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(54) **FLUORESCENT TUBE REPLACEMENT HAVING LONGITUDINALLY ORIENTED LEDS**

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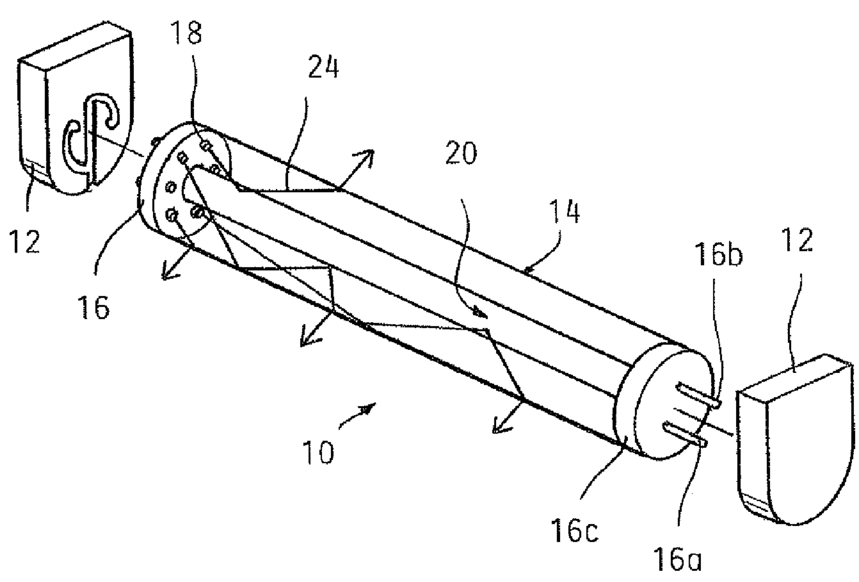
(57) **ABSTRACT**

An LED-based light for replacing a conventional fluorescent tube in a fixture is provided. The LED-based light includes an elongate light transmitting rod defining a bore and at least one LED positioned at one or both ends of the rod and oriented to produce light longitudinally into a portion of the rod radially outward of the bore. At least one connector is physically coupled to an end of the rod and electrically coupled to the at least one LED. The at least one connector is adapted for physical and electrical connection to the fixture. In operation, the directional light produced by the at least one LED is dispersed by way of reflection, refraction, and/or diffusion while traveling longitudinally through the rod to reduce the appearance of bright spots.

20 Claims, 3 Drawing Sheets



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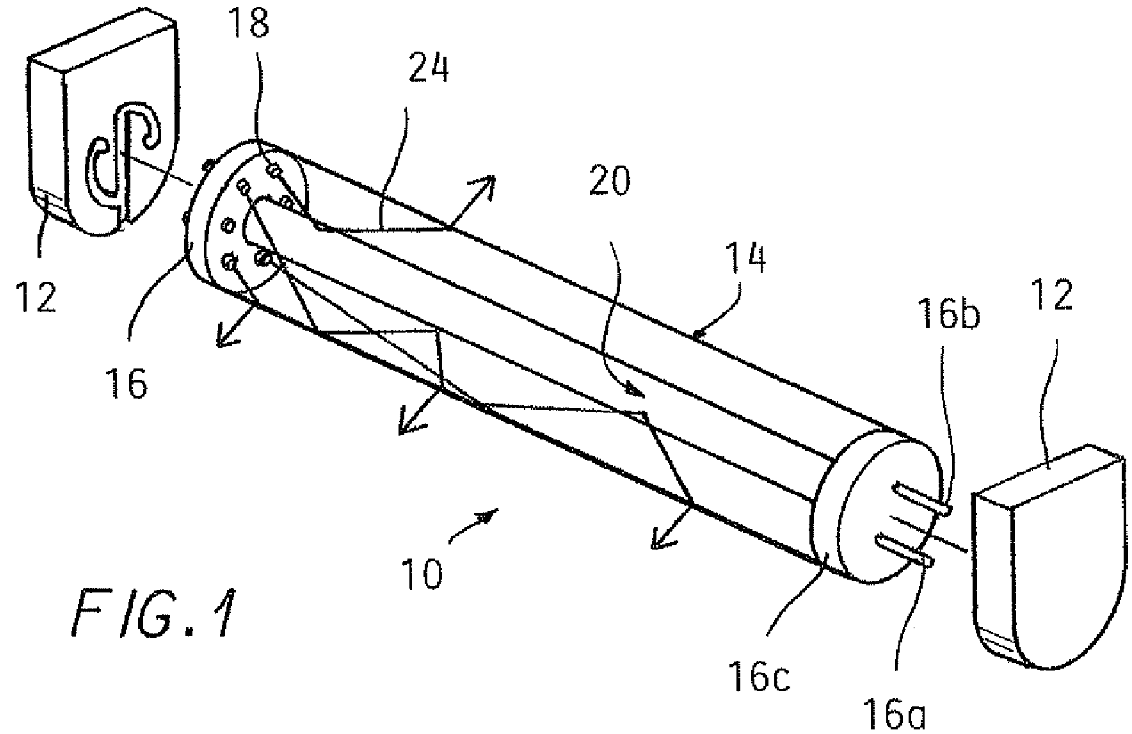

