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(54) Title: WEARABLE HEADLIGHT DEVICES AND RELATED METHODS

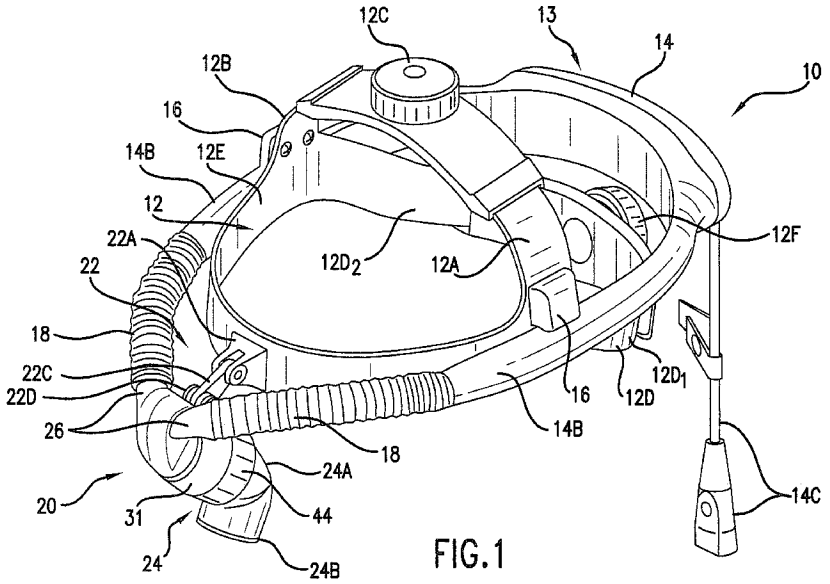

FIG.1

(57) Abstract: Wearable headlight devices and related methods are provided and can include a luminaire (20) that can include a housing (14) having a luminaire vent therein for receiving cooling air and a light source contained within the housing. An air moving device (30) can be located outside of the luminaire for facilitating cooling air intake through the luminaire vent. An exhaust tube (18) can be connected to the luminaire and the air moving device (30) to facilitate air flow of the cooling air between the luminaire and the air moving device.

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DESCRIPTION

WEARABLE HEADLIGHT DEVICES AND RELATED METHODS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of and priority to U.S. Provisional Patent Application Serial No. 61/414,739 filed November 17, 2010, and U.S. Patent Application Serial No. 13/069,288 filed March 22, 2011, the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The subject matter disclosed herein relates generally to headlights to be worn on a user's head to provide supplemental light. More specifically, the subject matter disclosed herein relates to wearable headlight devices and methods utilizing a light source such as a light emitting diode ("LED") devices.

BACKGROUND

Existing surgical headlights require a significant amount of light, approximately 400 lumens minimum for example, to provide sufficient illumination for a surgeon during a typical procedure. Surgical headlights must also be lightweight and typically weigh less than 400 grams for example, so that neck and head fatigue is minimized. To satisfy both conditions, the following architecture is utilized by most manufacturers: a remote Xenon light source is optically coupled to a fiber optic cable that transmits light energy to the luminaire which is mounted on a head wearable portion. The luminaire focuses the light and produces a spot of bright light typically 120mm in diameter at 400mm away from the luminaire. There are several disadvantages of this architecture. First, the surgeon is tethered to a large light source, which constrains his or her movement. Second, the light source takes up valuable room in the operating room. Third, the light source typically consumes about 380W of power. Fourth, the Xenon lamps are expensive and must be replaced periodically. Typical life is about 650 hours. Fifth, fiber optic cables are expensive, fragile and must be replaced periodically. Sixth, additional optical components and assemblies may be required for filtering out UV and IR.

LEDs are semiconductor devices that emit light by application of electrical power (watts). White light LED technology has advanced to the point where one LED can produce as much as 1200 lumens. This makes it a feasible light source for a surgical headlight luminaire. An LED surgical headlight can achieve light output and weight requirements. A problem however with LEDs is that they generate heat that must be addressed, and one of the major challenges LEDs pose in many applications is dissipating and/or removing the heat generated by an LED. Excess heat must be removed so that the semiconductor junction temperature does not exceed recommended maximum temperature. In addition, as the junction temperature of the LED rises, the efficiency also drops. LED light output is limited by its maximum heat junction temperature, so to increase light output without damaging the LED or reducing its operating efficiency, heat must be transferred quickly and efficiently.

There remains a need for improved headlight devices and methods that satisfy weight and light output expectations.

SUMMARY

It is an object of the present disclosure to provide novel headlight devices and methods, such as for surgical procedures for example, where the devices are efficiently cooled to maintain light output, efficacy (efficiency), reliability and life. It is another object to provide compact LED luminaire optics with enhanced light output.

A few objects of the presently disclosed subject matter having been stated hereinabove, and which are achieved in whole or in part by the presently disclosed subject matter, other objects will become evident as the description proceeds when taken in connection with the accompanying drawings as best described hereinbelow.

BRIEF DESCRIPTION OF THE DRAWINGS

A full and enabling disclosure of the present subject matter including the best mode thereof to one of ordinary skill in the art is set forth more particularly

in the remainder of the specification, including reference to the accompanying figures, in which:

Figure 1 illustrates a perspective view of an embodiment of a headlight device in accordance according to an embodiment of the subject matter disclosed herein;

Figure 2 illustrates an exploded view of the embodiment of the headlight device according to Figure 1;

Figure 3 illustrates a perspective view of an embodiment of an LED luminaire in accordance with the subject matter disclosed herein;

Figures 4A and 4B illustrate additional LED luminaire embodiments in accordance with the subject matter disclosed herein;

Figures 5A and 5B illustrate cross-sectional views along the length of the embodiments of the LED luminaire of Figures 4A and 4B to illustrate the internal configurations;

Figure 6 is a schematic cross-sectional view of an internal configuration of the luminaire embodiment of Figure 4B;

Figure 7 illustrates an exploded view of an embodiment of a light-emitting diode package in accordance with the subject matter disclosed herein;

Figure 8A illustrates a perspective view of an embodiment of a thermal conductive board that can be laminated to an embodiment of a printed circuit board ("PCB") used in the embodiment of the light-emitting diode package according to Figure 7;

Figure 8B illustrates a perspective view of an embodiment of the PCB used in the embodiment of the light-emitting diode package according to Figure 7; and

Figure 9 illustrates a perspective view of an embodiment of an optical construction or configuration that can be used in an embodiment of a luminaire in accordance with the subject matter disclosed herein; and

Figure 10 illustrates a schematic diagram of an embodiment of components that can be used to control the temperature of a light source in accordance with the subject matter disclosed herein.

DETAILED DESCRIPTION

Reference will now be made in detail to the description of the present subject matter, one or more examples of which are shown in the figures. Each example is provided to explain the subject matter and not as a limitation. In fact, features illustrated or described as part of one embodiment may be used in another embodiment to yield still a further embodiment. It is intended that the present subject matter cover such modifications and variations.

As noted above, improved headlights, such as wearable surgical headlights, and methods are disclosed herein that can utilize light emitting devices, such as for example light emitting diodes (LEDs). The use of LEDs in a wearable headlight device as disclosed herein has advantages over conventional Xenon based wearable headlights. For example and as disclosed in further detail herein, an LED headlight can be powered by a portable battery pack worn by the user, thus allowing freedom of movement. Also, an LED headlight does not require a remote light source since the LED can be integrated into the luminaire. Additionally, an LED headlight can consume for example only about 5% (20W) of power utilized by a Xenon light source. LED life can advantageously be for example up to 50,000 hours depending upon drive current and operating temperature. Finally, LED headlights do not require fiber optic cables, and white light LEDs advantageously do not generate significant amounts of UV or IR.

Figures 1 and 2 show a wearable headlight device generally designated **10** in accordance with some embodiments of the subject matter disclosed herein. Headlight device generally designated **10** can comprise a luminaire **20**. Headlight device **10** can optionally comprise a head wearable portion generally designated **12** with luminaire **20** attached to head wearable portion **12** as shown in Figures 1 and 2. Headlight device **10** is thus a medical device that can for example and without limitation be worn on a surgeon's head to provide supplemental light for surgical and medical procedures, whenever supplemental illumination, especially shadow-free coaxial illumination, is desired or required to facilitate a surgical or medical procedure. The intended user for headlight device **10** can be, for example, physicians, surgeons and other trained, qualified medical professionals providing medical or surgical

assistance. Intended patients can be any individuals undergoing surgical or medical procedures where additional illumination is deemed necessary by a practitioner performing a procedure.

Head wearable portion **12** can be plastic and can be configured to attach to and securely position one or more devices and can be adapted to be worn on a user's head. It is commonly configured and referred to as a headband. Head wearable portion **12** can comprise overhead straps **12A** and **12B** that can form an arch that can rest upon a top portion (or crown) of the head of the user. Head wearable portion **12** can be adjustable to fit the head of the user. For example, adjuster **12C**, such as a ratchet knob, can be used to adjust the position of overhead straps **12A** and **12B** relative to one another. For instance, if adjuster **12C** is rotated in a first direction, then overhead straps **12A** and **12B** can be pulled closer together to accommodate a smaller crown of the head. If the adjuster **12C** is rotated in a second direction opposite the first direction, then overhead straps **12A** and **12B** can be pushed away from each other to accommodate a larger crown of the head.

Head wearable portion **12** can comprise a rear headband portion **12D** and a front headband portion **12E**. As shown in Figures 1 and 2, rear headband portion **12D** can comprise two straps $\mathbf{12D_1}$ and $\mathbf{12D_2}$ and rear headband portion **12D** can also be adjustable. Rear headband portion **12D** can comprise an adjuster **12F** that can be used to adjust the position of straps $\mathbf{12D_1}$ and $\mathbf{12D_2}$ relative to one another to adjust to the head size of the user. For instance, if adjuster **12F** is rotated in a first direction, then straps $\mathbf{12D_1}$ and $\mathbf{12D_2}$ can be pulled closer together to accommodate a smaller head. If the adjuster **12F** is rotated in a second direction opposite the first direction, then straps $\mathbf{12D_1}$ and $\mathbf{12D_2}$ can be pushed away from each other to accommodate a larger head. Thus, with the adjustability for both the crown and the head size of the user, head wearable portion **12** can be comfortably conformed to the user's head. Head wearable portion **12** can utilize replaceable/disposable foam pad sets for front headband portion **12E**, rear headband portion **12D**, and overhead straps **12A** and **12B** for respectively padding the forehead, back and crown of

the user. Headband pads can attach to the headband via a hook and loop system.

