05 May 2006

BULKY LENS, LIGHT EMITTING UNIT, AND LIGHTING INSTRUMENT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The instant invention relates to an optical lens, a light-emitting unit, and a lighting instrument using the light-emitting unit. The lighting instrument may includes a hand-held tool such as a screwdriver, or a writing implement with a light-emitting unit, and a locking/unlocking system for locking up and unlocking a drawer of a desk or furniture with an optical signal contained a personal identification signal by means of a fundamental structure of such a hand-held tool.

2. Description of the Related Art

Recently, a thin flashlight, or an electric torch using a halogen lamp is commercially available. However, there is a drawback such that a battery used in this kind of the flashlight has a life of only about 3 hours in a continuously lighting condition and the life of the halogen lamp, itself, is so short.

On the other hand, a liquid crystal display (LCD) device is widely used in a personal computer, a word processor system, a compact portable television (TV), a car TV, and so forth. For illuminating such a LCD panel, a fluorescent discharge tube, i.e., fluorescent lamp, is used as a backlight. The fluorescent lamp has a problem of which is easy to damage or to degrade a performance, if the portable TV or the portable personal computer was fallen on the floor. When the fluorescent lamp used under a low temperature environment in winter, a lighting efficiency of the fluorescent lamp becomes low because a pressure of a mercury vapor in the lamp tube is lowered, so that a sufficient intensity cannot be obtained. Further, the fluorescent lamp has no stability and reliability sufficient for a long time operation. It is the most important problem that the fluorescent lamp dissipates large electric power. For example, in the portable personal computer, the power consumption of the LCD section is overwhelmingly large as compared with the power consumption of a microprocessor and a memory. Thus, it is difficult to operate the portable

TV or the portable personal computer for a long time, if the fluorescent lamp is used as the backlight. There is a problem of a strain of eyes caused by flickering of the fluorescent lamp, depending on a difference among individuals, as the fluorescent lamp flashes in pulsed fashion corresponding to a frequency of a power source. Therefore, in case of usage similar to direct lighting such as the backlight, there is also a problem of the strain of eyes, or an influence to a human body based on the strain of eyes, due to the light from the fluorescent lamp for a long time.

Turning now to a meeting for research conference or a lecture, a slide projection or a video projection is often performed and then a desktop is in darkness. If we intend to take notes in such the darkness, something to illuminate is convenient for us. Or, if we intend to make a note of a contents of a telephone called at night onto a pocket notebook in the darkness and we intend to record something during outdoor work at night or during night training, we need something like a lighting instrument. Further, on the occasion of maintenance, an inspection or repair of a large mechanical system such as an air conditioner or an engine, the inner part is dark even in the daytime. In such a case we often need something like a lighting instrument. However, if there is no assistant person who holds the lighting instrument, we must conduct required operation, holding the tool with one hand while lightning the corresponding position by the lighting instrument held by another hand. The work in this situation may be very bad for us. It may be inconvenient that we always carry and handle the hand-held tool for some situations or uses. Under this circumstance, the hand-held tool such as handy tool or writing implement, which can secure the sufficient luminance, and has an advantage to the workability in the dark and portability, has not been realized in spite of being awaited for a long time.

A semiconductor light emitting device, such as a light emitting diode (LED), converts directly an electric energy to an optical energy. Therefore, the semiconductor light emitting device has a performance of a high efficiency and a light emission without heat generation compared with an incandescent lamp, such as a halogen lamp, and a fluorescent lamp. The incandescent lamp converts the electric energy to thermal energy, and then, utilizes the radiation by the thermal energy. Thus, the conversion efficiency of the incandescent lamp is theoretically low and not beyond 1%. In the fluorescent lamp, the electric energy is converted to the electric discharge energy and the

conversion efficiency of the fluorescent lamp is also low. On the contrary, the LED can obtain the conversion efficiency of about 20% or more, and can easily accomplish the conversion efficiency of 1000 times or more compared with the incandescent lamp and the fluorescent lamp. Further, since the semiconductor light emitting device has a long life, which can be regarded as almost semi-permanent, and has no problem of flickering such as the one of fluorescent lamp, the emitted light from the semiconductor light emitting device is a light with no influence on human eyes, that is to say a gentle light for human.

In spite of outstanding performance of the LED, it is rare that the LED is used for a lighting instrument. Applications of the LED are limited in a narrowly restricted field, such as an indication lamp of a control panel of various devices, a display apparatus of electric board and so forth. Recently, an LED product for illuminating a keyhole is known partially, but it can illuminate only small area. Except for such a special case, in general, the LED does not used for illumination.

This is caused by the fact that a sufficient beam for a lighting instrument cannot be obtain by the LED, because of a light emitting active area of an LED is small such as about 1 mm^2 in spite of the fact that the luminance of the LED is extremely high. Fig. 2B shows a schematic view of optical system using a convex lens 101. In a simple consideration, it might be thought that the parallel beam of predetermined diameter can be obtained from the light of the LED by using the conventional optical system as shown in Fig. 2B. However, in practice, it is difficult to obtain a bright and parallel beam with a large diameter by the convex lens 101.

As described above, in case where the conventional optical system is used, the luminance on a target surface of lighting by the single LED does not reach the desired level. Thus, the luminous flux per unit area at any point on the irradiated surface is not enough. In a simple manner, one might suppose that, if the lighting instrument with a large number of the LED's arrayed in matrix is constructed, a certain luminance will be obtained. However, an expensive compound semiconductor is used as the main material for manufacturing the LED and advanced manufacturing technologies such as epitaxial growth and a diffusion of impurity are required at the present time. Therefore, a manufacturing cost of the LED has a certain limitation in reduction. Further, each of the materials of the semiconductors has a specific

circumstance, for example, an expensive sapphire substrate is used for the substrate of the epitaxial growth of a gallium nitride (GaN), which is well known as the semiconductor material for a blue LED.

In view of the manufacturing cost, it is not practical to provide the light-emitting unit (lighting instrument) by way of arraying a large number of the LED's so as to obtain a desired luminance, for example. In a current silicon (Si) device technology, a wafer having a diameter of 300mm has began to be used, however such a large diameter wafer cannot be obtained currently as a substrate for epitaxial growth of the compound semiconductor, which is the material of the LED. Moreover, it is difficult to manufacture the LED having a large light-emitting area fundamentally, since there is a problem on manufacturing technology such as uniformity of epitaxial growth.

By the way, on coming of the information-oriented society, the necessity of securing the private information of individuals is increased. Therefore, locking/unlocking system for the entrance of the specific room, the drawer of the desk, the drawer or door of the furniture, the lid of the seal box or accessory box, the door of the vault, and the lid of the cashbox, has become important. However, it is inconvenient that all the keys of a plurality of entrance-doors of the building, a plurality of entrance-doors of the room, and so forth, carrying around always. Therefore, a novel security system, which can cancel the inconvenience to carry the many keys (especially mechanical keys), is also long awaited.