FIG. 1

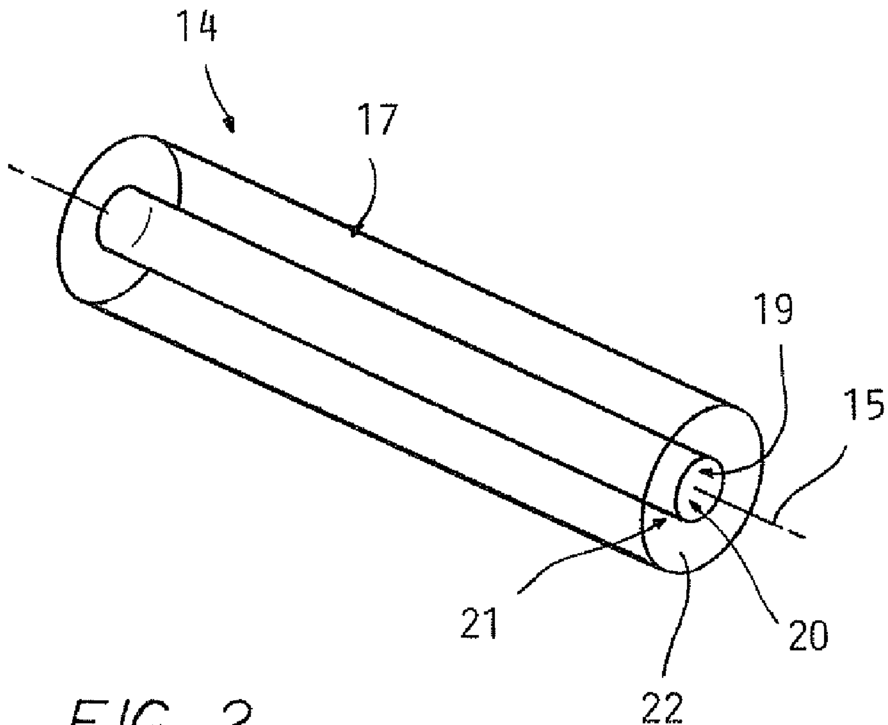

FIG. 2

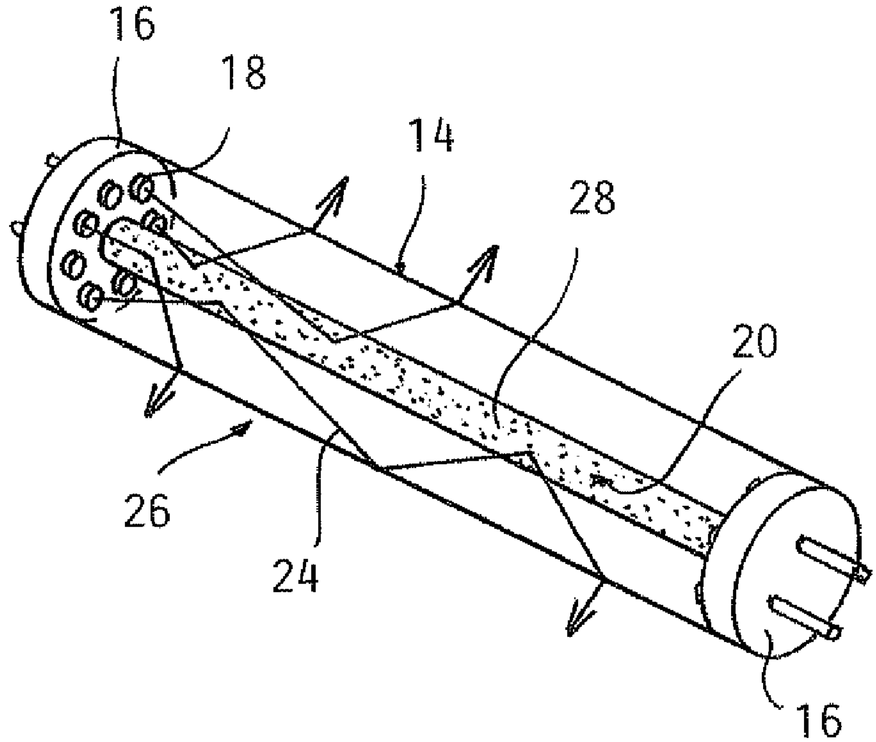

FIG. 3

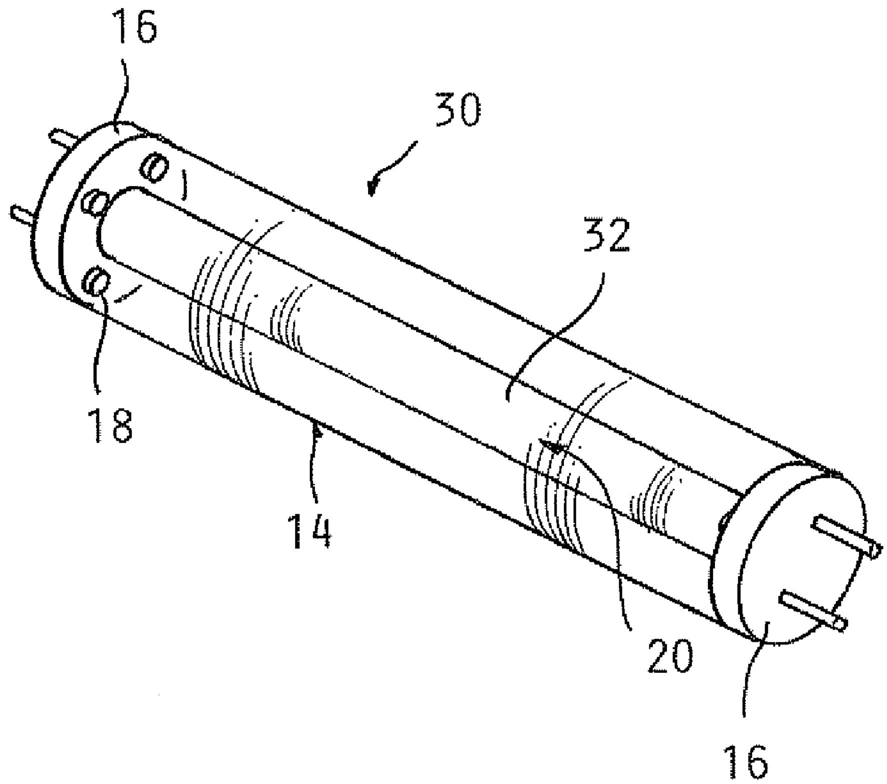

FIG. 4

