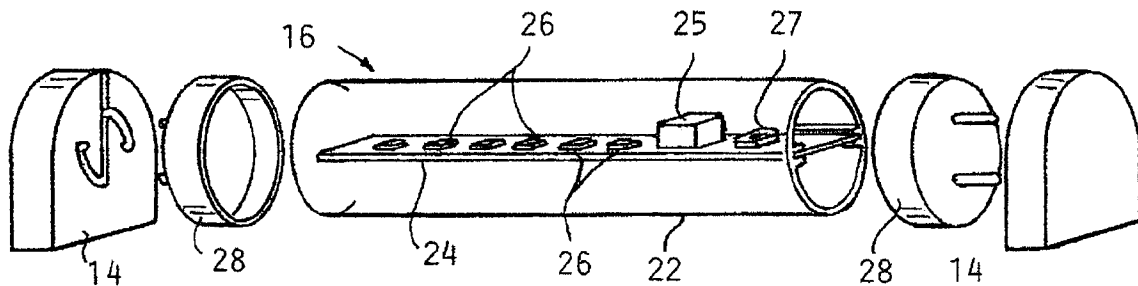




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 (54) **Title: LIGHT AND LIGHT SENSOR**



(57) **Abrégé/Abstract:**

An LED-based light tube for use in a conventional fluorescent fixture can feature a housing including a light transmitting portion. At least one electrical connector can be attached to the housing and configured for engagement with the conventional fluorescent fixture. At least one LED can be arranged to produce light in a direction toward the light transmitting portion. A sensor can be operable to detect a brightness level and output a corresponding signal. A controller can be in electrical communication with the at least one electrical connector and operable to control the at least one LED in response to the signal.

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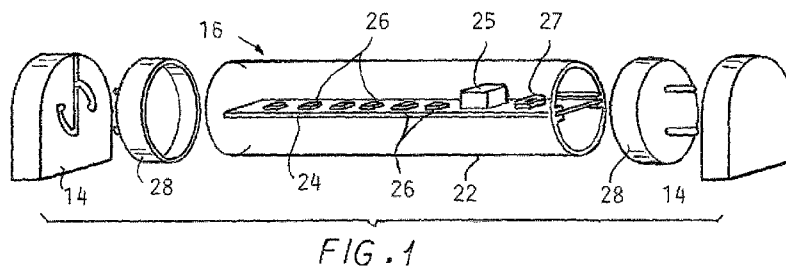
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## LIGHT AND LIGHT SENSOR

### FIELD

[0001/0002] An LED-based light as described herein relates to "smart buildings" that can automatically control lighting in response to various environmental conditions.

### BACKGROUND

[0003] Lights in buildings are generally controlled by switches, such as wall-mounted switches in the vicinity of one or more lights. The switch can include a dimmer for varying the brightness of one or more lights. However, lights are often left on when not needed, such as when no people are around the lights or when sources of light besides the lights (e.g., sunlight passing through windows and/or skylights) provide sufficient illumination.

### SUMMARY

[0004] Known smart buildings that can automatically control various environmental characteristics, such as a lighting brightness level, of one or more rooms of a building are typically expensive to manufacture and install. For example, known smart building components typically are not compatible with standard building fixtures, such as conventional fluorescent tube fixtures, and thus can require an electrician to install.

[0005] Examples of LED-based lights described herein can be used to transform a building with standard fixtures, such as standard fluorescent tube fixtures, into a smart building. Many advantages are offered by the LED-based lights described herein, such as allowing for a low-cost smart building and automatically providing an alert when an efficiency of the LED-based light becomes too low.

[0006] In one example of an LED-based light tube for use in a conventional fluorescent fixture, a housing includes a light transmitting portion. At least one electrical connector is attached to the housing and configured for engagement with the conventional fluorescent fixture. At least one LED is arranged to produce light in a direction toward the light transmitting portion. A sensor is operable to detect a brightness level and output a corresponding signal. A controller is in electrical communication with the at least one electrical connector and operable to control the at least one LED in response to the signal.

