentials, the
 13 basic module 500 embodies many of the essential features of several aspects of the present invention.
 14 The heat sink or frame 440 is shown, having the first side 452 and the second side 462, as well as
 15 the first end 524. The PC board 442, having a second end 438, is shown just below the frame 440.
 16 Not visible in the view of Figure 8C (But, see Figure 8D) is the spacer 512 between the PC board
 17 442 and the frame 440 within which the machine screw 478 passes to secure these two structures
 18 together. Also shown mounted on the first side 452 of the frame 440 are four lens/LED assemblies
 19 155, identified respectively by their associated lenses 454, 456, 458, and 460. Each assembly
 20 occupies a respective recess 444, 446, 448, and 450 machined into the first side 452 of the frame
 21 440. The bottom surface of each of the recesses 444, 446, 448, and 450 is machined at an angle
 22 relative to the normal axis 508 that is somewhat less than 90° so that the optical axis of the lens/LED
 23 assembly 155 installed therein is tilted in a predetermined direction by the amount of the previously
 24 described angle θ .

25
 26 Each lens/LED assembly 155 shown in Figure 8C includes its lens 454, 456, 458, and 460
 27 (each lens being configured like the lens 100 in Figures 4A, 4B, and 4C). Thus, each of the lens/LED
 28 assemblies 155 of Figure 8C includes a base 142, a substrate 144, and the concave light emitting
 29 surface 110 of the lens 100 having the plurality of concentric annular rings 120 formed thereon as

1 in the Figures 4A, 4B, and 4C. Close observation of the placement of the individual lens/LED
2 assemblies 155 reveals that each is canted at substantially the same (generally small) angle θ with
3 respect to the normal axis of each lens/LED assembly 155 but in a different azimuthal direction with
4 respect to the frame 440 and its normal or forward axis 508 (See Figure 8D). This relationship will
5 be described in detail with Figure 8D to follow.

6
7 The basic module 500 illustrated in Figure 8C is constructed as a rugged assembly of the
8 essential components of the light emitting module 430. All of the components are solid structures
9 fabricated of solid materials that are very resistant to breakage, particularly when secured in place
10 by the front bezel 468 and installed within the elongated housing 12 as shown in Figure 7. The
11 elongated housing is also constructed of materials highly resistant to damage from impact and other
12 mechanical hazards, as well as extreme environmental, chemical, and electrical conditions. When
13 assembled together, the components of the PLD 10 as described herein are designed to withstand
14 heavy use and abusive handling as is often encountered in industrial, security, military, and public
15 safety applications. Other techniques or modifications such as use of silicone sealants, potting
16 compounds, and the like may be used to provide enhanced protection from the effects of moisture
17 intrusion or contact with harsh chemical or environmental conditions.

18
19 Referring to Figure 8D, there is illustrated a side cross section view of the light emitting
20 module 430 of the embodiment of Figure 8B, taken generally along the longitudinal centerline or
21 axis 14 and with the switch bracket 480 removed. In this view, the forward axis 508 that is defined
22 normal to the first side 452 of the heat sink or frame 440 is shown oriented upward in the drawing
23 and placed at the location of the machine screw 478 and spacer 512 securing the PC board 442 to
24 the frame 440. The individual lens/LED assemblies 155 (associated with their respective lenses 454,
25 456, 458, and 460) are shown installed in their respective recesses 514, 516, 518, and 520. In
26 practice, a very thin layer of thermally conductive, double-sided tape (not shown) or other thermal
27 compound of the type well-known to persons skilled in the art may be placed in the interface
28 between each LED/lens assembly and the recess in the heat sink/frame 440.

1 Of particular interest in this view in Figure 8D is the orientation of the individual lens/LED
2 assemblies 155 in their respective recesses as shown in cross section 514, 516, 518, and 520. Each
3 of the recesses 514, 516, 518, and 520, and correspondingly the lens/LED assembly 155 installed
4 therein, is tilted in a different azimuthal direction relative to the forward axis 508 of the first side 452
5 of the heat sink or frame 440. The lens/LED assembly 155 for the lens 454 installed in the recess 514
6 is shown tilted to the right in Figure 8D by a predetermined angle of approximately 5° . That is, the
7 approximate angle between the optical axis of the lens/LED assembly 155 for the lens 454 and a
8 normal line passing through the LED at the plane of the frame 440 is approximately 5° . Similarly,
9 the lens/LED assembly 155 for the lens 456 installed in the recess 516 is shown tilted into the plane
10 of the drawing (i.e., away from the viewer) in Figure 8D by a predetermined angle of approximately
11 5° . Further, the lens/LED assembly 155 for the lens 458 installed in the recess 518 is shown tilted
12 out of the plane of the drawing (i.e., toward the viewer) in Figure 8D by a predetermined angle of
13 approximately 5° . Finally, the lens/LED assembly 155 for the lens 460 installed in the recess 520 is
14 shown tilted to the left in Figure 8D by a predetermined angle of approximately 5° . One can visualize
15 the light emitting assembly 430 from a point directly above the forward axis 508, looking downward
16 toward the assembly 430, wherein the optical axes of the four lens/LED assemblies 155 are tilted
17 away from each other at 90° intervals relative to the position of the forward axis 508, substantially
18 mimicking the four points of the compass, N, W, S, and E (for North, West, South, and East). This
19 arrangement provides the projected flood light beam pattern as illustrated in Figure 3 described
20 herein above.

21
22 In the illustrated embodiment of the PLD 10, the predetermined angles of the optical axes
23 of the individual lens/LED assemblies 155 is fixed at approximately 5° from the normal, i.e., from
24 an axis parallel to the forward axis 508. As indicated previously, depending upon the beam width
25 characteristics, number of light emitting assemblies, etc., the “predetermined angle” may vary. The
26 range of variation may typically be within approximately $\pm 3^\circ$ of the nominal 5° angle described
27 for the illustrated embodiment. This range, it will be appreciated allows for a wide variation in the
28 beam width characteristic in accordance with the one quarter beam width index also described herein
29 above. In other embodiments, larger “predetermined angles,” for example up to 15° may be

1 employed to achieve particular illumination results. Moreover, while in most cases the predetermined
2 angle is a non-zero angle, in some embodiments, at least one of the light emitting assemblies may
3 be oriented with respect to the reference forward direction at a predetermined angle of zero degrees.
4 Further, in other alternate embodiments, the angles of the optical axes may be varied or adjusted to
5 provide a particular illumination characteristic. It is even possible, with suitable structural revisions
6 apparent to persons skilled in the art, to provide for an adjustable flood light pattern by configuring
7 the structure of the light emitting module 430 to vary the angles of the optical axes of the individual
8 lens/LED assemblies 155.

9
10 Continuing with Figure 8D, the fifth lens/LED assembly 157 will be described. The fifth
11 assembly 157 may be identical with the lens/LED assembly 155 previously described with respect
12 to Figure 4C. However, the fifth lens/LED assembly 157, which may utilize a different lens or
13 include an LED having a different operating power level to provide a spot light beam, is otherwise
14 very similar to the lens/LED assembly 155. As before, the four individual forward (for the flood light
15 beam) lens/LED assemblies 155 include the LED (actually inside the hemispherical dome 550)
16 mounted on each base 510. The assembly thus includes the LED 510, the substrate 144 and the lens
17 itself 454, 456, 458, or 460.

18
19 Joining the right-hand end 524 of the heat sink or frame 440 in Figure 8D is the heat sink
20 extension 470. Supported on the heat sink extension 470 is a fifth top (for the spot light beam)
21 lens/LED assembly 157 (including the elements 530, 474, and 26) mounted within a cannister 472.
22 The cannister 472 is supported directly against the PC board substrate 474 of the top lens/LED
23 assembly 157 as held in place by the front lens support 476 acting in cooperation with the first array
24 bezel 468 as previously described with Figure 8A. The front lens support 476 has a lip that fits over
25 a corresponding ridge formed in the first array bezel 468. Once the lip is engaged with the ridge, the
26 front lens support 476 may be tilted toward the heat sink extension 470 until a resilient prong 540
27 having a hooked end 546 hooks through an edge of a hole formed in the heat sink extension 470, as
28 shown in cross section in Figure 8D.

1 Figure 8D includes additional detail of the first 222 and second 232 ON/OFF switches,
2 shown in their correct location but with the switch bracket 480 removed for clarity. The first switch
3 222, having a push button actuator 504, is shown enclosed within the cover 484 portion of the
4 flexible sealing bezel 502. Similarly, the second switch 232, having a push button actuator 506, is
5 shown enclosed within the cover 486 portion of the flexible sealing bezel 502. The first 222 and
6 second 232 switches are mounted against a flat surface formed into the second side 462 of the heat
7 sink or frame 440. Other structures shown in Figure 8D have been previously described.

