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(54) **Illumination apparatus**

(57) A light apparatus having:

a) a housing having a back side and a front light opening through which light can pass;
b) at least one light source within the housing emitting light in a forward and a rearward direction;
c) a lenticular lens sheet positioned behind the light source in the housing, the sheet having a plurality of parallel elongated, laterally convex, lens surfaces extending in a path to form a pattern geometrically following the contour of the light source, and facing the linear light source; and
d) a reflecting surface behind the lens surfaces to redirect light emitted from the light source in the rearward direction to the forward direction.

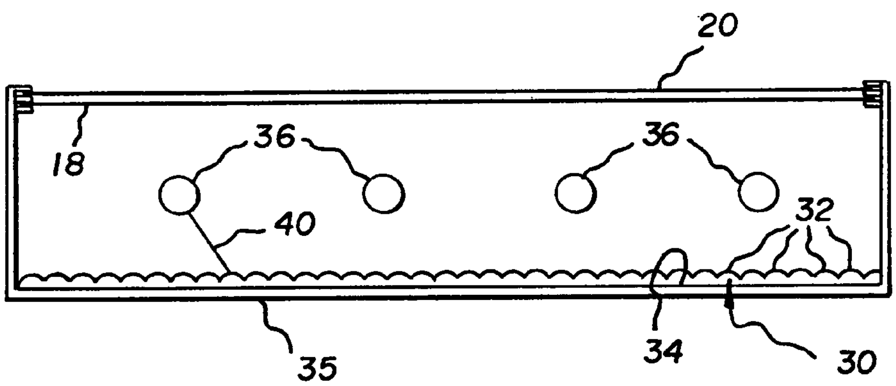


FIG. 3

EP 0 814 453 A2

Description

FIELD OF THE INVENTION

The present invention relates to a light apparatus useful for illuminating transparent displays.

BACKGROUND OF THE INVENTION

Illuminated displays which display images carried on a transparent substrate are well known, and are often used as advertising or other displays. Such displays typically have a housing which is enclosed except for a front light opening, across which the transparency carrying the image is to be positioned. A light source is positioned within the housing and behind the transparency. A plurality of elongated light sources, such as fluorescent tubes, are usually used as the light source. In order that the light source itself is not observed through the image carrying transparency, a diffuser in the form of a diffusing sheet, may be positioned between the light source and the transparency. Displays of the forегoing type may be used for transparencies carrying a regular two-dimensional image, such as formed from a photograph. More recently it has been known to use a transparency carrying an integral image.

Integral image elements which use a lenticular lens sheet, fly's eye lens sheet, or barrier strip sheet and a three-dimensional integral image aligned with the sheet, so that a user can view the three-dimensional image without any special glasses or other equipment, are known. Such imaging elements and their construction, are described in "Three-Dimensional Imaging Techniques" by Takanori Okoshi, Academic Press, Inc., New York, 1976. Integral image elements having a lenticular lens sheet (that is, a sheet with a plurality of adjacent, parallel, elongated, and partially cylindrical lenses) are also described in the following Unites States patents: US 5,391,254; US 5,424,533; US 5,241,608; US 5,455,689; US 5,276,478; US 5,391,254; US 5,424,533 and others; as well as allowed US patent application Serial Number 07/931,744. Integral image elements with lenticular lens sheets use interlaced vertical image slices which, in the case of a three-dimensional integral image, are aligned with the lenticules so that a three-dimensional image is viewable when the lenticules are vertically oriented with respect to a viewer's eyes. The image may be conveniently laminated (that is, adhered) to an integral or lenticular lens sheet. Similar integral image elements, such as described in US 3,268,238 and US 3,538,632, can be used to convey a number of individual two-dimensional scenes (such as unrelated scenes or a sequence of scenes depicting motion) rather than one or more three-dimensional images, the scenes being viewable at different respective angles with respect to the element.

It has previously been appreciated, at least with respect to regular two-dimensional images, that it is desirable to have the image, carrying transparency evenly illuminated from behind. This is particularly true in larger displays which have several laterally spaced elongated light sources. The regions on the transparency between the light sources will have less illumination. Thus, the use of the diffuser sheet previously mentioned. However, diffuser sheets are not entirely satisfactory in that the transparency is still not evenly illuminated by such linear or other light sources. Thus, US 5,195,818 and US 5,224,770 describe reflector arrangements in which the reflectors have parallel V-shaped grooves extending transverse to an elongated light source. However, for reasons recognized by the present invention and discussed below, such designs inherently will provide uneven illumination of a transparency.

It would be desirable then, to provide a light apparatus for illuminating a transparency from behind, which apparatus can provide good uniformity of illumination to the transparency.

SUMMARY OF THE INVENTION

The present invention realizes that even with simple reflectors or diffusers, illumination intensity at a location where the transparency is to be positioned, must necessarily decrease at positions which are between light sources. This is so since luminance must decrease with distance from any light source. Thus, because of this physical law, previous attempts to design various reflectors or diffusers which try to spread light more evenly between light sources can only have limited success. The present invention takes a different approach in recognizing that the source of the problem is simply the space that exists where there is no light source (such as between a plurality of light sources). While this could be overcome by providing more light sources, such an approach may not be practical given construction and operations costs. However, the present invention attempts to obtain an equivalent effect.

The present invention then provides a light apparatus which in a first aspect comprises:

a) a housing having a back side and a front light opening through which light can pass;
b) at least one light source within the housing emitting light in a forward and a rearward direction;
c) a lenticular lens sheet positioned behind the light source in the housing, the sheet having a plurality of parallel elongated, laterally convex, lens surfaces extending in a path to form a pattern geometrically following the contour of the light source, and facing the linear light source; and
d) a reflecting surface behind the lens surfaces to redirect light emitted from the light source in the rearward direc-

tion to the forward direction.

In a second aspect of the invention, the light apparatus comprises:

a) a transparency carrying an image for display;
b) at least one light source positioned behind the transparency to illuminate the transparency, the light source emitting light in a forward and a rearward direction;
c) a lenticular lens sheet positioned behind the light source, the sheet having a plurality of parallel elongated, laterally convex, lens surfaces extending in a path to form a pattern geometrically following the contour of the light source, and facing the linear light source; and
d) a reflecting surface behind the lens surfaces to redirect light emitted in a rearward direction from the light source, to the forward direction.

Another aspect of the present invention provides a light source, lenticular lens sheet behind the light source with lens surfaces facing the light source, and reflector behind the lens surfaces to redirect rearwardly emitted light, to the forward direction.

A light apparatus of the present invention can provide illumination of good uniformity to an image bearing transparency positioned forward of the light source, even though there may be considerable area behind the transparency at which there is no actual light source. For a light apparatus with a fixed number of light sources, illumination uniformity can be improved. Alternatively, the same illumination uniformity can be retained and the number of light sources reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described with reference to the drawings, in which:

FIG. 1 is a lateral cross-section view of a light apparatus illustrating the operation of a conventional reflecting surface;
FIG. 2 is a perspective view of a light apparatus of the present invention;
FIG. 3 is a lateral cross-section along the line 3-3 of FIG. 2;
FIGS. 4-8 illustrate a geometrical determination of the positioning of light sources and a lenticular lens sheet as used in the apparatus of FIG. 2;
FIG. 8A is a plot of calculated light distribution in an appratus of the present invention;
FIG. 9 is a lateral cross-section of an alternate light apparatus of the present invention;
FIG. 10 is a front view illustrating the shape of a lenticular lens sheet positioned behind a non-linear light source, in a further alternate light apparatus of the present invention; and
FIG. 11 is a lateral cross-section of the further alternate light source of FIG. 10 with the additional use of a collimating lens.