[0007] In one example of a system for measuring the efficiency of a light, an LED-based light includes at least one electrical connector compatible with a standardized light fixture, at least one LED, and a controller in electrical communication with the at least one electrical connector and operable to control the at least one LED. A sensor is in communication with the controller and operable to detect a brightness level. The controller is operable to estimate an efficiency of the at least one LED at least partially based on the brightness level detected by the sensor.

[0007a] In another example there is provided an LED-based light tube for use in a conventional fluorescent fixture comprising: a housing including a light transmitting portion; at least one electrical connector attached to the housing and configured for engagement with the conventional fluorescent fixture; at least one LED arranged to produce light in a direction toward the light transmitting portion; a sensor operable to detect a brightness level and output a signal corresponding to the detected brightness level; and a controller in electrical communication with the at least one electrical connector and operable to compare the signal to a predetermined value corresponding to a desired brightness level and control an amount of power provided to the at least one LED in response to the signal to adjust the light produced by the at least one LED to achieve the desired brightness level, wherein the controller is operable to estimate an efficiency of the at least one LED at least partially based on the brightness level detected by the sensor and wherein the estimated efficiency of the at least one LED is at least partially based on a comparison between a power consumption of the at least one LED and the brightness level detected by the sensor.

[0007b] In another example there is provided a system for measuring the efficiency of a light comprising: an LED-based light including at least one electrical connector compatible with a standardized light fixture, at least one LED, and a controller in electrical communication with the at least one electrical connector and operable to control the at least one LED; and a sensor in communication with the controller and operable to detect a brightness level, wherein the controller is operable to estimate an efficiency of the at least one LED at least partially based on the brightness level detected by the sensor and wherein the estimated efficiency of the at least one LED is at least partially based on a comparison

between a power consumption of the at least one LED and the brightness level detected by the sensor.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0008] FIG. 1 is a perspective view of an example of an LED light tube;
- [0009] FIG. 2 is a schematic perspective view of a smart building system;
- [00010] FIG. 3 is a schematic perspective view of yet another example of an LED light tube; and
- [00011] FIG. 4 is a flowchart illustrating operation of an example of an LED light tube.

DESCRIPTION

[00012] Figures 1-4 are discussed in reference to a light and a light sensor. As shown in FIG. 1, a light fixture 14 can accept an LED-based light 16. The light fixture 14 can be designed to accept standard fluorescent tubes, such as a T- 5, T-8, or T- 12 fluorescent tube, or other standard sized light, such as incandescent bulbs. Alternatively,

the fixture 14 can be designed to accept non-standard sized lights, such as lights installed by an electrician.

[00013] The LED light tube 16 can include a housing 22, a circuit board 24, LEDs 26, a pair of end caps 28, a controller 25, and a receiver 27 as shown in FIG. 1. The housing 22 as shown in FIG. 1 is a light transmitting cylindrical tube. The housing 22 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 or a circular shape can alternatively be used. Additionally, the housing 22 need not be a single piece as shown in FIG. 1. Instead, another example of a housing can be formed by attaching multiple individual parts, not all of which need be light transmitting. For example, such a housing can include an opaque lower portion and a lens or other transparent cover attached to the lower portion to cover the LEDs 26. The housing 22 can be manufactured to include light diffusing or refracting properties, such as by surface roughening or applying a diffusing film to the housing 22. For compatibility with the fixture 14 as discussed above, the housing 22 can have a length such that the light 16 is approximately 48" long, and the housing 22 can have a 0.625", 1.0", or 1.5" diameter.

[00014] The circuit board 24 as illustrated in FIG. 1 is an elongate printed circuit board. Multiple circuit board sections can be joined by bridge connectors to create the circuit board 24. The circuit board 24 as shown in FIG. 1 is slidably engaged with the housing 22, though the circuit board 24 can alternatively be clipped, adhered, snap- or friction-fit, screwed or otherwise connected to the housing 22. For example, the circuit board 24 can be mounted on a heat sink that is attached to the housing 22. Also, other types of circuit boards may be used, such as a metal core circuit board. Or, instead of a circuit board 24, other types of electrical connections (e.g., wires) can be used to electrically connect the LEDs 26 to a power source.