SUMMARY OF THE INVENTION

In view of these situations, it is an object of the present invention to provide a bulky lens such as a bullet-shaped lens, which can use a light source commercially available, such as an LED, and which can obtain a desired luminance, without necessity of a large number of light sources. For example, the semiconductor light emitting device, such as an LED and a semiconductor laser can be employed as the "light source."

Another object of the present invention is to provide a bulky lens for efficiently extracting a potential luminous energy of the light source commercially available, and which easily can change a light path and focus such as diverging or converging, without no geometrical treatment on itself.

Still another object of the present invention is to provide a light-emitting

unit with low price, the light-emitting unit has a sufficient luminance, a stability for a long period, and a reliability.

Still another object of the present invention is to provide a light-emitting unit having low power consumption and no flickering.

Still another object of the present invention is to provide a lighting instrument with long battery life and suitable for carrying.

Still another object of the present invention is to provide a hand-held tool with a light-emitting unit, which has a long duration of the battery power and can illuminate with the suitable luminance preventing from eyestrain. Thus, such the instrument achieves a localized illumination having a sufficient luminance on comparably wide area, without an assistant, and can work in the dark for a long period.

Still another object of the present invention is to provide a hand-held tool with a light-emitting unit, which has a simple structure with a small number of parts. Thus, a hand-held tool with a light-emitting unit, which is easy to manufacture, and easy to reduce the manufacturing cost and cost of a product is to be provided.

Still another object of the present invention is to provide a locking/unlocking system, which has a simple structure, and sends an optical signal by utilizing a structure of a hand-held tool with a light-emitting unit and performs the locking or unlocking by using the optical signal.

Still another object of the present invention is to provide a locking/unlocking system, which can cancel the inconvenience of carrying many of keys in bundle, such as keys of doors of a plurality of rooms, keys of drawers of a plurality of desks, and so forth.

Still another object of the present invention is to provide a locking/unlocking system, which has a small influence on peripheral devices and receive a small influence from peripheral devices such as a cellular phone.

Still another object of the present invention is to provide a locking/unlocking system, which easily visualizes a condition and is easy to troubleshoot the system.

Still another object of the present invention is to provide a locking/unlocking system, which is hard to be influenced by noises or direct rays of the sun, further does not lose the reliability by changing of the using condition.

A first aspect of the present invention inheres in a bulky lens comprising a bulky body having top and bottom portion and a cylindrical recess formed upward from the bottom portion of the bulky body. Here, a ceiling of the cylindrical recess serves as a first lens surface, the top portion of the bulky body serves as a second lens surface from which a light entering from the first lens surface exits, or to which a light can enter, the cylindrical recess serves as an accommodating portion for accommodating a main portion of a light source or a photo detector.

For example, if accommodating portion accommodates a main portion of the light source, the ceiling of the cylindrical recess serves as an incident surface and the top portion of the bulky body serves as a transmitting surface from which a light entering from the incident surface exits. And, if the accommodating portion accommodates a photo detector, the top portion of the bulky body serves as an incident surface, and the ceiling of the cylindrical recess serves as a transmitting surface from which a light entering from the incident surface exits.

Then, the cylindrical recess comprises the incident surface and a sidewall extended from the incident surface. In the present invention, "the bulky lens" includes a bullet-shaped lens, or an egg-shaped lens having a cylindrical outer surface. However, the cross sectional view of the bulky body perpendicular to the optical axis can be rectangle, or polygon. Then, the bulky body can be circular cylinder, rectangular cylinder (rectangular prism), or quasi- circular cylinder having a tapered portion like a cone. "The bulky lens" further includes a sliced bullet-shape so as to have slab geometry. In the slab geometry, light source is sandwiched by two opposing flat surfaces, but the bulky lens still have common transmitting surface having a predetermined radius of curvature. The geometry of "the bulky lens" further includes a semi cylindrical, or a barrel vault configuration. The incident surface has a first curved surface, and the transmitting surface has a second curved surface.

Transparent resin such as acrylic acid resin, and many kinds of glass material such as quartz glass, soda-lime glass, borosilicate glass and lead glass, and transparent plastic material is used as the transparent solid material for the wave guide portion. A crystal material such as a zinc oxide (ZnO), a zinc sulfide (ZnS), or a silicon carbide (SiC) may also be used as the wave guide portion.

According to the first aspect of the present invention the bulky lens can

use the "light source" commercially available, and easily obtain a desired luminance without necessity of numerous them. The luminance cannot be accomplished by a conventionally known optical system. Therefore, the luminance that cannot be predicted by technical common sense can be realized. For instance, while the LED has internal quantum efficiency and external quantum efficiency, the external quantum efficiency is lower than the internal quantum efficiency in general. By accommodating the LED in the accommodating portion (cylindrical recess) of the bulky lens according to the first aspect of the present invention, the potential luminous energy of the LED can effectively extracted with the efficiency nearly equal to the internal quantum efficiency.

According to the first aspect of the present invention the bulky lens can efficiently extract a potential luminous energy of the light source commercially available, and easily can change a light path and focus such as diverging or converging, without no treatment on itself.

Preferably, the "light source" is the LED emitting light with a predetermined diverging angle in a specific direction. Because, if the diverging angle in the specific direction of emitting light is known, optical design such as converging or diverging become easy, and a radius of curvature of the first and second curved surface can be selected easily. It should be noted that one of the first and the second curved surfaces could include a substantially flat surface with the infinite or near infinite radius of curvature. Because, if one of the first and second curved surface has a predetermined (finite), i.e., not infinite, radius of curvature, the converging or diverging of the light can be controlled. It should also be noted that the "predetermined diverging angle" can include 0°, i.e., the parallel beam. Even if the diverging angle is 90°, the light beam emitted from the light source can be acquired effectively, since the accommodating portion optically covers the main light-emitting portion of the light source, almost entirely. This cannot be achieved by the conventional optical system such as convex lens, concave lens or meniscus lens. Namely, inner wall portion of the accommodating portion other than the incident surface (ceiling portion) of the first curved surface can also function as an effective light incident portion.

A second aspect of the present invention inheres in a light-emitting unit comprising a light source and the bulky lens prescribed by the first aspect.

The light-emitting unit according to the second aspect of the present invention maintains reliability and stability for a long period operation. Because, even if the light source is accommodated within the cylindrical recess (accommodating portion) of the bulky lens, the heat of the light source does not influence thermally on the bulky lens, if we employ the light source with less generation of heat such as semiconductor light emitting devices.

The light-emitting unit according to the second aspect of the present invention can easily obtain the desired luminance with the small number of the light sources. This luminance cannot be achieved by the conventionally known optical system and provides a sufficient brightness, which could not be predicted by the common technical sense. Further, this light-emitting unit can have low power consumption and no flickering, if we employ the semiconductor light emitting devices..

Because, if the diverging angle in the specific direction of emitting light is known, optical design such as converging or diverging become easy, and a radius of curvature of the first and second curved surface can be selected easily. As described on the first aspect, one of the first and the second curved surfaces could include a substantially flat surface with the infinite or near infinite radius of curvature.

