

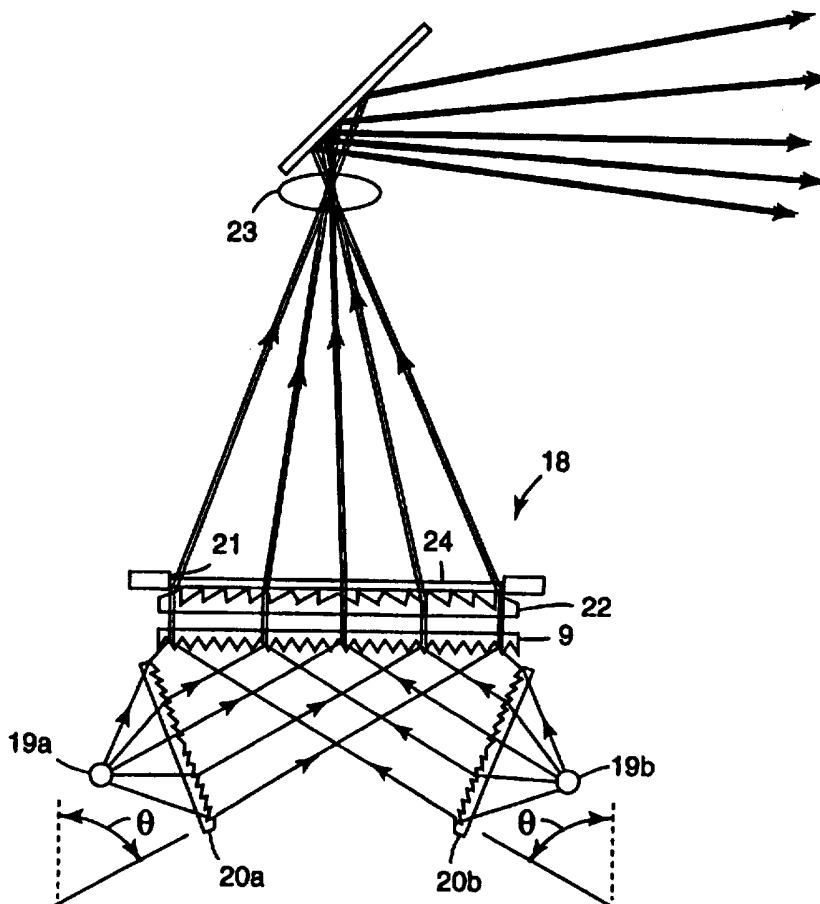


## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
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| <b>(21) International Application Number:</b> PCT/US95/12896<br><b>(22) International Filing Date:</b> 10 October 1995 (10.10.95)<br><br><b>(30) Priority Data:</b><br>08/344,135                      23 November 1994 (23.11.94)      US<br><br><b>(71) Applicant:</b> MINNESOTA MINING AND MANUFACTURING COMPANY [US/US]; 3M Center, P.O. Box 33427, Saint Paul, MN 55133-3427 (US).<br><br><b>(72) Inventors:</b> DREYER, John, Frederick; 3M Austin Center, 6801 River Place Boulevard, Austin, TX 78726-9000 (US). FESLER, Robert, Merl; 3M Austin Center, 6801 River Place Boulevard, Austin, TX 78726-9000 (US). VANDERWERF, Dennis, Frank; 3M Austin Center, 6801 River Place Boulevard, Austin, TX 78726-9000 (US).<br><br><b>(74) Agents:</b> ANDERSON, David, W. et al.; Minnesota Mining and Manufacturing Company, Office of Intellectual Property Counsel, P.O. Box 33427, Saint Paul, MN 55133-3427 (US). |           | <b>(81) Designated States:</b> CA, CN, JP, KR, SI, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).<br><br><b>Published</b><br><i>With international search report.<br/>         Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i> |

**(54) Title:** PROJECTOR WITH MULTIPLE LAMP LIGHT SOURCE**(57) Abstract**

A projection system (18) is described which efficiently combines the output from multiple lamps (19A, 19B) images of which are focused to a common point. The projected screen brightness is multiplied over that of a conventional single lamp of equivalent wattage. The screen brightness can be increased or diminished by switching individual lamps (19A, 19B) on or off, adjusting the light level for conventional overhead transparencies, or low transmission liquid crystal display projection panels.



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1                    PROJECTOR WITH MULTIPLE LAMP LIGHT SOURCE

2

3                    Field of the Invention

4                    The present invention relates to projection  
5                    systems or projectors, particularly transmissive  
6                    overhead projectors.

7

8                    Background of the Invention

9                    With the increasing use of full-color, computer-  
10                   generated and photographic transparencies, and liquid  
11                   crystal display (LCD) projection panels, there is a  
12                   need for projection systems of increased brightness.  
13                   This has been recently addressed by the use of higher  
14                   wattage tungsten-halogen lamps, metal-halide lamp  
15                   technology, and high-efficiency anti-reflection  
16                   coatings on the optical components. The use of higher  
17                   wattage tungsten filament lamps increases the  
18                   difficulty of cooling, and arc discharge lamps, such as  
19                   metal halide, are relatively expensive.

20                   In the past, several attempts to increase the  
21                   illumination level of projection systems were  
22                   characterized by the use of multiple lower wattage  
23                   lamps. In the case of episcopic projection, commonly  
24                   practiced in opaque projectors, it is simply necessary  
25                   to illuminate the opaque copy with light from several  
26                   sources. The scattered light from the copy which  
27                   enters a projection lens is then directed to the  
28                   screen. This type of projection system is described,  
29                   for example, in U.S. patent no. 4,979,813.

30                   In diasopic projection, light from a lamp is  
31                   collected by single or multiple condensing lenses,  
32                   passes through a projection transparency, and is  
33                   focused to the projection lens. This mode of  
34                   projection is commonly used in 35 millimeter and

1 overhead projectors, and gives a brighter projected  
2 image than episcopic projection. See, for example,  
3 U.S. patent nos. 3,547,530 and 3,979,160. However,  
4 since the condensing lens system can only efficiently  
5 focus light from one single point (lamp position) to  
6 another single point (projection lens position),  
7 diascope projection is usually limited to the use of a  
8 single lamp. This inherently limits the brightness  
9 which may be achieved on the screen.

