

Description

The present invention relates to bulk diffusers and, more specifically, to projection screens which incorporate bulk diffusers therein to control, primarily, the vertical dispersion of the projected light. Such screens are, for example, used in projection television systems.

Bulk diffusers may be described as including minute spheres embedded in a substrate of a slightly different index of refraction. The spreading characteristics of bulk diffusers are a function of the size and index of refraction of the spheres, the thickness and index of refraction of the substrate, and the loading density of the spheres in the substrate.

Bulk diffusers used in projection television screens are characteristically specified by their intensity half-angle. The intensity half-angle is defined as the angle at which the intensity falls to half the maximum intensity. It has been generally presumed that given a specific intensity half-angle, the intensity profile would be Gaussian. However, this could not explain the appearance of some of the artifacts seen on projection television screens, namely, (1) the picture is visible at much larger angles than the measured intensity half-angle, (2) the resolution of the screen is not as high as predicted, and (3) the screen has a lower gain than that predicted.

In a typical projection television screen, the bulk diffuser is specified to be 3mm thick and have an 8° intensity half-angle, it being assumed that the intensity profile would be Gaussian. In this typical bulk diffuser, the refractive indices of the spheres and the substrate are 1,53 and 1,49, respectively, the volume ratio of the spheres being equal to 2%, and the spheres having a range in diameters from 5 μm to 100 μm.

In the article "Diffraction Analysis of Bulk Diffusers for Projection Screen Applications", appearing in the Journal of The Optical Society A, December, 1985 p. 2337-2348, applicants disclosed a computer program for analyzing bulk diffusers which assumes that all the spheres have the same diameter. Using this program, the measured intensity half-angle of 8° and the range of diameters 5 to 100 μm, an effective sphere diameter is determined as equal to 17.3 μm. (The effective sphere diameter being the single diameter which accurately, within reasonable limits, represents the range in diameter of the spheres). The program may then be used to plot the predicted intensity as a function of angle for this diffuser. This plot is shown in Figure 1 along with the measured intensity for a sample bulk diffuser.

In this plot the abscissa represents the dispersion angle β of the dispersed light and the ordinate the intensity I as a fraction of the maximum intensity. The solid curve in the plot shows the measured intensity as a function of the angle. The dashed and the dotted curves show the predicted profile and a Gaussian one, respectively. By comparing the predicted and measured results to the curve corresponding to a Gaussian profile, it is clear that the predicted and measured profiles are not Gaussian.

The object of the present invention is to provide a bulk diffuser for a projection television screen which exhibits a Gaussian profile.

For a diffuser that spreads a collimated beam into a Gaussian beam, the intensity half-angle also corresponds to the angle that encloses half of the energy of the beam, the energy half-angle. Applicants have recognized that while diffusers have been described by the intensity half-angle, it is the energy half-angle that is the important parameter of the bulk diffuser.

The percentage of energy, $E(\beta)$, enclosed within a given angle β can be calculated by:

$$E(\beta) = 100 \left[\frac{\int_0^{\beta} I(\beta) \beta d\beta}{\int_0^{\infty} I(\beta) \beta d\beta} \right]$$

where $I(\beta)$ is the measured (or predicted) intensity as a function of angle. In accordance with the above formula, the predicted energy half-angle is 13.75° and the measured energy half-angle is 15.58°. With the above bulk diffuser, it was assumed that since the intensity half-angle was 8°, the energy half-angle would be 8°. This discrepancy explains the above-noted artifacts in the projection television screen.

With the above in mind, the method of selecting a bulk diffuser for a projection television screen comprises selecting a desired intensity half-angle, selecting the desired thickness of the bulk diffuser, and

determining the effective sphere diameter, the refractive index of the spheres, and the loading density of the spheres such that the energy half-angle is substantially equal to the intensity half-angle.

With the above and additional objects and advantages in mind as will hereinafter appear, the invention will be described with reference to the accompanying drawings, in which:

- 5 Figure 1 is a plot of the intensity as a function of angle for a typical bulk diffuser;
 Figure 2 is a cross-sectional view of a rear projection television screen;
 Figure 3 is a schematic diagram of a test arrangement for measuring the energy half-angle of a diffuser;
 and
 Figure 4 is a plot of the intensity as a function of angle for a bulk diffuser selected in accordance with the
 10 method of the invention.

Referring to Figure 2, a rear projection television screen is shown and includes a Fresnel lens F located opposite a projection light source (not shown). A lenticular lens array L is situated facing an audience viewing field. Arranged between the lenticular lens L and the Fresnel lens F is a bulk diffuser B. This rear projection television screen may be in accordance with U.S. Patent 4,573,764, to which reference may be
 15 had for greater detail.

The bulk diffuser B includes a substrate C having spheres S uniformly dispersed therein. The spheres S have a slightly greater (or possibly smaller) index of refraction than that of the substrate and as such, are able to diffuse any light passing through the bulk diffuser.