8
9 To summarize several of the features of the light emitting module of the illustrative
10 embodiment of the present invention, an array of a plurality of compact light emitting assemblies is
11 mounted on a frame configured as a heat sink. The frame serves the dual purpose of providing a
12 structural platform and a thermal management component. The frame further provides features that
13 ensures proper alignment of the light emitting devices wherein each light emitting assembly is
14 preferably but not necessarily disposed at a non-zero predetermined angle relative to a forward axis
15 normal to and defined at the location of the light emitting assembly. The predetermined angle is
16 selected to aim the individual light emitting assemblies in a direction that provides a predetermined
17 overlap of individual light beams of a given beam width preferably resulting in a uniform, high
18 brightness pattern on a target surface. The source of current connected to the light emitting devices,
19 as may be implemented on a printed circuit board, is also mounted on the frame, conveniently but
20 not necessarily on the side of the frame opposite the light emitting assemblies. The compact light
21 emitting module that is thus provided is readily adaptable to a variety of compact, high performance
22 lighting product configurations.

23
24 Several aspects of the features of the optical system of the illustrative embodiment of the
25 present invention include a unitary lens and light emitting device combination that produces a highly
26 uniform beam of light, corrected for distortions and gaps in illumination, throughout a full beam
27 width angle in the range of $40^{\circ}+/-10^{\circ}$. This lens/LED combination or light source unit is adaptable
28 for use principally in arrays of such light source units to provide optimum flood illumination from
29 a portable, hand held task lamp product. The unitary lens is formed as a solid body lens which

1 incorporates all of the necessary optical surfaces in a single piece unit, including the pattern-
2 correcting spherical refracting surface, concave in the forward direction of illumination, that smooths
3 out intensity variations in the overall illumination pattern. The light source unit provided by this
4 lens/LED combination may be arranged in many different arrays formed of a plurality of such light
5 source units for use in a wide variety of applications.

6
7 Several aspects of the features of the electrical circuit of the illustrative embodiment of the
8 present invention include a single drive circuit that is configured to drive disparate current loads of
9 first and second lighting arrays – combinations of compact light emitting devices – with the
10 respective regulated constant currents. Further, a configuration of first and second standard push
11 ON, push OFF, latching switches provides independent control of the two lighting loads wherein
12 each switch operates in three states including momentary ON, continuous ON, and OFF. The circuit
13 is readily adapted to providing continuous or pulsed drive to the lighting arrays. Also described are
14 optional circuit features that provide a dimming control, a strobe control, and a low battery indicator.

15
16 Another aspect of the electric circuit utilizes a single pole, single throw switch having
17 normally open contacts in a conductive path in a non-intuitive manner to sequentially provide three
18 operable states including latched engagement (path closed, circuit OFF), momentary disengagement
19 (path opened, circuit ON momentarily), and latched disengagement (path open, circuit ON until
20 switch actuated).

21
22 All of the features summarized in the preceding paragraphs may be combined in a single
23 combination task lamp and flashlight, providing a flood light having a uniform, high brightness beam
24 pattern and a spot light having a narrower, more focused beam pattern, each type of beam
25 independently controlled in a three-state sequence by simple push button switches. The two kinds
26 of light beams are produced by separate arrays of compact light emitting devices, which are both
27 driven by a single electrical circuit that provides disparate, regulated constant currents to the
28 respective LEDs. The optics and electronics are constructed in a single, ruggedized, compact module,

1 and the module enclosed within a slim, rugged housing and easily field replaceable with minimal
2 tools.

3
4 While the invention has been shown and described with particularity in only one of its forms
5 to illustrate the principles of the invention, the invention is not thus limited to the representative
6 embodiment but is susceptible to various changes and modifications that may occur to persons
7 skilled in the art in applying the invention to certain circumstances without departing from the scope
8 of the appended claims. For example, while specific dimensions, angles, materials and processes are
9 described for the representative embodiment, the invention is not limited to the specific example but
10 allows substantial variation of structural features and processes within the range of equivalents that
11 may occur to persons practicing the invention. Further, the numbers and arrangement of the LEDs
12 may be altered, or the power levels changed to provide particular lighting performance. The colors
13 of the LED emitters may be varied. The color of the lens unit or assembly or of the over lens may
14 be varied or made interchangeable for specific purposes. The overall shape of the housing for the
15 lamp may be varied to suit particular embodiments such as lanterns, area lighting, etc.

1 What is claimed is:

2
3 1. A light emitting module, comprising:
4 a frame configured as a heat sink having first and second opposite sides, and a forward axis
5 normal to the first side thereof; and
6 an array of a plurality N of light emitting assemblies connected to a source of current,
7 wherein each light emitting assembly (LEA) is mounted on the first side of the frame configured as
8 a heat sink such that an optical axis of each LEA is disposed at a non-zero first predetermined angle
9 relative to the forward axis.

10
11 2. The light emitting module (LEM) of Claim 1, wherein:
12 each LEA comprises a light emitting device (LED) and a unitary lens-and-reflector having
13 an optical axis oriented in a forward direction and configured for emitting light within a
14 predetermined beam width angle in the direction of the forward axis.

15
16 3. The LEM of Claim 1, wherein the first predetermined angle is in the range of 5 +/- 3
17 degrees.

18
19 4. The LEM of Claim 2, wherein the predetermined beam width angle is in the range of 40
20 +/- 10 degrees.

21
22 5. The LEM of Claim 2, wherein the ratio of twice the first predetermined angle to the second
23 predetermined angle is approximately one-to-four.

24
25 6. The LEM of Claim 1, comprising:
26 a light emitting drive circuit assembly attached to the second side of the frame configured
27 as a heat sink for providing the source of current to the plurality N of LEAs.

1 7. The LEM of Claim 1, wherein:

2 the first and second sides of the frame configured as a heat sink are substantially parallel and
3 flat, irrespective of heat radiating surfaces disposed thereon, and perpendicular to the forward axis.
4

5 8. The LEM of Claim 1, wherein:

6 the first and second sides of the frame configured as a heat sink are substantially parallel and
7 curved, irrespective of heat radiating surfaces disposed thereon, and perpendicular to the forward
8 axis defined at a central point of the frame configured as a heat sink
9

10 9. The LEM of Claim 8, wherein the shape of the curved frame configured as a heat sink is
11 selected from the group consisting of cylindrical, spherical, and aspherical.
12

13 10. The LEM of Claim 1, wherein at least one of the LEAs is mounted on the first side of the
14 frame configured as a heat sink such that the optical axis of emission of the at least one of the LEAs
15 is disposed parallel to the forward axis.
16

17 11. The LEM of Claim 10, wherein the optical axis of emission of the at least one of the
18 LEAs is coincident with the forward axis.
19

20 12. The LEM of Claim 1, wherein N is greater than or equal to two.
21

22 13. The LEM of Claim 1, wherein N equals four.
23

24 14. The LEM of Claim 3, wherein each LEA is mounted on and received by a seat formed
25 in the first side of the frame configured as a heat sink to align the optical axis of the respective LEA
26 at the first predetermined angle.
27

28 15. The LEM of Claim 1, wherein the optical axes of emission of the plurality N of the LEAs
29 diverge from each other.

1 16. The LEM of Claim 3, wherein the optical axes of emission of the plurality N of the LEAs
2 diverge from the forward axis and in a different direction from each other.

3
4
5 17. The light emitting module of Claim 1, wherein the light emitted by each of the plurality
6 of light emitting assemblies projects a substantially uniform beam of light for illuminating a target
7 surface.

8
9 18. The light emitting module of Claim 1, wherein the light emitted by the plurality of light
10 emitting assemblies together project a composite beam of light that provides a substantially uniform
11 pattern of light on a target surface.

12
13 19. The light emitting module of Claim 18, wherein the pattern of light is generally circular
14 upon a substantially flat surface oriented perpendicular to the forward axis of the light emitting
15 module.

16
17 20. The light emitting module of Claim 17, wherein the light emitted by the plurality of light
18 emitting assemblies together project a composite beam of light comprised of individual beams,
19 substantially circular in cross section, that overlap according to a predetermined configuration to
20 provide the predetermined configuration as a pattern of light on a target surface.

21
22 21. The light emitting module of Claim 1, wherein the frame comprises:
23 for each light emitting assembly, a mounting surface provided on the first side of the frame
24 that is disposed at the 5 ± 3 degree angle relative to a plane coincident with the first side of the
25 frame and perpendicular to the forward axis; wherein
26 each such mounting surface is disposed in a direction facing away from any other mounting
27 surface such that the optical axes of light emission of the light emitting assemblies mounted on the
28 mounting surfaces diverge from each other.

1 22. The light emitting module of Claim 1, wherein the frame comprises:

2 for each light emitting assembly, a mounting surface provided on the first side of the frame
3 that is disposed at the 5 ± 3 degree angle relative to a plane perpendicular to the forward axis;
4 wherein

5 one or more of such mounting surfaces is disposed in a direction facing away from any other
6 mounting surface such that the optical axis of light emission of the light emitting assembly mounted
7 on the mounting surface does not diverge from at least one other light emitting assembly.