10 Several attempts have been made to efficiently  
11 combine the output of multiple lamps and bring them to  
12 a common focus. U.S. patent no. 1,887,650 describes a  
13 system combining eight lamps, U.S. patent no. 3,770,344  
14 describes an overhead projector combining four lamps,  
15 and Japanese patent nos. 4-179046 and 5-199485 describe  
16 projectors combining two lamps. All of these devices  
17 suffer from a common deficiency in that the combined  
18 output from the lamps is not truly integrated. The  
19 combined lamp output beams are contiguous, yet  
20 spatially separated. The result is that should one  
21 lamp fail, the screen image brightness does not  
22 diminish uniformly, but rather individual sections of  
23 the screen image become completely dark, making part of  
24 the screen image unreadable.

25 True integration of the light from multiple  
26 sources, allowing them to be focused to a common point,  
27 is a more demanding task. U.S. patent no. 4,952,053  
28 describes an overhead projector combining two lamps,  
29 U.S. patent no. 5,231,433 describes a method for  
30 integrating two collimated light beams by means of a  
31 linear grooved reflector or a linear grooved refracting  
32 element. Japanese patent no. 5-232399 describes a  
33 method for combining and integrating the output of two  
34 lamps by means of a beam splitter and multiple-pass  
35 reflections. The efficiency of these systems is limited  
36 by the achievable reflectance of the reflector

1 coatings, geometric shading losses, and by the high  
2 chromatic dispersion of the refracting elements.

3

#### 4 Summary of the Invention

5       The current invention avoids the deficiencies of  
6 the prior art, providing a projection system with  
7 complete and efficient integration of the output of  
8 multiple light sources, to increase screen brightness.  
9 This is accomplished by a series of Fresnel collecting  
10 and focusing lenses, and a linear beam combining  
11 prismatic film that utilizes total internal reflection  
12 (TIR). The projection system can be in the form of an  
13 integrated projector designed to project electronically  
14 generated or stored information or in the form of an  
15 overhead projector adapted for full-size overhead  
16 transparencies, or the reduced format of LCD projection  
17 panels. The present invention further relates to a low  
18 profile overhead projector.

19

#### 20 Brief Description of the Drawings

21       Figure 1 is a cross-sectional view of a linear  
22 prismatic film of the prior art that deviates a beam of  
23 light by refraction and total internal reflection.

24       Figure 2 is a cross-sectional view of a 60° apex  
25 angle linear prismatic film of the current invention.

26       Figure 3 is a cross-sectional view of the  
27 prismatic film of the present invention and illustrates  
28 schematically the integration of two collimated light  
29 beams.

30       Figure 4 is a schematic illustration of a  
31 transmissive overhead projector system that combines  
32 and integrates the output of two lamps.

33       Figure 5 is a schematic illustration of an  
34 alternate arrangement of a projection system that  
35 combines and integrates the output of two lamps.

1        Figure 6 is a schematic illustration of a  
2 projection system that combines and integrates the  
3 output of four lamps.

4        Figure 7 is a perspective view showing desirable  
5 shapes of lenses for use in the present invention.

6        Figure 8 is a perspective schematic illustration  
7 showing condensing optics used with the present  
8 invention to form an elliptical shaped beam at the  
9 rectangular Fresnel lens collimator.

10       Figure 9 is a schematic illustration of an  
11 integrated liquid crystal projection system that  
12 combines and integrates the output of two lamps.

13

#### 14 Detailed Description of the Invention

15       U.S. patent no. 4,984,144 describes a dispersive  
16 linear prismatic film 1 that deviates a beam of light  
17 by refraction and total internal reflection, as shown  
18 in Figure 1. The isosceles triangle micro prisms 2  
19 have an apex angle  $\alpha$  of  $69^\circ$ . An incident ray 3 enters  
20 facet 4 at an entrance angle  $\theta$  of about  $75^\circ$ , where it  
21 is refracted. It is then totally internally reflected  
22 at facet 5, and ray 7 exits perpendicular to the planar  
23 face 8. The large entrance angle  $\theta$  of about  $75^\circ$  was a  
24 requirement for this prismatic lens in its intended use  
25 in a high aspect ratio light fixture.

26       Figure 2 shows the linear prismatic film 9 of the  
27 current invention, consisting of a series of isosceles  
28 triangle shaped micro prisms 10 with an apex angle  $\alpha$  of  
29  $60^\circ$ . When an extended area collimated light beam 11  
30 enters the film perpendicular to facet 12 at the  
31 specific entrance angle  $\theta$  of  $60^\circ$ , then the light rays  
32 13 exit perpendicular to plano surface 14 with the  
33 deviation occurring entirely by total internal  
34 refraction at facet 15. Since there is no refraction  
35 at surfaces 12 or 14, there is no dispersion and the  
36 ray deviation is independent of the refractive index of

1 the material. Moreover, since ray 11 of the entrance  
2 beam touches both the peak and valley of adjacent  
3 microgrooves, the entrance beam 11 completely fills the  
4 TIR facet 15, and there are no geometric losses or  
5 spurious ray deviations.

6 For the 60° apex angle film, Figure 3 illustrates  
7 that two collimated incident beams 16a and 16b can be  
8 efficiently and spatially combined. The individual  
9 exiting ray bundles 17a and 17b from the left and right  
10 incident beams 16a and 16b are interlaced on a micro  
11 scale, such that the intensity of light over the total  
12 area of the film 9 is effectively doubled.

13 For the linear prismatic beam-combining film 9 of  
14 the current invention, the following conditions need to  
15 be satisfied for most efficient operation:

- 16 1) The incident light 16a and 16b must be  
17 collimated so that light rays from each lamp  
18 enter the entire prismatic film 9 at the same  
19 entrance angle  $\theta$ ;
- 20 2) The preferred vertex angle  $\alpha$  of the linear  
21 prismatic beam-combining film 9 is 60° plus  
22 or minus 2°; and
- 23 3) The preferred entrance angle  $\theta$  of the  
24 collimated light entering the linear beam  
25 combining film is 60° plus or minus 3.5°.

26 If the prism vertex angle  $\alpha$  is greater than 62°,  
27 less than 90° of each reflecting facet is utilized.  
28 For example, for an acrylic plastic prismatic film with  
29 a refractive index  $n = 1.492$ , a vertex angle  $\alpha$  of 62°,  
30 and an entrance angle  $\theta$  of 63.5°, only about 90% of  
31 each reflecting facet is utilized. Excessive  
32 underfilling of the reflecting facets causes the  
33 collimated exit beams 17a and 17b produced by each  
34 adjacent microprism to be spatially separated, and dark  
35 banding begins to appear on the illuminated projection  
36 screen.