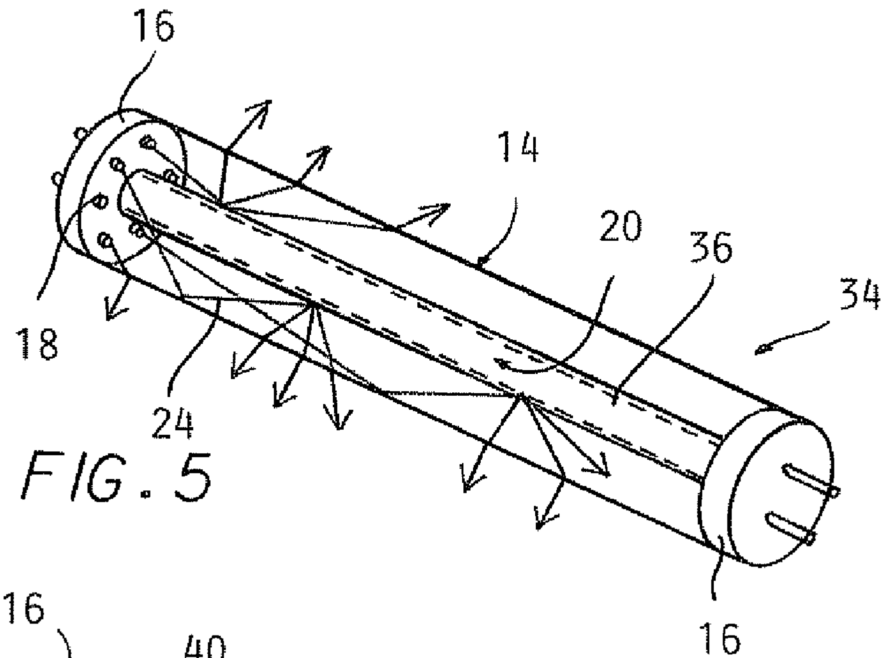

FIG. 5

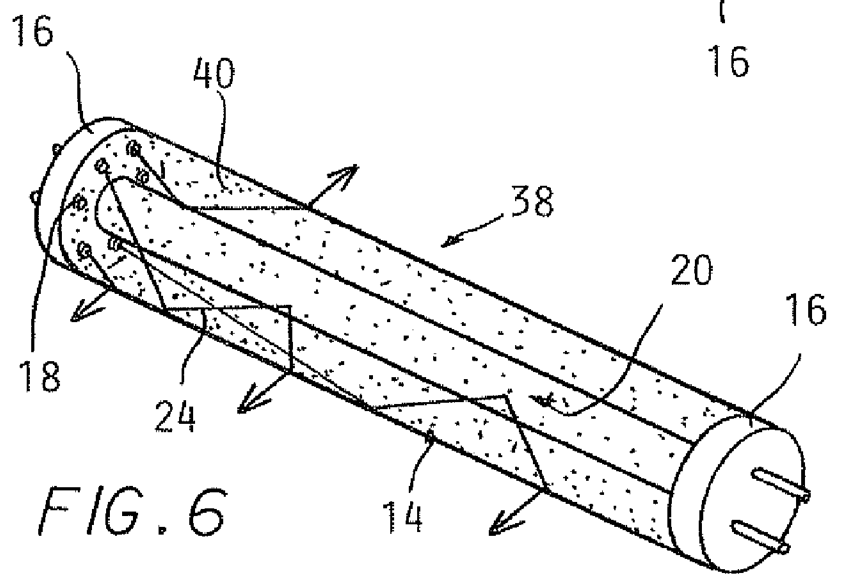

FIG. 6

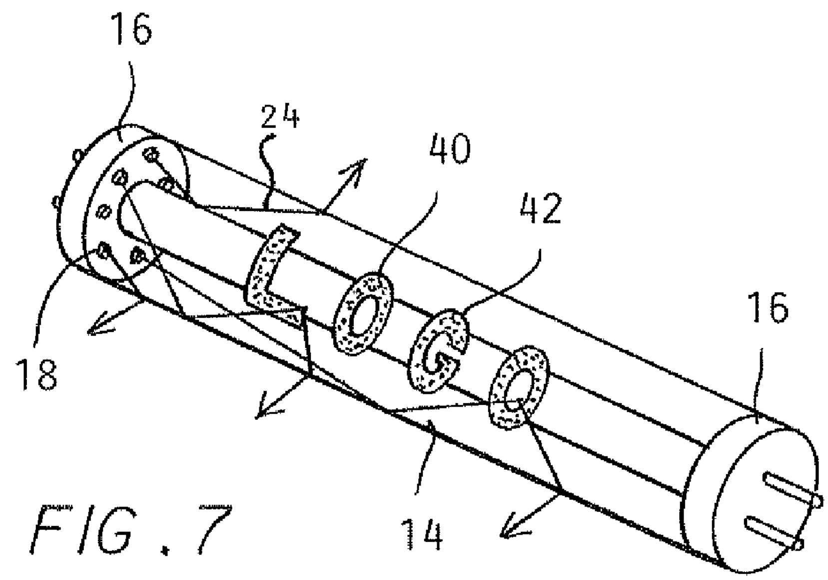

FIG. 7

FLUORESCENT TUBE REPLACEMENT HAVING LONGITUDINALLY ORIENTED LEDS

TECHNICAL FIELD

The present invention relates to an LED-based light for replacing a conventional fluorescent tube in a fluorescent fixture.