A luminaire generally designated **20** can be located along front headband portion **12E** of head wearable portion **12**. For example, a connector generally designated **22** can be used to hold luminaire **20** to front headband portion **12E** so that luminaire **20** can be positioned between the eyes of the head of the user. Connector **22** can include a connector base **22A** that can be rigidly attached to front headband portion **12E** by fasteners **22B** shown for example in Figure 2. A connector link **22C** can be rotatably connected to connector base **22A** on one end and rotatably connected to a connector receiver **22D** on luminaire **20**. Since connector receiver **22D** can be moved relative to the connector base **22A** through the rotatable connections with connection link **22C**, luminaire **20** can be moved relative to head wearable portion **12** and when in use, relative to the head of the user. In some embodiments, one or more links can be used. For example, connector link **22C** can be rotatably connected to connector base **22A** on one end and rotatably connected to a second link (not shown) that is rotatably connected to connector receiver **22D** on luminaire **20**. In such embodiments, increased rotation of luminaire **20** may be achievable. The position and orientation of luminaire **20** can thus be adjustable with force by the user but remain fixed during intended use.

Luminaire **20** can also comprise a luminaire housing **24** to contain the components of luminaire **20**. Luminaire housing **24** can comprise one or more venting tubes such as venting tubes **26** at a top end that can be distal from an outer lens **42** (Figure 3) of luminaire **20**. Venting tubes **26** can be used to vent or express hot air out of luminaire housing **24**. For example, head wearable portion **12** as shown in Figure 2 particularly can also comprise a controller **13** that can comprise a controller housing **14** that can hold a controller board **14A**. Controller housing **14** can also house an air moving device **30**, such as a fan, that can create an airflow. Thus, an active cooling system for headlight device **10** can include one or more exhaust tubes **18**, which can be or can include some flexible portion or portions, and controller housing **14** with air moving

device **30**, such as an exhaust fan. Controller **13** can also be located in any other suitable location and even not attached to head wearable portion **12**. In some embodiments, a single exhaust tube **18** can be provided to facilitate the airflow through and away from luminaire **20**. For example, a single exhaust tube **18** can run along a side or over a top portion of head wearable portion **12**.

While headlight device **10** is described with a head wearable portion that is separate from exhaust tubes **18**, in some embodiments, the exhaust tubes, such as exhaust tubes **18**, can comprise the head wearable portion. In such embodiments, exhaust tubes **18** can be rigid enough to hold luminaire **20** and control housing **14** on a head of a user. Luminaire **20** can be connected to exhaust tubes **18** to permit airflow to pass from luminaire **20** to exhaust tubes **18**, while also allowing luminaire **20** to be adjustable relative to exhaust tubes **18**.

Controller housing **14** can extend outward from head wearable portion **12** above rear headband portion **12D** and can be constructed, for example, of Radel® high temperature, UL94 VO engineering resin. Controller housing **14** can be the just the back portion in which controller board **14A** resides or both the front and back portions shown in Figure 2. Controller housing **14** can include air flow tubes **14B** that can be rigid and can be in fluid flow communication with air moving device **30**. Control housing **14** can be secured to head wearable portion **12** in a variety of manners. In the embodiment shown in Figures 1 and 2 for example, connectors **16** that can include fasteners **16A** can be used to secure controller housing **14** to overhead straps **12A** and **12B**. As shown, connectors **16** can be located respectively above a portion of air flow tubes **14B**. The one or more venting tubes **26** can be connected to air flow tubes **14B** by exhaust tubes **18**. Exhaust tubes **18** can be flexible to permit movement of luminaire **20** relative to head wearable portion **12**. Thus, through an airflow created by air moving device **30**, hot air can be pulled from luminaire housing **24** through the one or more venting tubes **26** and exhaust tubes **18** to air flow tubes **14B**. From air flow tubes **14B**, the air is pulled out and through air moving device **30**.

Controller housing **14** can also include a power connector **14C** that can be connected to a power supply to supply power to control board **14A** and air moving device **30** in controller housing **14**. Further, connector **14C** can also supply power to luminaire **20**. Both the cooling system and the power supply system are described further below.

As shown in Figure 3, luminaire **20** can comprise outer lens **42**. As shown in Figures 1, 2, 3, 4A and 4B, luminaire **20** can also comprise an iris controller **44** which can be rotatable relative to luminaire housing **24** for controlling the degree of dilation or constriction of an iris **60** (see Figures 5A, 5B, 6, and 9) within luminaire **20**. Iris controller **44** can comprise an exterior wheel to control the opening of iris **60**. Iris controller **44** can have an instrument feel provided by oring or wave spring, for example, to enhance the gripping of iris controller **44**. Luminaire housing **24** can also comprise an angled back **24A** that can reside below the portion of the housing in which LED light source **50** described further below resides. A mirror (Figure 9) can reside on an interior portion of angled back portion **24A** to angle the light generated by LED light source **50**. Luminaire housing **24** can also comprise an outer lens housing **24B** that extends outward from luminaire housing **24** and angled back portion **24A**. Outer lens housing **24B** can have outer lens **42** reside therein.

Luminaire housing **24** can comprise a suspension ring **31** that can include a luminaire skirt **31A**. Connector receiver **22D** can extend from suspension ring **31** to provide connection to head wearable portion **12** as described above. Luminaire housing **24** can also comprise luminaire vents. Luminaire vents can be constructed in many ways as apparent to a person skilled in the art. For example, luminaire housing **24** can include a vent ring **34A** (see Figure 4A) or **34B** (see Figure 4B). In Figure 4A, vent ring **34A** can have luminaire vents **36A** that are visible. Alternatively, as illustrated in Figure 4B, vent ring **34B** can have luminaire vents generally designated **36B** that can be constructed so luminaire skirt **31A** covers the luminaire vents **36B** so that an individual viewing the front of the luminaire cannot see vents **36B**. Above the suspension ring **31**, luminaire housing **24** can also comprise a vent tube portion that can include one or more venting tubes **26** as described previously.

As shown in Figures 5A, 5B and 6, luminaire **20** can comprise a light source **50**, a heat sinking device, or heat sink **52**, and optics **40** (see Figure 9 including iris control **44** in Figures 5A, 5B and 6) within the luminaire housing. Light source **50** can comprise one or more different or identical light sources, such as light bulbs, light-emitting diodes (LEDs), lasers, and the like. In the embodiments shown for illustration purposes, light source **50** can comprise an LED light source, which can comprise one or more LEDs. Heat sink **52** can reside in a heat sinking chamber in suspension ring **31** and can be in thermal communication with LED light source **50**. For example, heat sink **52** can be in direct contact with LED light source **50** or a thermal conductive material may reside between LED light source **50** and heat sink **52**.

As discussed above, the cooling system for luminaire **20** can comprise luminaire vents **36A**, **36B** or intake vents located within luminaire housing **24**. Luminaire vents **36A**, **36B** can receive cooling air that can pass over heat sink **52** and can be discharged from luminaire housing **24** through the one or more venting tubes **26** to a location outside of and away from luminaire **20** and heat sink **52**. As described above, air can be pulled and flow through luminaire vents **36A**. **36B**, over the heat sink to dissipate and remove heat through venting tubes **26** and exhaust tubes **18**. From there, the air that has now been heated by the heat sink can be pulled and flow through air flow tubes **14B** and through air moving device **30**. Air moving device **30** can generate the air flow that pulls air through the luminaire vents **36A**, **36B** and through air moving device **30**, expelling the heated air away from the head of the user. In some embodiments of the present subject matter, LED cooling can achieved by an air moving device **30** that comprises, for example, a Sunon® 1 Watt fan. Controller board **14A** can provide a thermal cut out that can shut down LED light source **50** if it overheats as described further below. The brightness of LED light source **50** can be controlled by controller board **14A** varying the current supplied to LED light source **50**.

As described previously, controller housing **14** can also have controller board **14A** residing therein which can control and/or adjust the operation of air moving device **30** and light source **50**. For example, controller housing **14** can

house a thermostat, a switch for a power supply, and switch for air moving device **30**. In such an embodiment, where the thermostat is in the controller housing **14**, a temperature sensor can be disposed in proximity to light source **50**. In one aspect, a thermostat **T** can be in proximity of the light source **50** as shown schematically in Figure 10. Wiring **53** can pass from controller board **14A** and connector **14C** through air flow tubes **14B**, exhaust tubes **18**, and venting tubes **26** to light source **50** to supply power to LED light source **50** and to provide communication to control and adjust the light output from light source **50**.

As shown in Figures 7, 8A and 8B, LED light source **50** can comprise an LED lens **50A** that can resides and be disposed over a mounting pad that can include electrical traces and the diodes (not shown) that will emit light when powered. The mounting pad and electrical traces can reside on a substrate that can form an LED base, or slug, **50B**. A printed circuit board (PCB) **54** can be electrically connected to LED **50**. PCB **54** can have an opening **54A** therethrough. A thermal conductive board, or heat sink pad, **56** can be laminated to PCB **54**. Thermal conductive board **56** can comprise a protrusion **56A** that can extend up through opening **54A** in PCB **54** and can be soldered directly to LED base **50B**. In some embodiments, thermal conductive board **56** and protrusion **56A** can be a conductive metal such as copper for example. Thermal conductive board **56** can be secured to heat sink **52** in a manner that will facilitate thermal transfer from thermal conductive board **56** to heat sink **52**.

A method of heat transfer from LED light source **50** that can be used in headlight device **10** to efficiently transfer heat energy from LED **50** can be conduction from LED base **50B**. Light output from LED light source **50** can be limited by its maximum heat junction temperature. To increase light output without damaging LED light source **50** or reducing its operating efficiency, heat can be transferred quickly and efficiently by reducing the thermal resistance at LED base **50B** so that the heat transfer rate can be increased. Copper protrusion **56A** can extend up through opening **54A** in PCB **54** and can be soldered directly to LED base **50B**, thereby greatly reducing thermal resistance. By soldering LED base **50B** directly to copper protrusion **56A** that extends

from copper thermal conductive board **56**, the thermal resistance can be greatly reduced. In some embodiments, LED light source **50** and heat sink **52** located inside of the luminaire can be in direct thermal contact with each other. To provide more surface area to remove heat from heat sink **52**, heat sink **52** can comprise a plurality of projections **52A** that extend from a back surface of heat sink **52** away from LED light source **50**.