1        On the other hand, when the prism vertex angle  $\alpha$   
2    is less than  $58^\circ$ ; less than  $90^\circ$  of the incident light  
3    rays 16a and 16b exit perpendicular to the film. For  
4    example, for an acrylic plastic prismatic film with a  
5    refractive index  $n = 1.492$ , a vertex angle  $\alpha$  of  $58^\circ$ ,  
6    and an entrance angle  $\theta$  of  $56.5^\circ$ , about 10% of the  
7    incident rays miss each reflecting facet. The light  
8    missing the reflecting facet exits the film in an  
9    uncollimated and uncontrolled direction, and does not  
10   contribute to the illumination on the projection  
11   screen.

12        Table 1 below illustrates the fraction of beam  
13    filling of each facet (BFF) for various vertex angles  $\alpha$   
14    of the film 9. Values of BFF less than unity represent  
15    underfilling of the reflecting facet, while values of  
16    BFF greater than unity represent overspilling of the  
17    reflecting facet. As explained above, more than 10% of  
18    the incident light is spatially separated or wasted at  
19    vertex angles  $\theta$  above  $62^\circ$  or below  $58^\circ$ , upon exiting  
20    the film 9.

21

Table 1

| $\alpha$ | $\theta$ | BFF   |
|----------|----------|-------|
| 50       | 42.3     | 1.55  |
| .        |          |       |
| 58       | 56.5     | 1.11  |
| 59       | 58.3     | 1.05  |
| 60       | 60.0     | 1.0   |
| 61       | 61.7     | 0.947 |
| 62       | 63.5     | 0.895 |
| .        |          |       |
| 70       | 77.7     | 0.446 |

It will be seen from Table 1 that the entrance angle  $\theta$  of the collimated light 16a and 16b generally changes in a similar fashion as the vertex angle  $\alpha$  changes, but the relationship is not linear. This is because at entrance angles  $\theta$  other than  $60^\circ$  the refractive index  $n$  of the material of the film has an effect. The exact relationship for the entrance angle  $\theta$  necessary to produce maximum screen illumination at a given vertex angle  $\alpha$  is given by the equation:

$$\theta = 90^\circ - \left( \frac{\alpha}{2} + \text{asin} \left( n \cos \left( \frac{3}{2} \alpha \right) \right) \right)$$

wherein:

$\theta$  = said angle of inclination of said collimated light

$\alpha$  = said included angle of said prism sides

$n$  = index of refraction of the material of said film.

1        Figure 4 shows a projection system 18 that  
2        efficiently integrates the output from two lamps 19a  
3        and 19b, providing uniform screen brightness when each  
4        lamp 19a or 19b is individually on, and doubling the  
5        screen brightness when both lamps 19a and 19b are on.  
6        Light sources 19a and 19b are positioned at the focal  
7        point of rectangular-shaped Fresnel lenses 20a and 20b,  
8        respectively, which collimate the light beams. Each  
9        collimated beam fills the stage aperture 21 at an  
10       entrance angle  $\theta$  of  $60^\circ$ . The stage aperture 21 can be  
11       square, to accommodate full-size overhead  
12       transparencies, or a reduced size rectangular format,  
13       to accommodate LCD projection panels. Near the stage  
14       aperture 21 is the  $60^\circ$  linear prismatic film 9. The  
15       integrated and collimated light exiting from the  $60^\circ$   
16       linear prismatic film 9 enters a circular Fresnel lens  
17       22 which focuses the light to the projection lens 23.  
18       A glass platen 24 is usually placed above the Fresnel  
19       lens 22 to supports the overhead transparency or LCD  
20       projection panel. If the projected facet widths of the  
21       linear prismatic film 9 are less than the resolving  
22       power of the eye at normal screen viewing distances,  
23       then each light source 19a and 19b appears to fully  
24       illuminated the entire screen. With both lamps 19a and  
25       19b on, the screen brightness is effectively doubled  
26       over the brightness produced by a single lamp 19a or  
27       19b.

28       Figure 5 shows an alternate arrangement using  
29       folding mirrors 25a, 25b, and 26, to combine the output  
30       of the two light sources 19a and 19b. An additional  
31        $60^\circ$  beam combining linear prism 9a is required.

32       Figure 6 shows a configuration that combines the  
33       output of four light sources 19a, 19b, 19c, and 19d.  
34       In this arrangement, the additional linear prismatic  
35       film element 9b, additional Fresnel lens collimators  
36       20c and 20d, and additional folding mirrors 25c and 25d

1 are shown. This cascading process can be further  
2 extended to integrate the output of additional light  
3 sources.

4       The beam shaping requirements to fill rectangular  
5 optical elements in this multiple lamp projection  
6 system are most easily achieved when these optical  
7 elements have an aspect ratio  $L/W$  that is close to  
8 unity, e.g. a square perimeter. To achieve this  
9 condition, it is preferable that the each additional  
10 optical element be oriented along the shorter side of  
11 the rectangular element preceding it. For the two lamp  
12 system shown in Figure 4 and illustrated again in more  
13 detail in Figure 7, with a rectangular linear prismatic  
14 element 9 having a length  $L_1 = 8$  units, and a width  $W_1 =$   
15 6 units ( $L_1/W_1 = 1.33$ ), if the Fresnel lens collimators  
16 20a and 20b (only 20a is shown) are oriented along the  
17  $W_1$  dimension, then the length  $L_2$  of the collimator is  $L_2$   
18  $= W_1 = 6$  units, and the width  $W_2$  of the collimator  $=$   
19  $L_1/2 = 4$  units, giving an aspect ratio  $L_2/W_2 = 6/4 =$   
20 1.5. If the Fresnel lens collimators were oriented  
21 along the  $L_1$  dimension, then the collimator aspect ratio  
22  $= L_2/W_2 = 8/3 = 2.67$ , and beam shaping is more difficult  
23 to achieve.

24       Similarly, for the four lamp system shown in  
25 Figure 6, with a square prismatic element 9 having a  
26 length  $L_1 = 12$  units, and a width  $W_1 = 12$  units, then  
27 the linear prismatic element 9a must have an aspect  
28 ratio  $L_2/W_2 = 12/6 = 2$ . If the Fresnel lens collimators  
29 20a and 20b are oriented along the  $W_2$  dimension, then  
30 the aspect ratio of the collimators  $= L_3/W_3 = 6/6 = 1$ ,  
31 which is the ideal beam shaping requirement.

32       It is also important to note that for each  
33 additional level of multiple light sources, e.g. two  
34 lamps, four lamps, eight lamps, etc., that the area of  
35 each additional linear prism element or Fresnel  
36 collimator, is halved. This limits the achievable

1 light collection and sets a practical limit on the  
2 number of lamps that can be integrated.

