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H4F FCW FD15 FD27A1 FD27B FD27C9 FD27D FD27E FD27G FD27H FD27M FD27R1 FD27S FD27V FD27X FD42V FD45

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(58) Field of Search
UK CL (Edition N) **G2J JX15 , G5C CHX , H4F FCW FDD**
INT CL^6 **G02F 1/1335 , H04N 13/00 13/04**
Online: EPODOC WPI JAPIO

(54) Light source and display

(57) A light source (1) comprises an array of contiguous transparent blocks (2), each of which contains a light emitter such as a cold cathode fluorescent tube (4). The blocks (2) have a transparent front surface which may be optically diffusing, the other surfaces being coated with a thin optically reflective layer so that each block (2) acts as a light guide. The tubes (4) are independently controllable, for instance so as to simulate a moving light source which may be controlled so as to track the position of an observer of a 3D or autostereoscopic display.

Such displays comprise two spatial light modulators in the form of liquid crystal devices and may further include one or more of the following features: curved reflectors arranged to deflect light from the light source through a spatial light modulators to form an image at a viewer location; an array of apertures in which the pitch of the apertures is greater than twice the aperture width and a parallax screen; means for reducing Moire fringes; spatial light modulators having a contrast which varies asymmetrically with a vertical viewing angle; and means for dynamically controlling the position of a viewing region.