PCB **54** is shown in Figures 7, 8A and 8B as two pieces for clarity. Thermal conductive board **56** can be a copper piece and can be laminated to board **54**, which can be a polyamide or FR4 board using epoxy laminating process common in the PCB industry. Protrusion **56A** can extend up through opening **54A** in PCB **54** and soldered directly to LED base **50B** of LED light source **50**. Direct soldering of LED solder pad to copper core board may yield a low thermal resistance, and thus a low junction temperature. This thermal cooling design enables LED light source **50** to generate more lumens in response to receiving more cooling, as compared to an LED receiving cooling from a heat sink that is not in direct thermal contact with the LED.

Optics **40**, shown in Figure 9, can provide an arrangement of optical components within the luminaire designed to efficiently capture light from LED light source **50** and to project the light with high quality characteristics along an axis that is at least proximate to being parallel to the line of sight of the wearer. These high quality characteristics can include projection of a pre-determined and adjustable light spot size at a particular distance from the wearer that can be substantially free of cosmetic defects (artifacts) and that can be projected in a direction and with a well-defined edge to limit shadowing and collateral glare.

Figures 5A, 5B, 6 and 9 illustrate LED luminaire optics **40** and its components in accordance with an embodiment of the subject matter disclosed herein. Optics **40** can be based on the principle of Koehler illumination and can comprise one or more condensing lens **43**, **45** and one or more objective lens **42**, **46** with iris **60** and folding mirror **48** placed in between. In the embodiment shown in Figures 5A, 5B, 6 and 9, a first condensing lens **43** is positioned proximate to lens **50A** of LED light source **50** to maintain a compact and cost effective format. First condensing lens **43** can be constructed from high index

glass. A second condensing lens **45** can be placed below and proximate to first condensing lens **43** to provide a doublet of elements. Second condensing lens **45** can also comprise high index glass, for example, Schott LaSFN 31 or optical equivalent. To maximize collection efficiency, the first condensing lens **43** can be placed in close proximity to the LED dome or lens **50A** and can be shaped as a meniscus lens. The optical design can feature a high curvature meniscus lens located a distance, for example, of about 0.25mm, from the LED dome for maximum light collection. The function of condensing lenses **43**, **45** can be to efficiently collect light (represented by the lines and arrows in Figure 9) from LED light source **50** and back-illuminate an iris **60** with a beam that has a uniform light distribution and can be properly sized to an opening in iris **60**.

To maintain a compact cost effective optics format, objective lenses can comprise first objective lens **46** and second (or outer) objective lens **42** to provide a split doublet. The light can pass through iris **60** toward first objective lens **46** which directs or focuses the light toward folding mirror **48**. First objective lens can comprise high index glass as well. The light can reflect off of folding mirror **48** at an angle toward outer objective lens **42** which can provide a light beam focused in the manner desired by the user. Second, or outer, objective lens **42** can also comprise high index glass. The function of first objective lens **46** and second (or outer) objective lens **42** can be to project the image of the iris opening at the prescribed spot diameter, with a high degree of light uniformity, no objectionable artifacts inside or outside the spot, and with good edge definition across the entire range of working distances and iris openings.

As shown in Figure 9, condensing lens **43** captures and focuses the light from LED light source **50** toward larger condensing lens **45** which in turn focuses the light through iris **60**. Particular attention can be paid to the selection of glasses and lens curvatures that yield a minimal amount of lateral chromatic aberration at the edge of the spot. The luminaire can utilize a classic Koehler optical design (projector optics) with an optical efficiency of, for example, about 71 %.

The compact LED luminaire optics **40** shown in Figure 9 particularly can be optimized with respect to one or more of the following factors: (1) large LED die combined with wide beam angle; (2) high collection efficiency in a compact and lightweight luminaire system; (3) simplicity of the optics train (minimal number of optical components including an adjustable iris diaphragm and a folding mirror); (4) high spot quality (uniformity and light output) at the prescribed working distance, for example, about 16 inches and for the full range of prescribed working distances, for example, about 10 inches to about 25 inches; and (5) a projected spot that does not have a "memory" of the square shape of LED light source **50** or its surface structure.

Headlight device **10** can be configured for either battery powered or direct powered use. For example, headlight device **10** can be configured for direct power and battery power, respectively. Such a headlight device can be designed to provide illumination to aid visualization during minor surgical, diagnostic, or therapeutic procedures.

Headlight device **10** can be a self-contained headlight system that can be operated using either battery or direct power supply. Using a battery pack **76** (see Figure 2) can give a surgeon complete portability allowing unrestricted movement in and around the operating suite. Power can for example be supplied by a medical grade 12VDC, 3.0A power supply. The direct power supply option **72** and **74** (see Figure 2) can be used as a primary power source for unlimited operating time, or as a back-up to the battery system. A 15VDC supply can power a linear power supply which can power LED light source **50** and air moving device **30**.

When headlight device **10** is powered by rechargeable battery packs, controller board **14A** can monitor the remaining battery power available and can provide both audible and visual feedback to the user. For example and without limitation, a five segment LCD bar display on the battery **76A** can provide visual feedback to the user representing its remaining charge status (0% to 100% in 20% increments). An audible notification can also be delivered to the user when a low battery condition is detected. A three-tone cycle can sound at approximately fifteen minutes of charge remaining and can be

repeated every three minutes to notify the user that a new battery pack generally designated **76** can be inserted or that a direct power supply can be attached to headlight device **10**.

Regarding power supply as mentioned previously, headlight device **10** can support AC line input. In some embodiments, as explained below, AC power supply can be connected to a transformer that converts the power supply to a DC power supply with a power connector **14C** of headlight device **10** being connected to the transformer. AC (wall power) operation option can include 3 distinct components: AC Power Cord **70** (see Figure 2), Medical Grade Switching Power Supply, and a replaceable low voltage power cord (not shown). AC Power can be delivered through a detachable country specific AC power cord **70** as shown in Figure 2 connecting to a medical grade power supply using standard IEC connector **70A** and a wall plug **70B**. AC power cords can include USA/JAPAN, UK, EU, AUSTRALIA, style connectors. AC Power cord length can be any desirable length, for example, about 8 feet +/- about 2 feet.

In some embodiments, connector **14C** can be a DC output side of a power supply and can have a 20 inch output cable with a connector for mating to headlight device **10**. In this manner, a power supply can be connected to headlight device **10** via a robust low voltage DC power cord **72**. The length of power cord **72** can be any desirable length that will allow for desired movement of the user, for example, about 20 feet. Low voltage DC power cord **72** can terminate in connector end **72A** and connector end **72B**. Connector end **72B** can be plugged into a connector on a transformer **74** or an umbilical cord (not shown) in transformer **74**. The umbilical cord can also be any desirable length. Connector end **72A** can be electrically connected with connector **14C** extending from controller housing **14**. Low voltage DC power cord **72** can be capable of withstanding heavy abuse including frequent crushing forces caused by foot traffic and being rolled over by wheeled medical devices to maintain electrical safety and conductivity. Low Voltage DC power cord **72** from the power supply to headlight device **10** can be flexible enough to facilitate easy coiling into a coil. Electrical connections from DC power cord **72** to headlight device **10** and

connector **14C** can be polarity non-specific. For example, controller **14A** can determine polarity and compensate for either condition. DC electrical connections can be robust, securely locking into place and capable of 3000 cycles without producing electrical intermittence and reduction in insertion/retention forces to less than about 3 lbs. Controller **14A** can have connector **14C** connected thereto. Connector **14C** can comprise have a low voltage DC cable terminating in a connector for connection to a battery and holster or DC power supply cable.

In addition to or alternatively, headlight device **10** as shown in Figure 2 for example can include a battery system **76** that can comprise a battery **76A**, a connection cable **76B** and a battery holster **76C**, as well as battery charger (not shown). Connection cable **76B** can comprise a low voltage DC cable terminating in a connector $\mathbf{76B_1}$ for connection to connector **14C**. Cable **76B** and connector $\mathbf{76B_1}$ can be the same as is used on the switching power supply that switches AC current to DC current. The circuitry in battery holster **76C** can provide an Audible Low Battery Warning function. The targeted volume of the tone can be loud enough to be heard in a busy operating room without being a distraction and can operate at different hertz and for different amounts of time to help indicate the level of battery power still available. Tones measured by an external microphone can approximate a sine wave. Battery **76A** can have a charge state indicator **76D**, such as a Liquid Crystal Display (LCD) Fuel Gauge. The battery charger (not shown) can be, for example, an INSPIRED ENERGY® single bay charger.

The color temperature for LED light source **50** can be set for the luminaire **20** based on the LED package used. Color temperature variability can be defined by standard binning by LED manufacturer. IR content can be a low percentage of total light output as measured from the luminaire. In one aspect and for example, UV content can also be a low percentage of total light output as measured from the luminaire. The light output of LED light source **50** can vary based on use and the LED package used within Luminaire 20. For example, the light output of LED light source **50** can be in one aspect no less than about 350 lumens at full power.

Iris **60** can have different numbers of leafs to provide adjustability for dilation or constriction of iris **60**. Iris **60** can be, for example, a 10 to 12 leaf iris that can provide a varying illumination spot diameter. The peak illuminance of the luminaire large spot can vary depending on the user's preference and the LED package used on luminaire **20**. The peak illuminance of the luminaire large spot can be bright enough to be used in surgery. The spot can advantageously have no perceptible dark center. The design of luminaire **20** can minimize objectionable artifacts outside or inside the illumination spot. Headlight spot quality and spot definition at a normal working distance (about 16 inches) can be preserved through entire excursion of light source dimmer.

Headlight device **10** can include different settings for the level of intensity of the light generated by light source **50**. Depending on the needs of a user, a wide range of settings for the level of light intensity can be employed. For example, in one aspect headlight device **10** can have a 4 position rotary switch (Off, Low, Med, and High) (not shown). Such a switch can be located on head wearable portion **12** and be easily accessible to the right hand of the user as well as to an attendant. Luminaire **20** and headlight device **10** can automatically switch to the low setting for the level of light intensity in the event of overheating. If overheating continues in a low setting, headlight device **10** can switch to a lower level default mode. Controller housing **14** can house a thermostatically controlled cooling fan that can be calibrated to maintain luminaire housing **24** that houses LED light source **50** at a predetermined temperature.