In the light-emitting unit according to the second aspect of the present invention, the accommodating portion accommodates the light source intervening a fluid or a flowing material having a second refractive index different from the first refractive index, preferably. Where the "fluid" means, a transparent gaseous material or liquid and the flowing material refers to a sol, a colloid or a gel.

Alternatively, the main light-emitting portion of the light source of the light-emitting unit according to the second aspect of the present invention can be an end portion of an optical fiber with a transmission portion consisting of a transparent material having a first refractive index, which optically connected to a predetermined light source, and the accommodating portion accommodates the end portion of the optical fiber intervening a fluid or a flowing material having a second refractive index different from the first refractive index.

A third aspect of the present invention inheres in a lighting instrument having a battery and the light-emitting unit according to the second aspect of the present invention. In the light-emitting unit, the light source has

terminals connected to an anode and a cathode of the battery.

The lighting instrument according to the third aspect of the present invention simplifies the structure and reduces the manufacturing cost, since the single semiconductor light emitting device can be used. The potential luminous energy of this semiconductor light emitting device can also be effectively extracted so as to obtain sufficient luminance necessary for illumination. Further, this lighting instrument has advantages of stability and reliability for a long period and has no flicker. Moreover, because of low power-consumption the battery life of the instrument is elongated.

The lighting instrument according to the third aspect of the present invention can also be used as the lighting instrument (backlight) for the LCD device of a portable personal computer, a word processor system, a compact TV, a car TV or the same as well as a flashlight. Further, it can apply to many kinds of electric product including a indirect illumination device.

Other and further objects and features of the present invention will become obvious upon an understanding of the illustrative embodiments about to be described in connection with the accompanying drawings or will be indicated in the appended claims, and various advantages not referred to herein will occur to one skilled in the art upon employing of the present invention in practice.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a schematic sectional view of a light-emitting unit according to a first embodiment of the present invention;

Fig. 2A shows an optical measurement system to show the technical advantage of the present invention, in which the beam intensity profiles were measured along y-direction, which is orthogonal to the optical axis along x-direction;

Fig. 2B shows an optical measurement system according to the conventional optical system for comparison with Fig. 2A.

Fig. 3 shows the beam intensity profiles measured along y-direction, which is orthogonal to the optical axis along x-direction, measured at distance $x = 1$m.

Fig. 4 shows the relationship between the maximum intensity and the

inverse square of the measured distance x

Fig.5 shows a schematic sectional view of a bullet-shaped lens as a first modification of the first embodiment of the present invention.

Fig. 6 shows a schematic sectional view of a bullet-shaped lens as the second modification of the first embodiment of the present invention.

Fig. 7 shows a schematic sectional view of a bullet-shaped lens as the third modification of the first embodiment of the present invention.

Fig. 8 shows a schematic sectional view of a light-emitting unit according to a second embodiment of the present invention.

Fig. 9 shows a schematic sectional view of a light-emitting unit according to a third embodiment of the present invention.

Fig. 10A shows a birds eye view of a light-emitting unit according to a fourth embodiment of the present invention.

Fig. 10B shows a schematic sectional view of the light-emitting unit according to the fourth embodiment of the present invention.

Fig. 11 shows a detailed birds eye view of a reflection mirror having a resin molded LED supported by an insulating material according to the fourth embodiment of the present invention.

Fig. 12A shows a birds eye view of a light-emitting unit according to a fifth embodiment of the present invention.

Fig. 12B shows a schematic sectional view of the light-emitting unit according to the fifth embodiment of the present invention.

Fig. 13 shows a schematic sectional view of the light-emitting unit according to a first modification of the fifth embodiment of the present invention.

Fig. 14 shows a schematic sectional view of the light-emitting unit according to a second modification of the fifth embodiment of the present invention.

Fig. 15 shows a schematic sectional view of a light-emitting unit according to a sixth embodiment of the present invention.

Fig. 16 shows a schematic sectional view of a lighting instrument according to a seventh embodiment of the present invention.

Fig. 17A shows a schematic sectional view of a lighting instrument according to an eighth embodiment of the present invention.

Fig. 17B shows a separated configuration of the lighting instrument according to the eighth embodiment.

Fig. 18 shows details of the lightning portion of the lighting instrument according to the eighth embodiment.

Fig. 19A shows a schematic sectional view of a lighting instrument according to a first modification of the eighth embodiment of the present invention.

Fig. 19B shows a schematic sectional view of the lighting instrument according to a second modification of the eighth embodiment of the present invention.

Fig. 20 shows a schematic view of a security system employing the lighting instrument according to a ninth embodiment of the present invention.

Fig. 21A shows a drawer installed under a desk top, in which the security system according to the ninth embodiment is installed.

Fig. 21B shows another schematic view of a security system according to the ninth embodiment of the present invention.

Fig. 22 shows another schematic view of a security system according to the ninth embodiment of the present invention.

Fig. 23 shows a schematic sectional view of a lighting instrument according to a tenth embodiment of the present invention.

Fig. 24 shows a schematic sectional view of an optical system employing the bullet-shaped lens according to another embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Various embodiments of the present invention will be described with reference to the accompanying drawings. It is to be noted that the same or similar reference numerals are applied to the same or similar parts and elements throughout the drawings, and the description of the same or similar parts and elements will be omitted or simplified. Generally and as it is conventional in the representation of optical instrument, it will be appreciated that the various drawings are not drawn to scale from one figure to another nor inside a given figure, and in particular that the layer thicknesses are arbitrarily drawn for facilitating the reading of the drawings.

In the following description specific details are set fourth, such as specific materials, process and equipment in order to provide thorough understanding of the present invention. It will be apparent, however, to one

skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known manufacturing materials, process and equipment are not set fourth in detail in order not unnecessary obscure the present invention.

(FIRST EMBODIMENT)

As shown in Fig. 1, the light-emitting unit according to a first embodiment of the present invention has a light source 1 emitting a light with a predetermined wavelength and a bulky lens 20 covering most entirely the light source 1. The bulky lens 20 of the first embodiment of the present invention is a bullet-shaped lens. This bullet-shaped lens 20 at least has a bulky body 4 having top portion 3 and bottom portion and a cylindrical recess 6 formed upward from the bottom portion of the bulky body. Here, a ceiling of the cylindrical recess 6 serves as a first lens surface (an incident surface) 2, the top portion of the bulky body serves as a second lens surface (a transmitting surface) 3 from which a light entering from the incident surface 2 exits, the cylindrical recess 6 serves as an accommodating portion 6 for accommodating a main portion of the light source 1.

The incident surface (a first lens surface) 2 is formed with the first curved surface 2. A sidewall is extended downward from the ceiling portion 2 to form the cylindrical recess 6. The transmitting surface (a second lens surface) 3 is formed with a second curved surface 3. The bulky body 4 consists of a solid material transparent to the wavelength of the light emitted from the light source 1.

As shown in Fig. 1, the light source 1 is a resin molded LED and has an LED chip 13 arranged on a stem connected in unity to a first pin 11, a resin 14 covering the LED chip 13, and a second pin 12 forming a pair with the first pin 11. The top of the main luminous portion of the resin molded LED 1 has a convex surface, as shown in Fig. 1. The light from the LED chip 13 is emitted in a predetermined diverging angle to the rightward on Fig. 1, because of the convex surface formed at the top of the resin 14.

