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(54) **INDEPENDENT MODULES FOR LED FLUORESCENT LIGHT TUBE REPLACEMENT**

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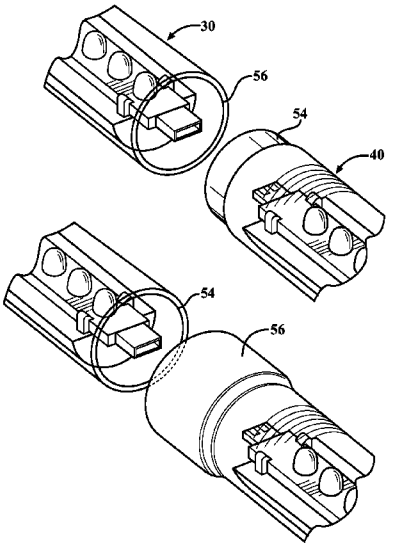
(57) **ABSTRACT**

Disclosed herein are embodiments of a LED fluorescent tube replacement lamp and lighting modules from which the lamp is constructed. One embodiment of a replacement lamp includes a plurality of interchangeable lighting modules that are configured to be electrically connected to adjacent modules. The interchangeable lighting modules can include end modules each having an end cap with pin connectors, at least one of the end modules includes electrical circuitry connected to the pin connectors for powering the modules. The lighting modules can also be center unit modules having LEDs mounted to a circuit board. The replacement lamps can be made from conceivable configurations of the lighting modules, requiring removal of only one module for repair or replacement.

19 Claims, 5 Drawing Sheets



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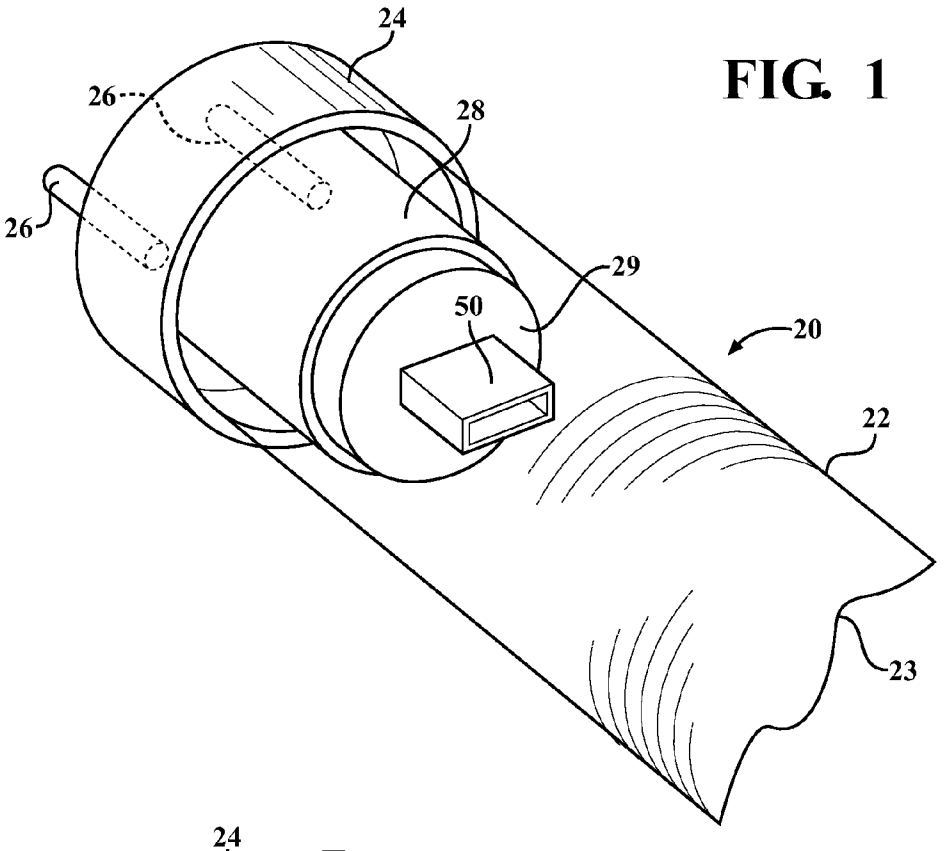