To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures.

EMBODIMENTS OF THE INVENTION

Referring first to FIG. 1, there is shown a lateral cross-section of a light apparatus similar to that of FIG. 2, but not using a lenticular lens sheet as used in the present invention. The apparatus shown comprises a plurality of linear, parallel, identical light sources 36a, 36b, such as linear fluorescent bulbs (extending in a direction perpendicular to the plane of the drawing). A diffuser sheet is positioned forward of light sources 36a, 36b, and forward and adjacent diffuser sheet 18 is a transparency carrying an image for viewing from a further forward position.

Reflector 8 is a flat specular reflector (although the same type of result is obtained with a diffuse reflector). Note that rays 9 from a back side of light source 36a necessarily spread outward as they travel toward reflector 8, and further spread after their reflection from reflector 8. Thus, while these reflected rays 9 will increase the total light received at diffuser 18 than would be received simply from rays 14, the intensity of illumination on diffuser 18 will necessarily decrease moving in a lateral direction away from light source 36a toward light source 36b. A similar result will be obtained from light source 36b, the net result being that even with reflector 9 present, illumination on diffuser 18 still necessarily decreases moving in a direction away from light sources 36a, 36b toward a mid-point 18a between those sources.

Turning now to FIG. 2 there is shown a light apparatus 10 of the present invention. Apparatus 10 includes an opaque housing 12 except for a front light opening 16 through which light can pass. Light opening 16 is defined by a light transmitting diffuser 18 (such as a translucent white plastic sheet) positioned to extend across the area defined by a front periphery 14. and a transparency 20 positioned adjacent and forward of diffuser 18. Transparency 20 is co-extensive with diffuser 18 and carries a visible image for display. Diffuser 18 and transparency 20 are shown mostly cut away in FIG. 2 so that the inside of light apparatus 10 can be more clearly seen. Transparency 20 can carry any type of image including a typical ordinary two-dimensional image (such as obtained from enlarging a conventional photograph) or may carry an integral image as described further below.

A plurality of identical linear light sources 36, such as linear fluorescent lamps, are positioned within housing 12 and emit light in a forward direction toward diffuser 18, and in a rearward direction. A lenticular lens sheet 30, of well known construction, is positioned adjacent an opaque back wall 35 of housing 12. Lens sheet 30 has a flat back surface 34 and a plurality of parallel, elongated and linear cylindrical lens surfaces 32 on a front side. Back surface 34 is preferably itself reflecting. To accomplish this it is preferably a somewhat diffuse reflecting surface which is integral with the remainder of lens sheet 30, such as may be obtained by a finely abrasive treatment of back surface 34 (for example, by fine sandblasting). Alternatively, back surface 34 can simply result from back surface 34 being flat and polished, and then solely relying upon internal reflection at back surface 34 (although this is less preferred). However, a separate reflecting layer (such as a reflecting metal or metal oxide coating) could be provided to make back surface 34 reflecting. For example back wall 35 could be forward reflecting. Such a separate reflecting layer is preferably positioned immediately adjacent back surface 34. It will be appreciated that back wall 35 could be omitted, particularly for example, if back surface 34 has an adjacent reflecting metal layer.

Note that lens surfaces 32 are in the form of a pattern which follows the contour of the light sources 36. By "contour" of the light sources is referenced the outline of the two-dimensional direct projection of the light sources 36 toward front light opening 16 (by direct projection is meant that rays are traced from the back toward the front in a direction 90 degrees to the front light opening 16). That is, the light sources 36 have a linear contour, therefore the lens surfaces 32 follow this contour and are therefore arranged in a linear pattern parallel to light sources 36. Thus, transparency 20 can be viewed from a forward direction when light sources 36 are energized. However, it will be appreciated in this application that such "following" does not have to be precise (that is, it does not have to be parallel to the contour). Some benefit will be obtained even as the lens surfaces deviate from the contour, although the uniformity of the light distribution at the diffuser plane will decrease. This feature in iteself could be used for aesthetic appeal where light uniformity is to be varied in some desired manner.

The use of the lenticular lens sheet to effectively fill in light on diffuser 18 at positions between light sources 36 will now be described. This first requires an understanding of lenticular geometry and optics followed by the application of such optics to the light apparatus geometry, such as apparatus 10. These aspects are discussed below in relation to FIGS. 4-8 in particular. Light incident on diffuser 18 arrives by three paths. First, light emitted by source 36 in a rearward direction imaged by the lenticules onto the back surface 34 of the lenticular sheet and re-directed in the forward direction by the next adjacent lenticule such as lenticule 42. This can be referenced as the first satellite image. Second, light imaged on the rear surface of the lenticular sheet and re-directed forward by the second adjacent lenticule, such as lenticule 43. This can be referenced as the second satellite image. Higher order satellite images exist in theory but are of insignificant intensity. Third, direct emission in a forward direction from the light source 36 to diffuser 18, illustrated in FIG. 8 (which occurs without any reflecting surface in the light apparatus).

Lenticular Geometry

The applicable optical paths for the first and second satellite images for the lenticular lens sheet 30, are shown in FIGS. 4 and 5, respectively. In Figure 4, a ray 40 enters a lenticule 41 and strikes the planar back surface 34 causing an illumination of the intercept point 44. Point 44 becomes an object for the next adjacent lenticule 42 and light is refracted from lenticule 42 along the refracted path 45. The initial angle of incidence "**a**" to a centerline 41c and the refractive index "**n**" of the lens sheet 30 relative to the external refractive index number "$\mathbf{n_o}$" determines by Snell's law the angle "**b**". For the sake of this discussion, the thickness "**t**" of lens sheet 30 will be substantially equal to the focal length of the lens surface 32. Such thickness is measured from the top of the convex lens surface (that is, it will be the maximum thickness). However, **t** need not be equal to the focal length, and could be modified to alter the distribution of intercept points resulting from the first and second satellite images if desired. Ray 40 is thereby refracted to ray 40r. Point 44 is the object of lenticule 42 at an angle "**c**" from its centerline 42c.

A ray 60 is the reflected path of photons emitted from point 44 toward the lens surface 32 of lenticule 42. Again by Snell's law, ray 60 is refracted to a new angle "**d**" as ray 60r. The spacing of lenticules 41 and 42 and other similar lenticules in the lens sheet 30 is "**p**". The values of **a**, **b**, **c** and **d** can then be determined to be given in equations (2), (5) and (7) below from the following geometric relationships:

$$n_o \sin a = n \sin b \qquad (1)$$

therefore:

$$\mathbf{b} = \mathbf{arcsin}\left(\frac{no}{n}\cdot\sin a\right) \qquad (2).$$

Also:

$$\mathbf{s} = \mathbf{t \cdot tan(b)} \qquad (3)$$

and:

$$\mathbf{tan\ c} = \left(\frac{p-s}{t}\right) \qquad (4)$$

therefore:

$$\mathbf{c} = \mathbf{arc\ tan}\left(\frac{p-s}{t}\right) \qquad (5)$$

Also:

$$\mathbf{n\ sin\ c} = \mathbf{n_o\ sin\ d} \qquad (6)$$

therefore:

$$\mathbf{d} = \mathbf{arc\ sin}\left(\frac{n}{no}\sin c\right) \qquad (7)$$

Figure 5 is similar to Figure 4 except that the second satellite image is analyzed. The equations given earlier are then expanded to include by the same reasoning, this second satellite case:

s is calculated as before.

$$\tan e = \left(\frac{2p-s}{t}\right) \quad e = \arc\tan\left(\frac{2p-s}{t}\right) \qquad (8)$$

$$n \sin e = n_o \sin f \qquad (9)$$

$$f = \arc\sin\left(\frac{n}{no}\sin e\right) \qquad (10)$$

Similar analyses can be applied to higher order satellites, although the amount of light emitted from point 504 at increasing angles **e** will lessen by the rules associated with Lambertian surface emissions.