BACKGROUND

Light emitting diodes (LEDs) have many advantages over fluorescent lights. LEDs are more efficient, last longer, and are less sensitive to vibrations and low temperatures. To take advantage of the benefits of LEDs, lights in the shape of conventional fluorescent tubes have been constructed to include LEDs. Known fluorescent tube-shaped lights using LEDs are constrained by the directional light output of the LEDs, in contrast to the uniform non-directional light output of fluorescent tubes.

BRIEF SUMMARY

Known lights including LEDs provide directional light output that may result in the appearance of bright spots on the light. Thus, known lights including LEDs may appear different from fluorescent lights, which are characterized by their uniform light distribution. An LED-based light according to the present invention can provide a more uniform light output than the some known lights including LEDs in order to more closely match the light distribution of a fluorescent light. In general, an LED-based light for replacing a conventional fluorescent tube in a fixture includes an elongate light transmitting rod defining a bore. At least one LED is positioned at one or both ends of the rod and oriented to produce light longitudinally into a portion of the rod radially outward of the bore. At least one connector is physically coupled to an end of the rod and electrically coupled to the at least one LED, and the at least one connector is adapted for physical and electrical connection to the fixture.

In another embodiment, an LED-based light for replacing a conventional fluorescent tube in a fixture is described. An elongate light transmitting rod defines a bore. Multiple LEDs are positioned at one or both ends of the rod and oriented to produce light longitudinally into a portion of the rod radially outward of the bore. A pair of bi-pin end caps is coupled to opposing ends of the rod, and at least one of the bi-pin end caps is in electrical communication with the multiple LEDs.

In yet another embodiment, a method of forming an LED-based light for replacing a conventional fluorescent light in a fixture includes providing an elongate light transmitting rod defining a bore, positioning at least one LED to produce light longitudinally into a portion of the rod radially outward of the bore, and attaching a pair of bi-pin end caps to opposing ends of the rod, with at least one of the end caps in electrical communication with the at least one LED.

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 LED-based light according to the present invention;

FIG. **2** is a perspective view of the rod of the LED-based light of FIG. **1**;

FIG. **3** is a perspective view of an LED-based light including a bored rod having an uneven light refracting texture on its inner circumference;

FIG. **4** is a perspective view of an LED-based light including a bored rod and a reflector positioned in the bore;

FIG. **5** is a perspective view of an LED-based light including a bored rod and a light diffusing material in the bore; and

FIG. **6** is a perspective view of an LED-based light including a bored rod having a textured outer surface.

FIG. **7** is a perspective view of an LED-based light including a bored rod having a textured outer surface in the shape of the word "LOGO".

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Embodiments of an LED-based light for replacing a conventional fluorescent tube in a fixture are illustrated in FIGS. **1-7**. FIG. **1** illustrates an LED-based light **10** for use in a fixture **12** designed to accept conventional fluorescent tubes. The light **10** includes an elongate light transmitting rod **14**, bi-pin end caps **16**, and LEDs **18** positioned between the rod **14** and one of the end caps **16**.

The rod **14** as shown in FIG. **2** defines a longitudinal axis **15**, an outer surface **17**, an inner surface **19**, and two end surfaces **21** extending radially between the outer surface **17** and inner surface **19**. A solid body portion **22** is the mass between the outer surface **17** and inner surface **19**. While not illustrated to scale, the rod **14** can be approximately 48" long with a 0.625", 1.0", or 1.5" diameter for engagement with the fluorescent fixture **12**. The rod **12** can be made from polycarbonate, acrylic, glass or another light transmitting material. That is, the rod **14** can be transparent or translucent. For example, a translucent rod **14** can be made from a composite, such as polycarbonate with particles of a light refracting material interspersed in the polycarbonate. While the illustrated rod **14** is cylindrical, the rod **14** can alternatively have a square, triangular, polygonal, or other cross sectional shape. Similarly, while the illustrated rod **14** is linear, the rod **14** can have an alternative shape, e.g., a U-shape. Also, each light **10** can include multiple rods **14** arranged end-to-end, in which case LEDs **18** can be positioned between the rods **14**.