[00015] The light 16 can include two bi-pin end caps 28 (i.e., each end cap 28 can carry two pins), one at each longitudinal end of the housing 22, for physically and electrically connecting the light 16 to the fixture 14. The end caps 28 can be the sole physical connection between the light 16 and the fixture 14. The end caps 28 can be electrically connected to the circuit board 24 to provide power to the LEDs 26. Each end cap 28 can include two pins, though two of the total four pins can be “dummy pins” that do not provide an electrical connection. Alternatively, other types of electrical connectors can be used, such as an end cap carrying a single pin. Also, while the end caps 28 are shown as including cup-shaped bodies, the end caps 28 can have a different configuration (e.g., the end caps 28 can be shaped to be press fit into the housing 22). One or both of the end caps 28 can additionally include electric components, such as a rectifier and filter.

[0010] The LEDs 26 can be surface-mount devices of a type available from Nichia, though other types of LEDs can alternatively be used. For example, although surface-mounted LEDs 26 are shown, one or more organic LEDs can be used in place of or in addition thereto. The LEDs 26 can be mounted to the circuit board 24 by solder, a snap-fit connection, or other means. The LEDs 26 can produce white light. However, LEDs that produce blue light, ultra-violet light or other wavelengths of light can be used in place of white light emitting LEDs 26.

[0011] The number of LEDs 26 can be a function of the desired power of the light 16 and the power of the LEDs 26. For a 48” light, such as the light 16, the number of LEDs 26 can vary from about five to four hundred such that the light 16 outputs approximately 500 to 3,000 lumens. However, a different number of LEDs 26 can alternatively be used, and the light 16 can output a different amount of lumens. The LEDs 26 can be evenly spaced along the circuit board 24, and the spacing of the LEDs 26 can be determined based on, for example, the light distribution of each LED 26 and the number of LEDs 26.

[0012] The controller 25 can be mounted on the circuit board 24, and can include a memory and a CPU for executing a program stored on the memory. That is, the controller 26 can include a microprocessor or other digital or analog circuit that performs the tasks described herein. The controller 25 can be in communication with the

LEDs 26, the end caps 28, and the receiver 27 via the circuit board 24, though the controller 25 can alternatively be in communication with the LEDs 26, end caps 28, and/or receiver 27 using wires or another connection. The controller 25 can also be configured to regulate the amount of power provided to the LEDs 26. That is, the controller 28 can govern the amount of power provided from the end caps 28 to the LEDs 26. The controller 28 can be in communication with multiple subsets of LEDs 26 (such as individual LEDs 26) for providing a different amount of power to one or more of the subsets of LEDs 26. Alternatively, a controller can be external of the light 16. For example, a controller can be coupled to the fixture 14 to control a light attached to the fixture 14.

[0013] The light 16 can additionally include a receiver 27 mounted on the circuit board 24. The receiver 27 can be in communication with the controller 25 as mentioned above and with a remote transmitter as is discussed below in greater detail. For example, the receiver 27 can be in communication with the transmitter using a standard wireless protocol (e.g., a radio standard, a cellular standard such as 3G, Bluetooth, or WiFi). The receiver 27 can alternatively be in communication with the transmitter in another manner such as hardwiring or via electric signals sent through the end caps 28. The receiver 27 can be configured to receive signals from the transmitter, and the receiver 25 can transmit received signals to the controller 25.

[0014] While the light 16 is shown as being compatible with standard sized fluorescent fixtures, an LED-based light having another shape, such as an incandescent bulb or another type of light, can alternatively be used. Also, other types of light sources, such as fluorescent or incandescent based light sources, can be used instead of the LEDs 26.

