

A LIGHT DIFFUSING DEVICE

The present invention relates to a light diffusing device which effectively diffuses a light component of a desired wavelength out of light emitted from a light source and conducted through a light transmission element, so that the desired light component may be exclusively directed to the outside of the light transmission element. The present invention also relates to an apparatus for uniform illumination which employs such a light diffusing device.

10 Light transmission elements are known in various forms as typified by quartz glass fibers, optical fibers made of plastics including acrylic resin and polycarbonate resin, and fine tubes or flat plates constituted by such fibers. Where it is desired to utilize the light
15 propagating through such a light transmission element for illumination purpose, for example, the light has to be diffused to be routed to the outside from the light transmission element.

Meanwhile, light coming out from such light transmission elements is usable to illuminate the dials of various meters installed, for example, in audio instruments and automotive vehicles. For such application, the
20 light is required to irradiate the dial of a meter to even intensity over the entire dial surface.

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According to the present invention there is provided a light diffusing device comprising:

a light transmission element for transmitting light emitted from a light source; and

a plurality of discrete light diffusing members positioned at spaced locations on said light transmission element, each of said light diffusing members being arranged to diffuse and discharge outwardly of said light transmission element only a specific wavelength-selected component of the light propagating through said light transmission element, at least one of said light diffusing members comprising a plurality of layers having different refractive indices.

The light transmission element may be made of optical fibers, and the light diffusing members may comprise epoxy resin, or silicon resin.

At least one of the light diffusing members may comprise a single-layer structure having a refractive index n_1 different from a refractive index n_0 of the light transmission element, and related to the latter refractive index n_0 by the relationship:

$$n_1/n_0 = 0.87 \text{ to } 1.3$$

At least one said single-layer light diffusing member may have a flat configuration, or a convex or concave lens configuration.

Also, at least one said plural-layer light diffusing member may have a flat configuration, or a convex or concave configuration.

The device may further comprise a reflector member carried on a surface portion of the light transmission element which is opposite to a surface portion which carries the light diffusing members.

Also, the light transmitting element may have a first end for receiving light from the light source, and a second end opposite the first end, a reflector member being disposed at said second end.

Reference will now be made to the accompanying drawings, in which:

Figure 1 is a view of a light diffusing device, not in itself in accordance with the invention, but illustrating a principle of operation of a light diffusing device;

Figure 2 is a view of a first embodiment of a light diffuser embodying the present invention;

Figure 3 is a view of a light diffusing device, again not in itself in accordance with the invention, but illustrating a principal of light diffusion.

Figure 4 is a view explanatory of a procedure for forming a concave lens-shaped light diffusing member shown in Figure 3;

Figures 5 and 6 are views illustrating a second embodiment of the present invention; and

Figure 7 is a view explanatory of a procedure for forming a concave lens-shaped double-layer light diffusing layer structure shown in Figure 6;

Figure 8 is a view of an example of conventional apparatuses for uniform illumination;

Figure 9 is a sectional side elevation of an apparatus for uniform illumination equipped with a light diffuser of the present invention;

Figure 10 is a schematic plan view of another embodiment of the uniform illumination apparatus with the light diffuser; and

Figure 11 is a section along line XI-XI of Figure 10.

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While the apparatus for uniform illumination employing a light diffusing device according to the present invention is susceptible of numerous physical embodiments, depending upon the environment and requirements of use, substantial numbers of the embodiments shown and described herein have been made, tested and used, and all have performed

in an eminently satisfactory manner.