For example, as shown in Figure 10, a temperature sensor **T**, such as a thermostat for example, can be disposed at least proximate or in contact with LED light source **50** to measure or determine the temperature of LED light source **50**. Temperature sensor **T** can be electrically connected to, or at least in communication with, controller **13** and/or air moving device **30**, such as a cooling fan. Alternatively, temperature sensor **T** can be electrically connected to, or at least in communication with, controller **13** and controller **13** can be electrically connected to, or at least in communication with, air moving device **30**. As the temperature sensed by the temperature sensor **T** changes,

controller **13** can automatically control temperature of LED light source **50**. For example, controller **13** can automatically control the speed of air moving device **30**, and thus the speed of airflow generated thereby. Further, controller **13** can automatically control an intensity of the light from LED light source **50**. These measures can facilitate control of the temperature of LED light source **50**, as described further below.

Headlight device **10** can in one aspect have a weight that can be less than or equal to about 400 grams with a target weight of about 330 grams. Headlight device **10** minus the padding can be cleaned with common cleaning and disinfection agents used in hospitals, e.g. 70% isopropyl alcohol and CAVICIDE® wipes. Sterilization may not be required. Headlight device **10** can be designed to hold up to normal every day handling in the operating room environment, including for example being dropped onto a tile floor from at least three feet. Gown clips can be supplied with each headlight device **10** to securely attach the electric cord to the surgical gown. All materials can be latex free.

LED headlight device **10** typical use can for example be four or more surgeries per day with about an hour per surgery average for about five days per week. For such average use, headlight device **10** can provide reliable service for at least three or more years. Headlight device **10** can comprise one luminaire and optionally head wearable portion, two battery packs, one battery holster, one battery charger with power supply, one AC power supply, one DC cable, and accessories and replacement parts.

Controller board **14A** in headlight device **10** can include software to control the intensity of light generated by LED light source **50** and air moving device **30**, such as a cooling fan, that draws air at a very low flow rate through vents **36A**, **36B** on the side and back of luminaire **20** thereby cooling LED light source **50** as necessary. The software can reside for example in controller board **14A**. There can also be software located in battery pack **76** that can provide audible notification to the user when the battery charge remaining is nearing its end.

The software can be a computer readable medium and can provide certain functionalities to controller board **14A** of headlight device **10**. The software can allow controller board **14A** to be able to read the temperature of LED light source **50** to within a small temperature range. The software can allow controller board **14A** to detect an open circuited LED temperature sensor as indicated by a temperature reading of below a predetermined temperature, for example, below freezing. The software can allow controller board **14A** to be able to detect an over-temperature condition or a short circuited LED temperature sensor as indicated for example by a temperature reading above a predetermined temperature. The software can allow controller board **14A**, upon detection of an out of range temperature condition, for example, temperatures outside of a range between the temperature below the temperature indicating an open circuited temperature sensor and the temperature indicating an over-temperature condition to be able to put LED light source **50** into a fault condition that is below the lowest setting of the level of light intensity for headlight device **10**, set the fan to its lowest speed, and/or lock the system from use until the power is cycled.

The range operating temperatures of headlight device **10** can vary depending on the LED package used and the desired need for energy efficiency and light output. During a low normal operating LED temperature range, the software can allow controller board **14A** to automatically set air moving device **30** to a minimum speed. During a midrange normal operating LED temperature range, controller board **14A** can automatically vary the speed of air moving device **30** ranging from a low speed to a high speed and proportional to the temperature. Thus, at this midrange temperature range, the speed of air moving device **30** can be variable. During a high normal operating LED temperature range where overheating may become a concern, the software can allow controller board **14A** to automatically set air moving device **30** to a high speed, such as a maximum speed for air moving device **30**. During a high temperature condition above the normal operating temperature range, the software can allow controller board **14A** to automatically set air moving device **30** to operate at its maximum level of performance and the light

source **50** can be reduced to its lowest setting for the level of light intensity. The software can allow controller board **14A** to be able to automatically switch to the lowest setting for the level of light intensity in the event of overheating. If overheating continues in this lowest setting, controller board **14A** can further reduce the level of light intensity below the lowest setting of the LED through the software.

The software can allow controller board **14A** to be capable of controlling the LED intensity as selected by the four-position rotary switch. The settings of control can, for example, be: Off, Low, Medium, and High. Software in either battery pack **76** or controller board **14A** or any other suitable location can provide an audible notification upon detection of a low battery condition. These audible notifications can vary in number and in timing. For example, a single audible notification can occur at a predetermined estimated time until the battery is expected to die with the audible notification occurring until the battery dies. Another example is provided below:

15 Minutes Remaining:	1 Audible Notification Cycle
12 Minutes Remaining:	1 Audible Notification Cycle
9 Minutes Remaining:	2 Audible Notification Cycle
6 Minutes Remaining:	3 Audible Notification Cycle
3 Minutes Remaining:	Audible Notification Cycle Repeats until the Battery is Fully Discharged

For example, when a low-battery condition is detected, the following notification sequences can occur. A tone sequence can be played when there is about 15 minutes of power remaining to indicate that there are about 15 minutes (+/- about 1 minute) remaining of power. A tone sequence can then be played one time at about 12 minutes of power remaining to indicate that there are about 12 minutes (+/- about 1 minute) remaining of power. At about 9 minutes of power remaining, a tone sequence can be played for a first time with a time interval followed by the tone sequence being played a second time to indicate that there are about 9 minutes (+/- about 1 minute) remaining of power. At about 6 minutes of power remaining, a tone sequence can then be played for a first time followed by a time interval followed by the tone sequence being

played a second time that is then followed by another time interval and the tone sequence being played a third time to indicate that there are about 6 minutes (+/- about 1 minute) remaining of power. With about 3 minutes of power remaining, tone sequences can be repeated with time intervals in between the tones to indicate that the battery is about to die until the power is off and/or the battery dies or is recharged or replaced.

Headlight device **10** as described herein can utilize an LED light source with an active cooling system. A thermostatically-controlled cooling fan can draw air at a very low flow rate through vents on the side and back of the luminaire, quietly cooling the LED. The air can be drawn through a system of vents and tubes, or ducts, and can be gently exhausted behind the surgeon. The headlight device can be designed to provide illumination to aid visualization during minor surgical, diagnostic, or therapeutic procedures. For example, as mentioned above, the headlight device can be used in neonate trans-illumination, ophthalmic procedures, or with photosensitive patients who have received photosensitizing agents (hematoporphyrin derivatives) within three months prior to the operation.

Embodiments of the present disclosure shown in the drawings and described above are exemplary of numerous embodiments that can be made within the scope of the appending claims. It is contemplated that the devices and related methods can comprise numerous configurations other than those specifically disclosed.

CLAIMS

What is claimed is:

1. A headlight device comprising:

a luminaire comprising a housing comprising a luminaire vent for receiving cooling air, and a light source contained within the housing;

an air moving device outside of the luminaire for facilitating cooling air intake through the luminaire vent; and

an exhaust tube connecting the luminaire and the air moving device to facilitate air flow of the cooling air between the luminaire and the air moving device.

2. The headlight device according to claim 1, further comprising a controller in communication with the luminaire and air-moving device.

3. The headlight device according to claim 2, wherein the controller comprises a controller housing in which a controller board and the air moving device reside.

4. The headlight device according to claim 3, wherein the control housing further comprises an air flow tube connected to the exhaust tube and configured to direct air flow from the exhaust tube to the air moving device.

5. The headlight device according to claim 2, wherein the controller is operable to automatically control temperature of the light source.

6. The headlight device according to claim 5, wherein the controller is operable to automatically control a speed of the air moving device and an intensity of the light generated from the light source to control the temperature of the light source.

7. The headlight device according to claim 6, wherein the controller is operable to set the air moving device to a low speed for a predetermined temperature range.

8. The headlight device according to claim 6, wherein the controller is operable to set the air moving device at a variable speed ranging from a low speed to a high speed and proportional to the temperature for a predetermined temperature range.

9. The headlight device according to claim 6, wherein the controller is operable to set the air moving device to a high speed for a predetermined temperature range.

10. The headlight device according to claim 6, wherein the controller is operable to set the air moving device to a high speed and the light source to a lowest setting of a level of the intensity of light for a predetermined temperature range.

11. The headlight device according to claim 5, wherein the controller is operable to switch intensity of the light source among the settings of Off, Low, Medium, and High.

12. The headlight device according to claim 1, wherein the light source comprises at least one light emitting diode (LED).

13. The headlight device of claim 12, wherein the luminaire further comprises:

a circuit board with an opening therethrough, the LED being electrically connected to the circuit board;

a thermal conductive board having a protrusion extending through the opening to be in thermal contact with the LED; and

a heat sink thermally coupled to the thermal conductive board.

14. The headlight device of claim 12, wherein the luminaire further comprises an optical assembly comprising:

a condensing lens;

an objective lens;

an iris control placed between the condensing lens and objective lens; and

a folding mirror disposed between the condensing lens and objective lens.

15. The headlight device of claim 14, wherein the condensing lens is disposed in close proximity to the LED and is shaped as a meniscus lens.

16. The headlight device of claim 12, wherein the luminaire further comprises an optical assembly comprising:

a first condensing lens and a second condensing lens;

a first objective lens and a second objective lens;

an iris control disposed between the condensing lenses and objective lenses; and

a folding mirror disposed between the first objective lens and the second objective lens.

17. The headlight device according to claim 1, wherein the air moving device comprises a fan.

18. The headlight device according to claim 1, wherein the exhaust tube comprises a head wearable portion to which the luminaire is attached.

19. The headlight device according to claim 1, further comprising a head wearable portion to which the luminaire and the exhaust tube is attached.

20. The headlight device according to claim 19, wherein the air moving device is at the rear of the head wearable portion and the exhaust tube extends around a side of the head wearable portion.

21. The headlight device according to claim 1, further comprising a battery pack, the battery pack being operable to alert the user when the battery is running low on power.