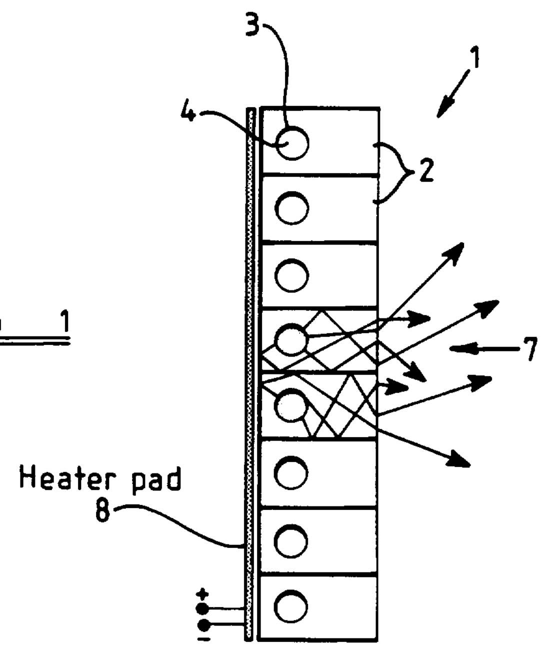


FIG 1

GB 2 294 350 A

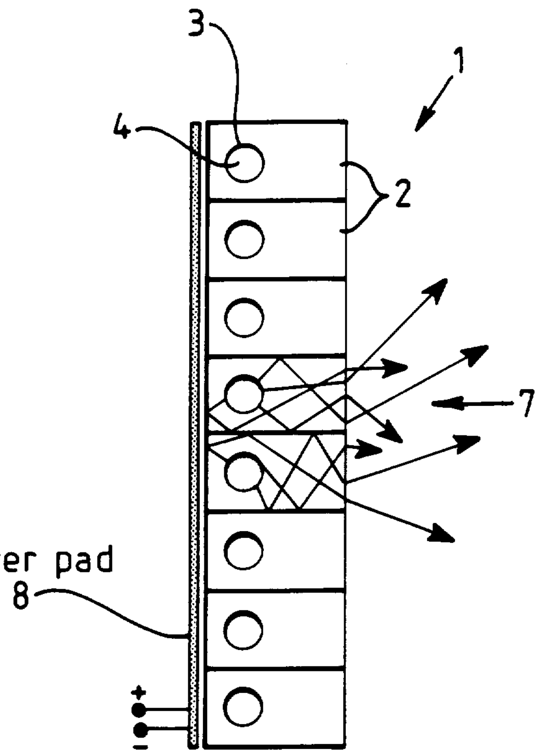
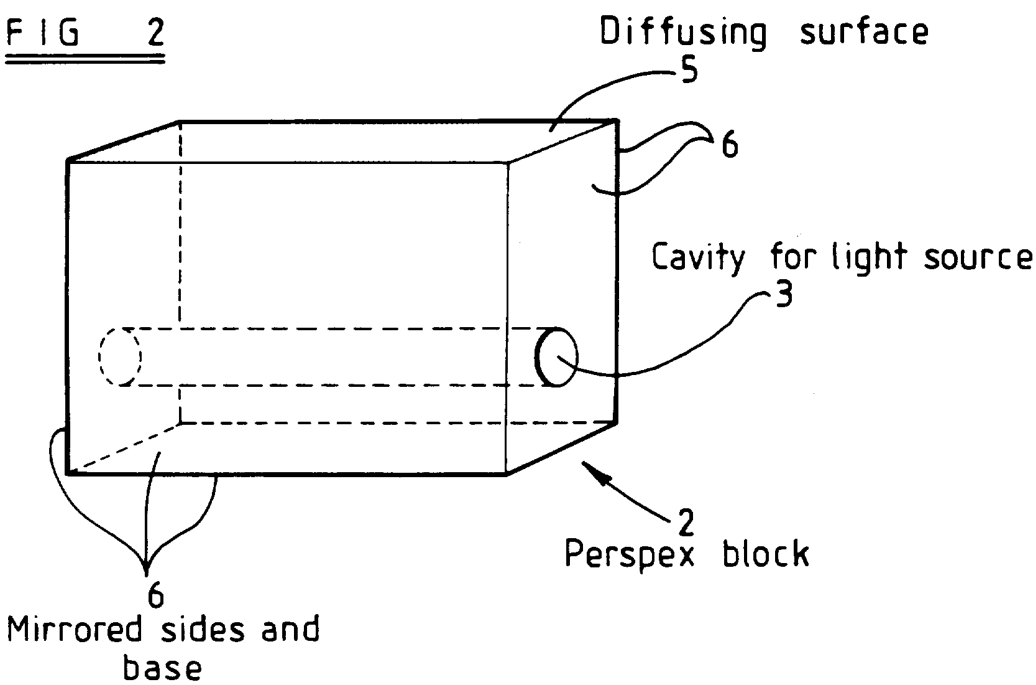

3
4
1
2
7
Heater pad
8
+
−

FIG 1

FIG 2


Diffusing surface
5
6
Cavity for light source
3
2
Perspex block
6
Mirrored sides and base