The surface treatment of the back surface 34 of lens sheet 30 will affect the efficiency of light transmitted along refracted ray 60r. A diffuse white surface is preferred over a plane unfinished surface. A diffuse "sandblasted" back surface 34 may be better than a plane surface polished surface. In any case, the addition of a metal or metal oxide layer behind back surface 34 can be used to improve reflectivity.

Apparatus Geometry

FIG. 6 is a portion of the view shown in FIG. 3 illustrating the first satellite image. As shown in FIG. 6, for any given photon path 40 exiting normal to the surface of light source 36 in a direction which intercepts the lenticular lens sheet 30, the incident angle is **a**. Therefore, the intercept distance from x_O (the central axis of the center of light source 36) is:

$$x_i = g \cdot \tan a \qquad (11)$$

where **g** is the distance from the tube center to the lenticular plane 002.

By the mathematics discussed in preceding "Lenticular Geometry" section, the photon refracts away from lenticular lens sheet 30 at angle **d** on a new ray 60r. This photon "hits" diffuser 18 at point 70 located at a distance "k_1" from x_o. The additional lateral translation (sometimes referenced as the x translation) of ray 60r is represented by x_r and can be calculated as:

$$x_r = (h + g) \cdot \tan d \qquad (12)$$

where **h** is the distance from diffuser 18 to axis x_0 and g is the distance from axis x_0 to lenticular lens sheet 30. Note that $k_1 = x_i + x_r$ for any value of **a**.

For the second satellite image, the same series of calculations can be made except replacing **c** with **e** and **d** with **f**.

A computer spreadsheet is a convenient way to calculate the series of intercepts similar to that at point 70 which result from other incident photon paths similar to the specific path 40, as shown in FIG. 7. FIG. 7 is a view the same as in FIG. 6 but illustrating the paths of additional light rays.

In FIG. 7 a series of photon paths at incrementally increasing angles 102, 103, 104, 105 result in refracted photon paths 102r, 103r, 104r, 105r respectively, and intercept diffuser 18 at "hit" points 112, 113, 114, 115, respectively. The distances k_1 in FIG. 6 corresponding to each of points 112, 113, 114, 115, can be calculated and plotted for display. An arrangement of equally distant points would be seen as a uniformly illuminated section of the diffuse plane.

It is particularly instructive from FIG. 7 to note that light from light source 36 emitted in a backward direction, is being refocussed by lenticular lens sheet 30 at a position between adjacent light sources 36. Light directed backward is not simply being reflected as would be the case with a simple planar reflector or reflected and scattered as would occur with a diffuse planar reflecting surface only. Thus, illumination at a position on diffuser 18 midway between adjacent light sources 36 can actually be increased such that illumination on diffuser 18 does not necessarily decrease toward a position midway between adjacent light sources 36.

Referring to FIG. 8, this is a view the same as FIG. 7 but showing the a similar set of photon paths emitted from a front side of light source 36 and directly intercept diffuser 18. Again, paths 201, 202, 203, 204 are normal to the surface of light source 369, but directed forward toward diffuser 18. The respective intercepts with diffuser 18 are at points 211, 212, 213, 214. These intercepts, k_0, can be calculated as follows:

$$k_0 = h \cdot \tan a \qquad (13)$$

For a distribution analysis, the values of **a** can be the same as the earlier, analysis of refracted photon paths, but are measured clockwise from the Y axis 291 of the coordinate system centered at $\mathbf{x_0}$.

The previously mentioned spreadsheet can calculate and plot the intercepts "hit" points 211, 212, 213, and 214 and the like by the addition of the appropriate equations.

Using the foregoing analysis a spreadsheet program by Microsoft Excel was used to analyze light ray intercepts (referenced as "Photon Path Intercepts" in FIG. 8A) on a diffuser 18 in a light assembly constructed according to FIG. 3 and having the parameters of TABLE 1. Note that in Table 1 all linear dimensions, including k_0, k_1, k_2, and have been normalized to the bulb spacing S_b. This simplifies the design of light boxes which might vary greatly in dimensions, by allowing the same set of calculations to be used for varying S_b.

The light ray intercepts between adjacent light sources 36 is plotted in FIG. 8A. The vertical axis is the ratio of box thickness **g** + **h** (which passes through the center of the lamp), normalized to the lamp spacing S_b. The horizontal axis is position as a ratio of lamp spacing (thus, another lamp would be present at position 1). Note that unlike the use of a flat reflector, such as shown and described above in connection with Figure 1, that the density of intercepts does not fall to a minimum at a position midway between adjacent light sources 36, but increases because of the effect of light being redirected by the lenticular lens sheet 30. The intercept density may not have a one-to-one correspondence with light intensity though, because of imperfections in the lenticular lens sheet 30 and efficiency of reflectance from the back surface 34. Of course, these are characteristics that can be controlled to some degree during production to optimize performance or cost.

It will be appreciated then that the above type of analysis can be used as a technque to construct

DESIGN OF LIGHT BOX USING LENTICULAR REFLECTOR

Lenticular Parameters											
External Index	n_0	1.000									
Lenticular Index	n	1.567									
Lent Thickness	t	.103									
Lent Pitch	p	.045									
Box & Lamp Geometry											
Blub Spacing	S_b	4.000									
Divisor (Optimizing Variables)		1.000									
Front Distance	h	1.500									
Back Distance	g	2.000	.500								
Box Thickness	g + h	1.500									
Normalzd to Sb	$(g + h)/S_b$	.375	.375	.375	.375	.375	.375	.375	.375	.375	.375
Photon Path Analysis (Rearward Emissions)											
Incident Angle	a	5.000	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000
Primary Refracted Angle	b	.056	.111	.166	.220	.273	.325	.375	.423	.468	.511
Lenticular Plane Intercept	s	.006	.011	.017	.013	.029	.035	.041	.046	.052	.058
Refracted 1st Satellite Photon Paths											
1st Satellite Location via P2	p - s	.040	.034	.028	.022	.017	.011	.005	-.001	-.007	-.012
1st Satellite Angle	c	41.146	36.772	31.820	26.252	20.070	13.338	6.204	-1.101	-8.297	-15.101
1st Satellite Refracted Angle	d	24.828	22.459	19.662	16.396	12.650	8.466	3.955	-.703	-5.284	-9.570
Optimum Energy Loc x	x_i	.175	.353	.536	.728	.933	1.155	1.400	1.678	2.000	2.384
Optim Refrcte Locus y	x_r	.925	.827	.715	.588	.449	.298	.138	-.025	-.185	-.337
Image Location (x+y)	k_1	1.100	1.179	1.251	1.316	1.381	1.452	1.539	1.654	1.815	2.046
Normalzd to Sb	k_1/S_b	.275	.295	.313	.329	.345	.363	.385	.413	.454	.512
Refracated 2nd Satellite Photon Paths											
2nd Satellite Location via P3	2*p - s	.085	.079	.074	.068	.062	.056	.050	.045	.039	.033
2nd Satellite Angle	e	61.912	60.217	58.322	56.190	53.780	51.050	47.951	44.444	40.503	36.136
2nd Satellite Refracted Angle	f	34.264	33.633	32.894	32.022	30.987	29.755	28.287	26.542	24.487	22.106
Optimum Energy Loc x	x_i	.175	.353	.536	.728	.933	1.155	1.400	1.678	2.000	2.384
Optim Refrcte Locus y	x_r	1.362	1.330	1.294	1.251	1.201	1.143	1.076	.999	.911	.812
Image Location (x+y)	k_2	1.537	1.683	1.829	1.979	2.134	2.298	2.477	2.677	2.911	3.196
Normalzd to Sb	k_2/S_b	.384	.421	.457	.495	.533	.575	.619	.669	.728	.799
Photon Path Analysis (Forward Emissions)					**Direct Emission Paths**						
Location Rel To Bulb Norm	k_0	.131	.264	.402	.546	.699	.866	1.050	1.259	1.500	1.788
Normalzd to Sb	k_0/S_b	.033	.066	.100	.136	.175	.217	.263	.315	.375	.447