While the energy half-angle $E(\beta)$ may be determined by using the above formula, applicants have
 20 developed an arrangement for directly measuring the energy half-angle $E(\beta)$. As shown in Figure 3, a low-power, for example 1mW, HeNe laser 10 generates a light beam which passes through the bulk diffuser B. All the light is collected and collimated by lens 12. Lens 14 focuses this light onto a detector 16. The lenses 12 and 14 are, for example, f/0.65 aspheric lenses. A power meter 18 connected to the detector 16 then gives a direct reading of the total energy in the diffused light beam. An iris diaphragm 20 situated at the exit
 25 of lens 12 is then stopped down until the meter registers half of the total energy of the light beam. The energy half-angle is then calculated by:

$$30 \quad E = \sin^{-1} \left[\frac{d}{2f} \right]$$

where d is the diameter of the iris diaphragm 20 corresponding to the half energy level, and f is the focal
 35 length of lens 12; d may be measured with calipers.

When aligning the system, it is important that the two strongly curved surfaces of the lenses 12 and 14 face each other. The iris diaphragm 20 should be as close to lens 12 as possible, and care should be taken to assure that the diffuser B is in the focal plane of lens 12 and the detector 16 is in the focal plane of lens
 40 14.

A bulk diffuser designed to yield a Gaussian intensity profile and an 8° energy half-angle in accordance with the invention has the following characteristics:

Diffuser thickness	3 mm,
Refractive index of substrate	1.49,
Refractive index of spheres	1.508,
Volume ratio	2%,
Effective sphere diameter	8 μ m,
5 μ m < sphere diameter < 25 μ m.	

As the diffusing properties of the bulk diffuser in the range of interest are determined by the product of the thickness and the loading density, rather than by one of these two parameters alone, a bulk diffuser with the same energy half-angle can be obtained with a different loading density, provided the thickness is
 55 inversely proportional to the loading density.

Figure 4 is a plot of the predicted intensity profile and a Gaussian profile. As in Figure 1 the dotted curve represents a Gaussian profile and the dashed curve the predicted dependence of the intensity as a function of the dispersion angle.

Numerous alterations of the structure herein disclosed will suggest themselves to those skilled in the

art. However, it is to be understood that the present disclosure relates to a preferred embodiment of the invention which is for purpose of illustration only and not to be construed as a limitation of the invention. All such modifications are intended to be included within the scope of the appended claims.

5 Claims

1. Bulk diffuser (B) for a rear projection screen, comprising a substrate (C) having a first index of refraction, the substrate being loaded with a plurality of spheres (S) having a range of diameters, which spheres have a second index of refraction which is different from the first index of refraction, characterized in that the loading density and the range of diameter of the spheres are such that the bulk diffuser spreads incident light in an intensity half-angle and an energy half-angle which are equal.
2. Bulk diffuser as claimed in Claim 1, characterized in that said second index of refraction is greater than said first index of refraction.
3. Bulk diffuser as claimed in Claim 1 or 2, characterized in that said intensity half-angle and said energy half-angle are substantially equal to 8 degrees.
4. Bulk diffuser as claimed in Claim 3, characterized in that said bulk diffuser has a thickness of 3 mm and said loading density of said spheres is 2 per cent.
5. Bulk diffuser as claimed in Claim 1, 2, 3 or 4, characterized in that said range of diameters of said spheres is from 5 to 25 μm .
6. Bulk diffuser as claimed in Claim 1, 2, 3, 4 or 5, characterized in that said first index of refraction is approximately 1.49 and said second index of refraction is approximately 1.508.

Patentansprüche

1. Massenstreukörper (B) für einen Hinterprojektionsschirm mit einem Substrat (C) mit einem ersten Brechungsindex, wobei das Substrat mit einer Anzahl von Kugeln (S) mit einem Gebiet von Durchmessern geladen wird, und diese Kugeln besitzen einen zweiten Brechungsindex, der vom ersten Brechungsindex abweicht, dadurch gekennzeichnet, daß die Ladungsdichte und das Durchmessergebiet der Kugeln derart sind, daß der Massenstreukörper einfallendes Licht unter einem Intensitäts-Halbwinkel und einem Energie-Halbwinkel verstreut, die einander gleich sind.
2. Massenstreukörper nach Anspruch 1, dadurch gekennzeichnet, daß der zweite Brechungsindex größer ist als der erste Brechungsindex.
3. Massenstreukörper nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß der Intensitäts-Halbwinkel und der Energie-Halbwinkel im wesentlichen gleich 8 Grad betragen.
4. Massenstreukörper nach Anspruch 3, dadurch gekennzeichnet, daß der Massenstreukörper eine Dicke von 3 mm hat und die Ladungsdichte der Kugeln 2 Prozent beträgt.
5. Massenstreukörper nach Anspruch 1, 2, 3 oder 4, dadurch gekennzeichnet, daß der Bereich der Durchmesser der Kugeln zwischen 5 und 25 μm liegt.
6. Massenstreukörper nach Anspruch 1, 2, 3, 4 oder 5, dadurch gekennzeichnet, daß der erste Brechungsindex ungefähr 1,49 und der zweite Brechungsindex ungefähr 1,508 betragen.