FIG. 1

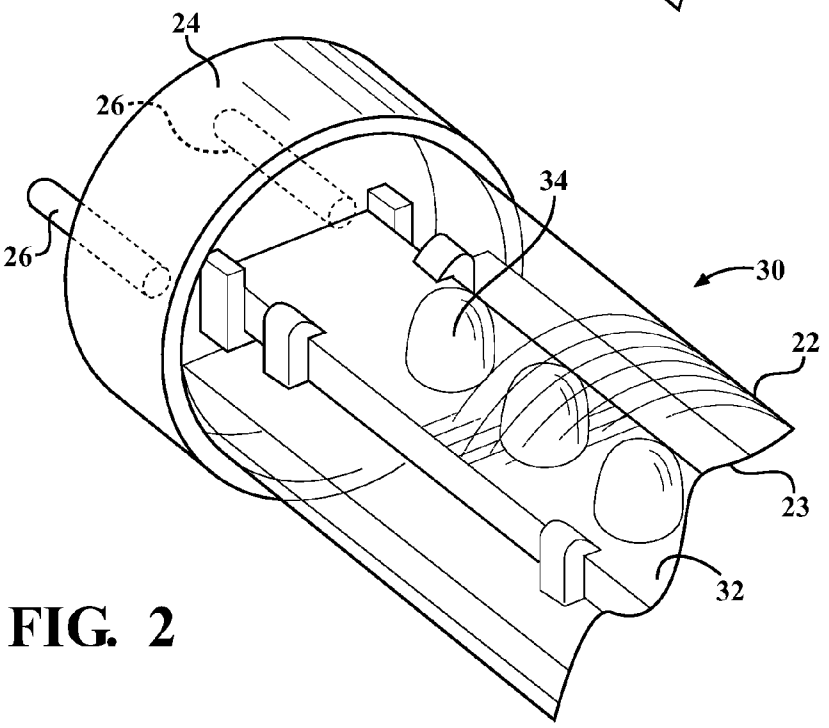


FIG. 2

FIG. 3

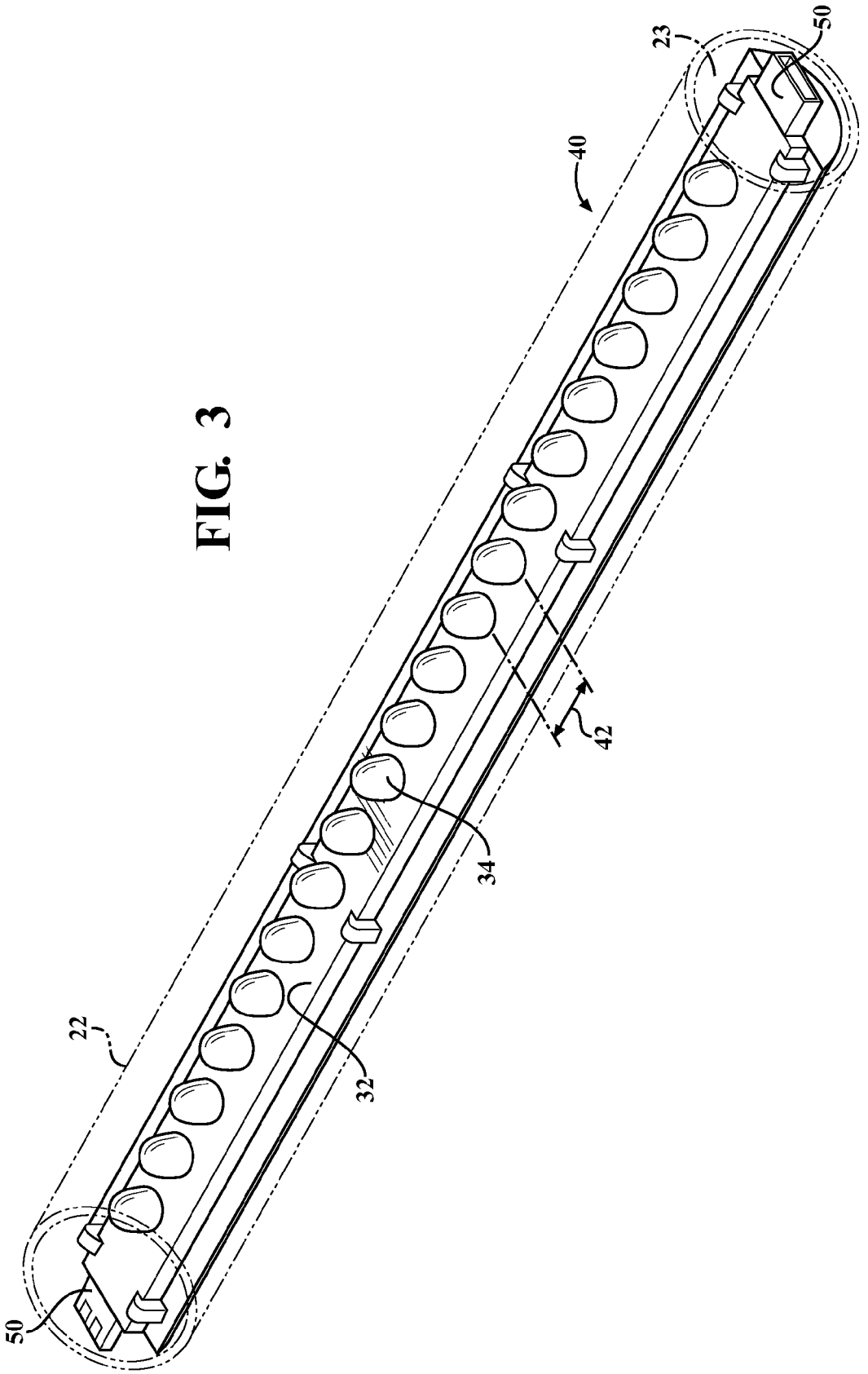