22. A method of operating a headlight device, the method comprising:

providing a headlight device comprising:

a luminaire comprising a housing comprising a luminaire vent for receiving cooling air, and a light source contained within the housing;

an air moving device outside of the luminaire for facilitating cooling air intake through the luminaire vent; and

an exhaust tube connecting the luminaire and the air moving device to facilitate air flow of the cooling air between the luminaire and the air moving device; and

controlling a temperature of the light source by generating airflow by the air moving device through the luminaire vents over the light source through the exhaust tube and through the air moving device.

23. The method according to claim 22, wherein controlling the temperature of the light source further comprises setting the air moving device to a low speed.

24. The method according to claim 22, wherein controlling the temperature of the light source further comprises setting the air moving device at a variable speed ranging from a low speed to a high speed and proportional to the temperature.

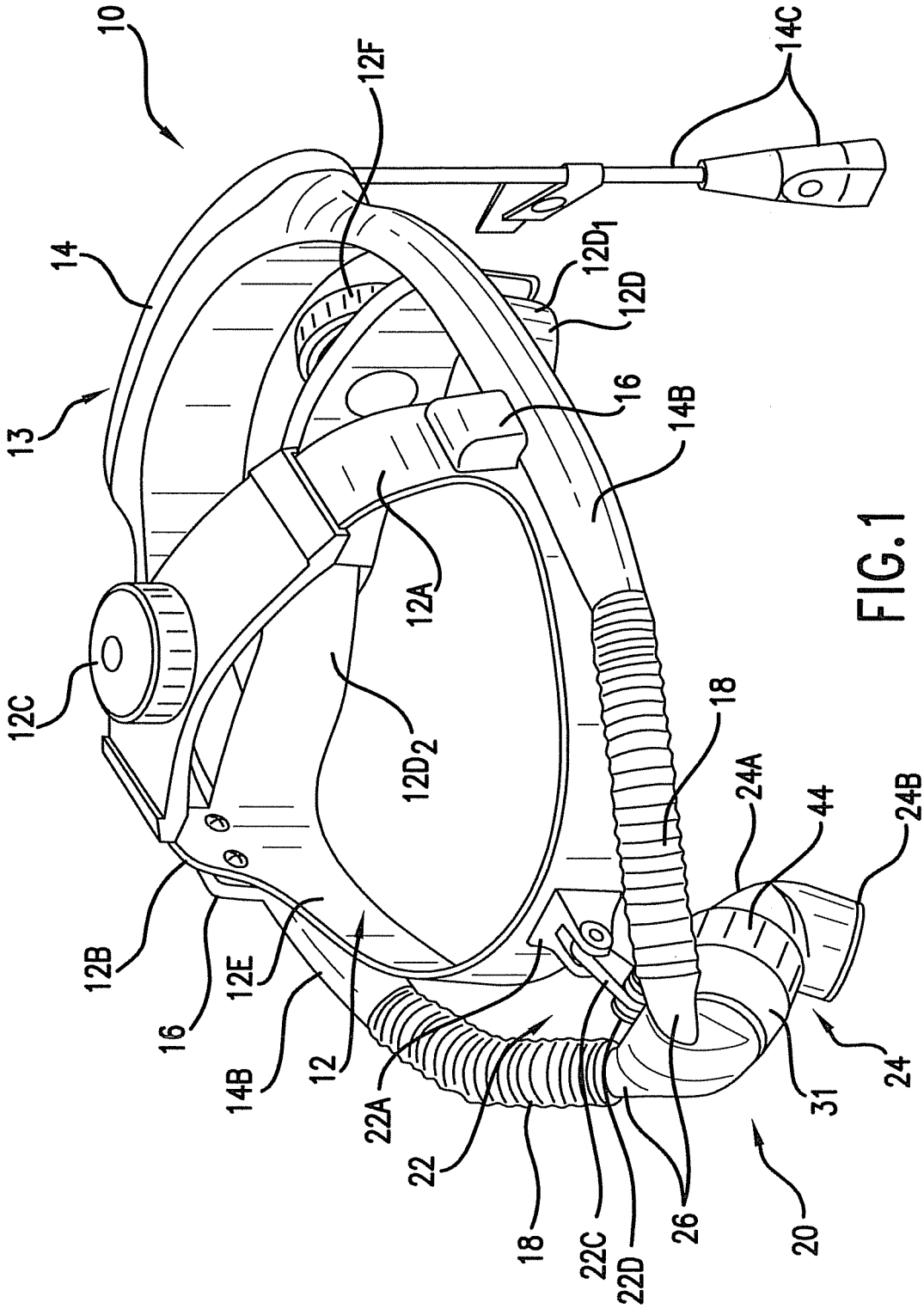
25. The method according to claim 22, wherein controlling the temperature of the light source further comprises setting the air moving device to a high speed.

26. The method according to claim 22, wherein controlling the temperature of the light source further comprises setting the air moving device to a high

speed and the light source to a lowest setting of a level of an intensity of the light generated by the light source.

27. The method according to claim 22, wherein controlling the temperature of the light source further comprises switching the intensity of the light source among the settings of Off, Low, Medium, or High.

28. The method according to claim 22, wherein the headlight device further comprises a battery pack and the battery pack is operable to provide an alert when the battery is running low on power.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14C
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12D
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12C
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22C
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FIG. 1

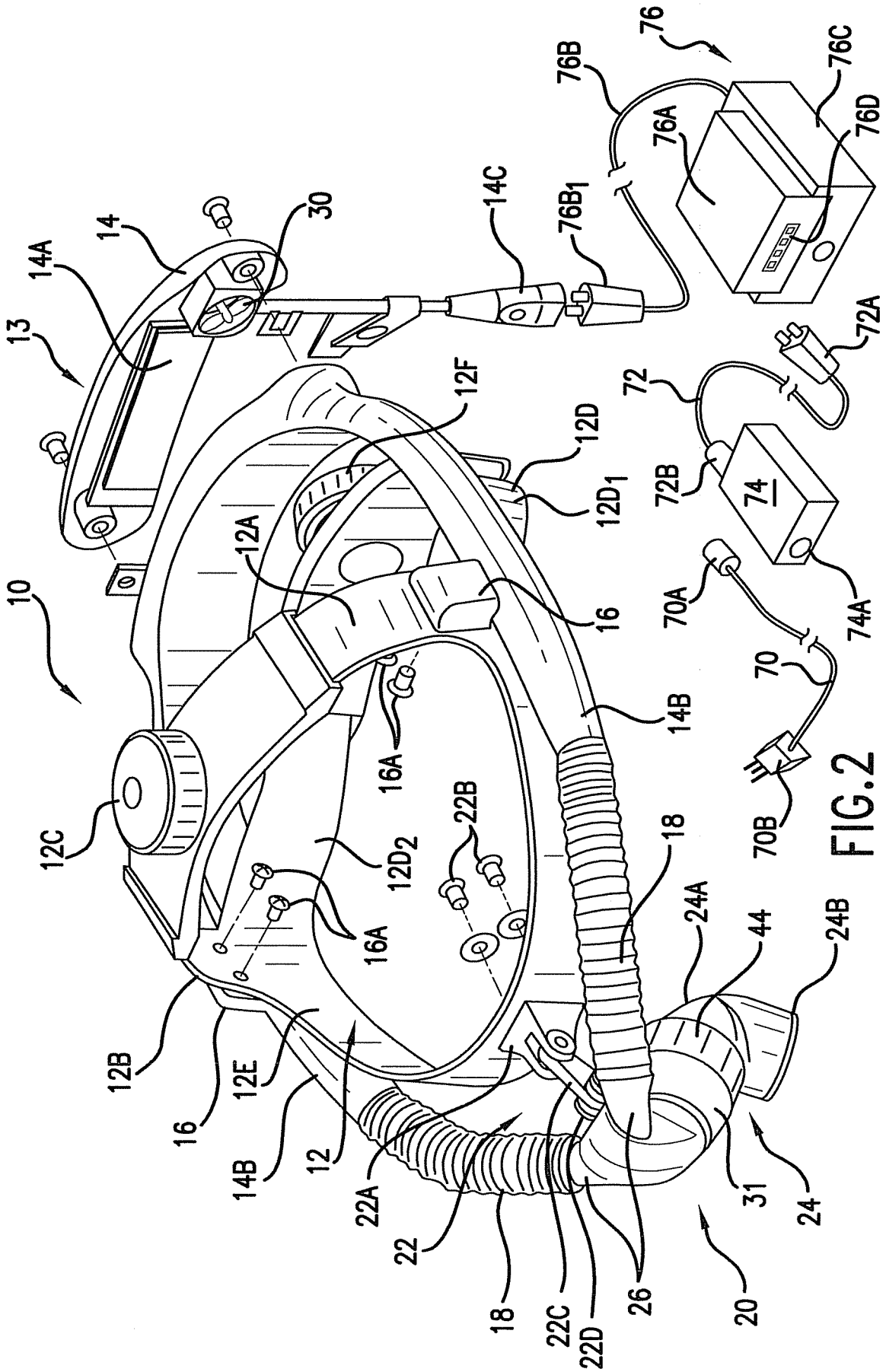
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FIG.2