[0015] As illustrated in FIG. 2, the fixture 14 can be in a building 11 including a light switch 31 and a light sensor 33, and the light 16 can be installed in the fixture 14. The light switch 31 can control whether power is provided to the fixture 14. However, as is mentioned above and described below in greater detail, the controller 25 can control whether power is provided to the LEDs 26, in which case the light switch 31 need not be included. Also, if the building 11 is a "smart" building, the controller 25 and switch 31 can be in communication (e.g., via a wired connection, or via a wireless transmitter and a



wireless receiver) such that the controller 25 can override the switch 31 to turn on the light 16 even when the switch 31 is in an off position or vice versa.

[0016] The light sensor 33 can detect a level of light in an area of the building 11 including the light 16, such as an amount of light that strikes the sensor 33. The light sensor 33 can include an integral transmitter for transmitting a light level signal  $\alpha$  to the receiver 27. The light sensor 33 can continuously transmit the signal, or the light sensor 33 can include a controller (e.g., a controller including a memory and a CPU for executing a program stored on the memory) for deciding when to transmit the signal. In addition to the light sensor 33, other sensors can be in communication with the light 16. For example, the building 11 can also include a motion sensor, a sensor for determining whether a door is ajar, a sensor for determining when a keypad or other type of lock is actuated, a voice-activated sensor, a clock or calendar, a light sensor for measuring an amount of light in the building 11 other than or including light provided by the light 16 (e.g., an amount of sunlight entering the building 11), a power supply monitor, and/or another type of sensor.

[0017] In operation, as shown by in FIG. 4, the light 16 produces light in step S1. In step S2 the light sensor 33 can measure the amount of light that strikes the sensor 33, and the light sensor 33 can transmit the light level signal  $\alpha$  to the receiver 27 as shown in step S3. The receiver 27 can communicate the light level signal  $\alpha$  to the controller 25 as shown in step S4.

[0018] In step S5, the controller 25 can analyze the light level signal  $\alpha$ . For example, the controller 25 can estimate a brightness of an area of the building 11 including the light 16, the controller 25 can compare the light level to a predetermined value (e.g., an amount of light comfortable for an ordinary person), or can analyze the light level signal  $\alpha$  in some other manner. Depending on the light level signal  $\alpha$ , the controller 25 can control the light 16 in various ways. For example, as shown in step S6, the controller 25 can adjust the brightness of light produced by the LEDs 26. If the light level signal  $\alpha$  indicates the amount of light detected is too high, the controller 25 can dim the LEDs 26 or turn a subset of the LEDs 26 off. Alternatively, if the amount of light is too low, the controller 25 can increase the brightness of the LEDs 26 or turn on a subset of the LEDs 26 that were previously off. Thus, the controller 25 can correct the amount

of light provided by the light 16 in response to changes in ambient light, such as if a level of natural light entering the area of the building 11 including the light 16 increases or decreases, or if other lights are turned on or off.

[0019] In another example not illustrated, the light 16 can initially not be producing light. The controller 25 can control the light 16 to begin producing light in response to the light level signal  $\alpha$ . For example, the light level signal  $\alpha$  can indicate that the amount of light in an area of the building 11 is below a predetermined level.

[0020] To avoid interference with the light sensor 33 by the light emitted by the LEDs 26, the light sensor 33 can sense ambient light during a short period, invisible to the eye, when the LEDs 26 are off. This short off period can occur due to line voltage zero-crossing, or a command from the controller 25.

[0021] Therefore, among other advantages, an occupant of the area of the building 11 including the light 16 can avoid having to make an effort to turn on the light.

[0022] Returning to FIG. 3, as another example of operation of the light 16 shown in step S7, the light level signal  $\alpha$  can be analyzed by the controller 25 to determine an efficiency of the light 16. For example, the controller 25 can compare the amount of detected light with a reference value, such as an amount of light detected at a previous date if the light 16 includes a clock and/or calendar. The previous date can be a date when conditions such as ambient light conditions were similar, such as a recent day at approximately the same time. The difference between the current amount of light being produced and the previous amount of light being produced can be used to calculate a change in efficiency of the light 16. The controller 25 can make this efficiency determination without turning the light 16 off, which can be beneficial if the light 16 is in a location such as a stairwell where a lack of light can be dangerous. As an alternative efficiency test, the controller 25 can compare the amount of detected light when the light 16 is on with an amount of light detected when the light 16 is off, with the difference being used to calculate an amount of light produced by the light 16.