The rest of resin molded LED 1 is formed in column shape with diameter (outside diameter) of 2 to 3 mm$^{\phi}$ other than the convex surface. The sidewall of the accommodating portion 6 of the bullet-shaped lens 20 is formed as a cylindrical surface of diameter (inside diameter) $2r$ of 2.5 to 4 mm so as to accommodate the main luminous portion of the resin molded LED 1. A spacer,

omitting to show, having a thickness of about 0.25 to 0.5 mm is inserted between the LED 1 and the accommodating portion 6 of the bullet-shaped lens 20 for fixing the LED 1 and the bullet-shaped lens 20. This spacer is arranged on the portion other than the main luminous portion of the LED 1, i.e., on leftward of the bottom surface of LED chip 13 in Fig. 1. The bullet-shaped lens 20 has a column shaped portion similar to the LED 1 other than the top portion having the transmitting surface 3, while the top portion is formed with the second curved surface 3 of convex shape. The diameter (outside diameter) $2R_0$ of the column shaped portion of the bullet-shaped lens 20 is 10 to 30 mm^{ϕ}. The diameter (outside diameter) $2R_0$ of the bullet-shaped lens 20 can be selected depending on a usage prescription of the light-emitting unit according to the first embodiment of the present invention. Therefore, the diameter $2R_0$ of 10 mm^{ϕ} or less and 30 mm^{ϕ} or more can be selected. However, to sufficiently collect the light emitted from the LED 1, it is preferable to satisfy the following equation:

$$R_0 > 3r \qquad \text{.....(1)}$$

Where R_0 is the outer radius of the bullet-shaped lens 20, and r is the inner radius of the accommodating portion 6.

The LED 1 according to the first embodiment of the present invention may be molded with the transparent material such as epoxy resin having a first refractive index n_1. Then, the bullet-shaped lens 20 accommodates the LED 1 with intervening air having a second refractive index n_0 different from the first refractive index n_1. The LED 1 may be accommodated in the accommodating portion 6 with intervening fluid or flowing material other than the air. Many kinds of the fluid can be used, whatever the gaseous material or the liquid is transparent to the wavelength of the light emitted from LED 1. Spacer oil or the like can be used between the LED 1 and the bullet-shaped lens 20 in the accommodating portion 6. Many kinds of the transparent material of a sol, a colloid or a gel can be used as the flowing material. The bullet-shaped lens 20 may have a third refractive index n_2 different from the second refractive index n_0. It is possible that the light from the LED chip 13 is converged or diverged, by appropriately selected the first refractive index n_1, the second refractive index n_0 and the third refractive index n_2. The light path may be designed that the third refractive index n_2 of the bulky body 4 of

the bullet-shaped lens 20 is gradually larger or gradually smaller.

In general, the light exits from the portion of the resin 14 other than the convex surface is not contributed for illumination but becomes a so-called stray light component. However, in the first embodiment of the present invention, these stray light components can be contributed effectively for illumination, since the resin molded LED 1 is contained in the accommodating portion 6 of the bullet-shaped lens 20, almost entirely, under the condition that R and r satisfy the equation (1). Therefore, the inside wall of the accommodating portion 6 other than the incident surface (ceiling portion) 2 formed by the first curved surface can be functioned as the incident portion of effective light. The stray light may be present between the LED 1 and the accommodating portion 6 of the bullet-shaped lens 20, based on the multiple reflection of a light at each boundary surface. These stray light components have not been extracted so as to contribute for illumination, by the conventionally known optical system such as shown in Fig. 2B with the convex lens 102. However, these stray light components enclosed within the accommodating portion 6 in the first embodiment of the present invention can be effectively collected. Resultantly, these stray light components may be contributed for illumination. By the detailed experiment by the inventors, it is preferable that the length L and the radius R of the curvature of the second curved surface 3 of the bullet-shaped lens 20 satisfy following equations:

$$0.93 < k(R/L) < 1.06 \qquad \ldots\ldots(2)$$

where

$$k = 1/(0.35n - 0.168) \qquad \ldots\ldots(3)$$

with n being the refractive index of the bullet-shaped lens 20. If the geometry of the bullet-shaped lens 20 satisfy equations (2) and (3), the collecting efficiency of the optical radiation emitted from the light source 1 improves very much.

As a result, the potential luminous energy of the LED chip 13 can be extracted effectively with the efficiency nearly equal to the internal quantum efficiency without depending on light extracting efficiency based on the shape of the resin 14 or the reflected component among the optical system.

In this way, the light-emitting unit according to the first embodiment of the present invention can secure luminous flux of a desired illuminating area for a light beam, and easily obtains a desired luminance, without necessity for a large number of the resin molded LED 1. The luminance cannot be accomplished by the conventional optical system such as the shown in Fig. 2B. Surprisingly, the luminance can be achieved by using only a single LED, which corresponds to that of the thin flashlight using the halogen lamp commercially available. Thus, the luminance that absolutely impossible to be predicted with the conventional common technical sense can be achieved by using the simple structure as shown in Fig. 1.

The optical measurement system of the present invention with the bullet-shaped lens 20 having the outer diameter $2R_0 = 30$ mm is shown in Fig. 2A, which is compared with that of Fig. 2B, showing the conventional optical system. Fig. 2B employs a very large convex lens 101having the outer diameter of 63 mm. By the optical measurement systems shown in Fig. 2A and 2B, the beam intensity profiles for both optical system were measured along y-direction, which is orthogonal to the optical axis along x-direction. In these measurements, a lux meter 102 is moved along the y-direction at predetermined distance x from the resin molded LED 1, and the results both measured at distance $x = 1$m are shown in Fig.3, with the result for bare resin molded LED 1. The similar results as shown in Fig.3 were obtained with various distances xs, and the results are plotted in Fig. 4. The ordinate of Fig. 4 shows the maximum intensity of the beam profile at each of the measured distances x, and the abscissa is measured as inverse square of the measured distance x. As shown in Fig. 4, the maximum intensity of the present invention follows "the inverse square law", but the results of the conventional optical system deviates from "the inverse square law". This means that the optical beam of the present invention is well parallel confined along the optical axis, but the optical beam of the conventional optical system is dispersed.

Furthermore, in the conventional optical system shown in Fig. 2B, additional instruments such as a lens holder and a drive mechanism other than shown in Fig. 2B are needed and an adjustment is complicated. On the contrary, the bullet-shaped lens 20 according to the first embodiment of the present invention achieves the diverging and converging of the light path with the simple structure.

The LED's of many colors (wavelengths) can use as the resin molded

LED 1 used as the light source for the light-emitting unit according to the first embodiment of the present invention. A white LED is preferable to use for illumination as the flashlight, because it is natural for eyes of human being. White LED's with many kinds of structures can be used. For example, the white LED may be constructed with the three LED chips of red (R), green (G) and blue (B) mounted adjacently, or layered vertically. In this case, six pins corresponding to three different color LED chips may be drawn out from the resin 14, or two external pins may be provided with combining the six pins into two by the internal connection in the resin 14. Further, if the one terminal (ground terminal) of each chip connected in common the four external pins are drawn out.