FIGURE 1

a light apparatus such as apparatus 10, so as to have the most uniform illumination on diffuser 18 given constraints such as the number of light sources 36 and size of front opening 16. It will also be understood that in the foregoing analysis the emitted photon paths were assumed to be normal to the light source. A more complete analysis could be performed by including consideration for the diffuse nature of the light source surface and the falloff of light intensity with distance. However, the analysis presented above is a convenient practical first order approximation which is sufficient for most purposes. Alternatively, for an apparatus having the foregoing constraints pre-determined, a second technique is simply to determine the spacing of lenticular lens sheet 30 and diffuser from light sources 36 experimentally. This can be done by simply varying the foregoing spacings manually until the best or a satisfactory uniformity of illumination on diffuser 18 is observed. Additionally, lenticular lens sheets having varying lenticule sizes, which are available commercially from Imaging Technology Internationl, Duluth, Georgia, USA and elsewhere, could be tried. Either technique can, if desired, be used to minimize non-uniformity of illumination at the area to be illuminated (for example, diffuser 18) given preselected constraints on the number and type of light sources and the area to be illuminated by them. Such non-uniformity can be determined by measuring light intensity across the area to be illuminated and calculating standard deviation or variance using statistical techniques.

Referring now to FIG. 9 there is shown a lateral cross-section of another light apparatus 10a of the present invention. Apparatus 10a is similar in construction to apparatus 10 of FIGS. 2 and 3. However, apparatus 10a has a curved image carrying transparency 20a positioned in front of a curved diffuser 18a, both of which extend to a back wall 35a (note that both transparency 20a and diffuser 18a are curved concavely about the direction of linear light sources 36). Two linear light sources 36, the same as those of apparatus 10, are positioned behind diffuser 18a and forward of two lenticular lens sheets 30a. Each lenticular lens sheet 30a is the same as sheet 30 in apparatus 10, but each only extends laterally outward from behind its corresponding light source 36 (that is, there is no lenticular lens sheet behind and between the two light sources 36. It will be appreciated that by proper adjustment of the curvature of diffuser 18a and transparency 20a, and the positioning of light sources 36, fairly uniform illumination on diffuser 18 can be obtained.

FIG. 10 illustrates a different pattern of lenticular lens elements. In particular, in FIG. 10 a light source 300 is provided which has a circular contour, such as a spherical light source. Lenticular lens sheet 30b in this case has parallel, elongated, convex lens surfaces 32b, which follow the circular contour of light source 300 and thus form a pattern of concentric circles. It should be noted here that "elongated" in the context of the lens surface shapes, does not require that they be linear, unless the contrary is indicated. Lenticular lens sheet 30b otherwise may be constructed in any of the manners described in connection with lens sheet 30 described above. A diffuser and transparency carrying an image, could be placed in sequence in front of such a light source. Alternatively, such a light source 300 and lens sheet 30b could be used with our without a diffuser as a light source to project light forwardly.

FIG. 11 shows a lateral cross-section across an apparatus incorporating the arrangement shown in FIG. 10. In the light apparatus 10b of FIG. 11, a housing 12b is opaque but has a front light opening defined by a convex lens in the form of a light transmitting Fresnel lens 302. Housing 12b includes a back wall 35b against which lens sheet 30b is positioned. Back wall 35b may have a forwardly reflecting surface adjacent lens sheet 30b, similar to back wall 35 described above. The light assembly 10b of FIG. 11 may have a diffuser positioned adjacent and in front of Fresnel lens 302. A transparency carrying an image may be positioned adjacent and in front of Fresnel lens 302 if it is desired to use light assembly 10b to display an image carried by such a transparency. Alternatively, the transparency can be omitted and the light assembly 10b, with or without diffuser, used as a forward projecting light source for other purposes. Note that Fresnel lens 302 tends to collimate light passing forwardly through it.

In the present invention the lenticular lens sheets have been described as having a "convex" lens surfaces. It will be understood that such lens surfaces may be physical convex surfaces (which is preferred), in the sense that they have a physical convexity. Alternatively, the convex lens surfaces can be functional ones, in the sens that the optical effect provided is the same as that provided by physical convex lens surfaces of leticules. In this latter regard is included lens sheets which may be physically flat on either side but use regions of varying indices of refraction through its volume configured in such a way as to provide (in conjunction with the surfaces of the sheet, such as a curved external surface, flat external surface or some other shape) the same optical deflection of light rays as would be provided by a lenticular lens sheet with physical convex lens surfaces. It will also be appreciated in the present invention that the back surface of the lenticular lens sheet may also be curved so as to either strengthen the lens effect or compensate for the curved focal plain which may be inherent in the lens construction. Consequently, the curvature on the back side may be of such a shape as to match the curvature of the focal plain of the lens.

Additionally, for particular applications, where a different distribution of light is desired, the entire lens sheet such as lens sheet 30, may be curved or otherwise shaped, such as curved concavely or convexly about an axis parallel to that of a linear light source. With reference to a "linear" light source in this application, it will be appreciated that such a source includes a line of individual sources (such as a line of spherical incandescent bulbs).

It will be appreciated that the light distribution to be received on the diffuser 18 could also be altered by altering the characteristics of the reflecting back surface 34. For example, bands of diffuse reflecting areas 400 could be provided, as shown in FIGS. 12 and 13, if it was desired to provide more diffuse satellite images. FIG. 12 shows the effect on the first satellite images while FIG. 13 shows the effect on the second satellite image. Alternatively, areas 400 could be colored if color effects were desired, or they could be angled zones if other effects were desired.