[0023] The controller 25 can calculate the efficiency by comparing the amount of light produced by the light 16 with the reference value (e.g., an amount of light produced by the light 16 operating under ideal conditions), or by comparing the amount of light produced by the light 16 with the amount of power consumed by the light 16 (which can

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be measured with an ammeter and voltmeter, a wattmeter, or another power measuring device either integral with the light 16, electrically coupled to the fixture 14, or at another location).

[0024] As shown in step S8, the controller 25 can also determine whether the light 16 should be replaced. For example, the controller 25 can compare the efficiency of the light 16 with a predetermined value to determine whether the light 16 should be replaced. The predetermined value can be a predetermined efficiency standard, such as the efficiency of the light 16 when new, the efficiency of an ideal light, a maximal output of the light 16, or some other value.

[0025] The controller 25 can also control the light 16 to indicate its efficiency, which can provide notice that the light 16 should be replaced. For example, the controller 25 can control the light 16 to display its efficiency using a digital read-out integral with the light 16, a bar of light having a length equivalent with the efficiency, or in another manner. Alternatively, the controller 25 can control the light 16 to display when the efficiency of the light 16 is below a predetermined value, such as by illuminating at least one of the LEDs 26 having a different color than surrounding LEDs 26, by causing at least one of the LEDs 26 to flash, or by controlling the light 16 in some other manner. Once the efficiency of the light 16 drops below the predetermined value, it can be understood that the light 16 should be replaced. Thus, the light 16 can signal to a maintenance worker or other personnel that the light 16 should be replaced.

[0026] Another light 40 as shown in FIG. 3 includes the housing 22, the circuit board 24, the controller 25, the LEDs 26, and the end caps 28 similar to the light 16. The light 40 can additionally include an integral light level sensor 42 and a transmitter 44. The light sensor 42 can be mounted on the circuit board 24 to receive power via the end caps 28, and the light sensor 42 can be in communication with the controller 25 and/or the transmitter 44. The light level sensor 42 can protrude from the housing 22 as shown in FIG. 3 or otherwise be positioned to sense an amount of light produced by at least some of the LEDs 26 (e.g., the sensor 42 can alternatively be contained within the housing 22, and one or more reflectors can be included to direct a portion of light toward the sensor 42). Alternatively, the light level sensor 42 can detect an amount of ambient

light. The amount of ambient light can include light produced by the LEDs 26. The sensor 42 can communicate the light level signal  $\alpha$  to the controller 25.

[0027] The transmitter 44 can be mounted on the circuit board 24 for receiving power via the end caps 28. The transmitter 44 can be in communication with the controller 25 and/or the light sensor 24 for receiving the light level signal  $\alpha$ . The transmitter 44 can be configured to transmit the light level signal  $\alpha$  to a remote location, such as a smart building control center or another smart building component.

[0028] With this configuration, the controller 25 in the light 40 can control the LEDs 26 and calculate an efficiency of the light based on the light level signal  $\alpha$  as discussed above in reference to the light 16. The light 40 can also indicate whether the light 40 should be replaced similar to as described above in reference to the light 16. Additionally, the inclusion of the transmitter 44 allows the light 40 to perform other functions. The transmitter 44 can transmit the light level signal  $\alpha$  to the remote location, allowing the light level signal  $\alpha$  to be used for controlling another component of a smart building (e.g., window shades, another light, or some other component of a smart building) or for another purpose. For example, the transmitter 44 can transmit an efficiency of the light 40 or an indication that the light 40 should be replaced to the remote location.