Transparent resin such as acrylic acid resin, and many kinds of glass material such as quartz glass, soda-lime glass, borosilicate glass and lead glass, and transparent plastic material is used as the bullet-shaped lens 20 in use with the light-emitting unit according to the first embodiment of the present invention. Furthermore, a crystal material such as ZnO, ZnS, or SiC may also be used. Still furthermore, a flexible material such as transparent rubber can be employed. Among above materials, transparent resin, such as acrylic acid resin, or transparent plastic material is suitable for mass production of the bullet-shaped lens 20. Therefore, once a mold is made and the bullet-shaped lens 20 is molded using the mold, then the mass production of the bullet-shaped lens easily realized.

FIRST MODIFICATION OF THE FIRST EMBODIMENT

As described above, the light-emitting unit according to the first embodiment of the present invention has a technical advantage that the changing of the light path, such as diverging or converging of light, and the focus point are easily achieved without treating the geometry of the light source (LED etc.) itself, by using the bullet-shaped lens. Especially, if the diverging angle in the specific direction of emitting light from the "light source" is known, optical design such as converging or diverging become easy, and a radius of curvature of the first and second curved surface can be selected easily.

Further, as shown in Fig. 5, outside of the first bullet-shaped lens 20, a bullet-shaped lens 23 is arranged, and a transparent material 24 is arranged outside of the bullet-shaped lens 23. Thus, the diameter of light beam from

resin molded LED 1 can be further enlarged so as to obtain a larger irradiation area. The bullet-shaped lens 23 formed with a solid material transparent to the wavelength of the light, comprises an accommodating portion for accommodating the first bullet-shaped lens 20 and having a third curved surface on a ceiling portion, and a transmitting surface formed with a fourth curved surface faced to the third curved surface. The transparent material 24 formed with a solid material transparent to the wavelength of the light, comprises an accommodating portion for accommodating the bullet-shaped lens 23 and having a fifth curved surface on a ceiling portion, and a transmitting surface formed with a sixth curved surface faced to the fifth curved surface.

As shown in Fig. 5, the LED 1 in the first modification of the first embodiment of the present invention is molded with the transparent material such as epoxy resin having a first refractive index n_1. Then, the first bullet-shaped lens 20 having a third refractive index n_2 accommodates the LED 1 with intervening air having a second refractive index n_0. The bullet-shaped lens 23 having a fourth refractive index n_3 accommodates the first bullet-shaped lens 20 with intervening air having a second refractive index n_0. Further, the transparent material 24 having a fifth refractive index n_4 accommodates the bullet-shaped lens 20 23 with intervening air. The LED 1, the first bullet-shaped lens 20 and the bullet-shaped lens 23 may be accommodated respectively in the accommodating portion intervening a fluid or a flowing material other than the air. The light path may be designed that the third refractive index n_2, the fourth refractive index n_3 or the fifth refractive index n_4 is gradually larger or gradually smaller.

In case of the first modification of the first embodiment of the present invention, the beam diameter can be broadened. If the beam diameter broadened too wide, the luminance is degraded. Thus, the light-emitting unit is not suitable for the flashlight, but suitable for a backlight (indirect lighting system) which requires illuminating in uniform. Therefore, if the ordinary LED is used for the backlight (indirect lighting system), a lighting point of the LED brightens as the spot and the unevenness of the brightness becomes conspicuous. If the beam diameter enlarged to about 50 – 100 mm^{ϕ}, backlighting in uniform is available.

SECOND MODIFICATION OF THE FIRST EMBODIMENT

As shown in Fig. 1, the bullet-shaped lens has the accommodating

portion 6 with the concave first curved surface 2, and transmitting surface 3 of the convex second curved surface 3. However, Fig. 1 shows mere example and many shapes that can be adopted as the first curved surface 2 and the second curved surface 3 depending on the usage condition.

Fig. 6 shows a bullet-shaped lens 21 having transmitting surface 3 of the concave second curved surface 3 as the second modification of the first embodiment of the present invention. If the concave second curved surface 3 as shown in Fig. 6 is used the light tends to diverge and uniformity suitable as the backlight can be obtained.

THIRD MODIFICATION OF THE FIRST EMBODIMENT

Fig. 7 shows the bullet-shaped lens 22 having the accommodating portion 6 with the convex first curved surface 2, and transmitting surface 3 of the convex second curved surface 3 as the third modification of the first embodiment of the present invention. By the detailed experiment by the inventors, it is preferable that the height Δ of the convex first curved surface 2 satisfy following equation:

$$0.025 < \Delta / R < 0.075 \qquad \ldots\ldots(4)$$

If the geometry of the bullet-shaped lens 20 satisfies equations (4), the uniformity of luminous intensity on the irradiated surface improves very much.

(SECOND EMBODIMENT)

Fig. 8 shows a schematic sectional view of a light-emitting unit according to a second embodiment of the present invention. As shown in Fig. 8, the light-emitting unit according to the second embodiment of the present invention has a main light-emitting portion 23 of a light source, emitting a light with a predetermined wavelength and a bulky lens 20 covering most entirely the main light-emitting portion 23. The bulky lens 20 of the second embodiment of the present invention is a bullet-shaped lens. This bullet-shaped lens 20 has an accommodating portion 6 formed as a cylindrical recess for accommodating a main luminous portion of the light source. The accommodating portion 6 has a ceiling portion 2 serving as the incident surface (a first lens surface) formed with the first curved surface 2 and a sidewall

extended from the ceiling portion 2 to form the cylindrical recess. The bulky lens 20 further has a transmitting surface (a second lens surface) 3, formed at the top portion, with a second curved surface 3 from which a light entering from the incident surface 2 exits. The bulky body 4 couples between the incident surface 2 and the transmitting surface 3, and consist of a solid material transparent to the wavelength of the light emitted from the light source. The "the main light-emitting portion" is the end of an optical fiber bundle 23 each having a transparent material of the first refractive index.

The optical fiber bundle 23 comprises a plurality of optical fibers 23a, 23b, 23c, and so forth. The optical fibers 23a, 23b, 23c, and so forth emit lights within the predetermined diverging angle to the rightward on Fig. 8. The optical fibers 23a, 23b, 23c, and so forth forming the optical fiber bundle 23 may be shaped in straight or in twisted. Of course the single optical fiber may be substituted for the optical fiber bundle 23.