Referring to Figure 1, the principle of operation of a light diffusing device is schematically illustrated. The reference numeral 10 designates a light source which may be, for example, a bulb, fluorescent lamp, laser, light emitting diodes (LED) or output end of a fiber optic bundle. Light emitted from the light source 10 is incident on the adjacent end of a light transmission element 12 having a refractive index n_0 . Typical examples of the light transmission element 12 may be quartz glass fibers, optical fibers made of plastics such as acrylic resin or polycarbonate resin, or fine tube or flat plate made up of such fibers. A light diffusing material, such as silicon resin or epoxy resin, is applied to a surface of the light transmission element 12 to form light diffusing layers 14. Each of these layers 14 has a refractive index n_1 different from that n_0 of the light transmission element 12. The refractive index n_1 is preselected such that its ratio to the refractive index n_0 , n_1/n_0 , lies within the range of about 0.87-1.3. Thus, light emitted from the light source 10 and conducted through the element 12 is routed to the outside through the respective light diffusing layers 14. It will be seen that a light component having any desired wavelength can be picked up through the diffusing layers 14 if the refractive index n_1 of the diffusing layers 14 is selected accordingly.

Referring to Figure 2, a light diffuser embodying the present invention is shown and in which the same structural parts as those of Figure 1 are designated by like reference numerals. The light diffuser comprises light diffusing sections 16, 18 and 20 arranged in succession on the light transmission element 12. The light diffusing section 16 is constituted by a single light diffusing layer 16a having a refractive index n_1 .

The light diffusing section 18 is made up of two light diffusing layers 18a and 18b having refractive indexes n_1 and n_2 , respectively. The light diffusing section 20 is formed by three light diffusing sections 20a, 20b and 20c whose refractive indexes are n_1 , n_2 and n_3 , respectively. If the refractive indexes n_1 , n_2 and n_3 of the respective layers are different from one another, light components of different wavelengths will come out through the respective light diffusing sections 16, 18 and 20. For example, the light diffusing section 16 may provide a light component L_1 necessary for illumination, the light diffusing section 18 a light component L_2 with thermic rays R removed by the diffusing layer 18b by reflection, and the light diffusing section 20 a light component L_3 with thermic rays R and ultraviolet rays V intercepted respectively by the diffusing layers 20b and 20c. It will be readily understood that where the light diffusing sections 16, 18 and 20 are carried on one side of the light transmission element 12, a reflecting layer 22 may be laid on the other side of the light transmission element 12 where the sections 16, 18 and 20 are absent. It will also be clear that where the light from the light source 10 enters the element 12 in parallel thereto, a reflecting layer 24 may be laid on the end of the element 12 opposite to the light input end.

Referring to Figure 3, another form of light diffuser is shown which employs generally lens-shaped light diffusing sections. A light diffusing section 26 is in the form of a convex lens having a refractive index n_1 , while a light diffusing section 28 is in the form of a concave lens having the same refractive index n_1 . Light, therefore, will be converged by the light diffusing section 26 and dispersed by the light diffusing section 28. The convex lens can be formed in a desired shape merely by dropping resin



onto the light transmission element 12, the shape depending on the viscosity and surface tension of the resin, its contact angle with the light transmission element 12, etc. The concave lens, on the other hand, can be formed by the procedure generally demonstrated in Figure 4. In Figure 4, a suitable amount of resin with the refractive index n_1 is filled in a bore 32 of a masking film 30 and, after the resin has been hardened, the masking film 30 is removed to leave the concave lens on the light transmission element 12. The curvature of the concave lens depends on the surface tension of the resin, inside diameter of the masking film 30, etc. If desired, each light diffusing section may be formed by a plurality of convex or concave lenses laid one upon the other, as exemplified by the structure shown in Figure 5.