[0029] The light 40 can also include another sensor, such as a motion detector, in communication with the controller 25 and/or the transmitter 44. In this case, the controller 25 can take signals other than the light level signal  $\alpha$  into consideration in controlling the LEDs 26. For example, the controller 25 can turn the LEDs 26 off even though the light level sensor 42 detects a low level of light if the motion sensor has not detected movement for a certain amount of time. As a similar example, the controller 25 can turn the LEDs 26 off even though the light level sensor 42 detects a low level of light if a clock or calendar in communication with the controller 25 indicates the time is not during standard working hours.

[0030] The scope of the claims should not be limited by the preferred embodiments set forth above, but should be given the broadest interpretation consistent with the description as a whole.

**What is claimed is:**

1. An LED-based light tube for use in a conventional fluorescent fixture comprising:
  - a housing including a light transmitting portion;
  - at least one electrical connector attached to the housing and configured for engagement with the conventional fluorescent fixture;
  - at least one LED arranged to produce light in a direction toward the light transmitting portion;
  - a sensor operable to detect a brightness level and output a signal corresponding to the detected brightness level; and
  - a controller in electrical communication with the at least one electrical connector and operable to compare the signal to a predetermined value corresponding to a desired brightness level and control an amount of power provided to the at least one LED in response to the signal to adjust the light produced by the at least one LED to achieve the desired brightness level, wherein the controller is operable to estimate an efficiency of the at least one LED at least partially based on the brightness level detected by the sensor and wherein the estimated efficiency of the at least one LED is at least partially based on a comparison between a power consumption of the at least one LED and the brightness level detected by the sensor.
2. The LED-based light tube of claim 1, further comprising a circuit board disposed within the housing, and wherein the at least one LED, sensor and controller are mounted on the circuit board.
3. The LED-based light tube of claim 1 or 2, wherein the at least one LED, the sensor and the controller are in electrical communication with the at least one electrical connector.

4. The LED-based light tube of any one of claims 1 to 3, wherein the at least one electrical connector includes a pair of bi-pin electrical connectors attaching to opposing ends of the housing.
5. The LED-based light tube of any one of claims 1 to 4, wherein the estimated efficiency of the at least one LED is at least partially based on a comparison of the brightness level detected by the sensor with a reference brightness level.
6. The LED-based light tube of any one of claims 1 to 5, wherein the controller is operable to activate an alarm when the estimated efficiency of the at least one LED is below a predetermined amount.
7. The LED-based light tube of claim 6, wherein the alarm includes at least one of operating another LED that produces colored light, displaying the efficiency of the at least one LED on a display, and operating the at least one LED in a flashing pattern.
8. The LED-based light of any one of claims 1 to 7, further comprising a transmitter operable to transmit at least one of the brightness level and the estimated efficiency of the at least one LED.
9. A system for measuring the efficiency of a light comprising:
  - an LED-based light including at least one electrical connector compatible with a standardized light fixture, at least one LED, and a controller in electrical communication with the at least one electrical connector and operable to control the at least one LED; and
  - a sensor in communication with the controller and operable to detect a brightness level,
  - wherein the controller is operable to estimate an efficiency of the at least one LED at least partially based on the brightness level detected by the sensor and wherein the estimated efficiency of the at least one LED is at least partially based on a

comparison between a power consumption of the at least one LED and the brightness level detected by the sensor.

10. The system of claim 9, wherein the controller is operable to control the at least one LED in response to the brightness level detected by the sensor.

11. The system of claim 9 or 10, wherein the controller is operable to activate an alarm when the estimated efficiency of the at least one LED is below a predetermined value.

12. The system of claim 11, wherein the alarm includes at least one of operating another LED that produces colored light, displaying the efficiency of the at least one LED on a display, and operating the at least one LED in a flashing pattern.

13. The system of any one of claims 9 to 12, wherein the estimated efficiency of the at least one LED is at least partially based on a comparison of the brightness level detected by the sensor with a reference brightness level.