As shown in FIG. **2**, the rod **14** further defines a bore **20**. The bore **20** as illustrated is cylindrical and coaxial with the rod **14**. Alternatively, the bore **20** can have a different cross sectional shape, such as a square, triangle, polygon, or other shape. The cross-sectional shape of the bore **14** can vary over the length of the rod **14**. For example, the diameter of the bore **20** can be small adjacent the LEDs **18** and grow larger moving down the length of the rod **14**. Moreover, the bore **20** can extend only a portion of the length of the rod **14**, and the bore **20** can be off center, i.e., not aligned with the longitudinal axis **15** of the rod **14**.

Referring back to FIG. **1**, the LED-based light **10** includes one of the bi-pin end caps **16** at each of its ends **21** for physically and electrically connecting the light **10** to the fixture **12**. The bi-pin end caps **16** can contain elements for physical and electrical connection to the LEDs **18**. For example, the end caps **16** can contain a reflector, a heat sink, and/or an electric circuit including a circuit board. Alternate devices for physically and electrically connecting the LEDs **18** can be used, such as a metal core circuit board or physically attaching the LEDs **18** directly to the rod **14** and wiring the LEDs **18** together. Each end cap **16** includes two pins, **16*a*** and **16*b***, for a total of four pins. However, only two of the four pins must provide an electrical connection between the fixture **12** and the LEDs **18**; the other two pins can be "dummy pins". Also, while the end caps **16** are shown as including cup-shaped bodies **16***c* engaged with the rod **14** by sliding the end caps **16** over the ends **21** of the rod **14**, end caps can have differently shaped bodies **16***c*. For example, the end caps **16** can include projections press-fit into the bore **20** for connection to the rod **14**, or the ends caps **16** can be screwed to the rod **14**. Additionally, end caps having other types of connectors, e.g., single-pin connectors, can be used depending on the design of the fixture **12**.

The LEDs **18** as illustrated in FIG. **1** are positioned at one of the ends **21** of the rod **14** and oriented to face parallel to its longitudinal axis **15**. As a result of the position of the LEDs **18**, the LEDs **18** can produce light that travels longitudinally into the solid body portion **22** of the rod **14** through one of its ends **21**. However, the LEDs **18** can be oriented at various angles relative to the longitudinal axis **15** while still producing light that travels longitudinally into the rod **14**. The angle at which LEDs **18** can be oriented relative to the axis **15** can be a function of the viewing angle of the LEDs **18**, the longitudinal distance light is desired to travel, and the light directing properties of the rod **14**. Additionally, LEDs **18** can be positioned at both ends of the rod **14** instead of just one end as illustrated in FIG. **1**.

The number of LEDs **18** can be a function of the desired power of the light **10** and the power of the LEDs **18**, and the LEDs **18** can be evenly spaced in a circular pattern around the bore **20** as shown in FIG. **1**. However, the LEDs **18** can be alternatively be spaced at other intervals, such as clustered on a side of the light **10** oriented facing a space to be illuminated. LEDs **18** can additionally be positioned at various locations along the length of the rod **12**. For example, LEDs **18** can be attached to opposing ends of the rod **14** for producing light that enters the rod **14** from both ends. If the light **10** includes multiple rods **14**, LEDs **18** can be positioned at the rod **14** junctions.

The LEDs **18** 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 **18** are shown, one or more organic LEDs can be used in place of or in addition thereto. The LEDs **18** can be attached to a printed circuit board in one of the end caps **16** as described above, and the LEDs **18** included in the LED light assembly **14** emit white light. However, LEDs that emit blue light, ultra-violet light or other wavelengths of light can be used in place of white light emitting LEDs **18**.

Due to the shape of the bored rod **14** and the position and orientation of the LEDs **18**, light produced by the LEDs **18** enters the solid body portion **22** of the rod **14** as illustrated by light rays **24** in FIG. **1**. The light rays shown in FIG. **1**, as well as any light rays **24** included in FIGS. **3**-**7**, are for illustrative purposes only and are not intended to accurately portray the actual dispersion of light from the LEDs. Each LED **18** produces light in a generally conical pattern; not all light travels parallel to the longitudinal axis **15** of the rod **14**. As a result, after the light enters the rod **14**, a portion of the light encounters the outer surface **17** at an angle greater than an angle of incidence required for refraction and is reflected back toward the surface **19**. Another portion of light refracts through the outer surface **17** shortly after entering the rod. Similarly, a portion of light is reflected off the inner surface **19** after entering the rod **14**. Such light can exit through the outer surface **17** if the light encounters the surface **17** at an angle smaller than the angle of incidence, or the light can be reflected back toward the inner surface **19**. As a result of light reflecting between the surfaces **17** and **19**, different portions of light travel different distances through the rod **14** before exiting the rod. In other words, light is emitted from the rod **14** at various distances along its longitudinal axis **15**. Thus, the light **10** can provide a distribution of light adequately uniform to simulate a fluorescent tube.