FIG. 4

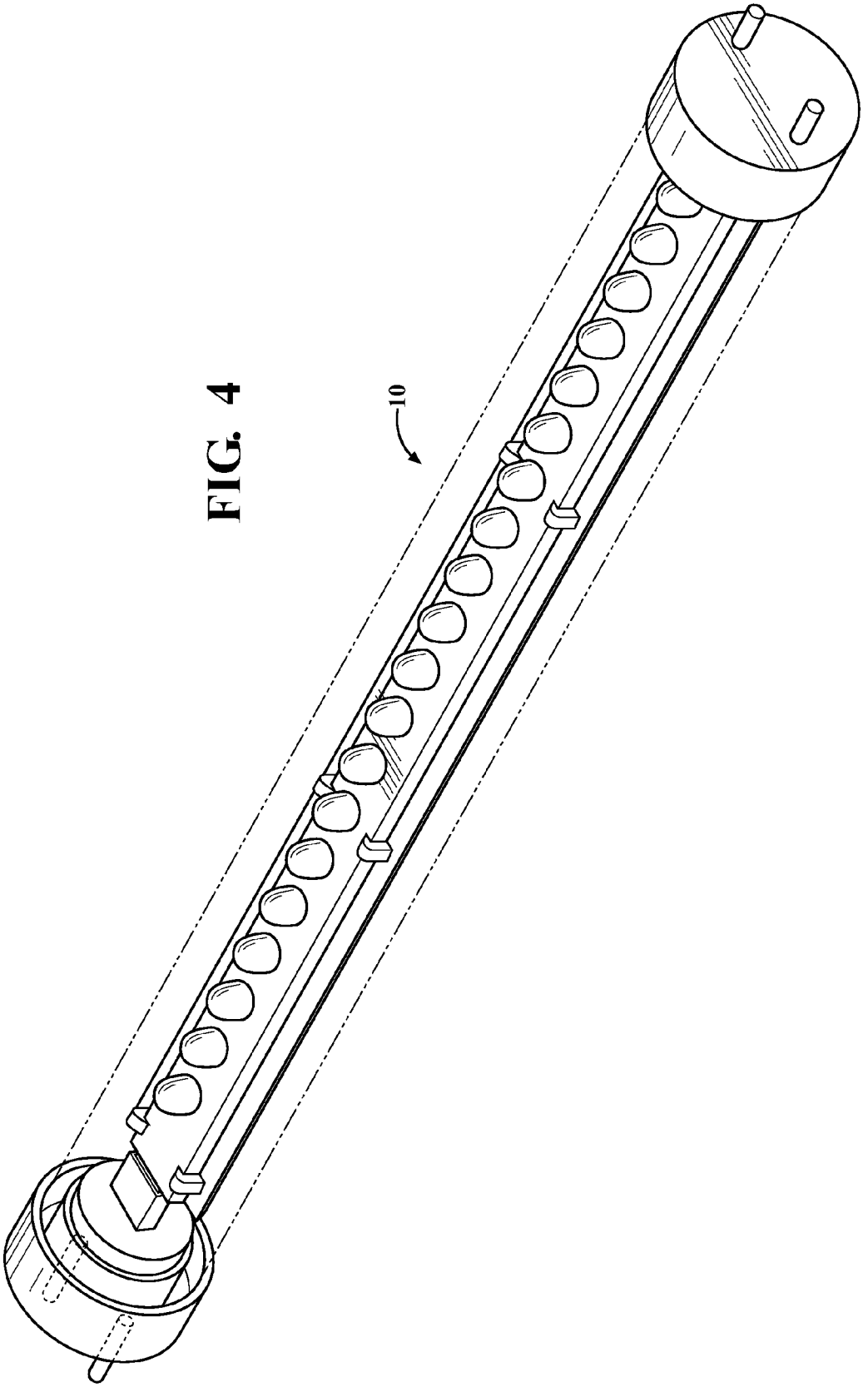
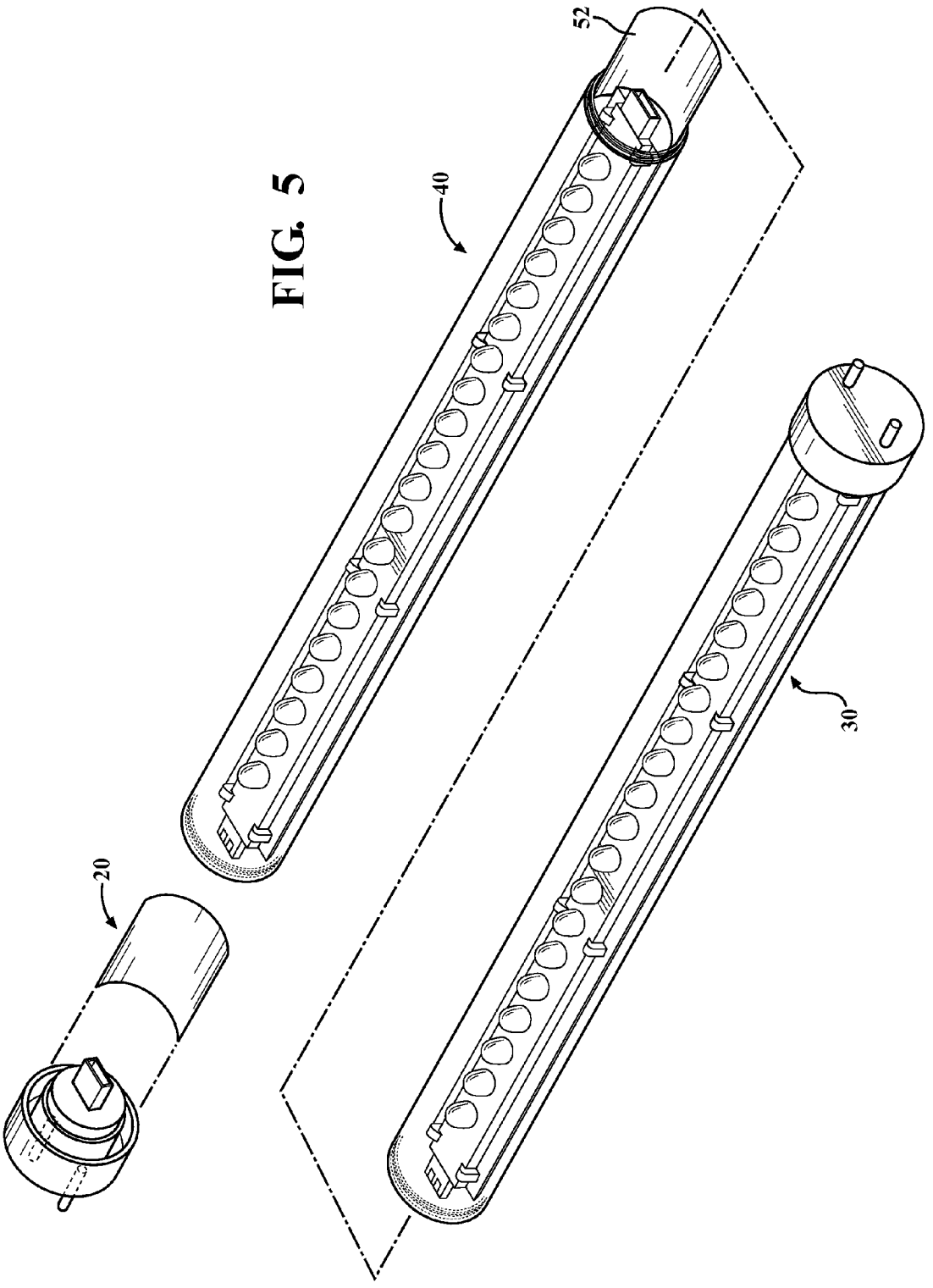