8
9 23. The light emitting module of Claim 1, wherein a light emitting assembly comprises:

10 the unitary lens-and-reflector; and

11 a light emitting device (LED) situated at a radial center of a substantially hemispherical and
12 transparent cap, the LED mounted on a substrate having a heat sink surface on a side opposite the
13 LED; wherein

14 the unitary lens-and-reflector includes a cylindrical, recessed port for receiving the
15 substantially hemispherical and transparent cap therein such that the LED is located approximately
16 at a focal point of the reflector portion of the unitary lens-and reflector.

17
18 24. The light emitting module of Claim 23, wherein the unitary lens-and-reflector comprises:

19 an optical axis extending from an emission surface of an LED defining a forward direction
20 of light emission and a plurality of refracting and reflecting elements disposed in sequence along the
21 central axis for forming and directing a beam of light having a circular cross section and substantially
22 uniform intensity throughout the cross section, into a predetermined angle of emission; wherein

23 the unitary lens-and-reflector is formed of a solid, optical quality thermoplastic material.
24

1 25. The light emitting module of Claim 24, wherein the unitary lens-and-reflector comprises:
2 an aspherical, cup-shaped reflecting surface providing total internal reflection of light emitted
3 from a light source located at a focal point thereof along the optical axis and outside a critical angle
4 relative to the optical axis; and further enclosing

5 a spherical refracting surface disposed in the path of the reflected light, centered on and
6 normal to the optical axis, concave in the forward direction of the reflected light and intersecting the
7 aspherical reflecting surface equidistant from the optical axis around a perimeter of the spherical
8 refracting surface; and

9 an aspherical refracting surface open toward the forward direction, disposed within the space
10 enclosed within the aspherical reflecting surface and centered along the optical axis between the light
11 source and the spherical refracting surface, for projecting light rays, emitted within the critical angle,
12 in a diverging beam.

13
14 26. The light emitting module of Claim 1, wherein the LED is a light emitting diode.

15
16 27. The light emitting module of Claim 1, wherein first and second LEAs having a beam
17 width angle of Q degrees are disposed at the first predetermined angle relative to the forward axis
18 such that the total angle between the respective optical axes of the first and second LEAs is
19 approximately one-fourth of the beam width angle Q of each first and second LEA when the
20 respective first and second optical axes are disposed in a common plane with and diverging from the
21 forward axis.

22
23 28. The light emitting module of Claim 27, wherein:

24 each LEA comprises a light emitting device (LED) and a unitary lens-and-reflector having
25 a optical axis oriented in a forward direction and configured for emitting light within the beam width
26 angle Q.

27
28 29. The light emitting module of Claim 27, wherein the beam width angle Q is approximately
29 40 degrees and the first predetermined angle is approximately 5 degrees.

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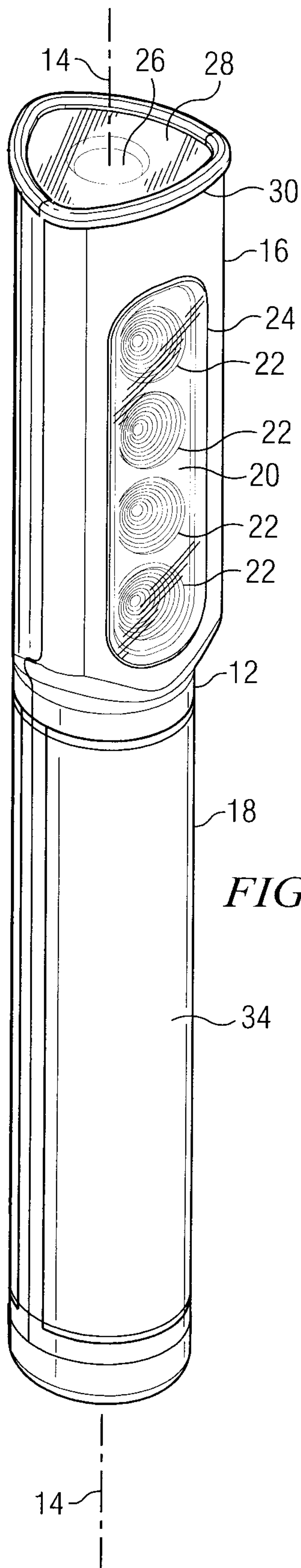