FIG. **3** illustrates a light **26** similar to the light **10** of FIG. **1**, except the inner surface **19** of the rod **14** includes an uneven light reflecting texture **28**. The texture **28** alters the angle of incidence of rays **24** relative to the inner surface **19**. As a result, the light reflecting texture **28** can increase the efficiency of the light **26** by reducing the amount of light that refracts into the bore **20**. The texture **28** consists of light directing structures such as ridges, dots, bumps, dimples and/or other uneven surfaces. The light directing structures can vary in density across the length of the rod **14**, with the structures less dense adjacent the LEDs **18** and more dense longitudinally and/or circumferentially spaced from the LEDs **18**. The varying density of the light directing structures allows a lower percentage of light to be dispersed where the amount of light is high (i.e., adjacent the LEDs **18**) and a higher percentage of light to be dispersed where the amount of light is low (i.e., longitudinally spaced from the LEDs **14**). Greater light dispersion increases the amount of light exiting the rod **14**, thereby achieving a substantially uniform distribution of light along the entire length of the rod **14**. Similarly, the texture **28** can include surfaces angled slightly relative to the longitudinal axis **15** adjacent the LEDs **18** and surfaces angled greater relative to the longitudinal axis **15** spaced from the LEDs **18**. The placement of the structures making up the light directing texture **28** can be determined by software, such as the software disclosed in Michael Zollers, "Integrated Optimization Capabilities Provide a Robust Tool for LED Backlight Design," *LEDs Magazine* (October 2006), pp. 27-29, which is hereby incorporated by reference, though the placement can alternatively be determined by hand-calculation or experimentation.

FIG. **4** illustrates a light **30** similar to the light **10**, except the light **30** includes a reflector **32** positioned in the bore **20**. The reflector **32** can be a mirror made of glass or plastic with a metallic coating on its backside and can include a diffusing surface (not shown) if desired. As described above, the LEDs **18** are spaced around the bore **20** and emit light longitudinally into the rod **14**. A portion of the light contacts the inner surface **19**, and some of this light refracts through the surface **19** into the bore **20**. The light entering the bore **20** can be reflected by the reflector **20** back into the rod **14**, where it can then pass through the outer surface **17** and illuminate a space to be illuminated. As a result, the reflector **32** increases the efficiency of the light **30**.

FIG. **5** illustrates a light **34** similar to the light **10**, except the bore **20** of the light **34** includes a light diffusing material **36**. The light diffusing material **36** can be, for example, silicone, epoxy, or clear polyurethane. The material **36** diffuses light entering the bore **20**. The diffused light travels through the bore **20** until it contacts the inner surface **19** at an angle such that the light refracts back into the rod **14**. By dispersing light entering the bore **20**, the light diffusing material **36** can aid in more uniformly distributing light from the rod **14**. Further, the light diffusing material **36** may have a higher coefficient of thermal conductivity than the rod **14**, such as when silicone is used as the material **36**. As a result, the material **36** can act as a heat sink by dissipating heat produced by the LEDs **18**.

FIG. **6** illustrates a light **38** similar to the light **10**, except the outer surface **17** includes an uneven light reflecting texture **40** similar to the previously described texture **28**. The texture **40** can vary over the length of the rod **14**, for example by varying the density or geometry of the structures making up the texture **40** as described above in reference to the texture **28**. Additionally, the texture **40** can be shaped to form an alphanumeric character, a picture, or another shape. For example, as shown in FIG. 7, the word "LOGO" **42** is formed from the texture **40**. By forming light reflecting texture **40** in the shape of alphanumeric characters and/or pictures, a greater amount of light exits the rod **14** through the "LOGO" **42** than other areas of the surface **17**. Thus, the alphanumeric characters and/or pictures appear more brightly lit than the remainder of the outer surface **17** of the rod **14**. The portion of the outer surface **17** not including the word "LOGO" **42** can also be textured for controlling the passage of light through the remainder of the outer surface **17**, though with a different texture than the texture **40** forming "LOGO" **42**.