As to the type of image carried by a transparency described above, as already mentioned such an image can be a conventional two-dimensional image obtained from enlarging a conventional photograph or the like. However, such an image may particularly be an integral image for use with a lenticular lens sheet (thus, it will have interlaced strips from multiple two-dimensional images, as described above; integral images specifically constructed for lenticular lens sheets are sometimes referenced as "lenticular images"). The strips are to be aligned with individual lenses of an integral lens sheet so that each of the images is viewable when a user's eyes are at the correct angle relative to the imaging element. The integral image can be one or more three-dimensional images, one or more two dimensional images, or any combination of the foregoing. By a "three-dimensional image", is meant an integral image which, when viewed through the lens, has a visible depth element. A depth element means the ability to at least partially look around an object in the scene. This can be obtained by interlacing lines from different perspective views of the same scene (that is, views from different angular positions with respect to the scene). Thus, a three-dimensional image necessarily includes at least two views of a scene. By a two-dimensional image is referenced an image which, when viewed in the final product, does not have any viewable depth element.

The invention has been described with reference to a preferred embodiment. However, it will be appreciated that variations and modifications can be effected by a person of ordinary skill in the art without departing from the scope of the invention.

PARTS LIST

002	Lenticular Plane
8	Reflector
9	Rays
10, 10a	Apparatus
10b	Assembly
12, 12b	Housing
13	Front Periphery
14	Rays
16	Opening
18	Diffuser
18a	Mid-Point
20, 20a	Transparency
30, 30a, 30b,	Lens Sheets
32, 32b	Lens Surfaces
34	Back Surface
35, 35a, 35b	Back Wall
36, 36a, 36b	Light Sources
40, 40r	Ray
40	Path
41	Lenticules
41c, 42c	Centerline
43	Lenticule
44	Point
45	Refracted Path
60, 60r	Rays
70	Point
102, 103, 104, 105	Angles
102r, 103r, 104r, 105r	Paths
112, 113, 114, 115	"Hit" Points
201, 202, 203, 204	Paths
211, 212, 213, and 214	"Hit" Points
291	Y Axis
300	Light Source
302	Fresnel Lens
400	Areas
504	Point

Claims

1. A light apparatus comprising:

a) a housing having a back side and a front light opening through which light can pass;
b) at least one light source within the housing emitting light in a forward and a rearward direction;
c) a lenticular lens sheet positioned behind the light source in the housing, the sheet having a plurality of par-

allel elongated, laterally convex, lens surfaces extending in a path to form a pattern geometrically following the contour of the light source, and facing the linear light source; and

d) a reflecting surface behind the lens surfaces to redirect light emitted from the light source in the rearward direction to the forward direction.

2. A light apparatus according to claim 1 wherein the light source contour and lens pattern are circular.

3. A light apparatus according to claim 1 wherein the light source is linear and the lens pattern is linear.

4. An apparatus according to claim 1 wherein the reflecting back surface comprises a diffuse reflecting surface.

5. An apparatus according to claim 1 wherein the lenticular lens sheet is positioned behind the light source at a distance which minimizes non-uniformity of illumination within the extent of the front light opening.

6. A light apparatus comprising:

a) a transparency carrying an image for display;
b) at least one light source positioned behind the transparency to illuminate the transparency, the light source emitting light in a forward and a rearward direction;
c) a lenticular lens sheet positioned behind the light source, the sheet having a plurality of parallel elongated, laterally convex, lens surfaces extending in a path to form a pattern geometrically following the contour of the light source, and facing the linear light source; and
d) a reflecting surface behind the lens surfaces to redirect light emitted in a rearward direction from the light source, to the forward direction.

7. A light apparatus according to claim 6 wherein the light source is linear and the lens pattern is linear.

8. A light apparatus comprising:

a) at least one linear light source emitting light in a forward and rearward direction;
b) a lenticular lens sheet positioned behind the light source, the sheet having a plurality of elongated, parallel cylindrical lens surfaces oriented in the same direction as, and facing, the linear light source; and
c) a reflecting surface behind the lens surfaces to redirect light emitted from the light source in the rearward direction to the forward direction.

9. A light apparatus comprising:

a) a housing having a back side and a front light opening through which light can pass;
b) at least one linear light source within the housing emitting light in a forward and a rearward direction;
c) a lenticular lens sheet positioned behind the light source in the housing, the sheet having a plurality of elongated, parallel cylindrical lens surfaces oriented in the same direction as, and facing, the linear light source; and
d) a reflecting surface behind the lens surfaces to redirect light emitted from the light source in the rearward direction to the forward direction.

10. An apparatus according to claim 9 additionally comprising an image carrying transparency positioned forward of the light source.

11. An apparatus according to claim 10 wherein the transparency comprises a lenticular element having a lenticular image and a lenticular lens sheet positioned forward of the image.