3 Figure 9 shows a projection system that  
4 efficiently integrates the output of two lamps, as is  
5 also illustrated in Figure 4, again providing uniform  
6 screen brightness when each lamp is individually on,  
7 and doubling the screen brightness when both lamps are  
8 on. A polarization-modulating display 32, such as a  
9 liquid crystal display, is positioned between Fresnel  
10 lens 22 and the 60° linear prismatic film 9 to define  
11 an optical window through which light from the lamps is  
12 directed. This liquid crystal display panel 32  
13 comprises a layer of liquid crystalline material which  
14 can be of a twisted nematic or a supertwisted nematic  
15 enclosed between two transparent substrates or plates.  
16 Each of these plates may comprise a transparent control  
17 electrode which can be divided into a large number of  
18 columns and rows, thus defining a large number of image  
19 elements in the display panel. These image elements  
20 are controlled by driving the electrodes, and the image  
21 display panel is referred to as passively controlled.  
22 Alternatively, one of the substrates can be provided  
23 with an electrode while the other is provided with  
24 semi-conductor drive electronics. A device employing  
25 this type of control is referred to as an actively  
26 controlled image display panel.

27

#### 28 Example

29 Described below with respect to Figure 7, and  
30 further illustrated in Figure 8, is a specific  
31 arrangement that has been constructed for use as an LCD  
32 overhead projector. The rectangular stage aperture  
33 size has a length  $L_1 = 228.6$  millimeters (9.0 inches)  
34 and a width  $W_1$  of 171.5 millimeters (6.75 inches),  
35 giving an aspect ratio of  $L_1/W_1 = 4/3$ , a common ratio  
36 for many LCD projection panels. The light source

1 filaments 26 (only one is shown) are positioned about  
2 11 millimeters behind a pair of glass condensers 27  
3 which collect and direct light to the Fresnel lens  
4 collimator a. The light sources 26 are 400 watt, 36  
5 volt flat mandrel capsule types, ANSI Code designation  
6 EVD. A spherical reflector 28 having a diameter of 60  
7 millimeters and a radius of curvature of 32.5  
8 millimeters focuses the back rays in the forward  
9 direction. An aspheric symmetric Pyrex condenser 29,  
10 having an approximate focal length of 55 millimeters  
11 and a diameter of 60 millimeters, focuses the light  
12 from the lamps 26 into a light cone of circular cross-  
13 section. A square optical crown glass cylinder lens 30  
14 having an approximate focal length of 175 millimeters,  
15 and dimensions of 82 by 82 millimeters, is placed in  
16 close proximity to the Pyrex condenser 29. This  
17 cylinder lens 30 further compresses this circular cone  
18 of light in one direction to form an elliptical shaped  
19 beam 31. The single element Fresnel lens collimators  
20 20a have a focal length of 178 millimeters, operate  
21 between  $f/.75$  and  $f/1.0$ , and are oriented symmetrically  
22 at  $30^\circ$  from the vertical. The height  $W_2$  of the Fresnel  
23 collimator 20a is half the length  $L_1$  of the stage  
24 aperture,  $W_2 = 114.3$  millimeters (4.5 inches), and the  
25 width  $L_2$  of the Fresnel collimator 20a is the width of  
26 the stage aperture,  $L_2 = 171.5$  millimeters (6.75 inches).  
27 The aspect ratio  $L_2/W_2$  of the collimating Fresnel lens  
28 is 1.5. To efficiently fill the rectangular aperture  
29 of the collimating Fresnel lens, the following  
30 relationship should be approximated:  $L_2/W_2 = A/B$ , where  
31 A and B are the major and minor axes of the elliptic  
32 cross-section 31 of the light beam at the plane of the  
33 Fresnel collimator as shown in Figure 8.  
34 As illustrated in Figure 4, the  $60^\circ$  linear  
35 prismatic film 9 was fabricated in 2 millimeter thick  
36 acrylic plastic, with dimensions slightly larger than

1 the stage aperture, and the width of each individual  
2 prismatic groove 10 was about 0.5 millimeters. A  
3 rectangular acrylic Fresnel lens 22, having a focal  
4 length of about 325 millimeters, groove widths between  
5 0.5 and 0.125 millimeters, and approximately the same  
6 size as the linear prismatic film 9, was placed between  
7 the linear prismatic film 9 and a glass platen 21  
8 defining the stage aperture. A triplet projection lens  
9 23 of 330 millimeter focal length projected an image of  
10 the stage to fill a 60 inch wide screen at  
11 approximately 6.7X magnification.

12 With this configuration, an average screen  
13 illumination of 140 foot-candles was measured from each  
14 individual lamp, and an average screen illumination of  
15 280 foot-candles with both lamps operating. This is  
16 equivalent to the brightness of a 7000 lumen square  
17 aperture overhead projector projecting a 60 inch square  
18 image.

19 It can be appreciated by those skilled in the art,  
20 that by the use of additional folding mirrors in the  
21 configurations described, modifications of the  
22 arrangement of optical components can be achieved.  
23 These modifications can reduce the base height of the  
24 projector by variation of width and length of the  
25 projector base containing these components. It will  
26 also be appreciated that although specific examples of  
27 the invention have been illustrated, the invention is  
28 more generally applicable to any device which requires  
29 collimated light in the optical path.  
30

## 1 Claims:

2

1 1. A projection system for projecting an image  
2 onto a screen comprising :

3 an enclosure having an optical window;

4 a linear beam-combining film having a flat  
5 first surface defining a plane and a structured second  
6 surface opposite said first surface, said structured  
7 surface having a plurality of linear triangular prisms  
8 each having two sides having an included angle ranging  
9 from about 58° to about 62°; and

10 at least one light source disposed at least  
11 one end of said film and emitting collimated light in a  
12 direction which is perpendicular to the axes of said  
13 linear prisms and inclined at an angle ranging from  
14 about 56.5° to about 63.5° with respect to a  
15 perpendicular to said plane of said film such that said  
16 light is directed to substantially totally illuminate  
17 one of said two sides of said linear prisms and is  
18 totally internally reflected within said film to exit  
19 said flat first surface and be directed toward the  
20 optical window as a collimated beam.

1 2. A projection system according to claim 1  
2 wherein said angle of inclination of said collimated  
3 light from said light source is related to said  
4 included angle of said prism sides by the equation:

$$\theta = 90^\circ - \left( \frac{\alpha}{2} + \arcsin \left( n \cos \left( \frac{3}{2} \alpha \right) \right) \right)$$

6 wherein:

7  $\theta$  = said angle of inclination of said collimated light

8  $\alpha$  = said included angle of said prism sides

9  $n$  = index of refraction of the material of said film.