The lights shown in each of FIGS. **1** and **3-7** can include additional features not illustrated. For example, a diffusing layer can be wrapped around the exterior of the rod **14** or positioned to line the bore **20**.

The above-described embodiments have been described in order to allow easy understanding of the invention and do not limit the invention. On the contrary, the invention is intended to cover various modifications and equivalent arrangements included within the scope of the appended claims, which scope is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structure as is permitted under the law.

What is claimed is:

1. An LED-based light for replacing a conventional fluorescent tube in a fixture, the LED-based light comprising:

an elongate light transmitting rod having a first end and an opposing, second end and defining a bore extending at least partially between the first end and the second end, the bore having an outer surface spaced apart from an outer surface of the rod such that a material of the rod fills a portion of the rod between the outer surface of the bore and the outer surface of the rod;

at least one LED positioned at one or both of the first and second ends of the rod and oriented to produce light longitudinally into the portion of the rod radially outward of the outer surface of the bore; and

a connector physically coupled to the first end or the second end of the rod, the connector adapted for physical connection to the fixture.

2. The LED-based light of claim **1**, wherein the rod includes an uneven light refracting texture.

3. The LED-based light of claim **2**, wherein the texture varies over a length of the bore.

4. The LED-based light of claim **2**, wherein the texture is less dense adjacent the at least one LED and more dense further away from the at least one LED.

5. The LED-based light of claim **2**, wherein the light refracting texture is shaped in the form of one of an alphanumeric character and a picture.

6. The LED-based light of claim **1**, wherein the bore encloses a reflector.

7. The LED-based light of claim **1**, wherein the bore encloses a light diffusing material.

8. The LED-based light of claim **7**, wherein the light diffusing material includes silicone.

9. An LED-based light for replacing a conventional fluorescent tube in a fixture, the LED-based light comprising:

an elongate light transmitting rod having a first end and an opposing, second end and defining a bore extending at least partially between the first end and the second end, the bore having an outer surface spaced apart from an outer surface of the rod such that a material of the rod fills a portion of the rod between the outer surface of the bore and the outer surface of the rod;

multiple LEDs positioned at one or both of the first and second ends of the rod and oriented to produce light longitudinally into the portion of the rod radially outward of the outer surface of the bore; and

a pair of bi-pin end caps coupled to the opposing ends of the rod, at least one of the bi-pin end caps in electrical communication with the multiple LEDs.

10. The LED-based light of claim **9**, wherein the rod includes an uneven light refracting texture.

11. The LED-based light of claim **10**, wherein the texture varies over a length of the bore.

12. The LED-based light of claim **10**, wherein the texture is less dense adjacent the LEDs and more dense further away from the LEDs.

13. The LED-based light of claim **10**, wherein the light refracting texture is shaped in the form of one of an alphanumeric character and a picture.

14. The LED-based light of claim **9**, wherein the bore encloses one of a reflector and a light diffusing material.

15. The LED-based light of claim **1**, wherein the at least one LED is positioned at the one or both of the first and second ends of the rod radially outside an inner edge of the LED-based light defined by the outer surface of the bore and within an outer edge of the LED-based light defined by the outer surface of the rod.

16. The LED-based light of claim **9**, wherein the multiple LEDs are positioned between an outer edge of the LED-based light defined by the outer surface of the rod and an inner edge of the LED-based light defined by the outer surface of the bore and between a respective one of the pair of bi-pin end caps coupled to the opposing ends of the rod and one of the first and second ends of the rod.

17. A method of forming an LED-based light for replacing a conventional fluorescent tube in a fixture, the method comprising:

providing an elongate light transmitting rod defining a bore, the bore having an outer surface spaced apart from an outer surface of the rod such that a material of the rod fills a portion of the rod between the outer surface of the bore and the outer surface of the rod;

positioning at least one LED to produce light longitudinally into the portion of the rod radially outward of the outer surface of the bore; and

attaching a pair of bi-pin end caps to opposing ends of the rod, with each of the pair of end caps in physical communication with an opposing mount of the fixture.

18. The method of claim **17**, further comprising forming an uneven light reflecting texture on the rod.

19. The method of claim **17**, further comprising placing a reflector in the bore.

20. The method of claim **17**, further filling the bore with silicone.

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