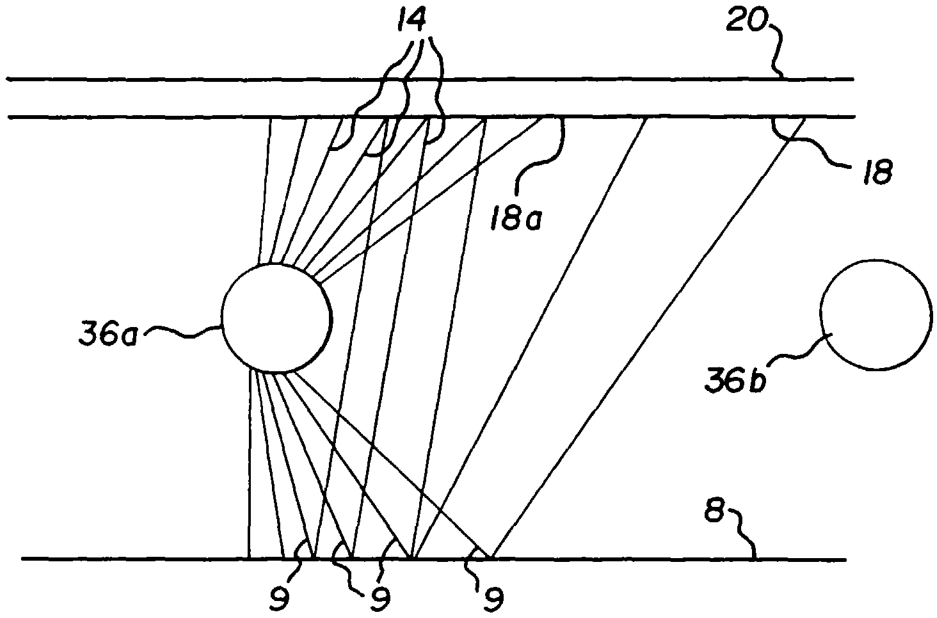


FIG. 1

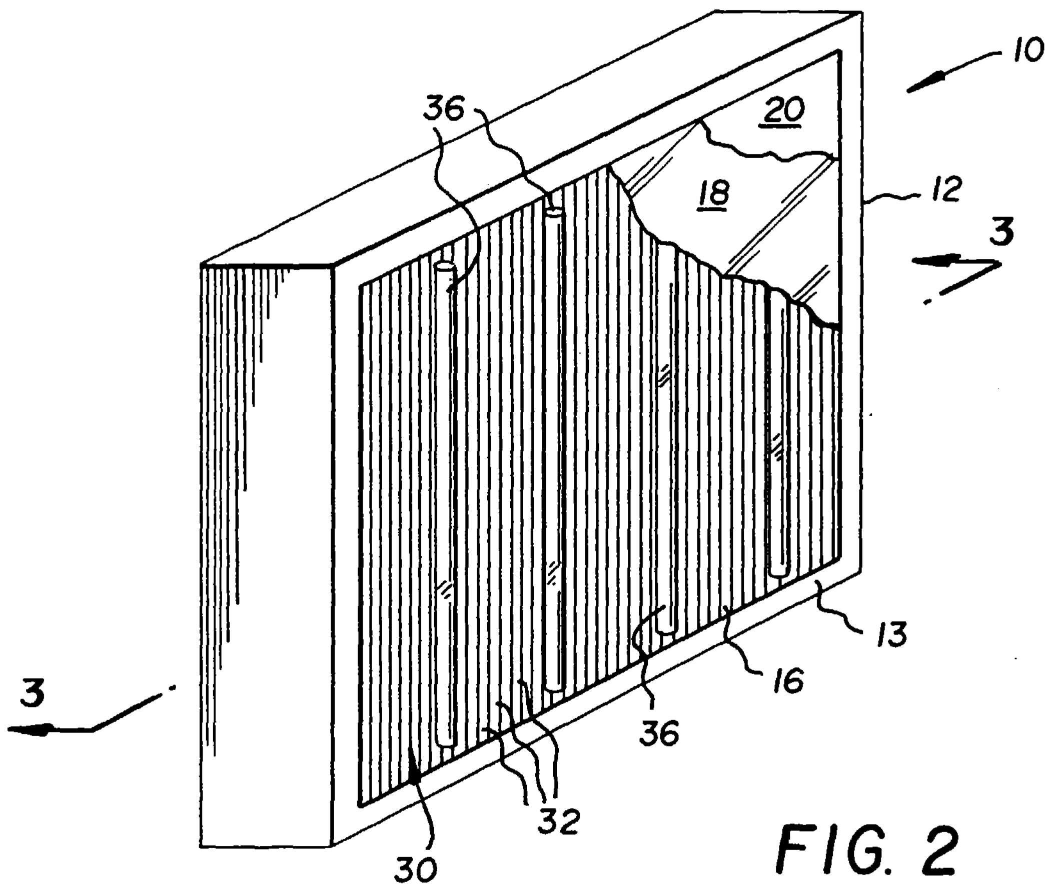


FIG. 2

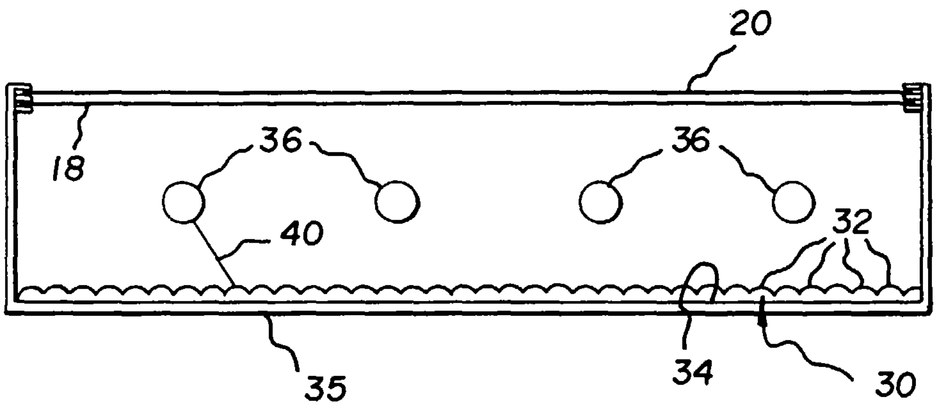


FIG. 3

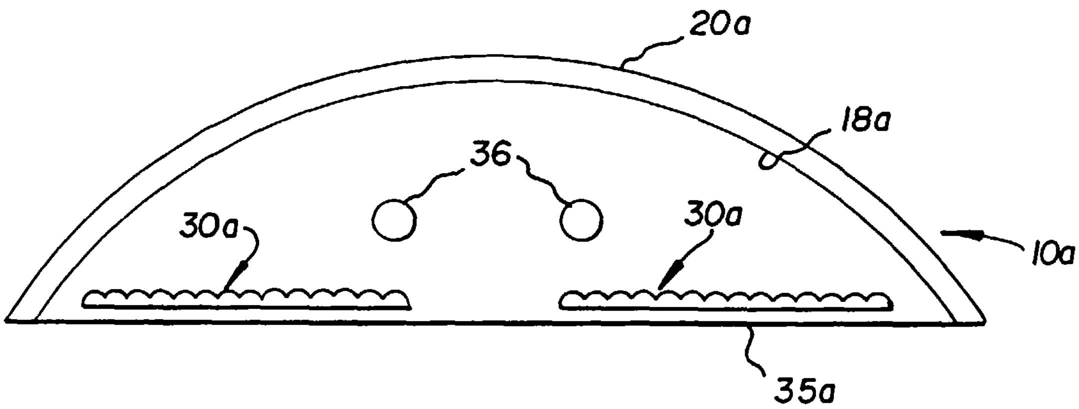


FIG. 9