1           3.    A projection system according to claim 1  
2    further including at least a second light source  
3    emitting collimated light in a direction which is  
4    perpendicular to the axes of said linear prisms and  
5    inclined at an angle ranging from about 56.5° to about  
6    63.5° with respect to a perpendicular to the plane of  
7    said film such that said light is directed to  
8    substantially totally illuminate the other of said two  
9    sided linear prisms and is totally internally reflected  
10   within said film to exit said flat first surface and be  
11   directed toward the optical window as a collimated  
12   beam.

1           4.    A projection system according to claim 3  
2    wherein said angle of inclination of said collimated  
3    light from said light source is related to said  
4    included angle of said prism sides by the equation:

$$\theta = 90^\circ - \left( \frac{\alpha}{2} + \arcsin \left( n \cos \left( \frac{3}{2} \alpha \right) \right) \right)$$

7    wherein:  
8     $\theta$  = said angle of inclination of said collimated light  
9     $\alpha$  = said included angle of said prism sides  
10    $n$  = index of refraction of the material of said film.

1           5.    A projection system according to claim 3  
2    wherein said light emitting from each light source  
3    illuminates all portions of the screen.

1           6.    A projection system according to claim 1  
2    wherein said optical window is rectangular.

1           7.    A projection system according to claim 6  
2    further comprising a rectangular-shaped collimator for  
3    collimating said light from said light source.

1           8.    A projection system according to claim 7  
2 wherein said rectangular-shaped collimator is a Fresnel  
3 lens.

1           9.    A projection system according to claim 7  
2 wherein said rectangular collimator has a length to  
3 width aspect ratio of not greater than 2.