FIG. 1

10

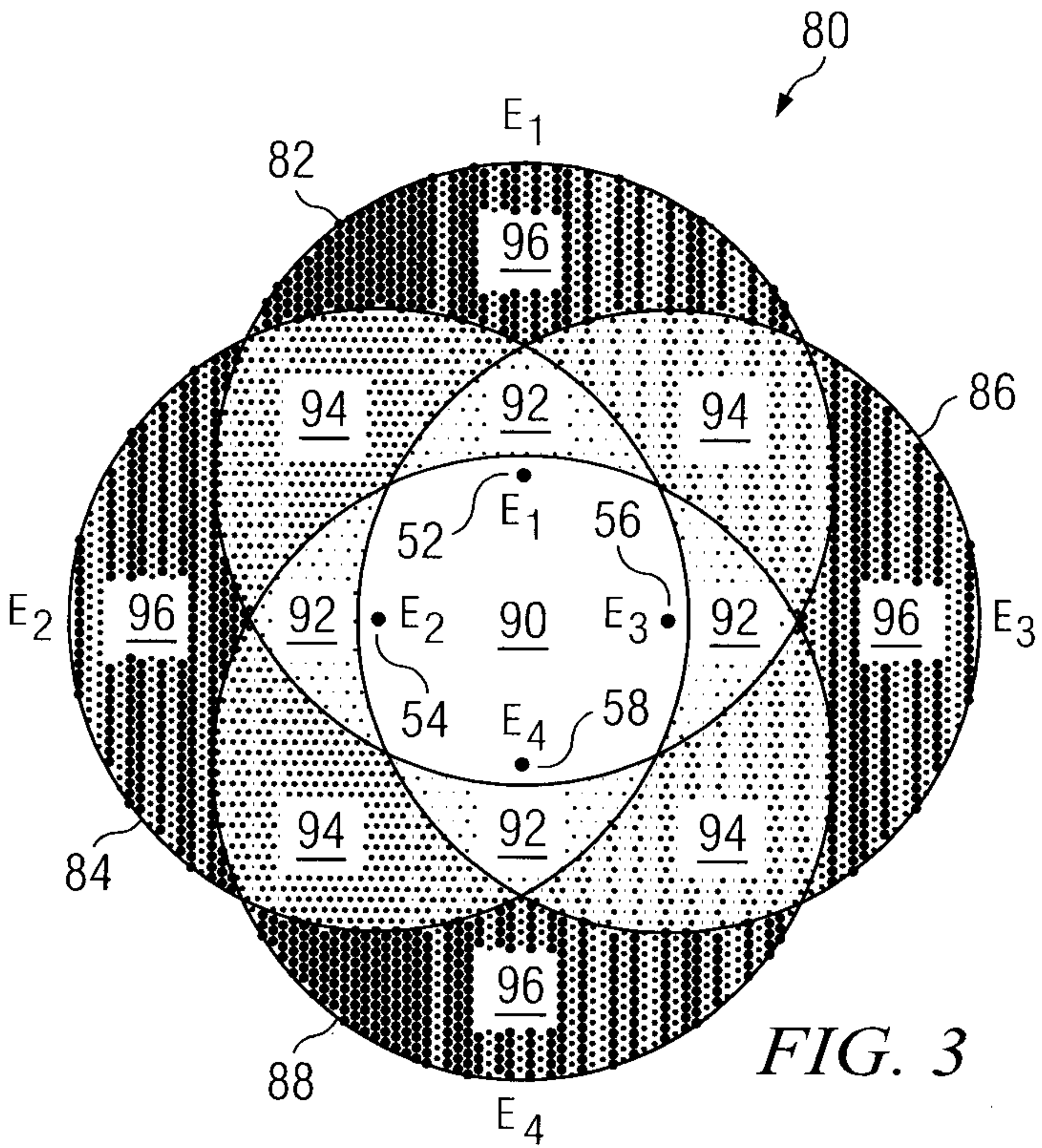


FIG. 3

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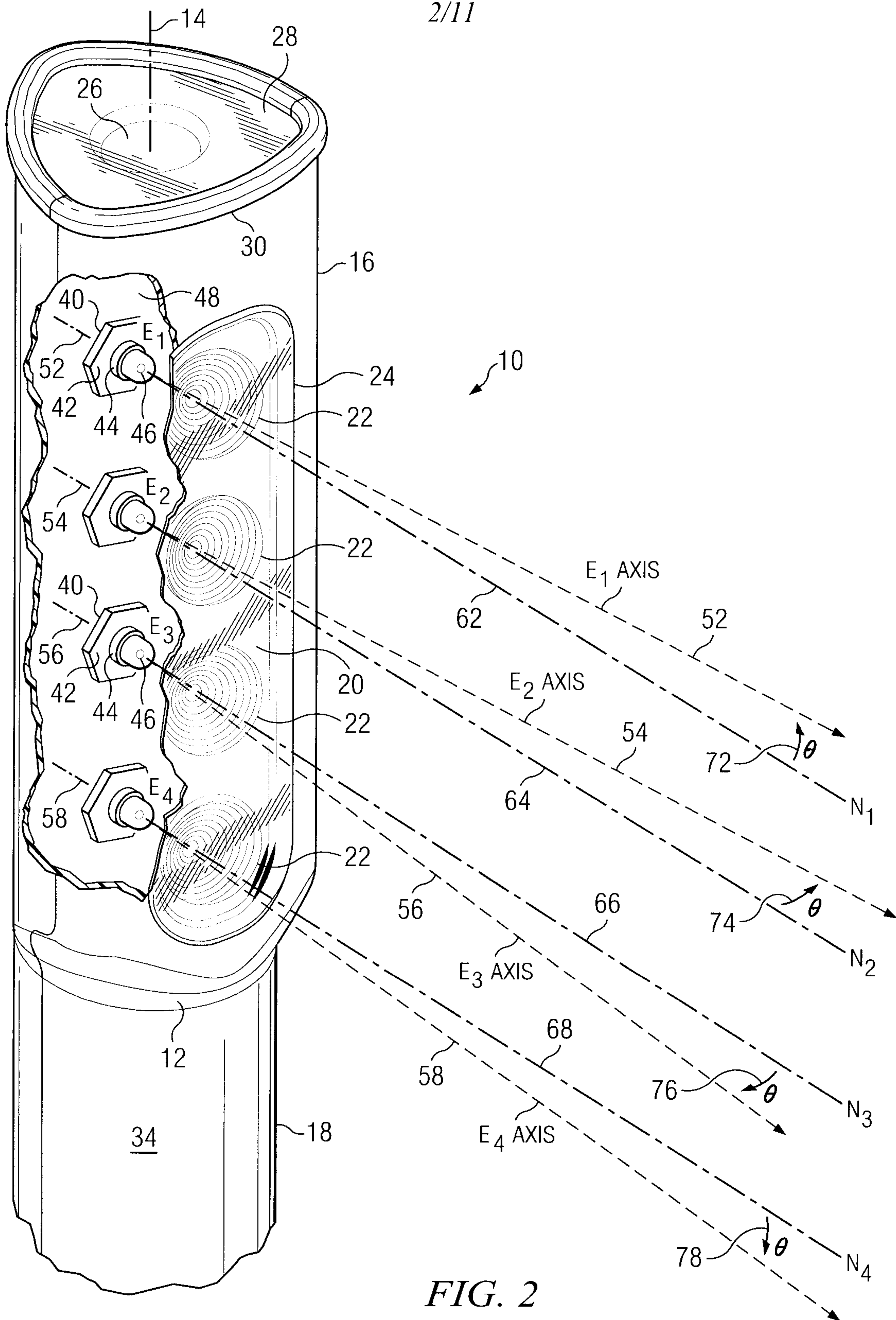
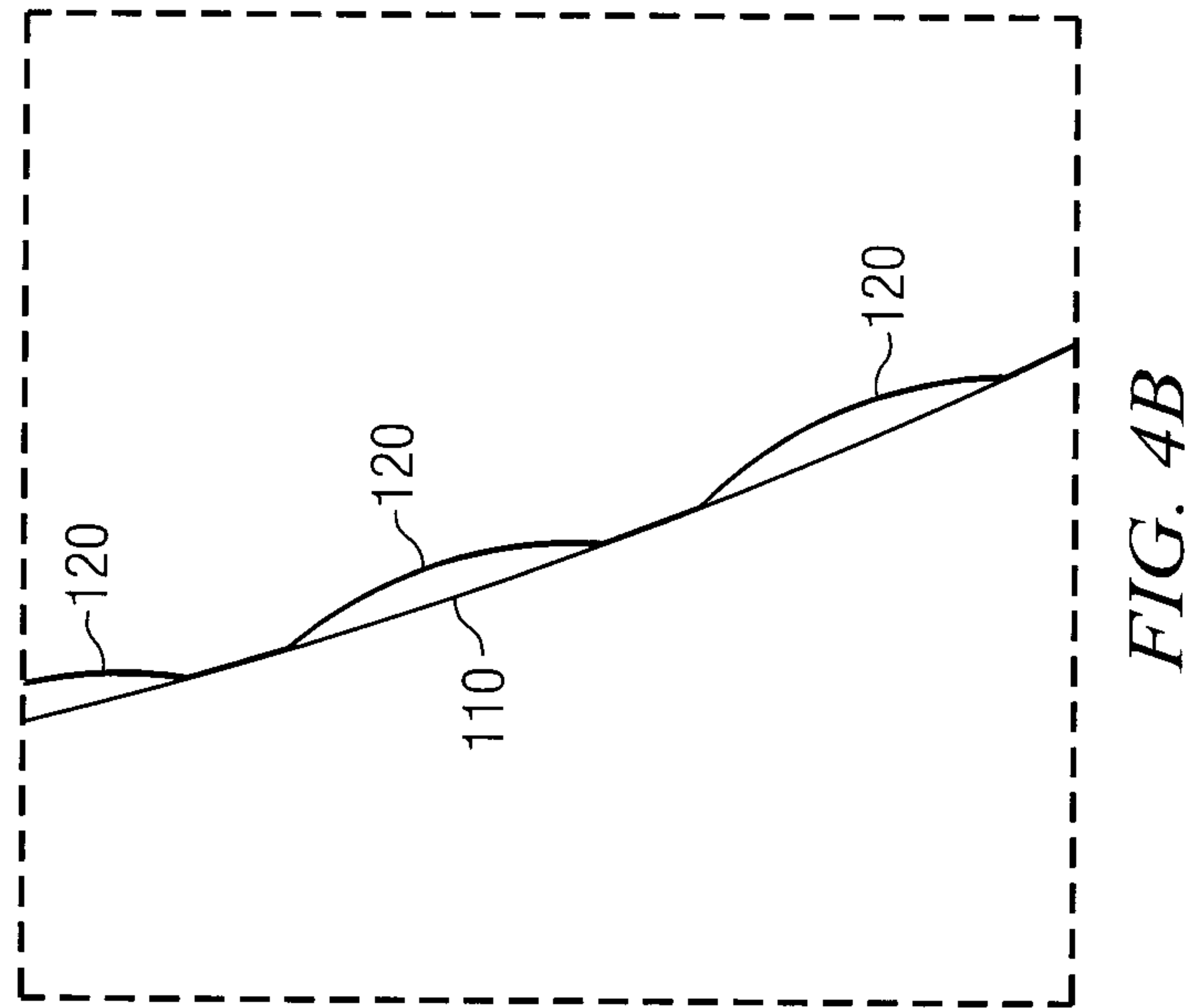
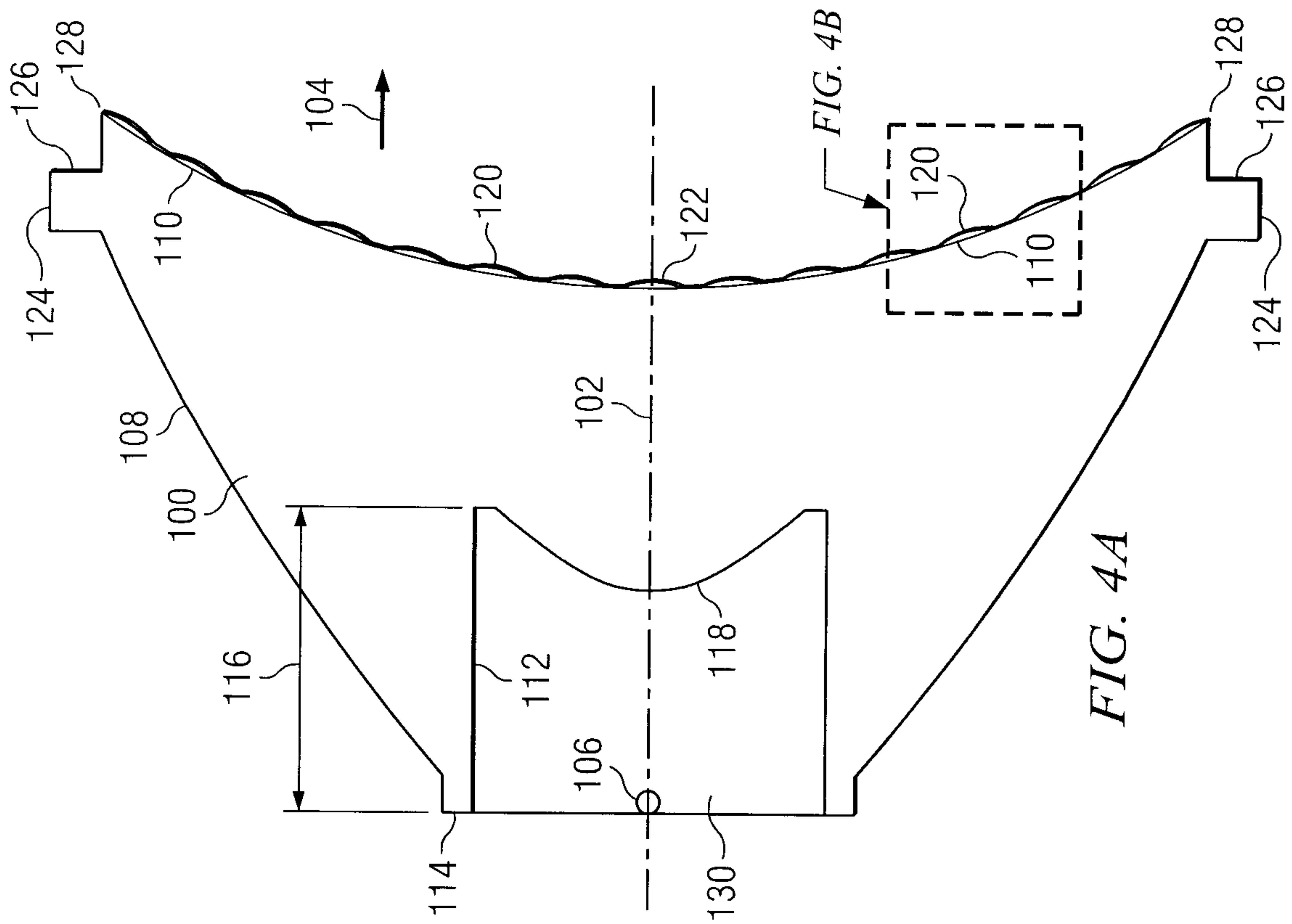