FIG. 5



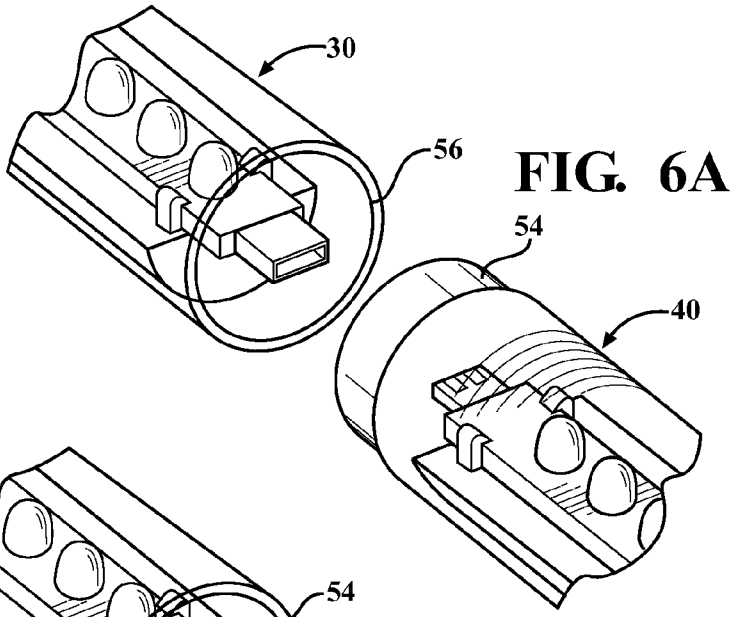


FIG. 6A

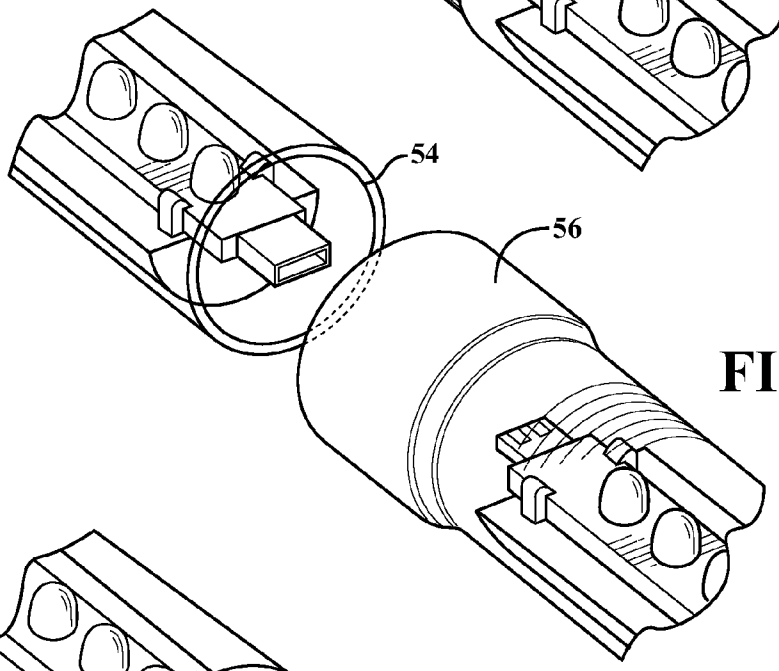


FIG. 6B

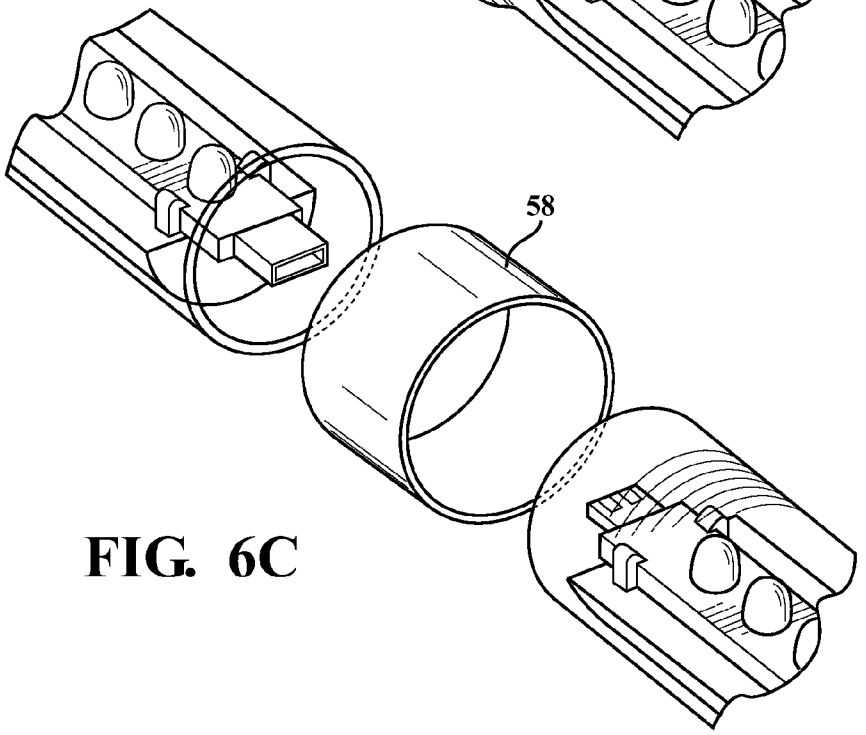


FIG. 6C

INDEPENDENT MODULES FOR LED FLUORESCENT LIGHT TUBE REPLACEMENT

This application claims priority to U.S. Provisional Patent Application No. 61/362,504, filed Jul. 8, 2010, which is incorporated herein by reference in its entirety.

BACKGROUND

The present invention relates, in general, to a light emitting diode (LED) based light for replacing a conventional fluorescent light in a fluorescent light fixture and, in particular, to lighting modules that can be replaced individually.

Fluorescent tube lights are widely used in a variety of locations, such as schools and office buildings. Although conventional fluorescent bulbs have certain advantages over, for example, incandescent lights, they also pose certain disadvantages including, inter alia, disposal problems due to the presence of toxic materials within the glass tube.

LED-based tube lights which can be used as one-for-one replacements for fluorescent tube lights having appeared in recent years. One such LED-based fluorescent replacement light includes LEDs mounted on an elongated circuit board in a semi-cylindrical metal housing which also serves as a heat sink for the LEDs. A semi-circular shaped lens snaps onto the heat sink to cover the LEDs and disperse light from them. Typically, when an LED needs to be replaced or power conversion circuitry needs to be replaced, the entire light fixture may need replacement.

SUMMARY

Disclosed herein are embodiments of a LED fluorescent tube replacement lamp and lighting modules. On embodiment of a replacement lamp includes a plurality of interchangeable lighting modules that are configured to be electrically connected to adjacent modules. The interchangeable lighting modules can include end modules