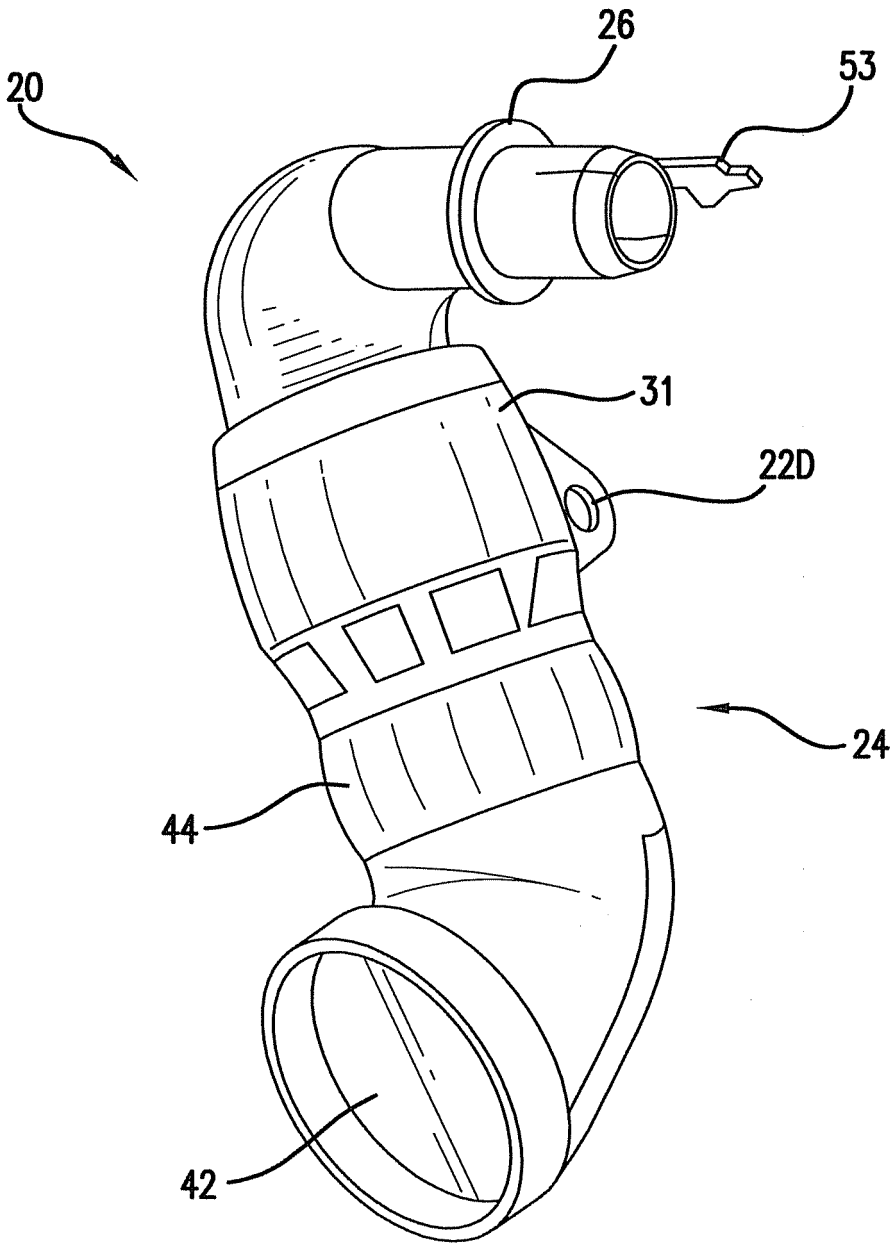

FIG.3

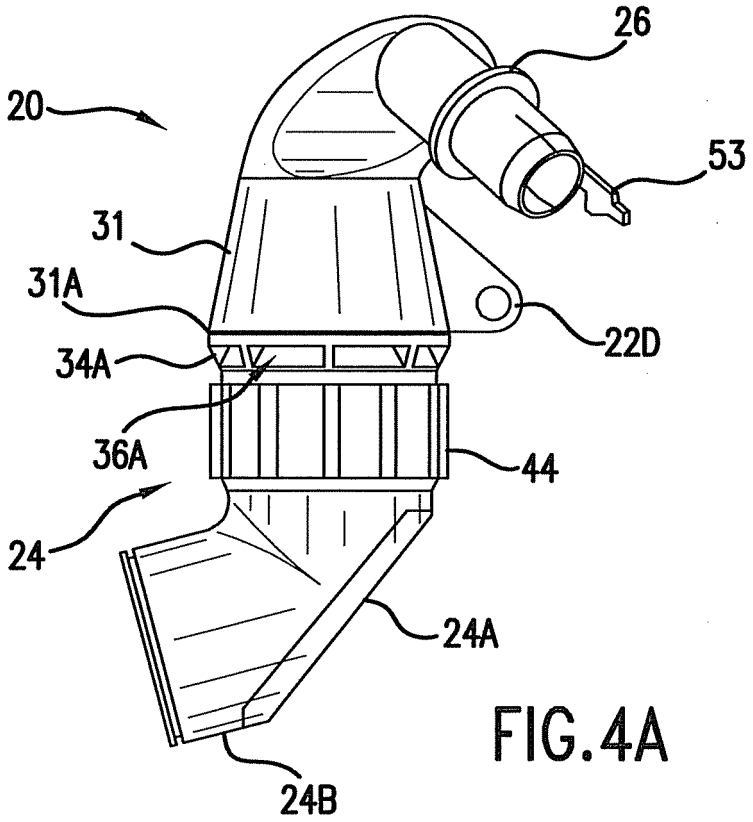
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FIG.4A

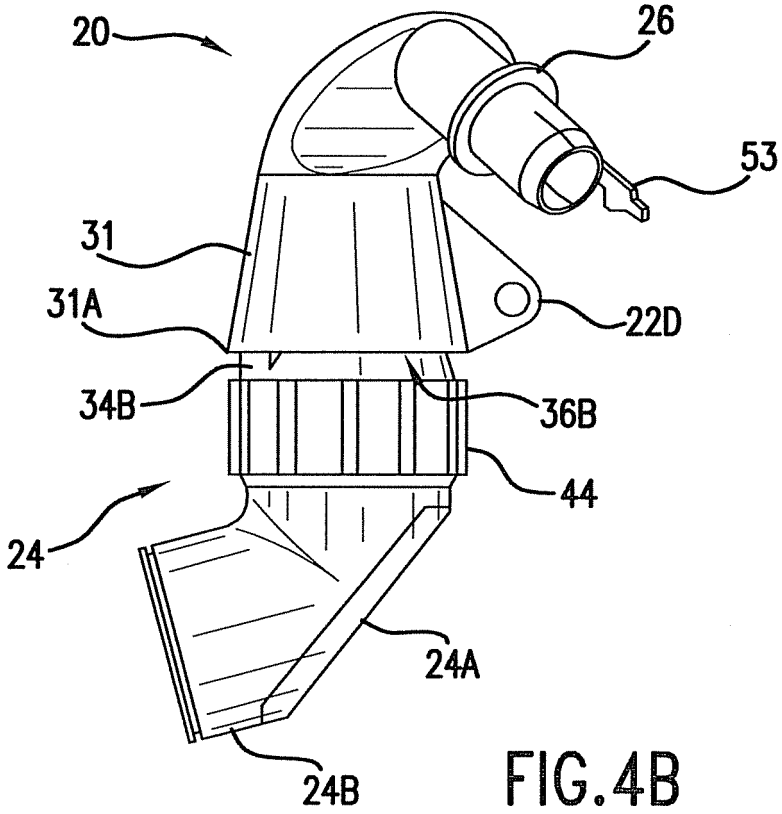
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FIG.4B

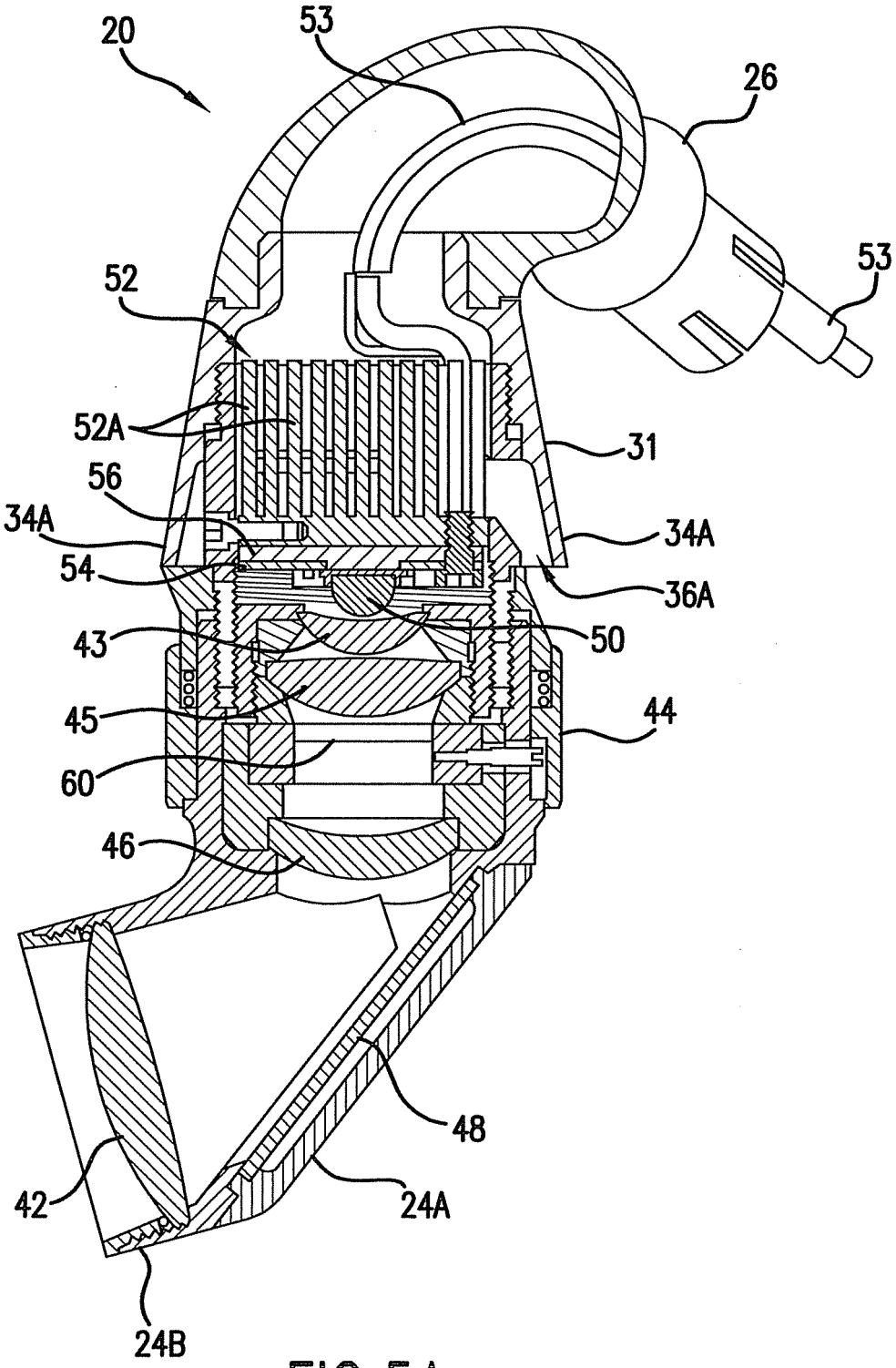
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FIG.5A