FIG. 2

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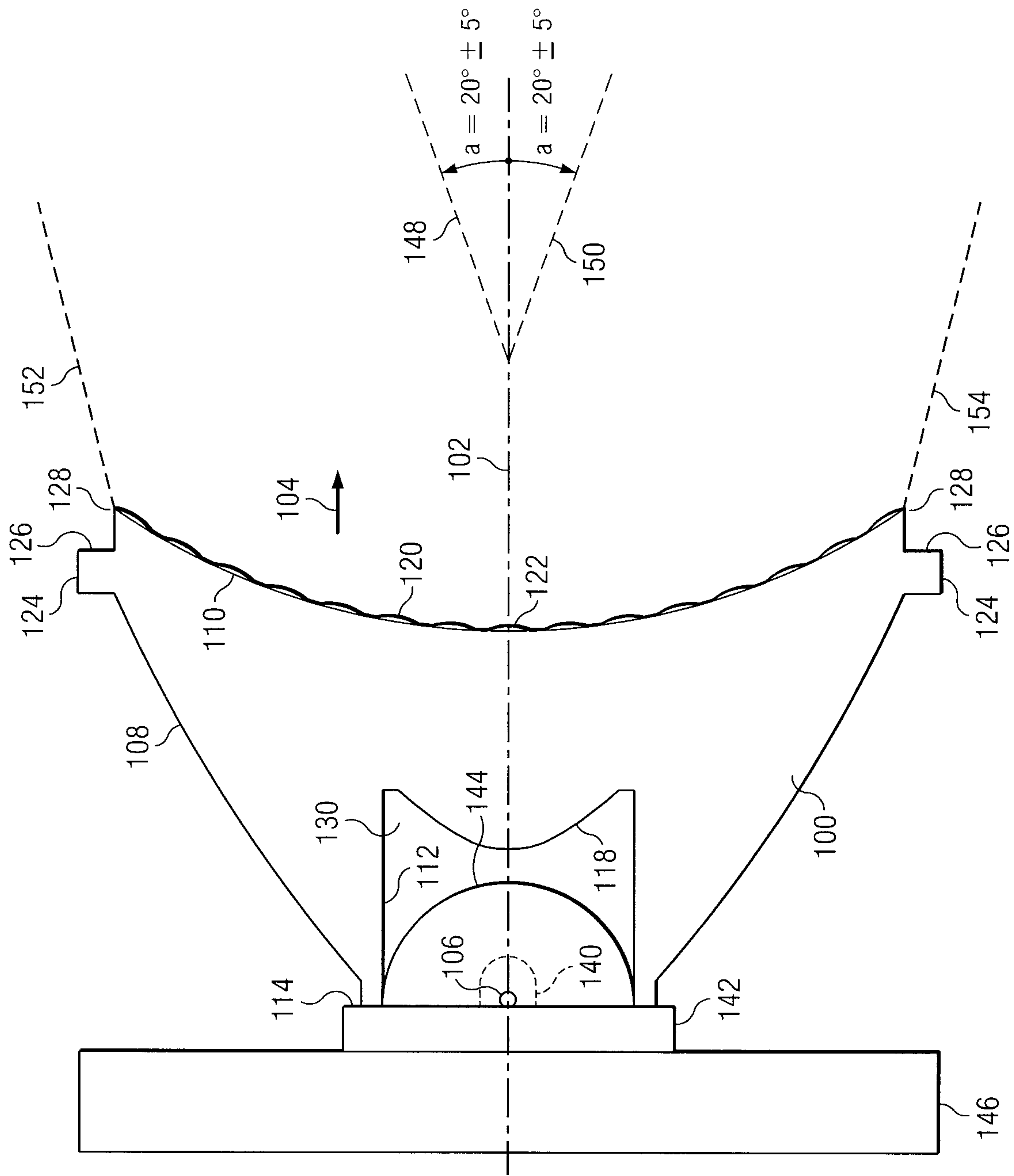