each having an end cap with pin connectors, at least one of the end modules including electrical circuitry connected to the pin connectors for powering the modules. The lighting modules can also include center unit modules using LEDs mounted to a circuit board. The replacement lamps can be made from conceivable configurations of the lighting modules, requiring removal of only a module for repair or replacement.

BRIEF DESCRIPTION OF THE DRAWINGS

The description herein makes reference to the accompanying drawings wherein like reference numerals refer to like parts throughout the several views, and wherein:

FIG. **1** is a perspective view of an embodiment of an interchangeable lighting module disclosed herein;

FIG. **2** is a perspective view of another embodiment of an interchangeable lighting module disclosed herein;

FIG. **3** is a perspective view of yet another embodiment of an interchangeable lighting module disclosed herein;

FIG. **4** is a perspective view of an embodiment of a LED replacement lamp including interchangeable lighting modules as disclosed herein;

FIG. **5** is a perspective view of a support component for use with the interchangeable lighting modules disclosed herein; and

FIGS. **6**A-C are perspective views of embodiments of the interchangeable lighting modules having mating ends.

DETAILED DESCRIPTION

FIGS. **1-3** illustrate lighting modules according to embodiments disclosed herein. The lighting modules can each be configured with other modules so that in the aggregate the modules form an LED replacement lamp **10**, shown in FIG. **4**, that can be used in, for example, an existing fluorescent lamp fixture (not shown) that may have been previously used in a light system for a fluorescent lamp. The fixture can contain a ballast (not shown) which can be connected between a signal source and the replacement lamp **10**.