Referring to Figure 5, which shows a second embodiment of the invention, a light diffusing section 26' comprises a double-layer convex lens structure made up of two lenses 26a and 26b having different refractive indexes n_1 and n_2 , respectively. Likewise, a light diffusing section 28' comprises a double-layer concave lens structure constituted by two lenses 28a and 28b whose refractive indexes are also n_1 and n_2 , respectively. Stratifying a plurality of lenses of different refractive indexes in the manner shown and described will make it possible to pick up a component of a desired wavelength out of the light routed to the light diffusing section. For example, where visible light is emitted from the light source 10 to become incident on the light transmission element 12 which is provided with the double-layer concave structure 28' as shown in Figure 6, the diffusing lens 28a reflects thermic rays R and the lens 28b intercepts ultraviolet rays V. Again, when the light diffusing sections are carried on one side of the light transmission element 12, a reflecting layer 22' may be laid on the other side where the light diffusing sections are absent; when the

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light from the light source 10 enters the light transmission element 12 in parallel thereto, a reflecting layer 24' may be laid on the end of the element 12 opposite to the light input end. Figure 7 shows a procedure for forming the concave lens structure or diffusing section 28' on the light transmission element 12, which procedure is essentially similar to the procedure described with reference to Figure 4. In Figure 7, a suitable volume of resin 28a with the refractive index n_1 is charged and hardened in a bore 32' of a masking film 30', then a suitable amount of resin 28b with the refractive index n_2 is hardened on the first resin 28a, and finally the masking film 30' is removed. The curvature of the resulting concave lens structure is determined by the surface tension of the resin, the inside diameter of the masking film, etc.

It will thus be seen that the light diffuser in any one of the foregoing embodiments of the invention is capable of selectively discharging a light component having a specific wavelength at a desired position of a light transmission element. For example, light for illumination can be picked up with thermic rays separated therefrom. Such selective separation of light permits an object of illumination to be formed of a material which is rather poor in resistivity and stability to heat and the like though useful in optical function. This ensures a wider range of selection of materials for objects of illumination.

Reference is hereby directed to copending patent application no. 8522686 which is divided from this present application, and which is directed to an invention embodied by the arrangements now to be described with reference to Figures 8 to 11 of the drawings.

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Now, audio and other acoustic instruments carry various kinds of indication plates and level meters which should be uniformly illuminated throughout their surfaces, due to the nature of such equipments. However, the source voltage presently available for an illumination device is supplied by the secondary winding of a transformer and not higher than about 12-24V. This, coupled with the fact that a lamp serving as a light source cannot

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be large due to limitations in design and space, makes the intensity of illumination on the indication plates insufficient and uneven regardless of the illumination system, i.e. transmission type or reflection type. Moreover, in an illumination system using LED's, for example, as a light source, a number of such samples are required, rendering the wiring intricate and the cost prohibitive.

In an automotive vehicle, on the other hand, various meters are arranged on an instrument panel in front of the driver's seat. These meters, particularly the speedometer, have to be illuminated to an even intensity distribution over the entire surfaces of their dials. Figure 8 indicates a conventional automotive speedometer and its associated illuminating arrangement. Shown in Figure 8 are a light source 34 in the form of a lamp, a reflector 36 in the form of a mirror, and a dial 38. As well known to the art, the distance between the reflector 36 and the dial 38 is made larger at a point A close to the lamp 34 than at a point B far from the lamp 34, in an effort to achieve an even distribution of intensities. The intensity, however, unavoidably drops in a position remote from the lamp 34 due to the nature particular to such a system, while a substantial space must be allocated in the aspect of structure. Furthermore, the speedometer of the kind concerned requires a disproportionate number of manufacturing steps as well as a disproportionate cost.

Referring to Figures 9-11, there are shown two different embodiments of light diffuser which are designed to serve as an illumination apparatus capable of eliminating all the drawbacks discussed above. In Figure 9, the illumination apparatus comprises a light source 40 similar to the light source employed in the foregoing embodiments, a light transmission element 42 also similar to the one previously described, and a number of light diffusing layers 44

carried on the light transmission element 42. The refractive index n_1 of the diffusing layers 44 is chosen such that its ratio to the refractive index n_0 of the light transmission element 42 lies within the range of 0.87-0.95.