FIG. 4C

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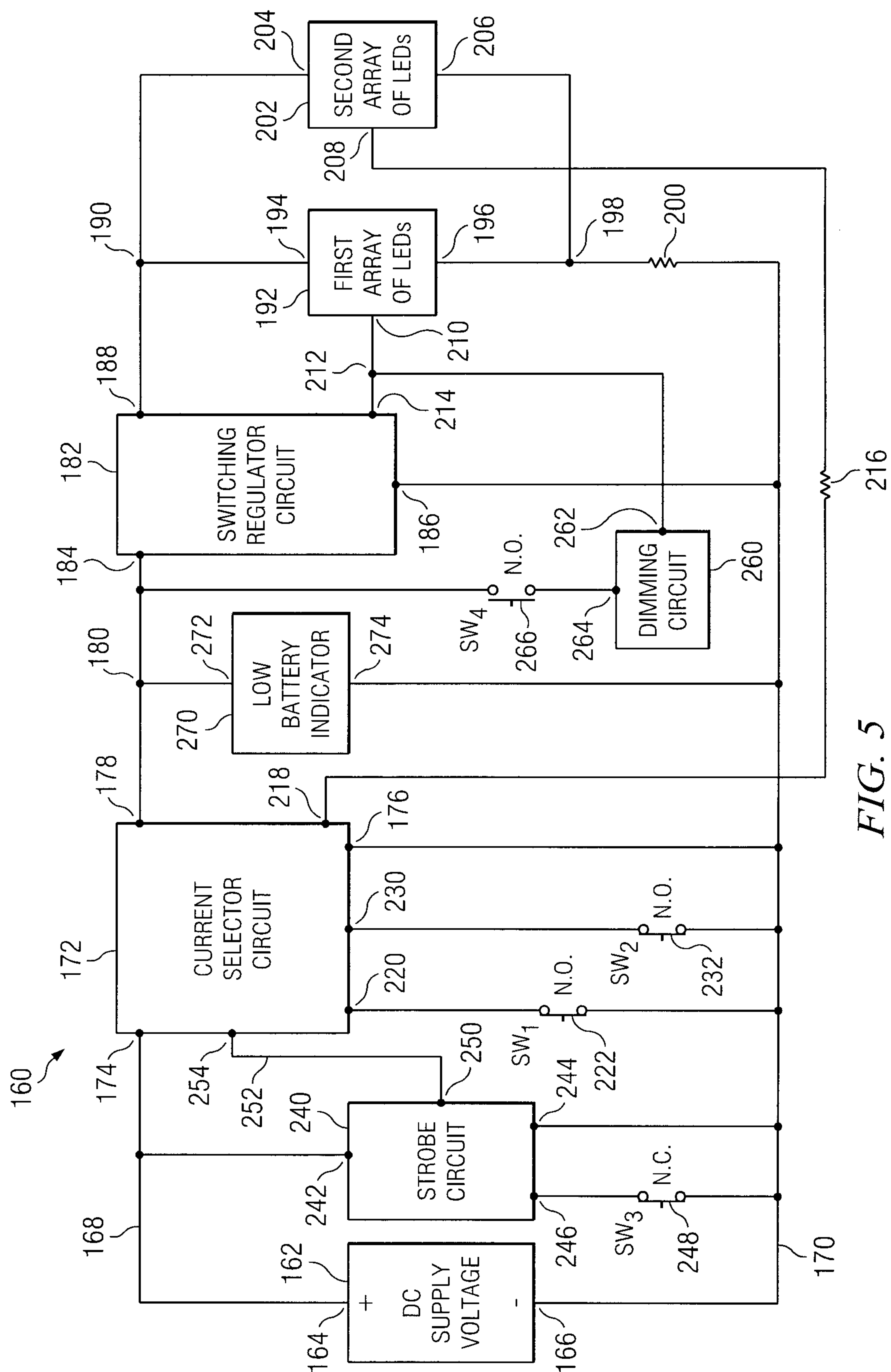
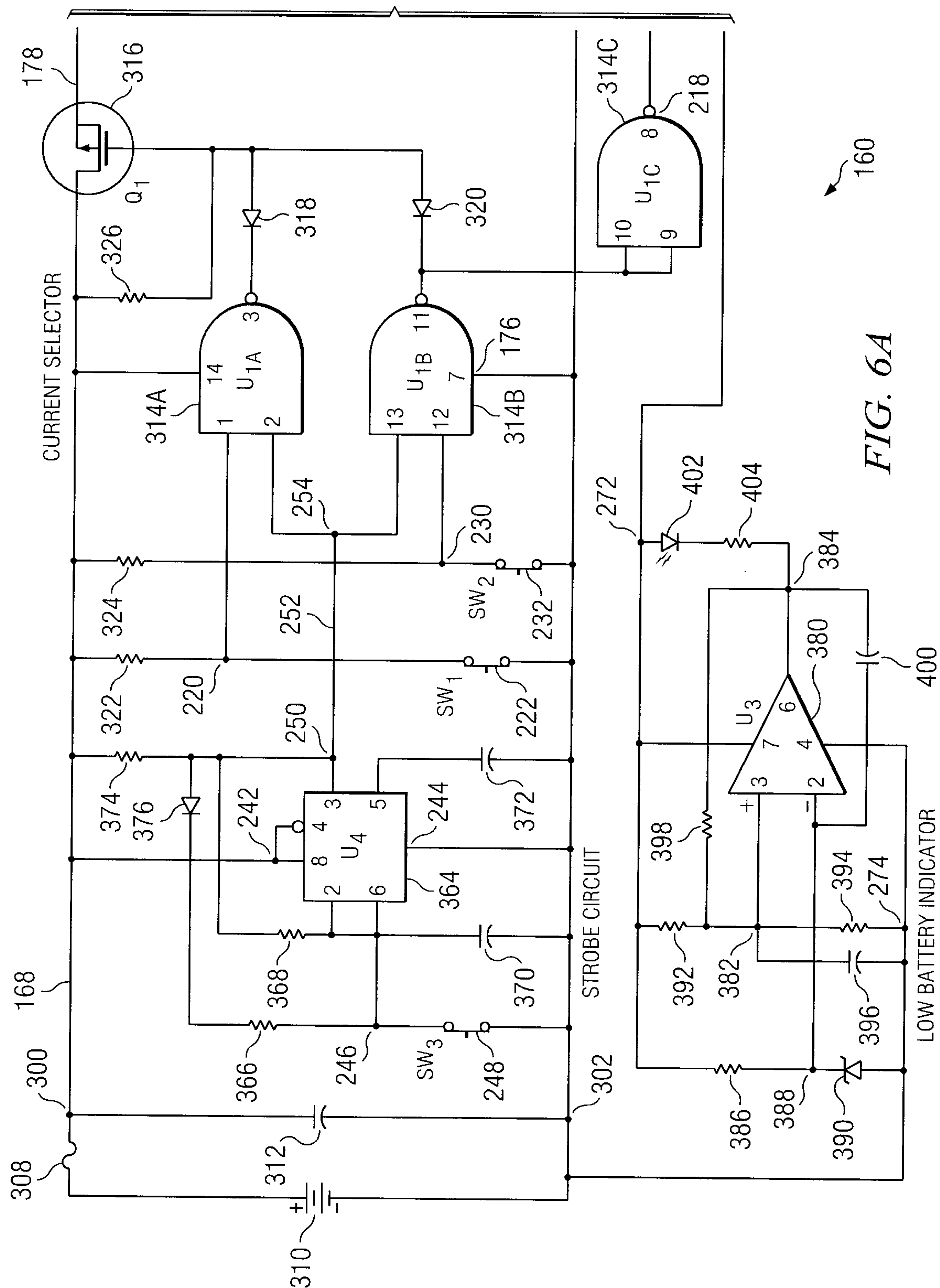


FIG. 5

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TO
FIG. 6B



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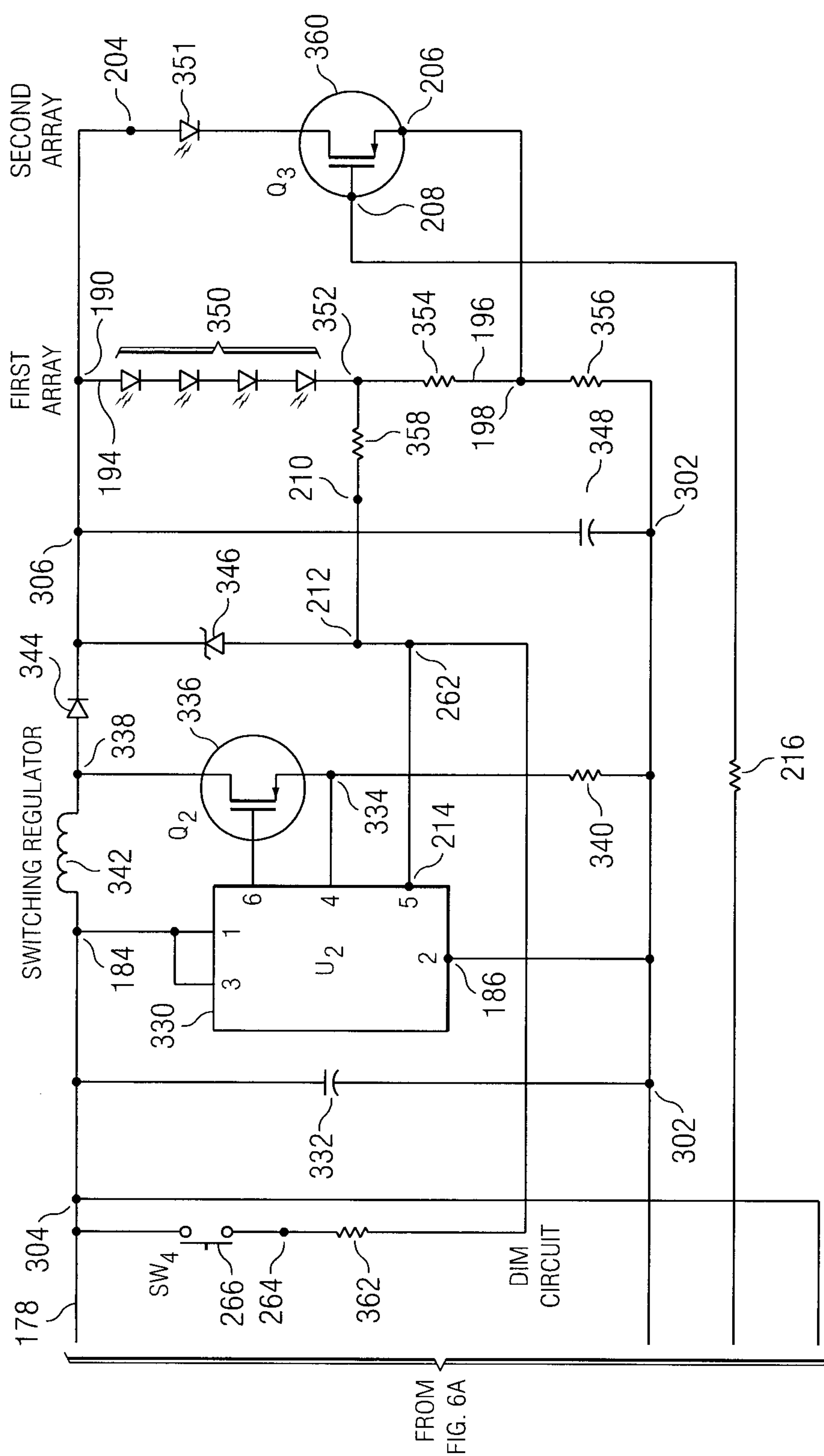