Optical fiber 23 is formed into a column shape with the diameter (outside diameter) of 4 to 5 mm$^{\phi}$, for example. The sidewall of the accommodating portion 6 of the bullet-shaped lens 20 is formed as a cylindrical surface of diameter (inside diameter) of 4.5 to 6 mm$^{\phi}$ so as to accommodate the end portion of the optical fiber bundle 23. A spacer, omitting to show, having a thickness of about 0.25 to 0.5 mm is inserted between the optical fiber bundle 23 and the accommodating portion 6 of the bullet-shaped lens 20 for fixing the LED 1 and the bullet-shaped lens 20. The bullet-shaped lens 20 is column shaped other than the top portion, the convex shaped top portion serves as the transmitting surface 3 with the second curved surface. The diameter (outside diameter) of the column shaped portion of the bullet-shaped lens 20 is 10 to 30 mm$^{\phi}$. The diameter (outside diameter) of the bullet-shaped lens 20 can be selected depending on a usage of the light-emitting unit according to the second embodiment of the present invention. Therefore, the diameter of 10 mm$^{\phi}$ or less and 30 mm or more can be selected.

The optical fiber bundle 23 according to the second embodiment of the present invention comprises a plurality of optical fibers 23a, 23b, 23c, and so forth, each of which has a clad having a first refractive index n_1. Then, the bullet-shaped lens 20 accommodates the end portion of the optical fiber bundle 23 with intervening the air having a second refractive index n_0 different from the first refractive index n_1. The end portion of the optical fiber bundle 23 may be accommodated in the accommodating portion 6 intervening a fluid or a

flowing material other than the air. The bullet-shaped lens 20 may have a third refractive index n_6 different from the second refractive index n_0. It is possible that the light from the end portion of the optical fiber bundle 23 is converged or diverged, by appropriately selected the first refractive index n_1, the second refractive index n_0 and the third refractive index n_6. The light path may be designed that the third refractive index n_6 of the bullet-shaped lens 20 is gradually larger or gradually smaller.

The stray light may be present between the end portion of the optical fiber bundle 23 and the accommodating portion 6 of the bullet-shaped lens 20, based on the multiple reflection of a light at each boundary surface. These stray light components have not been extracted so as to contribute for illumination by conventional known optical system such as convex lens, concave lens or meniscus lens. However, these stray light components can be contributed for illumination, resultantly, since these stray light components enclosed within the accommodating portion 6 in the second embodiment of the present invention.

In this way, the light-emitting unit according to the second embodiment of the present invention can select voluntarily the desired illuminating area for a light beam contribution for illumination, and easily obtain a desired luminance.

The light source for entering the predetermined light from the other end of the optical fiber bundle 23 is not limited to the semiconductor light emitting device. Because the end portion of the optical fiber bundle 23 accommodated within the accommodating portion 6 of the bullet-shaped lens 20 can keep in low-temperature, even if the light from the incandescent lamp is used. Therefore, by using the light source other than the semiconductor light emitting device, the limitation of the luminous flux which defined with the light emission of the LED such as the light-emitting unit according to the first embodiment of the present invention is avoided, and the extremely bright illuminating system is accomplished.

As a matter of course, the shape of the end portion of the optical fiber bundle 23 is not limited the shape shown in Fig. 8.

(THIRD EMBODIMENT)

As shown in Fig. 9, the light-emitting unit according to a third

embodiment of the present invention uses incandescent lamp as the claimed light source 1 instead of the LED used in the first embodiment and instead of the optical fiber used in the second embodiment. That is, accommodating portion 6 of the bulky lens (or the bullet-shaped lens) 20 accommodates the incandescent lamp 1. Other parts and elements are similar to the first and second embodiments, and these descriptions are omitted here.

However, since the incandescent lamp such as the halogen lamp emits thermal energy, heat resistive transparent resin, quartz glass, or crystal material such as ZnO, ZnS, or SiC should be used as the material of the bullet-shaped lens 20.

(FOURTH EMBODIMENT)

Figs. 10A-10B and 11 show schematic view of a light-emitting unit according to a fourth embodiment of the present invention. As shown in Figs. 10A-10B and 11, the light-emitting unit according to the fourth embodiment of the present invention has a reflection mirror 31 at the bottom portion of a bulky body 4 so as to improve the collecting efficiency of the emitted light from the light source 1, which is accommodated in the accommodating portion 6. The bulky lens 25 of the fourth embodiment of the present invention is an egg-shaped lens having a circular cylindrical sidewall. As shown in Fig. 10B, the resin molded LED 1 is supported by insulating material 16. By the insulating material 16 the first pin 11and the second pin 12 are electrically isolated from each other so as not be short circuited by the reflection mirror 31, even if the reflection mirror 31 is made of metallic material. As shown in Fig. 11, the resin molded LED 1 supported by insulating material can be separated or attached to the bullet-shaped lens 25 easily. Other parts and elements are similar to the first embodiment, and these descriptions are omitted here.

(FIFTH EMBODIMENT)

As shown in Figs. 12A-12B, the light-emitting unit according to a fifth embodiment of the present invention uses a plurality of disk type surface molded LED 81, 82, 83, 84,.... as the claimed light source 1 instead of the single resin molded LED used in the first embodiment. That is, accommodating portion 6 of the bulky lens (the bullet-shaped lens) 20

accommodates the plurality of disk type surface molded LED 81, 82, 83, 84,....arranged on a flexible substrate 33 made of polyethylene terephthalate (PET), for example. Other parts and elements are similar to the first and second embodiments, and these descriptions are omitted here.

FIRST MODIFICATION OF THE FIFTH EMBODIMENT

As shown in Fig. 13, the light-emitting unit according to the first modification of the fifth embodiment of the present invention has a reflection mirror 31 at the bottom portion of an egg-shaped lens 25 so as to improve the collecting efficiency of the emitted light from the light source 81, 82, 83, 84,..., which is accommodated in the accommodating portion 6.

SECOND MODIFICATION OF THE FIFTH EMBODIMENT

As shown in Fig. 14, the light-emitting unit according to the second modification of the fifth embodiment of the present invention has a reflection mirror 31 similar to the first modification. In the second modification, a plurality of LED chip 61, 62 , 63,.....are vertically stacked instead of employing quai-planary arranged surface molded disk type LED 81, 82, 83, 84,...so as to increase the light intensity, without deteriorating the focal point.

(SIXTH EMBODIMENT)

As shown in Fig. 15, the light-emitting unit according to a sixth embodiment of the present invention has a plurality of light source 1a, 1b, 1c, 1d,...and a bulky lens 26 covered most entirely the plurality of light source 1a, 1b, 1c, 1d,.... This bulky lens 26 has a plurality of incident surface 2a, 2b, 2c, 2d,..... formed with first curved surfaces, a plurality of accommodating portions 6a, 6b, 6c, 6d,..... for accommodating light source 1a, 1b, 1c, 1d,....so as to increase the luminous intensity on the irradiated surface by the light-emitting unit. Other parts and elements are similar to the first and second embodiments, and these descriptions are omitted here.

In the sixth embodiment of the present invention, the geometry of the bulky lens 26 need not be the exact shape of the known bullet. That is, the shape of the bulky body 4 can have sliced bullet-shape so as to have slab geometry. In the slab geometry, light source 1a, 1b, 1c, 1d,...can be arranged one dimensionally, sandwiched by two opposing flat surfaces, but the bulky

lens 26 has a common transmitting surface 3 having a predetermined radius of curvature.