FIG. **1** shows an embodiment of an end unit module **20** configured for use with other modules to produce the lamp **10** shown in FIG. **4**. This embodiment of an end unit module **20** can include a tubular housing **22** defining a through-bore **23**. The housing **22** is shown having an end cap **24** over one end of the housing **22**. The end cap **24** can have two pins **26**, for example, to physically and electrically connect the end unit module **20**, and the aggregate lamp in which it is incorporated, to the fixture. The pins **26** can be electrically connected to a power converter **28** if needed, as shown in FIG. **1**. The end **29** of the power converter **28** opposite the pins **26** has connecting means **50** for electrical connection to a circuit board of an adjacent module within the replacement lamp **10**. When the end unit module **20** is in use in a replacement lamp **10**, the power converter **28** provides the appropriate power to the LEDs in the replacement lamp **10**.

Another embodiment of an end unit module **30** is shown in FIG. **2**. In this embodiment, the end unit module **30** has a tubular housing **22** defining a through-bore **23** and having an end cap **24** as described above. The end cap **24** has two pins **26** as in the first embodiment. However, in this embodiment, the pins **26** are directly electrically connected to a circuit board **32** to provide power to LEDs **34** from the fixture. Power conversion, if needed, is done externally of the lamp. The LEDs **34** are supported by the circuit board **32** as shown in FIG. **2**. The end **36** of the circuit board **32** opposite the pins **26** has connecting means **50**, similar to the connecting means **50** shown in FIG. **1** or **3**, such as bridge connectors, for connecting to the circuit board of an adjacent module in the replacement lamp **10**.

FIG. **3** illustrates a center module **40**, one or more of which can be used with one or more end unit modules **20**, **30** to produce an aggregate replacement lamp **10**. The center module **40** has a tubular housing **22** defining a through-bore **23** within which a circuit board **32** spans the length of the housing **22**. LEDs **34** are mounted at predetermined intervals **42** along the circuit board **32**. Each end of the circuit board **32** can have connecting means **50**, such as bridge connectors, to connect each end unit to an adjacent center or end module as disclosed herein.

FIGS. **1-3** are provided by way of example and are not meant to be limiting. The end unit module **20** in FIG. **1**, for example, could incorporate a portion of a circuit board with a number of LEDs, the portion of the circuit board being disposed in electrical connection with the power converter. The end unit module **30** of FIG. **2**, for example, may only contain a portion of a circuit board with no LEDs mounted on it.

The housing **22** in any of the embodiments disclosed herein can be made from polycarbonate, acrylic, glass or another light transmitting material (i.e., the housing **22** can be transparent or translucent). For example, a translucent housing **22** can be made from a composite, such as polycarbonate with particles of a light refracting material interspersed in the polycarbonate. While the illustrated housing **22** is cylindrical, housings having a square, triangular, polygonal, or other cross sectional shape can alternatively be used. Similarly,

while the illustrated housing **22** is linear, housings having an alternative shape, e.g., a U-shape can alternatively be used. Additionally, the housing **22** need not be a single piece as shown in FIGS. **1-3**. Instead, another example of a housing can be formed by attaching multiple individual parts, not all of which need be light transmitting. For example, a housing **22** for a module can be formed by attaching multiple individual parts, such as an opaque lower portion and a lens or other transparent cover attached to the lower portion to cover the LEDs **34**. The housing **22** as shown in FIGS. **1-3** can be manufactured to include light diffusing or refracting properties, such as by surface roughening or applying a diffusing film to the housing **22**. Additionally, the housing **22** can define a groove for slidably receiving the circuit board **32** for those modules with circuit boards **32**.

The circuit board **32**, as illustrated in FIGS. **2** and **3**, is an elongate printed circuit board. The circuit board **32** can be slidably engaged with a groove of the housing **22** or the circuit board **32** can alternatively be clipped, adhered, snap-fit or friction-fit, screwed or otherwise connected to the housing **22**. For example, the circuit board **32** can be mounted on a heat sink that is attached to the housing **22**. Other types of circuit boards may be used, such as a metal core circuit board. Alternately, instead of a circuit board **32**, other types of electrical connections (e.g., wires) can be used to electrically connect the LEDs **34** to the power converter **28** shown in FIG. **1** or to bridge connectors described later. Additional electrical components, such as a rectifier and a filter, can also be mounted on the circuit board **32**.

LEDs **34** in a center module and end unit module of a replacement lamp **10** can include at least one LED, a plurality of series-connected or parallel-connected LEDs, or an LED array. At least one LED array can include a plurality of LED arrays. Any type of LED may be used in LEDs **34**. For example, LEDs can be high-brightness semiconductor LEDs, an organic light emitting diodes (OLEDs), semiconductor dies that produce light in response to current, light emitting polymers, electro-luminescent strips (EL) or the like. The LEDs **34** can be surface-mount devices of a type available from Nichia. The LEDs **34** can be mounted to the circuit board **32** by solder, a snap-fit connection, or by other means. The LEDs **34** can produce white light. However, LEDs that produce blue light, ultra-violet light or other wavelengths of light can be used in place of or with white light emitting LEDs **34**. Although the embodiments will be discussed with reference to modules that solely contain LEDs, other embodiments of lighting modules do not have to be exclusively limited to LEDs. For example, other embodiments of lighting modules may contain a combination of a fluorescent lamp and LEDs.