FIG. 6B

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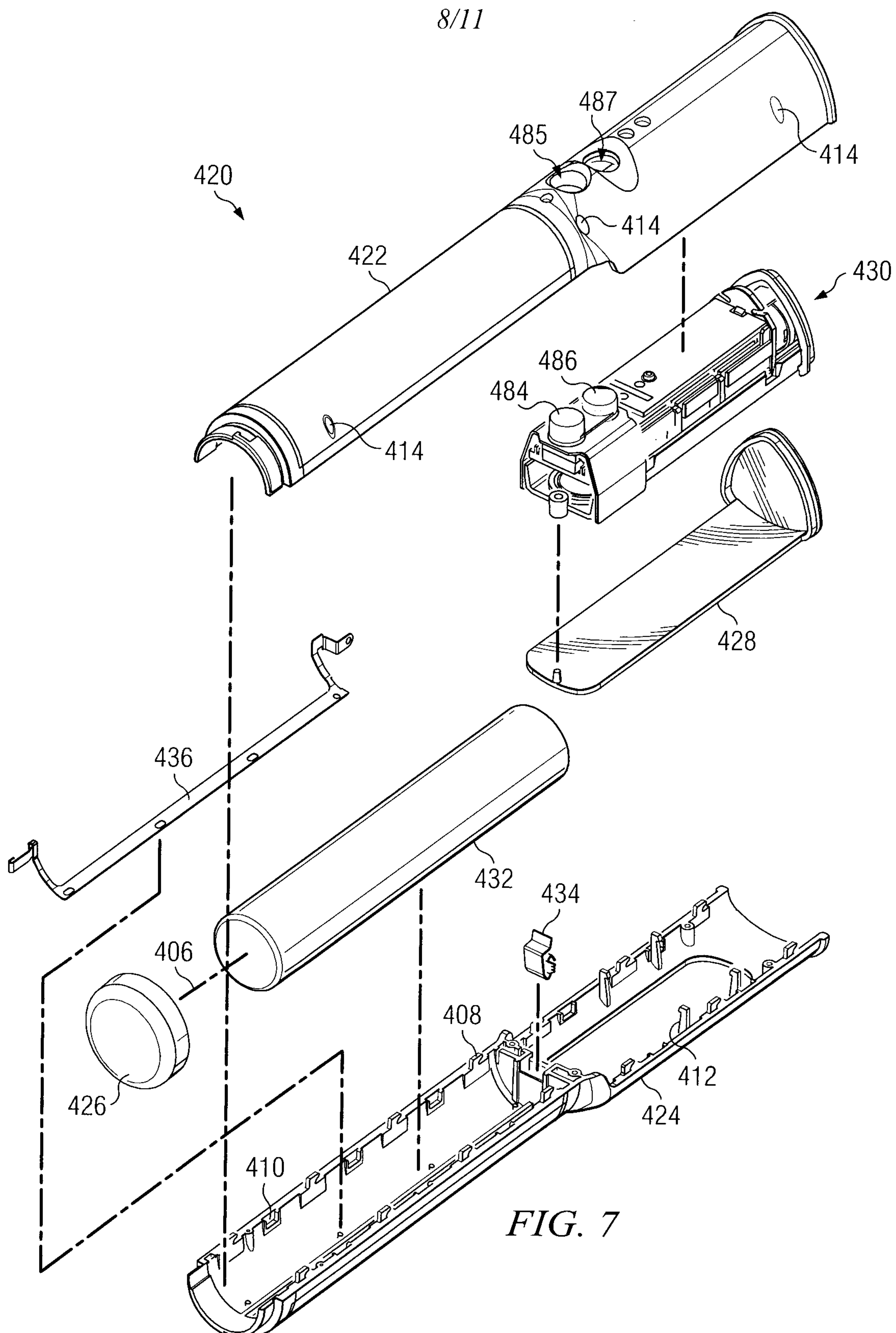
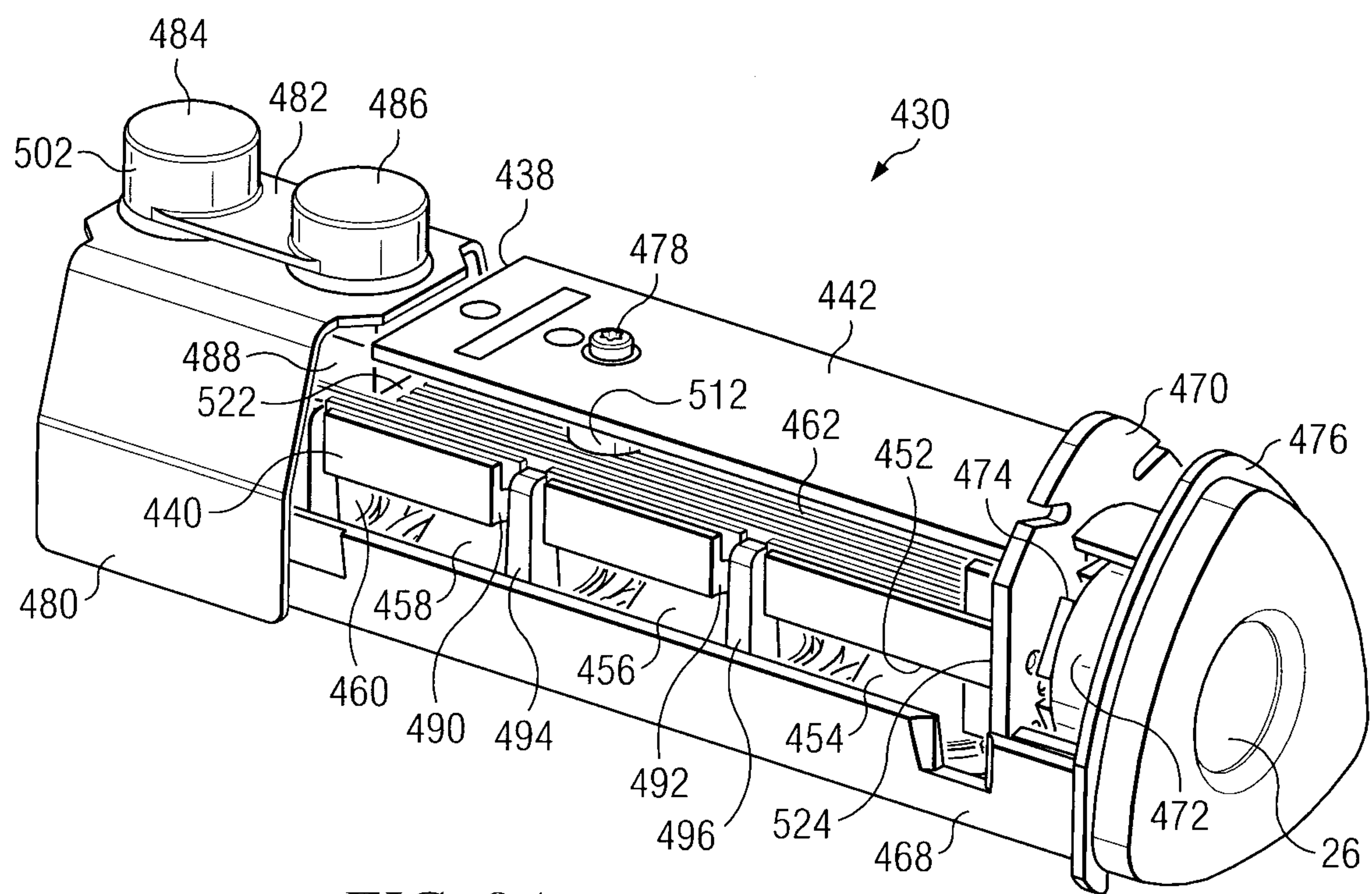


FIG. 7

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*FIG. 8A*

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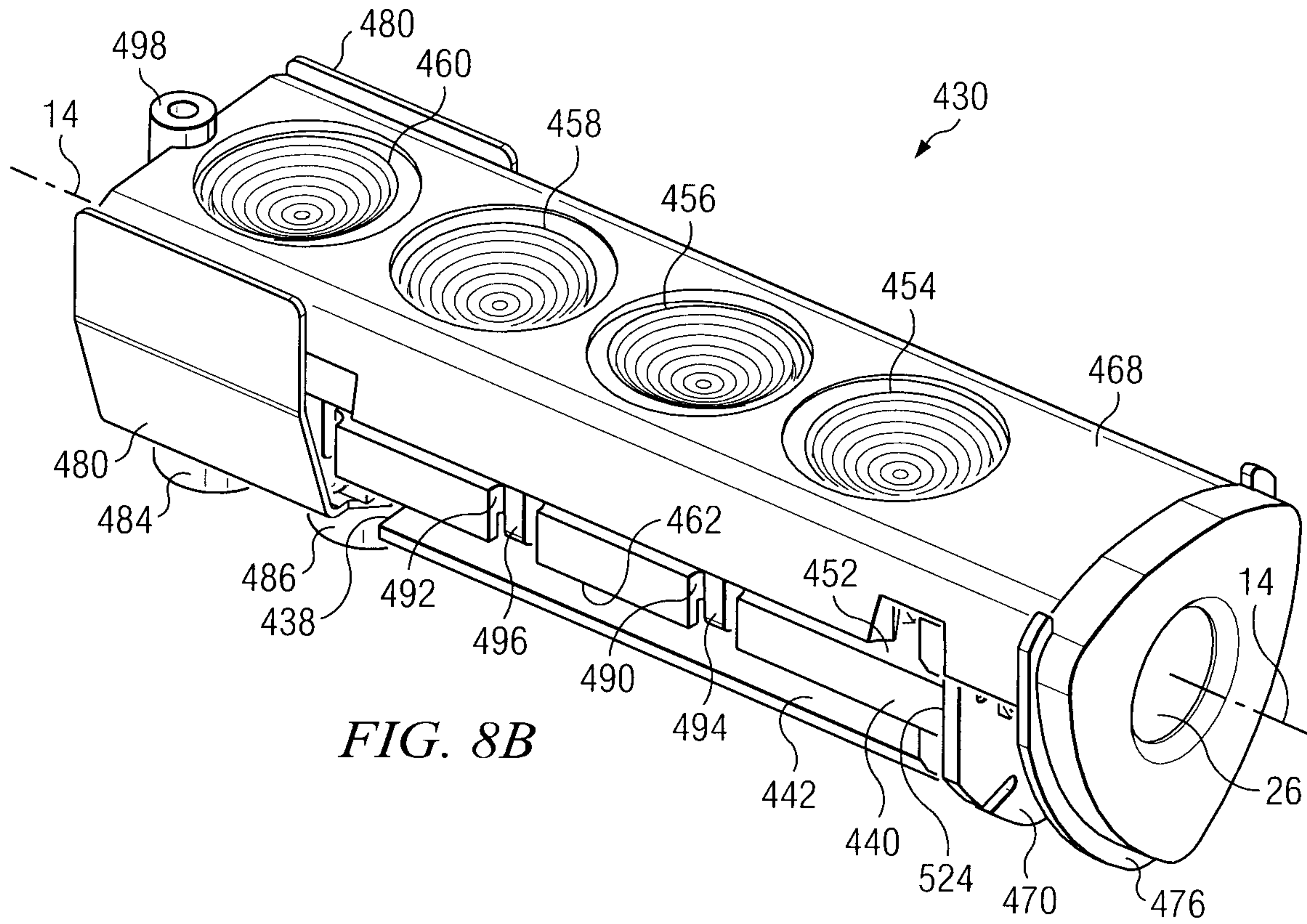