(SEVENTH EMBODIMENT)

A lighting instrument or the like may be assembled with a plurality of light-emitting units according to the first to sixth embodiments. In this case, one dimensional, two-dimensional or three-dimensional arrangement of the light-emitting units can be selected.

As shown in Fig. 16, a lighting instrument according to a seventh embodiment of the present invention assembles two-dimensionally a plurality of bulky lenses (bullet-shaped lenses) 20a, 20b, 20c, ..., each accommodating light source 1a, 1b, 1c, ...so as to irradiate selectively and uniformly with high luminous intensity on the desk top, for example.

The bullet-shaped lenses 20a, 20b, 20c, ...are arranged and attached to the supporting board 72, and light sources 1a, 1b, 1c, ...are attached to the circuit board 66. The opposing supporting board 72 and the circuit board 66 are connected each other by supporting members 71a and 71b. On the circuit board 66, driving circuit for the light sources 1a, 1b, 1c, ...is disposed, and the driving circuit is covered by the circuit board case 65. The circuit board case 65, the driving circuit, the supporting board 72 and the circuit board 66 are installed in a lighting case 63. The supporting board 72 is attached to the lighting case 63 through attaching members 73a and 73b. On the top of the lighting case 63, a plug 61 having electrodes 61a and 61b is disposed. Insulating plate 62 insulates the electrodes 61a and 61b. By leads 64a and 64b, electric power is supplied to the driving circuit.

(EIGHTH EMBODIMENT)

A pen type thin flashlight (portable lighting instrument) can be constructed by using this white LED as the resin molded LED 1 (See the first embodiment), and by containing a battery case and a battery (for example a size "AA" battery) in the battery case so as to apply the predetermined voltage the white LED 1. Thus, the flashlight is constructed that an anode and a cathode of this battery are connected to the terminals of the white LED 1. As a result, the flashlight (portable lighting instrument) which has a simply

structure and manufactured in low cost, is provided. This flashlight (portable lighting instrument) has an advantage of stability and reliability for a long period, and especially has an advantage of a long battery life because of less power consumption never predicted in conventional.

As shown in Fig. 17A, a lighting instrument according to an eighth embodiment of the present invention is a hand-held tool, which has a lightning portion 302 and writing portion 301. Where, the "hand-held tool" means a writing implement, or a ballpoint pen. The lightning portion 302 has a LED1 covered by the bullet-shaped lens 20, power supply portion. The LED1 has the resin 14 and supporting member 15. Battery 241, 242 installed in the battery case 323 with a spring 225 construct the power supply portion for driving the LED1. In the power supply portion, a circuit room 226 having a switch for controlling the power supply is also installed. The power supply portion further has a clip 230 so as to be easily attached to the pocket of the suit. The writing portion 301 includes a pen shaft 210 formed with a transparent material 211, which has a hollow portion for accommodating the bullet-shaped lens 20. The light from the bullet-shaped lens 20 is introduced into the transparent material 211 serving as the pen shaft 210 and an object to be illuminated is locally illuminated, so that an extremely high luminance can be obtained.

As shown in Fig.17B, when the bullet-shaped lens 20 and the transparent material 211 are detachably assembled with screw members 218 and 228, output light from the bullet-shaped lens 20 can be used as output light of a flashlight or a signal transmitter. On the other hand, when light having a very high intensity is not required, the bullet-shaped lens 20 and the transparent material 211 are fixed to each other, and the bullet-shaped lens 20 are detachable to each other, so that light emitted from a top portion 219 of pen shaft 210 can be used as an illumination source. When a light scattering portion 219 is provided in the vicinity of the pen point 214, a local illumination can be conducted over a relatively wide range. The transparent material 211 has a cavity portion with cylindrical shape, and the cavity portion accommodate an ink cartridge 215, which is connected to the pen point 214.

Details of the lightning portion 302 are shown in Fig.18. As shown in Fig. 18, the light source 1 has a resin14 and an LED chip 13 arranged on a stem connected in unity to a first pin 11, and a second pin 12 forming a pair with the first pin 11. The first pin 11 and the second pin 12 are insulated and

supported by the insulating member 19. From the battery 224 through switch 226, electric power is supplied to the first pin 11 and the second pin 12.

Since the hand-held tool or equipment according to the eighth embodiment of the present invention uses a LED1, power consumption can be reduced and illumination time can be prolonged. Furthermore, this hand-held tool is configured with a simple structure.

As shown in Fig. 19A, another lighting instrument according to a modification of the eighth embodiment of the present invention can have a cap 231 to protect the pen point 214. The cap 231 has a clip 232 so as to be easily attached to the pocket of the suit. And as shown in Fig. 19B, another pen point 140 instead of the ballpoint pen can also employed. Further, as a propelling pencil, a fountain pen, a magic marker, a caligrapy-bush-pen, or a toiletry set such as a lipstick, the structure of the eighth embodiment can be employed.

(NINTH EMBODIMENT)

As the key-less security system, locking/unlocking system, which performs the locking or unlocking based on the matching of encrypted signals by using infrared beam or supersonic wave, is considered. However, infrared beam and supersonic wave cannot be visualized. If the output power becomes insufficient by the consumption of the battery this system is not operable of course. Therefore, the cause of failures by which the system is not operable should be directly determined by discriminating whether the battery power has been emptied or other failure of the signal outputting circuitry.

In view of above situation, according to ninth embodiment of the present invention, light emitted from the LED includes personal information so that unlocking/locking of a specific object can be performed by confirming correspondence between the personal information emitted from the hand-held tool and the personal identification information registered in a memory installed in the object to be locked. For example, it is possible to use the intensity ratio of light of the respective wavelengths of red (R), green (G), and blue (B) emitted from a multi-colored LED 410 as the personal identification information. The multi-colored LED 410 may be structured with the three LED chips of red (R), green (G) and blue (B), which are layered vertically. By controlling electric power by battery 344 and control circuit 346 in the

transmitter circuit 304, each of the intensity of RGB colors is controlled so as to provide the personal identification information. And the specific color can be detected by the photo detector 350 operated with battery 307 in the receiver circuit 305, so as to operate the lock mechanism 306.

Fig. 21A shows a drawer 583 installed under a desk top 581. The front plate 585 has a hole 584 to guide a light to detector 505. To the detector 505, a driving circuit 507 and lock mechanism 560 is connected. The cylinder of the lock mechanism 560 is inserted to a hole 582 so as to protect the opening of the drawer 583. The front plate 585 may have a cone-shaped hole 584, which will perfectly match the outer geometry of the top portion 219 of pen shaft 210 so that detector 505 can directly receive the specific pattern delineated on the surface of the top portion 219. In this case, the spatial pattern delineated on the top portion 219 can serve the personal identification information.