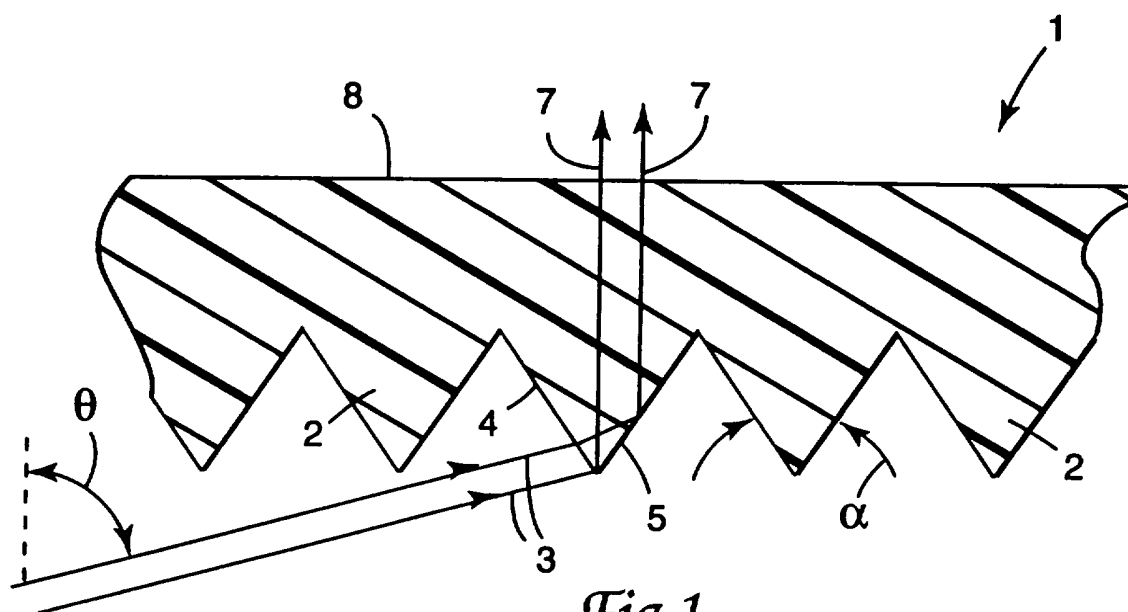


*Fig. 1*  
Prior Art

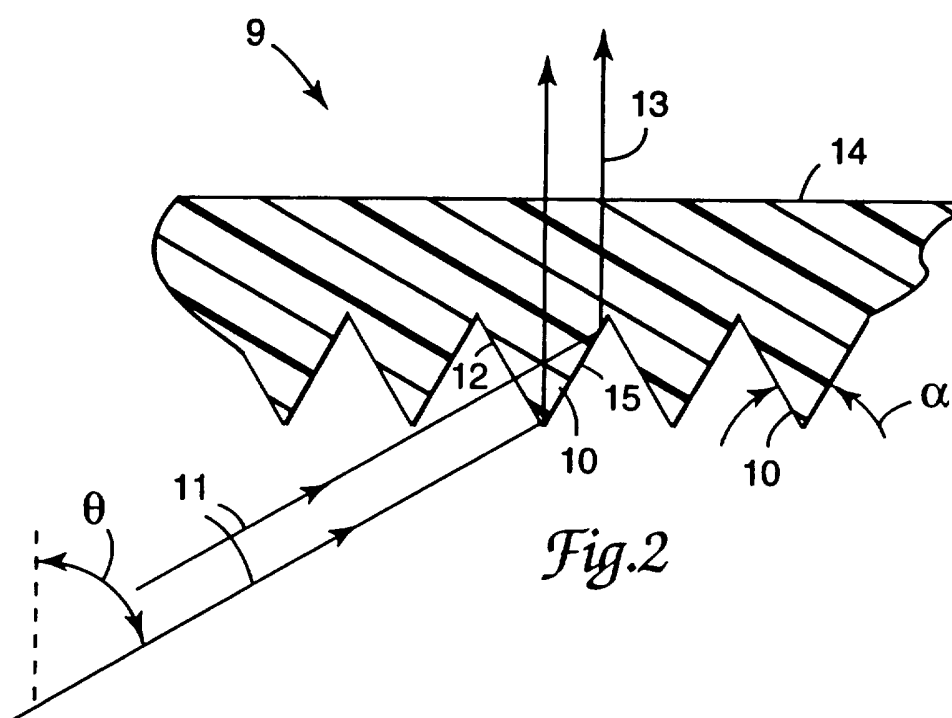
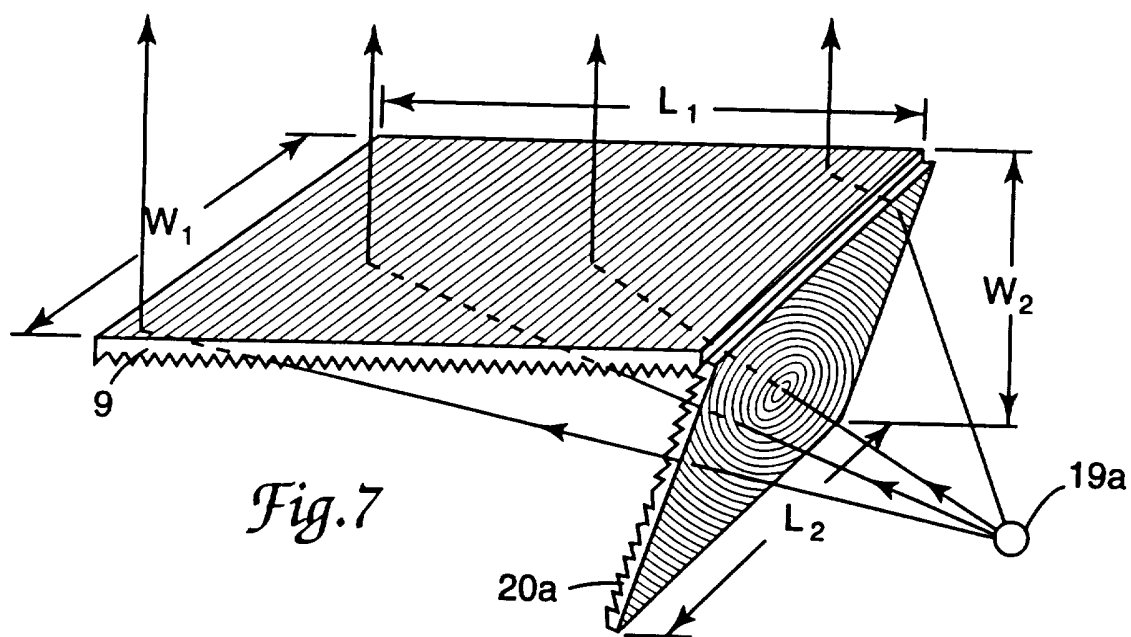
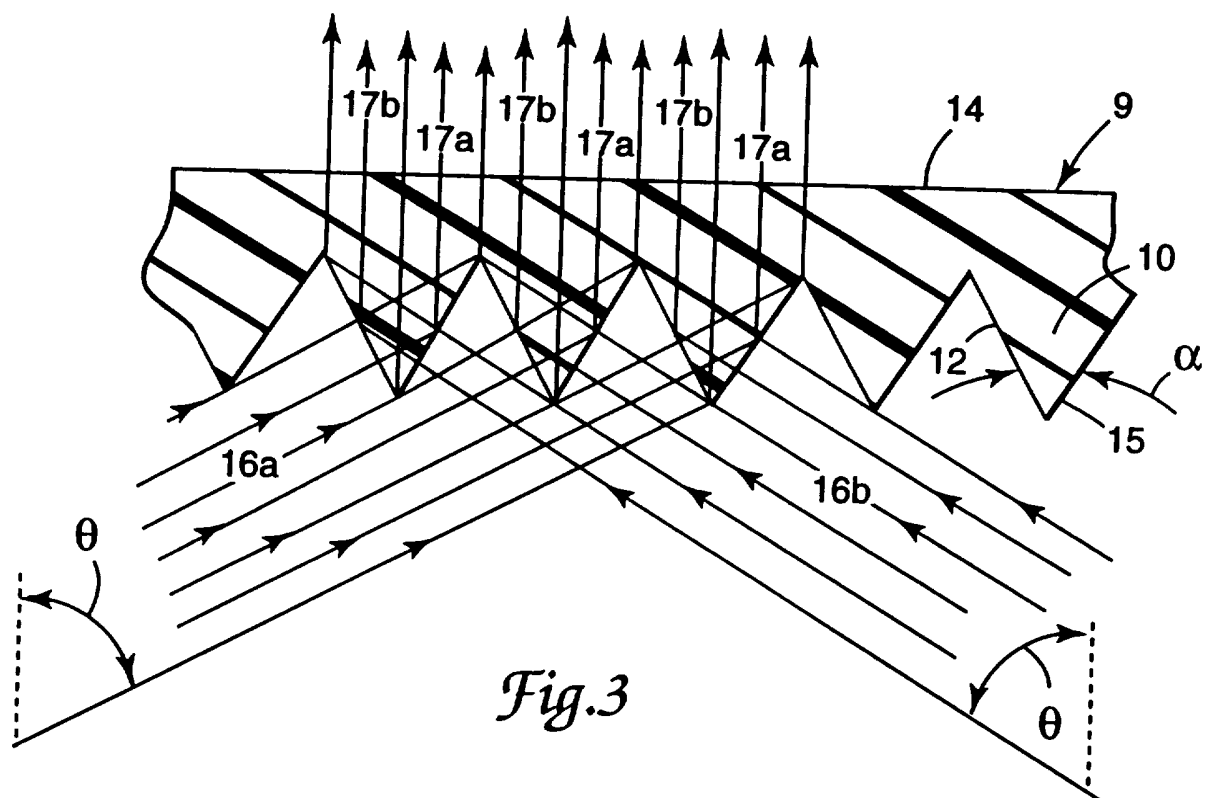
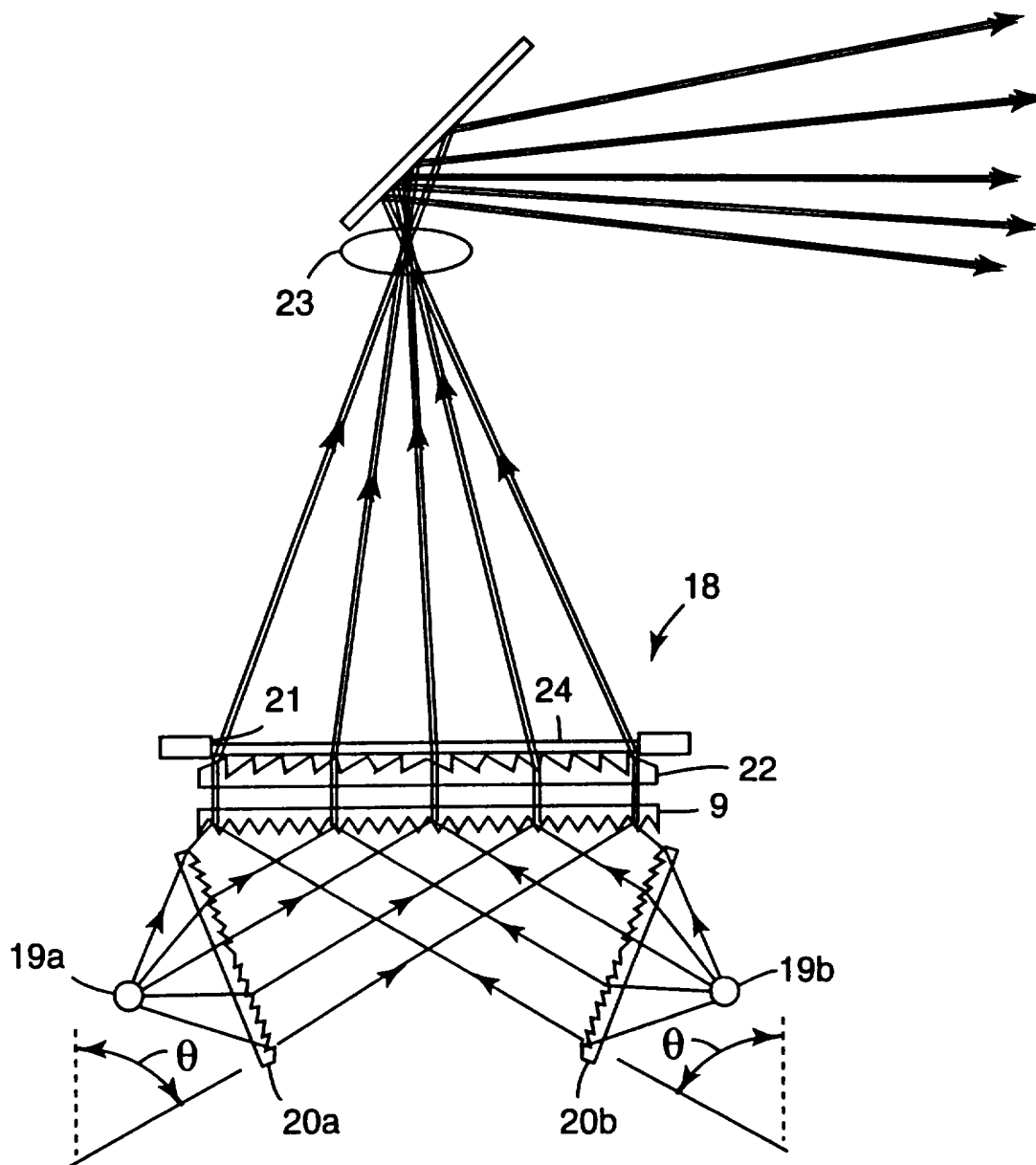
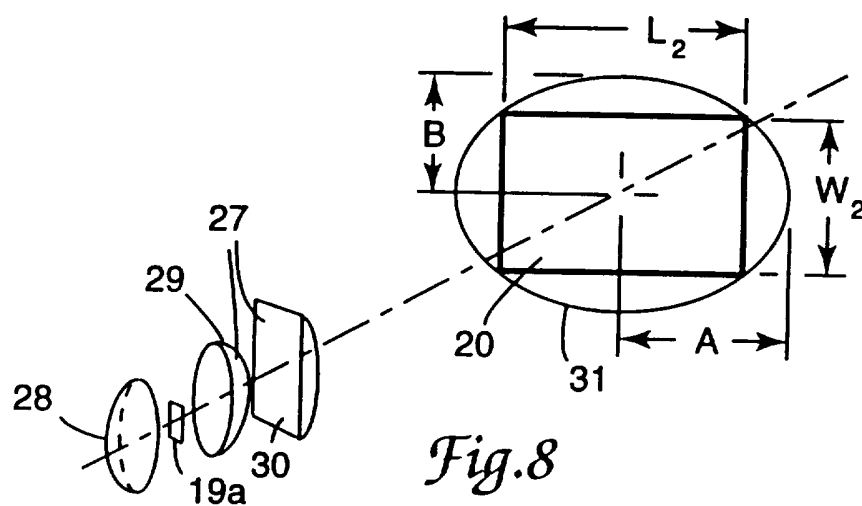
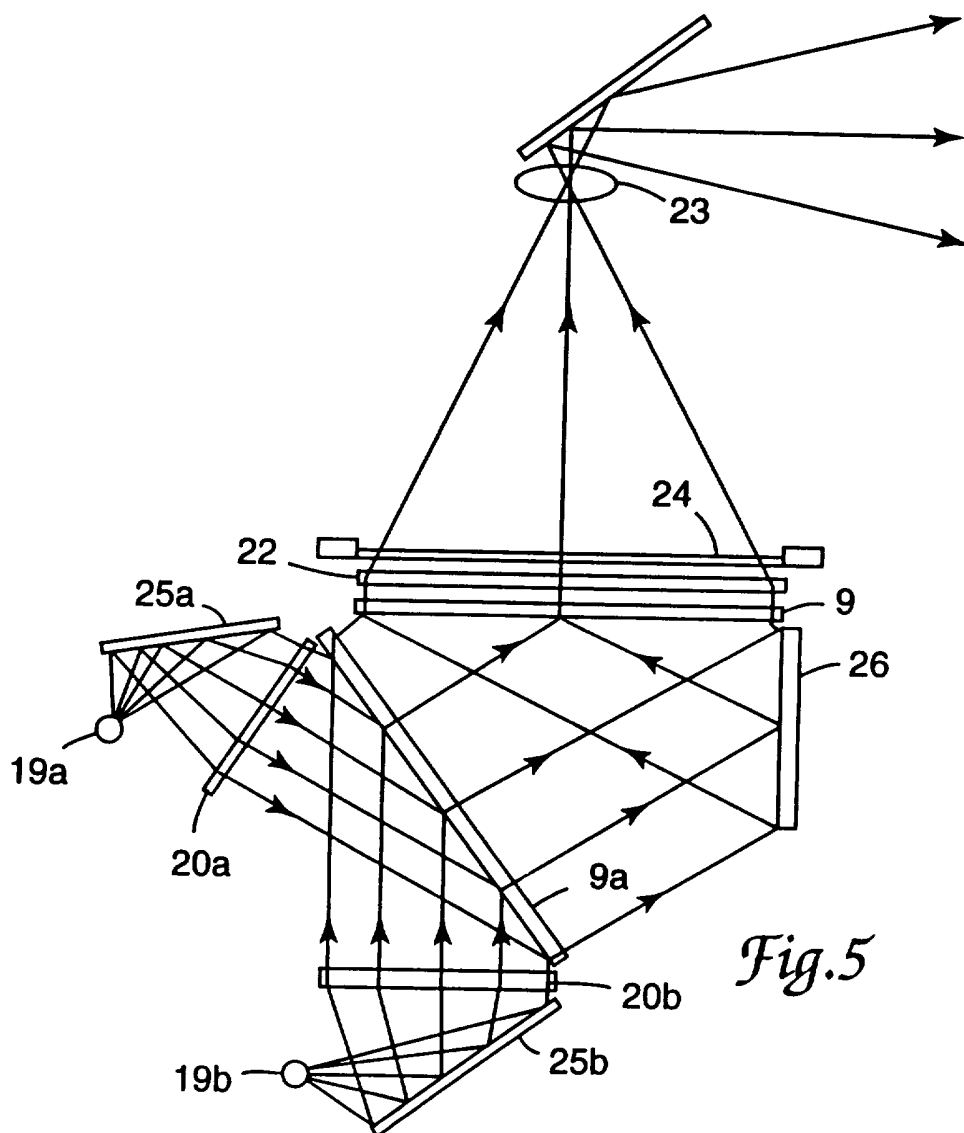
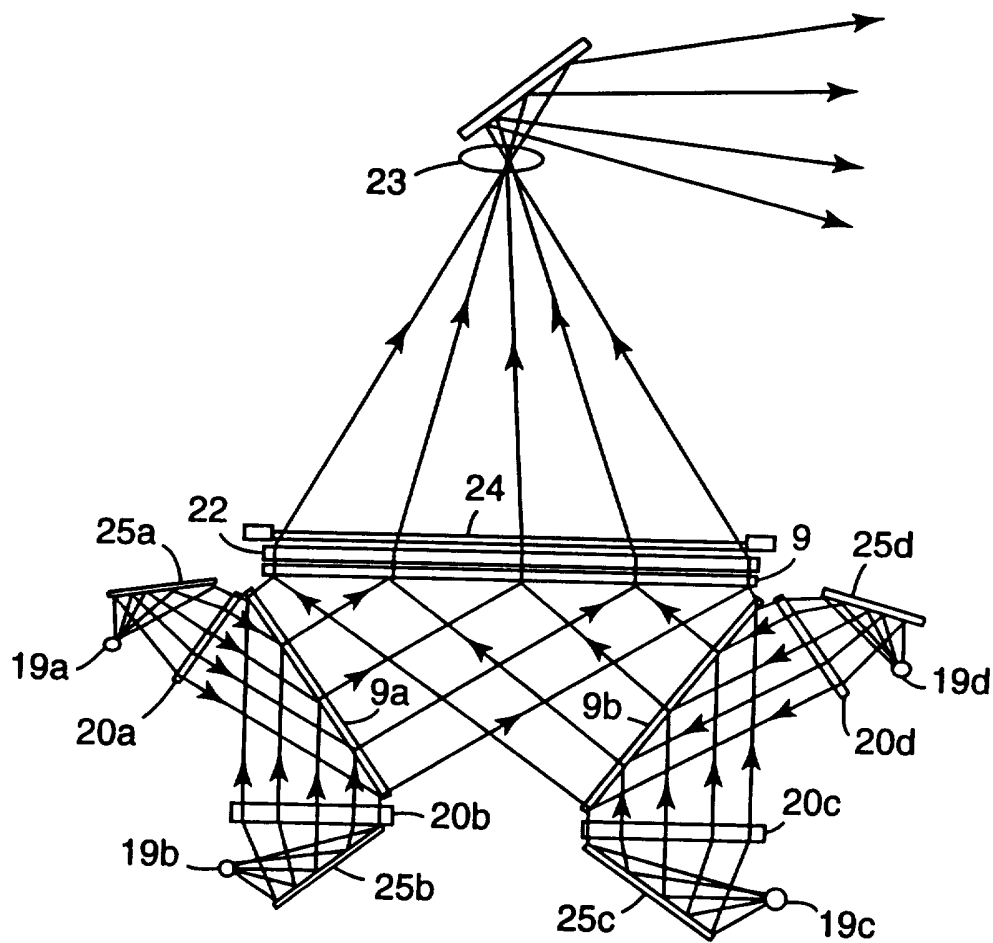
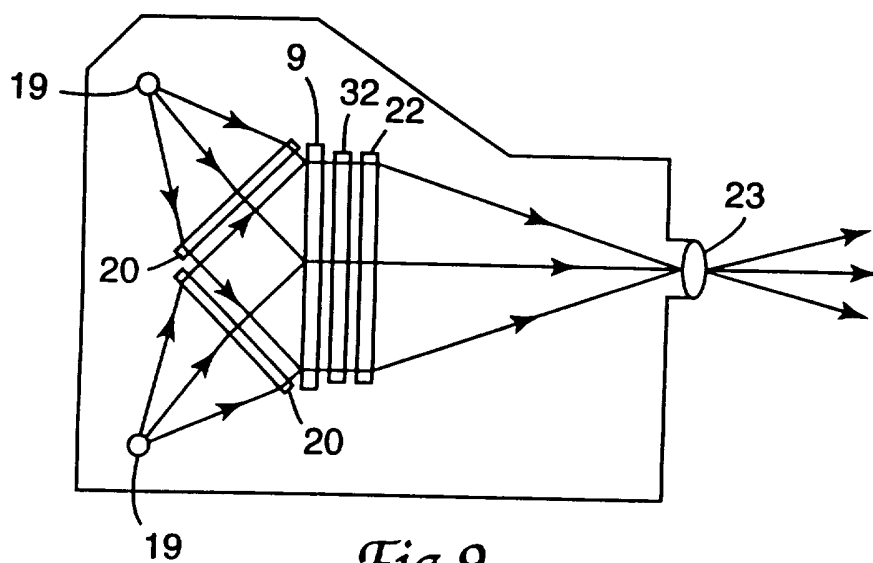


*Fig. 2*



*Fig.4*



*Fig. 6**Fig. 9*

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 95/12896

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 G03B21/132 G02B27/14 G02B5/04

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G03B G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages                         | Relevant to claim No. |
|------------|------------------------------------------------------------------------------------------------------------|-----------------------|
| A          | EP,A,0 607 582 (MINNESOTA) 27 July 1994<br>see abstract; figure 2<br>---                                   | 1,6-8                 |
| A          | US,A,4 984 144 (COBB ET AL.) 8 January<br>1991<br>cited in the application<br>see claim 1; figure 1<br>--- | 1                     |
| A          | US,A,1 887 650 (LARNER ET AL.) 15 November<br>1932<br>cited in the application<br>---                      | 1                     |
| A          | WO,A,92 16871 (SEIKO EPSON CO.) 1 October<br>1992<br>see abstract; figure 50B<br>-----                     | 1                     |

☐ Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Date of the actual completion of the international search

12 March 1996

Date of mailing of the international search report

27. 03. 96

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl,  
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## INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 95/12896

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
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