14. The system of any one of claims 9 to 13, wherein the at least one electrical connector includes a pair of bi-pin electrical connectors compatible with a standard fluorescent tube fixture.

15. The system of any one of claims 9 to 14, wherein the LED-based light further comprises a circuit board, and wherein the at least one LED, the controller and the sensor are mounted on the circuit board.

16. The system of any one of claims 9 to 14, wherein the sensor is remote from the LED-based light and operable to transmit a signal corresponding to the brightness level, the LED-based light further comprising a receiver in communication with the sensor and the controller.

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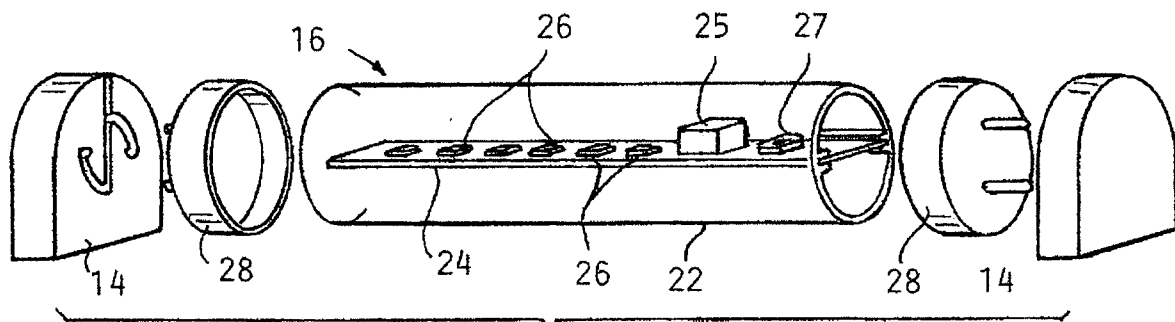


FIG. 1

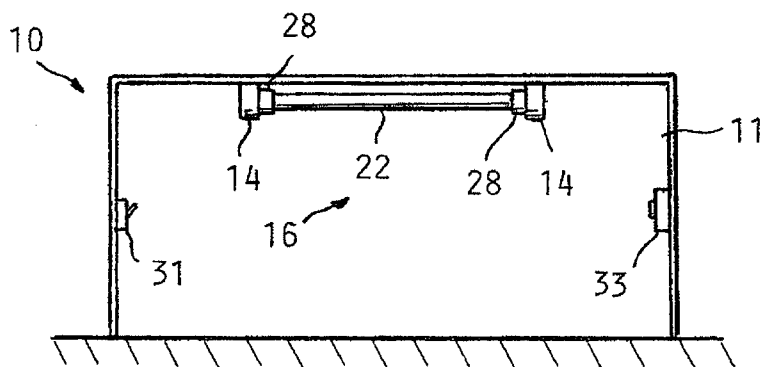


FIG. 2

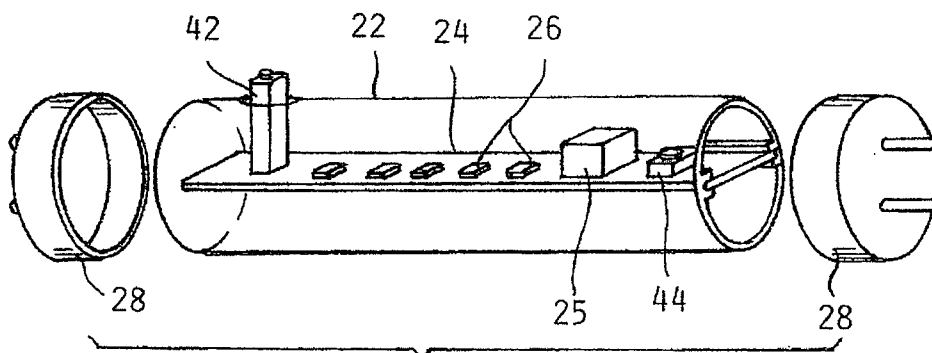


FIG. 3



FIG. 4