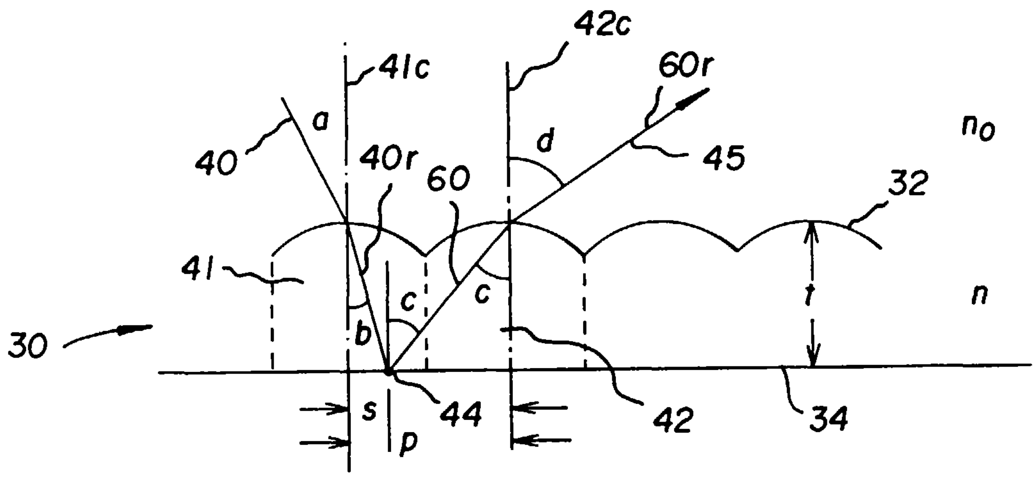

42c
41c
60r
a
d
40
40r
60
45
n0
32
41
c
c
t
n
30
b
s
44
42
34
p

FIG. 4

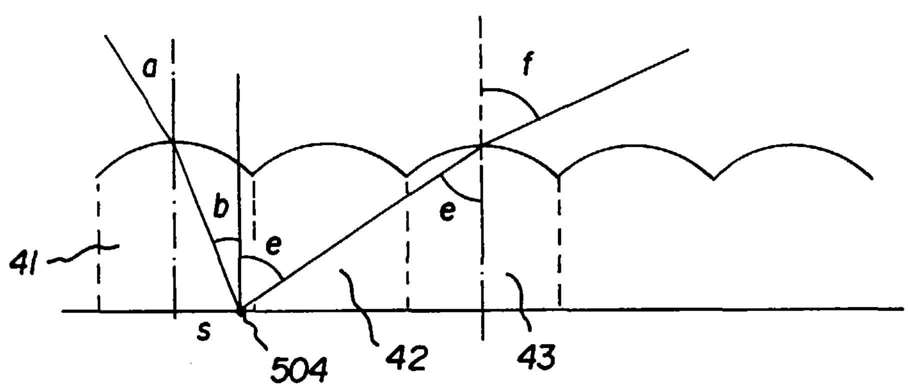
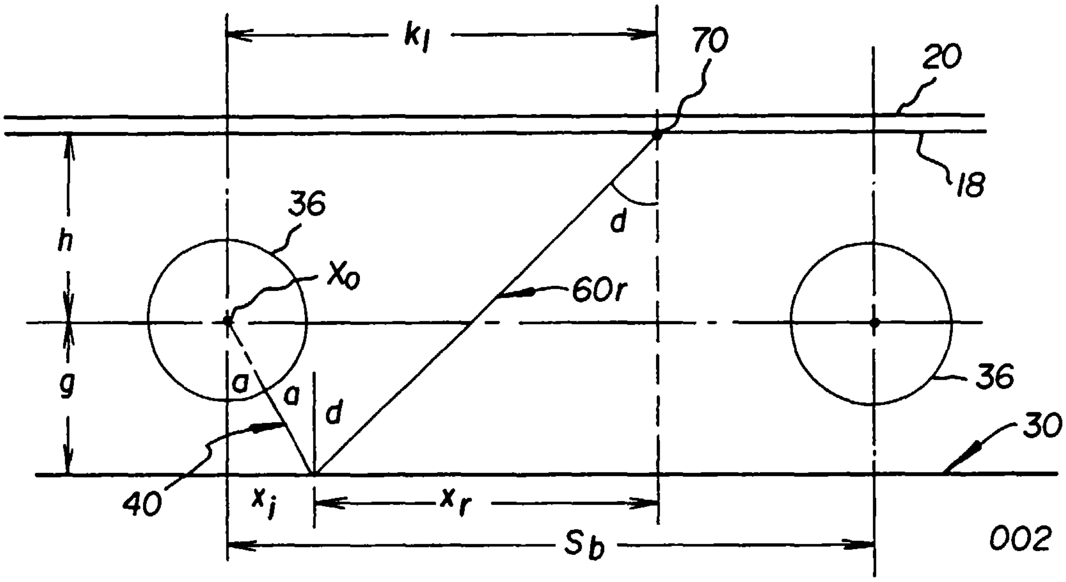
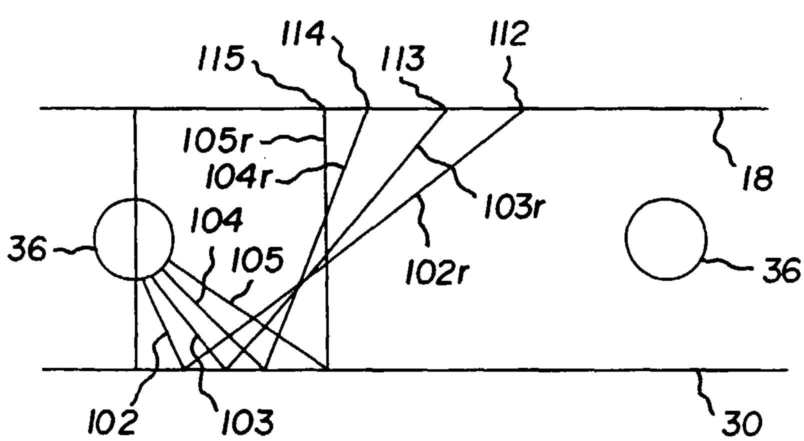