In the embodiments of modules having end caps **24** with pins **26**, one of the two pins **26** can be a "dummy pin" that does not provide an electrical connection. Alternatively, instead of pairs of pins **26** as shown, other types of electrical connectors depending on the type of fixture, can extend from the end cap **24** into the housing **14**. For example, a single pin **26** can be used instead of two pins **26** for compatibility with a single pin fixture. Alternatively, both pins **26** can be "dummy pins" that do not provide an electrical connection, thereby requiring the use of such module with another end module that provides the electrical connection with the fixture.

Further, the end caps **24** may not have any pins **26** or the end caps **24** could have a plurality of pins. For example, dummy pins in number from 1-4, for example only, may be provided on one or both end caps **24**. Since the pins **26** are "dummy pins" that do not provide an electrically connection, and function merely to support the assembly in a light fixture, electrical conductors may be brought into the fixture at any location, such as from the side of the fixture, for example only. An optional connector may be provided on any one or any combination of the fixture, lamp or conductors to connect the electrical conductors to the modules.

The power converter **28** can convert the power received through the fixture into power usable by and suitable for the LEDs **34**. The power converter **28** can include one or more of an inrush protection circuit, a surge suppressor circuit, a noise filter circuit, a rectifier circuit, a main filter circuit, a current regulator circuit and a shunt voltage regulator circuit. The current regulator circuit can be connected to LEDs **34**. The power converter **28** can be suitably designed to receive a wide range of currents and/or voltages from a power source.

The modules **20**, **30**, **40** can be manufactured so that a particular combination of modules forms a replacement lamp **10** such as that shown in FIG. **4**. The number of modules required to complete a replacement lamp **10** is shown by way of example and is not meant to be limiting. For example, a replacement lamp **10** may be produced from two end modules such as the modules **30** of FIG. **2** or the modules **20** of FIG. **1**; each further including a circuit board with LEDs. A replacement lamp **10** can be produced from two end units and one or more of a center unit **40**. For compatibility with the fixture as discussed above, the modules **20**, **30**, **40** can have a length such that the aggregate replacement lamp **10** is approximately 48" long. Of course, the overall lamp **10** can have other suitable dimensions.

The number of LEDs **34** in an overall replacement lamp **10** can be a function of the desired power of the lamp **10** and the power of the LEDs **34**. For a 48" light, the number of LEDs **34** can vary from about five to four hundred such that the lamp **10** outputs approximately 500 to 3,000 lumens. However, a different number of LEDs **34** can alternatively be used, and the lamp **10** can output a different amount of lumens. The LEDs **34** can be evenly spaced along the circuit board **32**, and the spacing of the LEDs **34** can be determined based on, for example, the light distribution of each LED **34** and the number of LEDs **34**. Accordingly, the modules **30**, **40** having LEDs **34** will contain LEDs in a number and a spacing such that the aggregate lamp **10** will produce the required lumens output.

The modules **20**, **30**, **40** can be sold as an aggregate replacement lamp **10** as shown in FIG. **4** and as the individual modules. When a module of the replacement lamp **10** requires maintenance or to be replaced, the module can be removed and either replaced with a new module or repaired and replaced, leaving the other modules in the lamp **10** in tact. The ability to replace modules rather than an entire lamp reduces the cost of the using LED replacement lighting systems. The modules also make repair and maintenance easier.

As discussed, the modules **20**, **30**, **40** connect one circuit board **32** to another circuit board **32** or the power converter **28** to circuit board **32** via connecting means **50**, such as bridge connectors. The bridge connectors can be appropriate male and female connectors or hermaphroditic connectors. Other connecting means known to those skilled in the art are contemplated. The housing **22** of a module **20**, **30**, **40** can contact an adjacent housing such that the housing ends are flush. The connecting means **50** can provide sufficient support to maintain the modules **20**, **30**, **40** within the lamp **10**. In another embodiment, the modules **20**, **30**, **40** may comprise a bridge support **52** shown in FIG. **5** that can either be a separate piece that snaps onto the connected circuit boards **32**, spanning the connecting means **50**, to reinforce the modules **20**, **30**, **40** within the lamp **10**. It is also contemplated that the housing **22** of the modules **20**, **30**, **40** have mating ends as shown in FIGS.

6A-6C. In FIG. 6A, one module **20** can have a male end **54** while the adjacent module **40** can have a female end **56**. FIG. 6B illustrates another example of mating ends **56**, **57**. These are provided by means of example and are not meant to be limiting. Other configurations can be used that produce a similar result.

In FIG. 6C, a separate sleeve **58** can be provided with a module that is configured so that adjacent ends **56** of modules frictionally slide into opposing ends of the sleeve **58**. The sleeve **58** can provide additional support to the lamp **10** where the modules connect. The sleeve **58** can be made of the same material as the housing **22** so that it is less noticeable to the naked eye when the lamp **10** is in use.

To prevent shock that can occur if a module **20**, **30**, **40** is removed while the lamp **10** is in the fixture, the modules will fit together such that a module cannot be removed unless the aggregate lamp **10** is removed from the fixture. It is also contemplated that the modules **20**, **30**, **40** can be configured such that the mechanical interface between adjacent modules has a mechanical safety feature to prevent electrical shock. For example, the mechanical interface can have a locking mechanism to prevent the modules from becoming decoupled; where the recharging interface can only be unlocked if the entire replacement lamp **10** is removed from the light fixture. When the lamp **10** is removed from the fixture, the power source is decoupled.