FIG. 8B

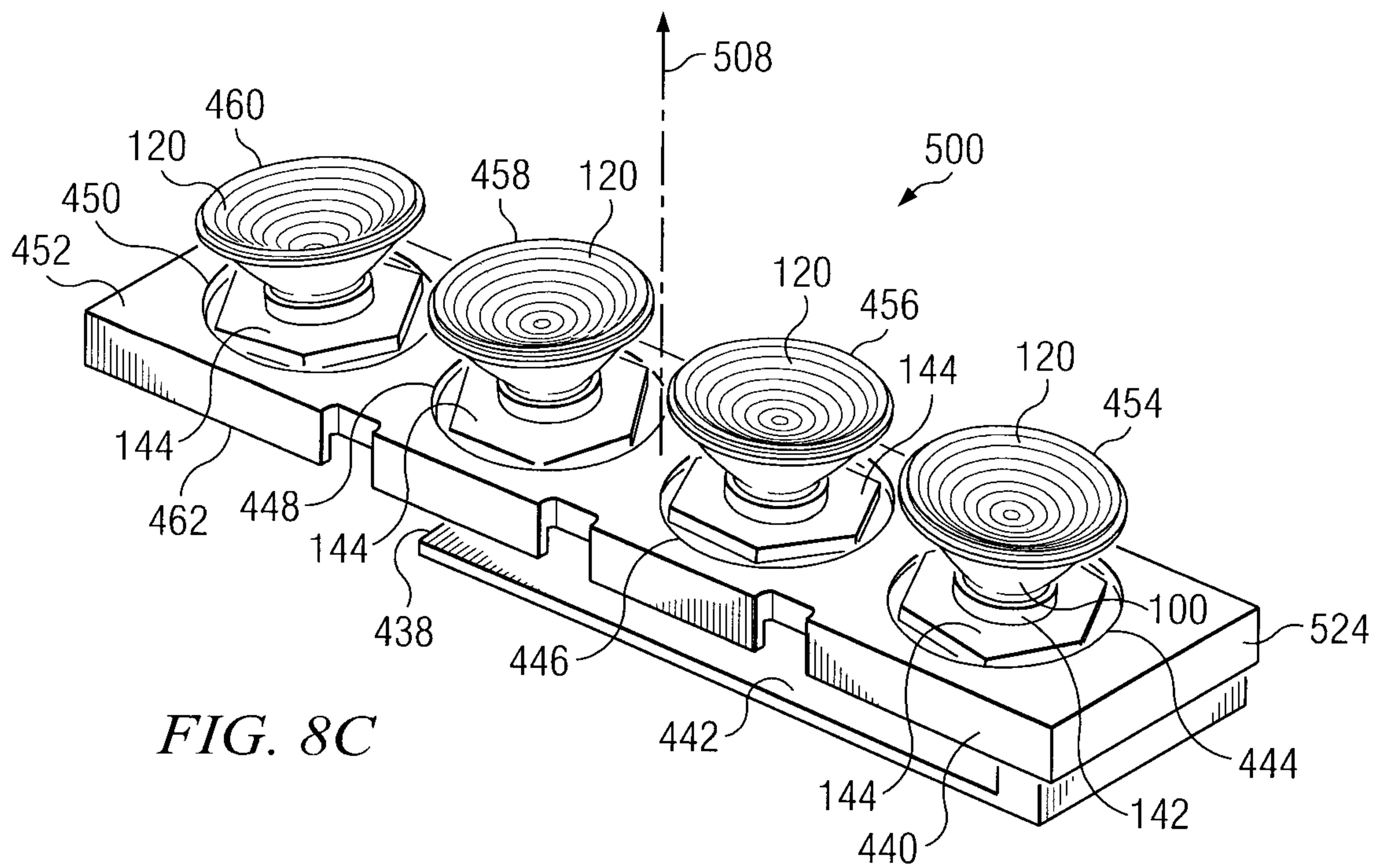


FIG. 8C

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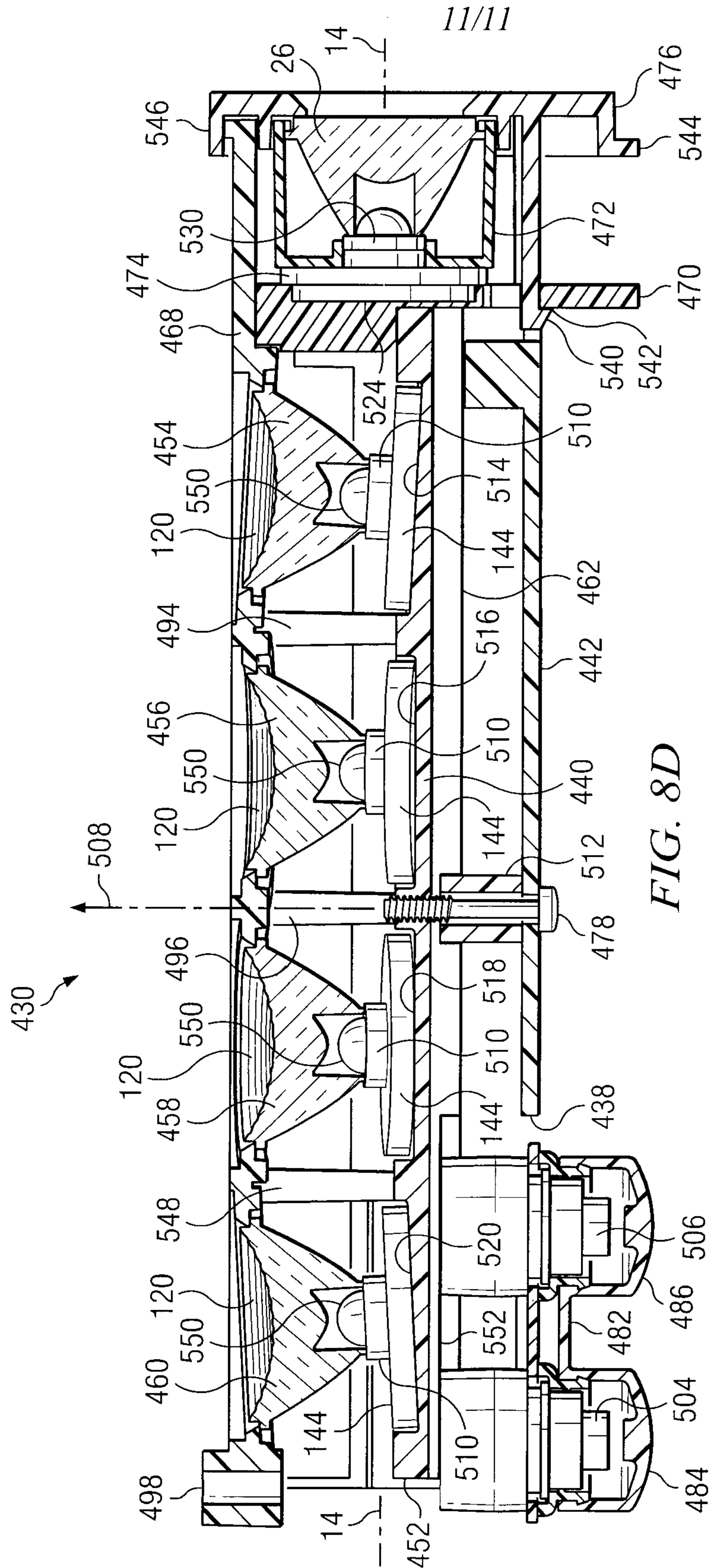


FIG. 8D