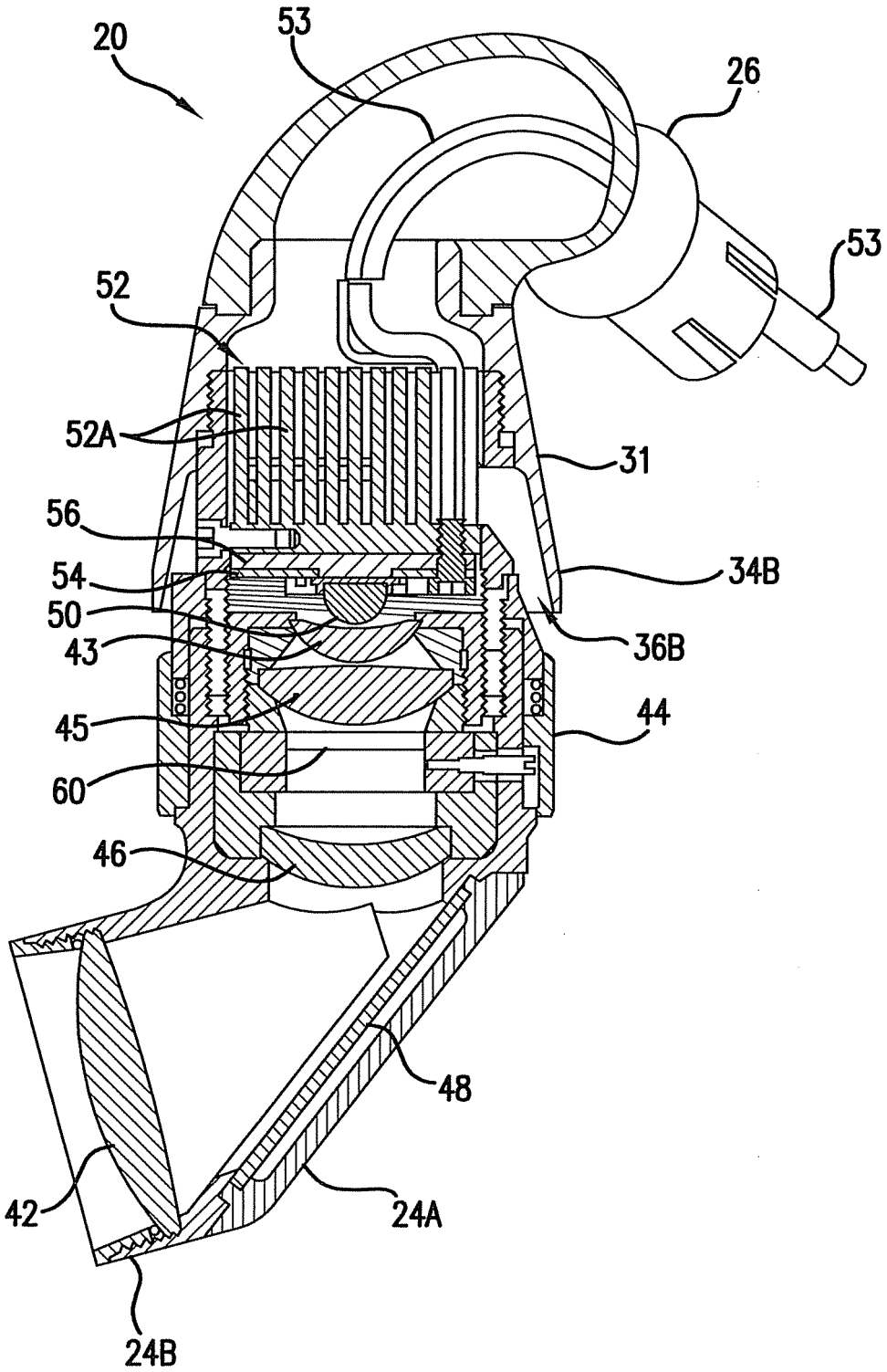

FIG.5B

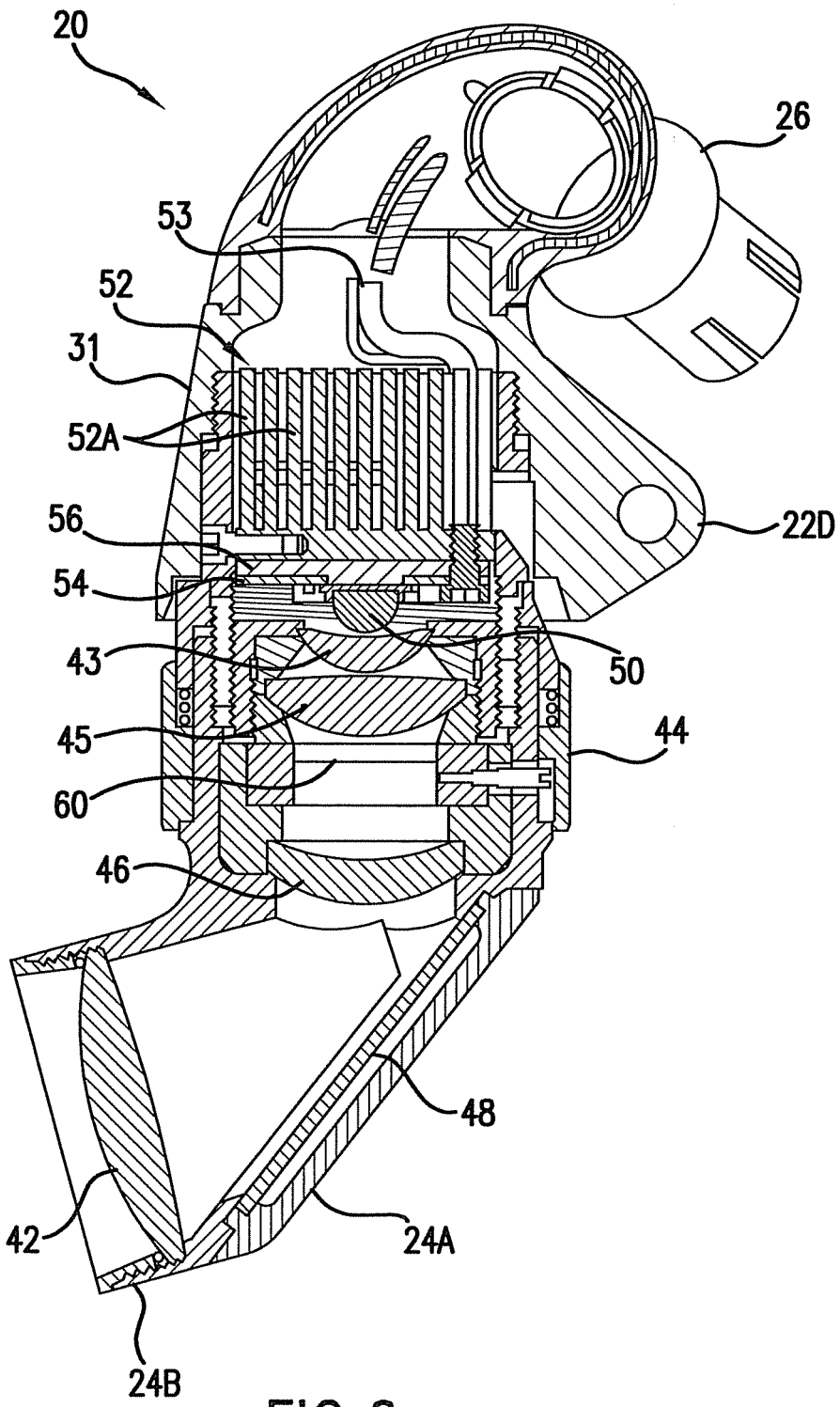

FIG.6

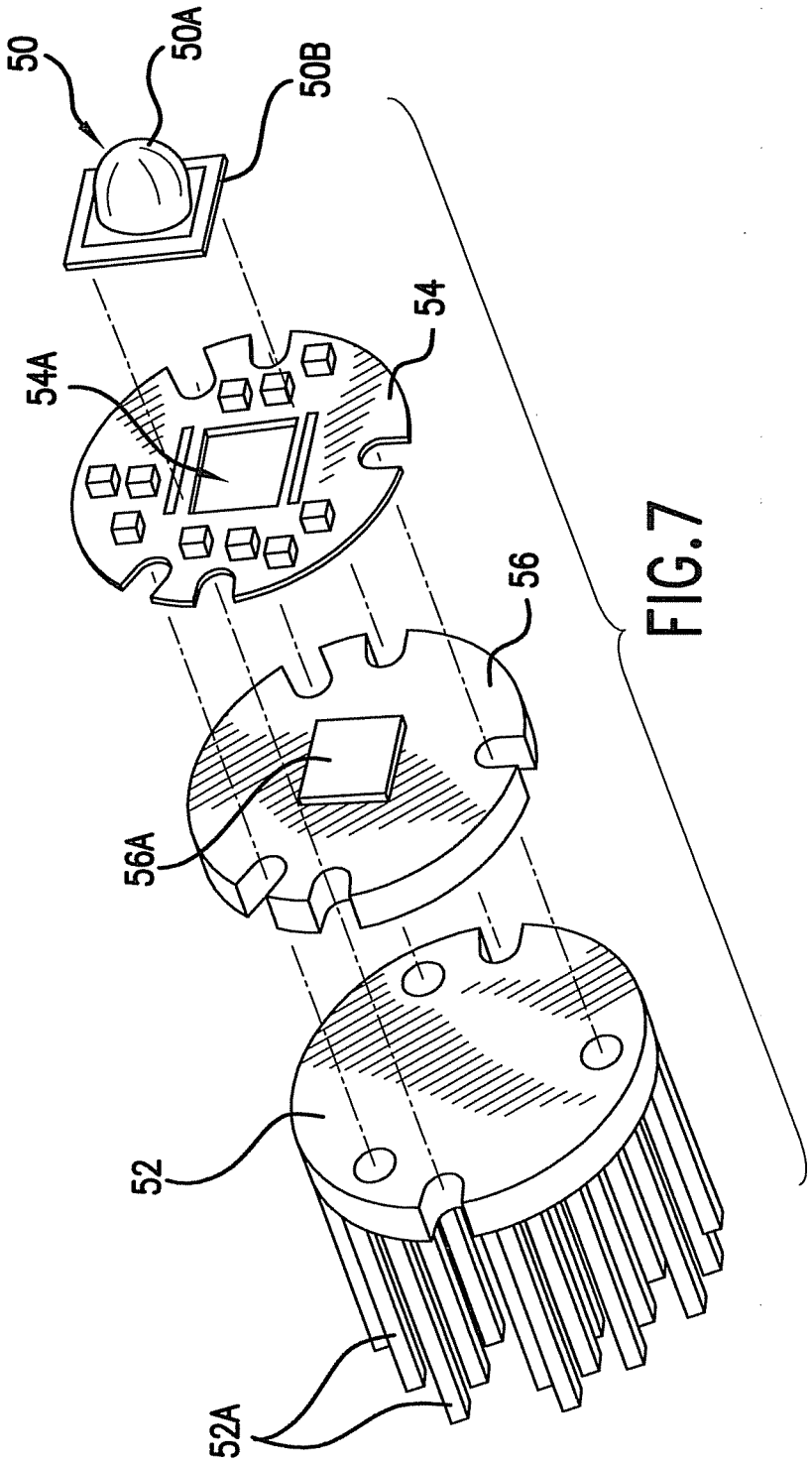

FIG.7

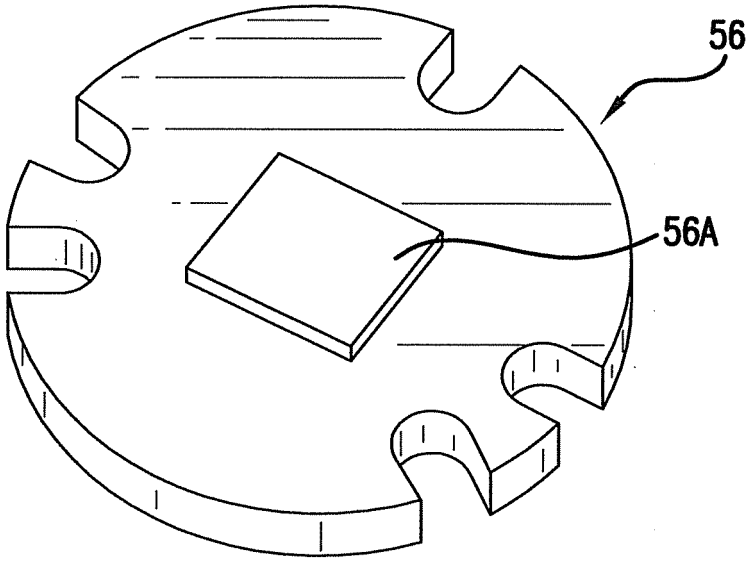

FIG.8A

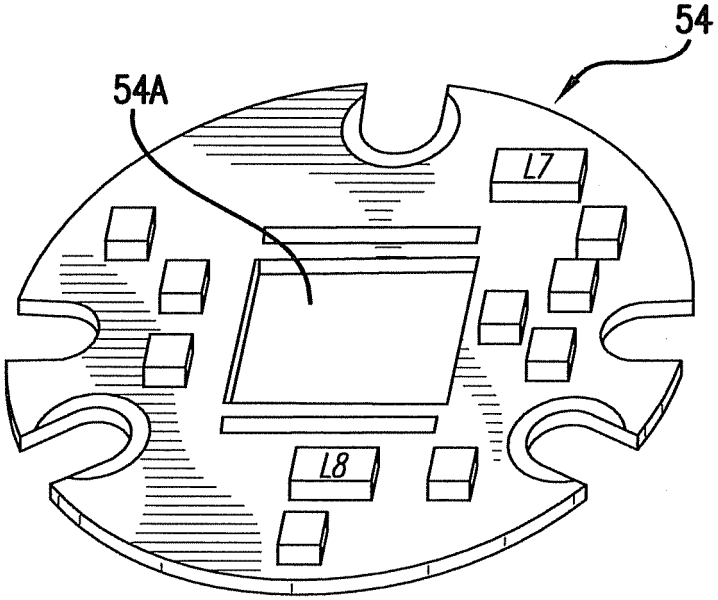

FIG.8B

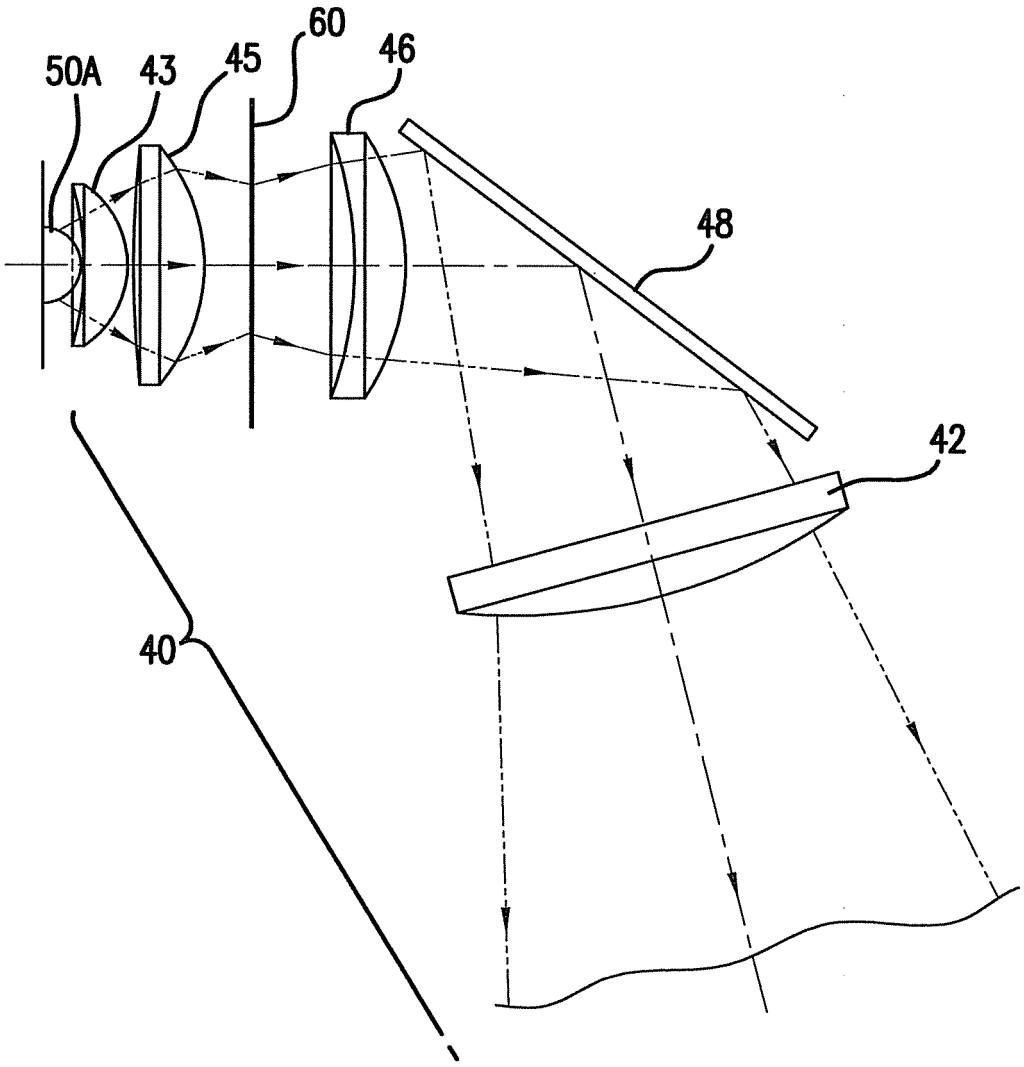

FIG.9

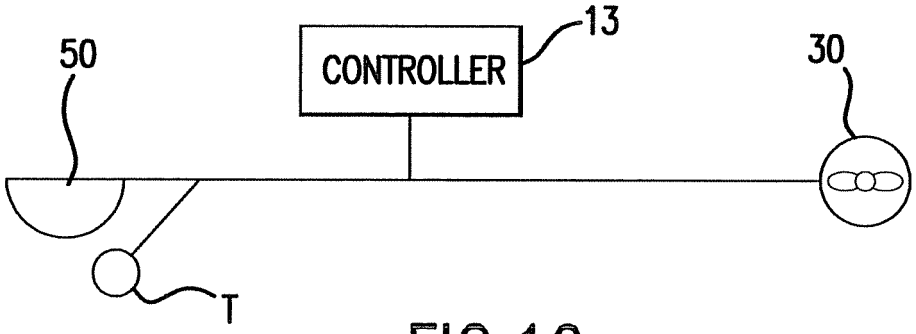

FIG.10

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/060799

A. CLASSIFICATION OF SUBJECT MATTER
INV. F21V21/084
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F21V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2009/225534 A1 (THOMAS DANIEL [US] ET AL) 10 September 2009 (2009-09-10) paragraphs [0020], [0025] figures 1-9b	1-28

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 March 2012	29/03/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Amerongen, Wim

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2011/060799

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009225534 A1	10-09-2009	US 2009225534 A1	10-09-2009
		WO 2009111784 A2	11-09-2009

专利名称(译)	可穿戴式头灯装置及相关方法		
公开(公告)号	EP2641018A1	公开(公告)日	2013-09-25
申请号	EP2011801882	申请日	2011-11-15
申请(专利权)人(译)	INTEGRA生命科学公司		
当前申请(专利权)人(译)	INTEGRA生命科学公司		
[标]发明人	STRONG JAMES TAMBURRINO RICHARD A RYAN JOHN M LESEBERG ROGER W GOLDFAIN ERVIN BABSON DAVID M STEPHENS DAVID MARTELLARO ANGELO		
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摘要(译)

提供了可穿戴式头灯装置和相关方法，并且可包括灯具（20），该灯具（20）可包括壳体（14），壳体（14）中具有用于接收冷却空气的灯具通风口和容纳在壳体内的光源。空气移动装置（30）可位于灯具外部，以便于通过灯具通风口进入冷却空气。排气管（18）可以连接到灯具和空气移动装置（30），以促进冷却空气在灯具和空气移动装置之间的空气流动。