The independent modules **20**, **30**, **40** can be configured such that the electrical circuitry in the end modules **20**, **30**, i.e. the pin **26** connection, the power converter **28** or the circuit board **32**, will prevent the flow of electricity from the power source to the modules unless the power circuitry senses an appropriate circuit resistance between the ends. For example, the electrical circuitry will not operate until it senses that no connecting means **50** remains unconnected.

The independent modules containing the power converter **28**, such as module **20**, can be configured to operate across a range of power draws, such that upgrading to more efficient LEDs requires the replacement of only certain modules, such as the center module **40**. It is also contemplated that modules containing LEDs can be removed so that the individual LEDs can be replaced within a module. The module with the updated LEDs can than be reinstalled with existing end modules to form an updated replacement lamp **10**.

While the invention has been described in connection with certain embodiments, it is to be understood that the invention is not to be limited to the disclosed embodiments but, on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims, which scope is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures as is permitted under the law.

What is claimed is:

1. A LED fluorescent tube replacement lamp comprising:
- a plurality of interchangeable lighting modules, wherein adjacent modules are electrically connected, the plurality of interchangeable lighting modules including:
- two end modules each including an end cap with at least one end connector, at least one of the end modules including electrical circuitry connected to the at least one end connector for powering the end modules;
- at least one center module including electrical circuitry; and
- a housing coupled between the two end modules and encompassing the at least one center module, the housing including a plurality of coaxially adjacent housing segments;
- wherein any one of the two end modules and the at least one center module is replaceable with a like module.

2. The lamp of claim **1** further comprising:
- at least one another connector providing an electrical connection to the at least one center module.

3. The lamp of claim **2** wherein:
- the at least one another connector mechanically couples the at least one end cap to the at least one center module.

4. The lamp of claim **2** further comprising:
- the electrical circuitry in the at least one center module includes a circuit board with at least one electrically connected LED; and
- the at least another connector electrically connects the at least one end cap to the circuit board in the at least one center module.

5. The lamp of claim **1** wherein:
- the at least one end connector on at least one of the end caps includes two connectors.

6. The lamp of claim **1** wherein:
- the two end modules and the at least one center module are replaceably electrically connected.

7. The lamp of claim **1** wherein:
- the electrical circuitry in at least one of the end modules includes a power converter.

8. The lamp of claim **1** further comprising:
- a coupler sleeve joining adjacent housing segments.

9. The lamp of claim **1** further comprising:
- a bridge support spanning and interconnecting two adjacent housing segments.

10. The lamp of claim **1** further comprising:
- adjacent ends of two adjacent modules nestingly engageable.

11. A LED fluorescent tube replacement lamp comprising:
- a plurality of interchangeable, electrically connected lighting modules, the plurality of lighting modules including:
- two end modules, each including a housing, an end cap mounted in one end of the housing and having at least one end connector, at least one of the end modules including electrical circuitry connected to the at least one end connector for powering the lighting modules;
- at least one center module including a housing encompassing a circuit board, at least one LED mounted on the circuit board, and bridge connectors coupled to opposing ends of the circuit board for separable connection to adjacent light modules;
- the end modules and the least one center module coaxially arranged, with adjacent ends of the two end modules and the at least one center module joined into a unitary housing; and
- wherein any one of the two end modules and the at least one center module is replaceable with a like module.

12. Lighting modules usable in a fluorescent tube replacement lamp comprising at least one of:
- an end unit module including:
  - a tubular housing having an end cap on one end, the end cap having at least one end connector; and
  - a power converter within the tubular housing and electrically connected to the at least one pin connector, the power converter having electrical connecting means on an end opposite the end cap; and
- a center unit module including:
  - a tubular housing;
  - electrical circuitry within the tubular housing coupled between electrical connecting means at opposing ends of the housing; and
  - at least one LED coupled to the electrical circuitry in the housing, wherein the end unit module and center unit

module are configured to interface with an adjacent end unit or center module such that the electrical connects means electrically connect adjacent modules.

13. A LED fluorescent tube replacement lamp comprising:

a plurality of interchangeable lighting modules, wherein adjacent modules are electrically connected, the plurality of interchangeable lighting modules including:

two end modules each including an end cap with at least one end connector, at least one of the end modules including electrical circuitry connected to the at least one connector for powering the end modules; and

at least one center module including electrical circuitry, the at least one center module including a plurality of center modules; and

bridge connectors carried on the plurality of center modules for connecting the plurality of center modules;

wherein any one of the two end modules and the at least one center module is replaceable with a like module.

14. The lamp of claim **13** wherein:

the at least one end connector on at least one of the end caps includes two connectors.

15. The lamp of claim **13** wherein:

the two end modules and the at least one center module are replaceably electrically connected.

16. The lamp of claim **13** wherein:

the at least one another connector mechanically couples the at least one end cap to the at least one center module.

17. The lamp of claim **13** further comprising:

at least one another connector providing an electrical connection to the at least one center module.

18. The lamp of claim **17** further comprising:

the electrical circuitry in the at least one center module includes a circuit board with at least one electrically connected LED.

19. The lamp of claim **18** wherein:

the at least another connector electrically connects the at least one end cap to the circuit board in the at least one center module.

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