While light from the light source 40 enters the light transmission element 42 and propagates in the direction indicated by an arrow, it comes out through the respective diffusing layers 44 to illuminate a desired object. In this instance, the luminous flux density is high in the area adjacent to the light source 40 but progressively lowered toward the end of the element 42 remote from the light input end. As a result, the amount of discharged light naturally decreases in the area remote from the light source, disabling uniform illumination to be accomplished. In light of this, the embodiment shown in Figure 9 has a characteristic feature that the diffusing layers 44 are made progressively thinner from the one closest to the light source over to the one farthest from the same. Such a thickness distribution of the layers 44 is reflected by an amount of light attenuation which progressively decreases from the layer 44 closest to the light source over to the layer 44 farthest from the same, thereby setting up uniform illumination for a desired object. The back surface 46 and/or the end surface 48 of the light transmission element 42 may be constituted by a reflecting mirror surface in order to more effectively utilize the light incident on the element 42, as described in conjunction with the previous embodiments.

Referring to Figures 10 and 11, another device includes a plurality of light diffusing layers 50. These layers 50, different from the layers 44 shown in Figure 9, are arranged to such a density which is lowest in a position closest to a light

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source 40' and made progressively higher toward a position farthest from the light source 40', though their thicknesses are common to each other. Illumination accomplished with the arrangement of the layers 50 is as even as that achievable with the layers 44.

Various modifications will become apparent to those skilled, without departing from the scope of the appended claims.

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CLAIMS:

1. A light diffusing device comprising:
a light transmission element for transmitting light emitted from a light source; and
a plurality of discrete light diffusing members positioned at spaced locations on said light transmission element, each of said light diffusing members being arranged to diffuse and discharge outwardly of said light transmission element only a specific wavelength-selected component of the light propagating through said light transmission element, at least one of said light diffusing members comprising a plurality of layers having different refractive indices.
2. A light diffusing device as claimed in claim 1, in which the light transmission element is made of optical fibers.
3. A light diffusing device as claimed in claim 1 or claim 2, in which the light diffusing members comprise epoxy resin.



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4. A light diffusing device as claimed in claim 1 or claim 2, in which the light diffusing members comprise silicon resin.

5. A light diffusing device as claimed in any preceding claim, in which at least one of the light diffusing members comprises a single-layer structure having a refractive index different from a refractive index of the light transmission element.

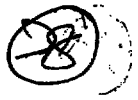
6. A light diffusing device as claimed in claim 5 in which:

$$n_1/n_0 = 0.87 \text{ to } 1.3$$

where n_0 is the refractive index of the light transmission element and n_1 the refractive index of the single-layer light diffusing member or members.

7. A light diffusing device as claimed in claim 5 or claim 6 wherein at least one said single-layer light diffusing member has a flat configuration.

8. A light diffusing device as claimed in claim 5 or claim 6 wherein at least one said single-layer light diffusing member has a convex lens configuration.



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9. A light diffusing device as claimed in claim 5 or claim 6 wherein at least one said single-layer light diffusing member has a concave lens configuration.

10. A light diffusing device as claimed in any preceding claim, wherein at least one said plural-layer light diffusing member has a flat configuration.

11. A light diffusing device as claimed in any preceding claim, wherein at least one said plural-layer light diffusing member has a convex lens configuration.

12. A light diffusing device as claimed in any preceding claim, wherein at least one said plural-layer light diffusing member has a concave lens configuration.

13. A light diffusing device as claimed in any preceding claim further comprising a reflector member carried on a surface portion of the light transmission element which is opposite to a surface portion which carries the light diffusing members.

14. A light diffusing device as claimed in any preceding claim wherein the light transmitting element has a first end for receiving light from the light



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source, and a second end opposite the first end, and wherein there is further provided a reflector member disposed at said second end.

15. A light diffusing device substantially as hereinbefore described with reference to figure 2 of the accompanying drawings.

16. A light diffusing device substantially as hereinbefore described with reference to figure 5 of the accompanying drawings.

17. A light diffusing device according to claim 1 and substantially as hereinbefore described with reference to figure 6 of the accompanying drawings.