Revendications

1. Diffuseur de masse (B) pour un écran à projection par transparence comportant un substrat (C) présentant un premier indice de réfraction, le substrat étant chargé d'une pluralité de sphères (S) ayant une gamme de diamètres, lesdites sphères présentant un second indice de réfraction différant du premier indice de réfraction, caractérisé en ce que la densité de chargement et la gamme de diamètres des sphères sont telles que le diffuseur de masse répand la lumière incidente en un demi-angle

art. However, it is to be understood that the present disclosure relates to a preferred embodiment of the invention which is for purpose of illustration only and not to be construed as a limitation of the invention. All such modifications are intended to be included within the scope of the appended claims.

Claims

1. Bulk diffuser (B) for a rear projection screen, comprising a substrate (C) having a first index of refraction, the substrate being loaded with a plurality of spheres (S) having a range of diameters, which spheres have a second index of refraction which is different from the first index of refraction, characterized in that the loading density and the range of diameter of the spheres are such that the bulk diffuser spreads incident light in an intensity half-angle and an energy half-angle which are equal.
2. Bulk diffuser as claimed in Claim 1, characterized in that said second index of refraction is greater than said first index of refraction.
3. Bulk diffuser as claimed in Claim 1 or 2, characterized in that said intensity half-angle and said energy half-angle are substantially equal to 8 degrees.
4. Bulk diffuser as claimed in Claim 3, characterized in that said bulk diffuser has a thickness of 3 mm and said loading density of said spheres is 2 per cent.
5. Bulk diffuser as claimed in Claim 1, 2, 3 or 4, characterized in that said range of diameters of said spheres is from 5 to 25 μm .
6. Bulk diffuser as claimed in Claim 1, 2, 3, 4 or 5, characterized in that said first index of refraction is approximately 1.49 and said second index of refraction is approximately 1.508.

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2. Massenstreuungkörper nach Anspruch 1, dadurch gekennzeichnet, daß der zweite Brechungsindex größer ist als der erste Brechungsindex.
3. Massenstreuungkörper nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß der Intensitäts-Halbwinkel und der Energie-Halbwinkel im wesentlichen gleich 8 Grad betragen.
4. Massenstreuungkörper nach Anspruch 3, dadurch gekennzeichnet, daß der Massenstreuungkörper eine Dicke von 3 mm hat und die Ladungsdichte der Kugeln 2 Prozent beträgt.
5. Massenstreuungkörper nach Anspruch 1, 2, 3 oder 4, dadurch gekennzeichnet, daß der Bereich der Durchmesser der Kugeln zwischen 5 und 25 μm liegt.
6. Massenstreuungkörper nach Anspruch 1, 2, 3, 4 oder 5, dadurch gekennzeichnet, daß der erste Brechungsindex ungefähr 1,49 und der zweite Brechungsindex ungefähr 1,508 betragen.

Revendications

1. Diffuseur de masse (B) pour un écran à projection par transparence comportant un substrat (C) présentant un premier indice de réfraction, le substrat étant chargé d'une pluralité de sphères (S) ayant une gamme de diamètres, lesdites sphères présentant un second indice de réfraction différant du premier indice de réfraction, caractérisé en ce que la densité de chargement et la gamme de diamètres des sphères sont telles que le diffuseur de masse répand la lumière incidente en un demi-angle



d'intensité et en demi-angle d'énergie qui sont égaux.

2. Diffuseur de masse selon la revendication 1, caractérisé en ce que ledit second indice de réfraction est supérieur audit premier indice de réfraction.
3. Diffuseur de masse selon la revendication 1 ou 2, caractérisé en ce que ledit demi-angle d'intensité et ledit demi-angle d'énergie sont sensiblement égaux à 8° .
4. Diffuseur de masse selon la revendication 3, caractérisé en ce que l'épaisseur dudit diffuseur de masse est égale à 3mm et en ce que la densité de charge desdites sphères est égale à 2 pour-cent.
5. Diffuseur de masse selon la revendication 1, 2, 3 ou 4, caractérisé en ce que ladite gamme de diamètres desdites sphères est comprise entre 5 et 25 μm .
6. Diffuseur de masse selon la revendication 1, 2, 3, 4 ou 5, caractérisé en ce que ledit premier indice de réfraction est de l'ordre de 1,49 et en ce que ledit second indice de réfraction est de l'ordre de 1,508.