a
f
b
e
e
41
s
504
42
43

FIG. 5



k_l
70
20
18
h
36
X_o
d
60r
g
a
a
d
36
30
40
x_i
x_r
S_b
002

FIG. 6



115
114
113
112
105r
104r
103r
18
104
36
105
102r
36
102
103
30

FIG. 7

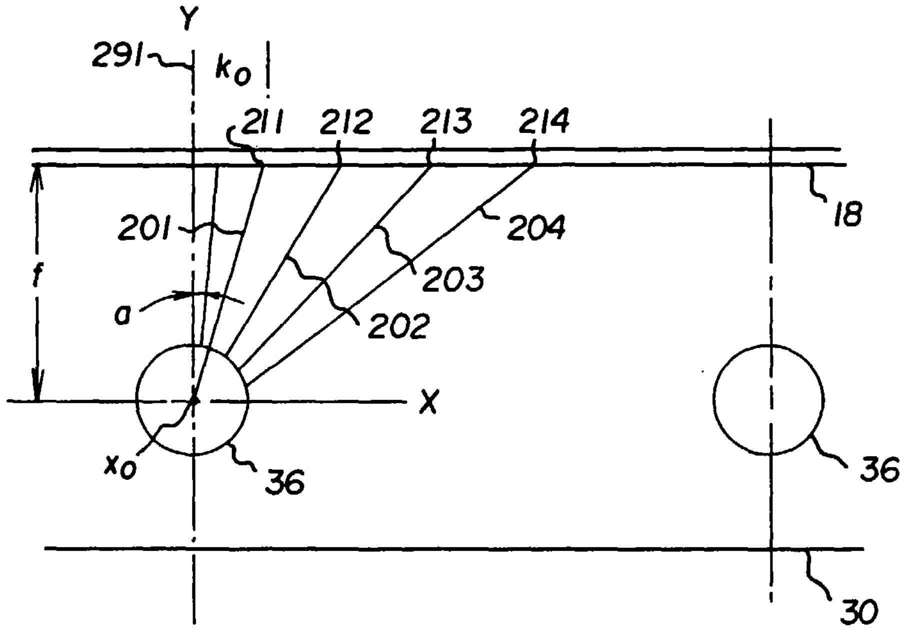

Y
291
k_o
211
212
213
214
18
201
204
203
f
a
202
X
x_o
36
36
30

FIG. 8

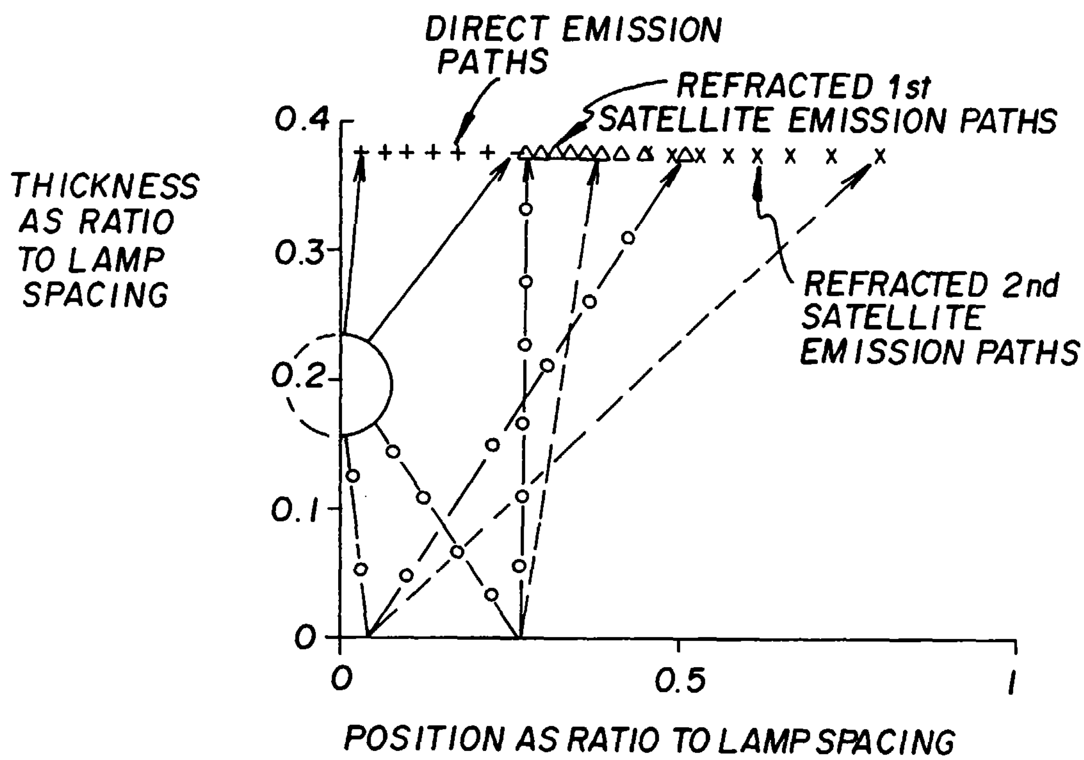

DIRECT EMISSION PATHS
REFRACTED 1st SATELLITE EMISSION PATHS
THICKNESS AS RATIO TO LAMP SPACING
0.4
0.3
0.2
0.1
0
REFRACTED 2nd SATELLITE EMISSION PATHS
0
0.5
1
POSITION AS RATIO TO LAMP SPACING

FIG. 8A

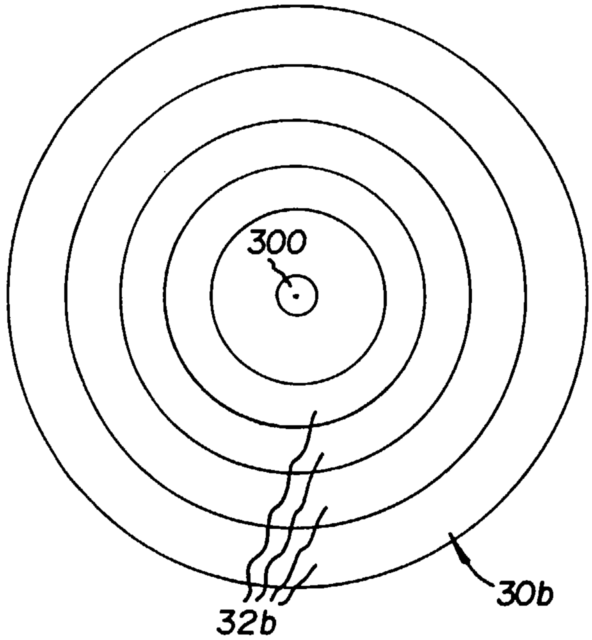


FIG. 10

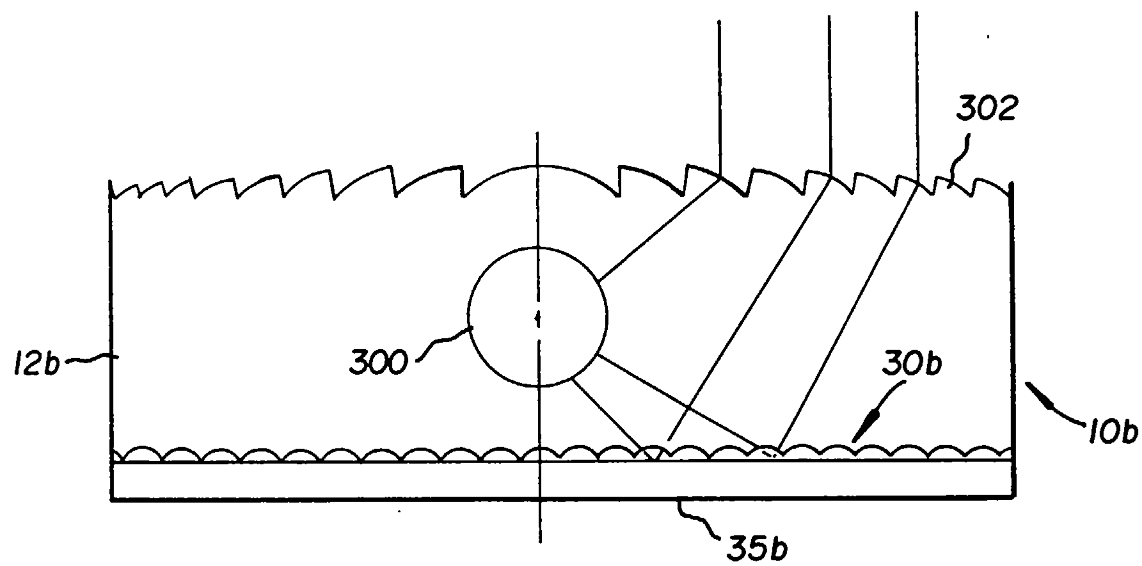


FIG. 11

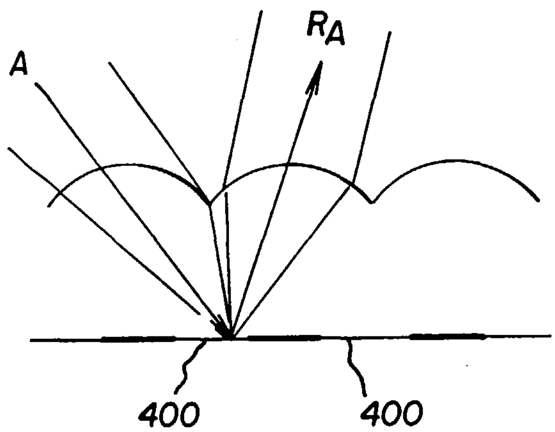


FIG. 12

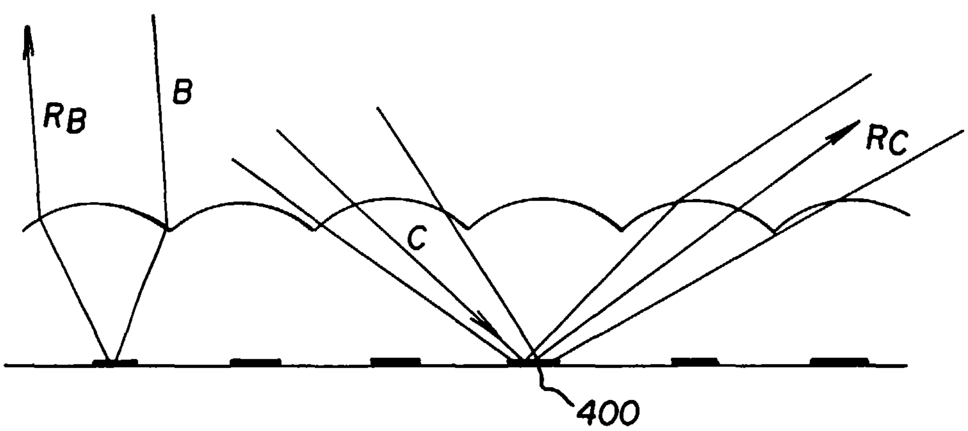


FIG. 13