Fig. 22 explain the lock/unlock mechanism employing the intensity ratio of light of the respective wavelengths of RGB colors emitted from a red LED 410 (R), a green LED 410 (G) and a blue LED 110(B). By employing modulator 400, the electric power supplied by battery 344 is controlled so as to provide the personal identification information. The modulator 400 can define each of output intensities of the red LED 410 (R), green LED 410 (G) and blue LED 110(B). Further, the modulator 400 can define respective pulse width, or phases of the radiations from the red LED 410 (R), green LED 410 (G) and blue LED 110(B). The receiver circuit 305 has a red detector 51 (R), a green detector 51 (G) and a blue detector 51 (B), which can independently receive the RGB colors through filters. The lock mechanism 306 has level discriminators 611, 612, 613 connected to the red detector 51 (R), green detector 51 (G) and blue detector 51 (B), and waveform shapers 621, 622, 623 connected to the level discriminator 611, 612, 613, respectively. The outputs of the waveform shapers 621, 622, 623 are fed to a comparator 631, and the comparator 631 compare with data stored in the RAM 632 to identify the personal identification information. According to the results of the comparator 631, the operation of the lock driver 640 is controlled.

(TENTH EMBODIMENT)

As shown in Fig. 23, a lighting instrument according to a tenth embodiment of the present invention is a hand-held tool has a lightning portion

302 and power portion 311. Here, the "hand-held tool" means a screwdriver. The lightning portion 302 has same structure as already explained in the eighth embodiment, but the outer diameter of the circuit room 226 is formed larger to ease the operation. The power portion 311 includes a power shaft 210D formed with a transparent material 211, which has a hollow portion for accommodating the driver shaft 115. The light from the bullet-shaped lens 20 is introduced into the transparent material 211 serving as the power shaft 210D and a screw to be turned is locally illuminated, so that an extremely high luminance can be obtained.

(OTHER EMBODIMENTS)

Various modifications will become possible for those skilled in the art after receiving the teaching of the present disclosure without departing from the scope thereof. As described above, the present invention is illustrated with the first to tenth embodiments. However, it should not be understood that the description and the attached drawings as parts of this disclosure limit the scope of the present invention. It will be appreciated for those skilled in the art that the many kind of the alternative modifications, embodiments and utilizations are available.

For example, as shown in Fig. 24, the bullet-shaped lens 20 of the present invention can accommodate a photo detector 9 in the accommodating portion 6 instead of the light source 1 so as to construct a detecting unit. As shown in Fig. 24, the photo detector 9 such as a pin diode or an avalanche photodiode is arranged on a stem connected in unity to a first pin 11. In this case, the top portion 4 of the bulky body serves as an incident surface (a second lens surface), and the ceiling 2 of the cylindrical recess 6 serves as a transmitting surface (a second lens surface) from which a light entering from the incident surface 4 exits. By the configuration of Fig. 24, a very high efficiency of photo detection is possible with a compact optical system.

The outside surface of the bullet-shaped lens 20-26 must not be optical smooth. The uneven surface such as crystal glass can be formed to guide a light to detector 505.

For fixing the LED in the bullet-shaped lens, the spacer is inserted between the LED and the accommodating portion 6 of the bullet-shaped lens in the first to fourth embodiments described above. However, the other means

such as adhesives, screws and a clamp mechanism can be used for fixing, of course.

Thus, the present invention of course includes various embodiments and modifications and the like which are not detailed above. Therefore, the scope of the present invention will be defined in the following claims.

WHAT IS CLAIMED IS:

1. A bulky lens comprising:

a bulky body having a top portion, a bottom portion,

and a cylindrical portion disposed between the top and bottom portions, the cylindrical portion having an outer diameter $2R_o$; and

a cylindrical recess having an inner diameter $2r$, formed in the bulky body directed towards upward from the bottom portion of the bulky body, configured such that the inner diameter $2r$ satisfies the relation $2R_o > 6\ r$,

wherein a ceiling of the cylindrical recess serves as a first lens surface, the top portion of the bulky body serves as a second lens surface from which a light entering from the first lens surface exits, or to which a light can enter, the cylindrical recess serves as an accommodating portion for accommodating a main portion of a light source or a photo detector.

2. A bulky lens comprising:

a bulky body having top and bottom portion;

a cylindrical recess formed upward from the bottom portion of the bulky body;

and

a reflection mirror formed at the bottom portion of the bulky body,

wherein a ceiling of the cylindrical recess serves as a first lens surface, the top portion of the bulky body serves as a second lens surface from which a light entering from the first lens surface exits, or to which a light can enter, the cylindrical recess serves as an accommodating portion for accommodating a main portion of a light source or a photo detector.

3. A bulky lens comprising:

a bulky body having top and bottom portion;

a cylindrical recess formed upward from the bottom portion of the bulky body;

and

another cylindrical recess formed upward from the bottom portion of the bulky body,

wherein a ceiling of the cylindrical recess serves as a first lens surface, the top portion of the bulky body serves as a second lens surface from which a light entering from the first lens surface exits, or to which a light can enter, the cylindrical recess serves as an accommodating portion for accommodating a main portion of a light source or a photo detector.

4. A light-emitting unit comprising:

a light source;

a bulky body having a top portion, a bottom portion, and a cylindrical portion disposed between the top and bottom portions, the cylindrical portion having an outer diameter $2R_o$; and

a cylindrical recess having an inner diameter $2r$, formed in the bulky body directed towards upward from the bottom portion of the bulky body, configured such that the inner diameter $2r$ satisfies the relation $2R_o > 6r$,

wherein a ceiling of the cylindrical recess serves as an incident surface, the top portion of the bulky body serves as a transmitting surface from which a light entering from the incident surface exits, and the cylindrical recess accommodates a main portion of the light source.

5. A light-emitting unit comprising:

a light source;

a bulky body having top and bottom portion;

a cylindrical recess formed upward from the bottom portion of the bulky body; and

a reflection mirror formed at the bottom portion of the bulky body,

wherein a ceiling of the cylindrical recess serves as a first lens surface, the top portion of the bulky body serves as a second lens surface from which a light entering from the first lens surface exits, or to which a light can enter, the cylindrical recess serves as an accommodating portion for accommodating a main portion of a light source or a photo detector.

6. A light-emitting unit comprising:

a light source;

a bulky body having top and bottom portion;

a cylindrical recess formed upward from the bottom portion of the bulky body; and

another cylindrical recess formed upward from the bottom portion of the bulky body,

wherein a ceiling of the cylindrical recess serves as a first lens surface, the top portion of the bulky body serves as a second lens surface from which a light entering from the first lens surface exits, or to which a light can enter, the cylindrical recess serves as an accommodating portion for accommodating a main portion of a light source or a photo detector.

7. A lighting instrument comprising:

a battery;

a light source emitting having terminals connected to an anode and a cathode of the battery;

a bulky body having top and bottom portions; and

a cylindrical recess formed in the bulky body directed towards upward from the bottom portion of the bulky body,

wherein a ceiling of the cylindrical recess serves as an incident surface, the top portion of the bulky body serves as a transmitting surface from which a light entering from the incident surface exits, and the cylindrical recess accommodates a main portion of the light source.

8. The lighting instrument of claim 7, further comprising a reflection mirror formed at the bottom portion of the bulky body.

9. The lighting instrument of claim 7, further comprising another cylindrical recess formed upward from the bottom portion of the cylindrical.

10. The lighting instrument of claim 7, further comprising modulator connected between to the battery and the light source.