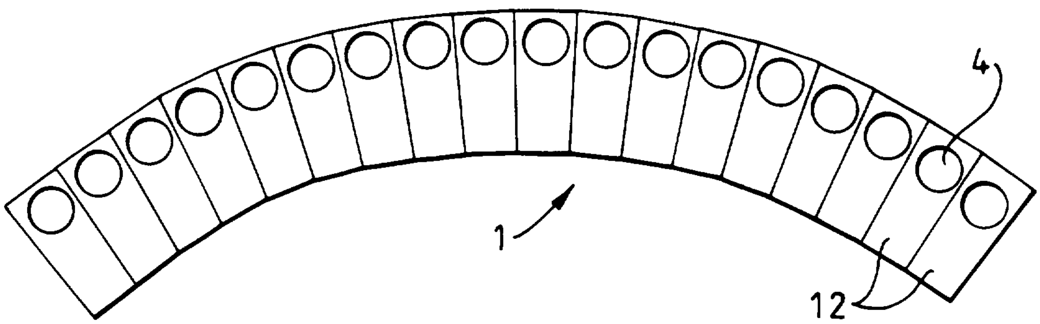


FIG 3

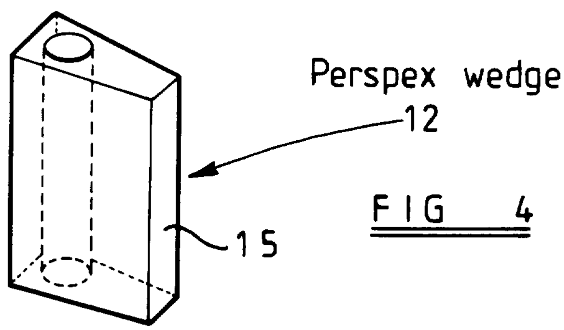


FIG 4

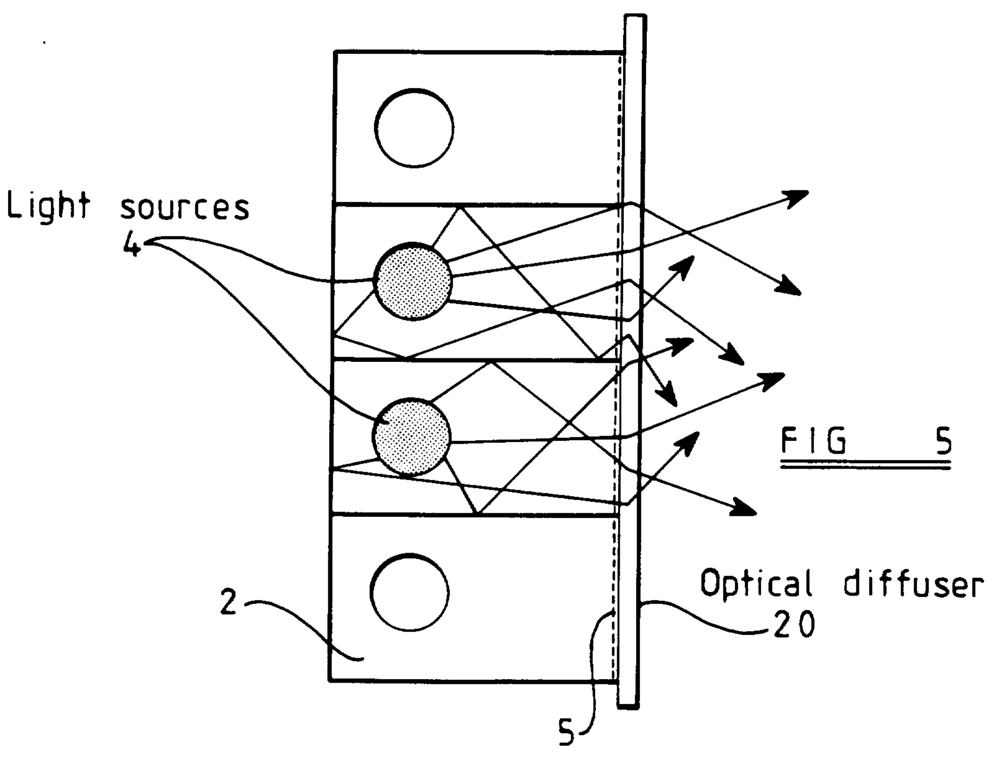


FIG 5

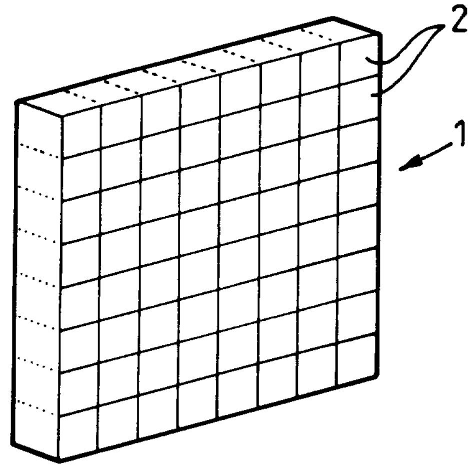


FIG 6

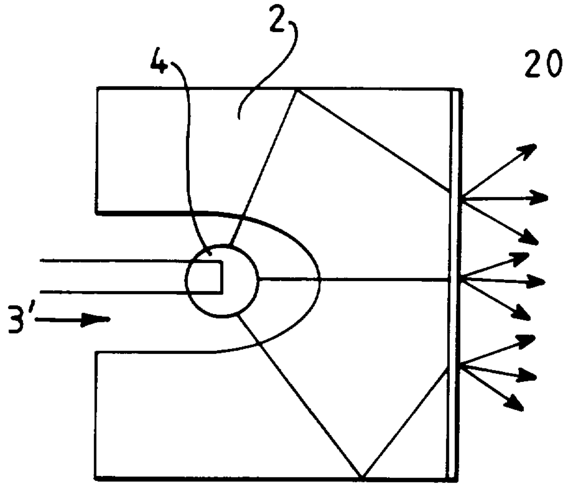


FIG 7

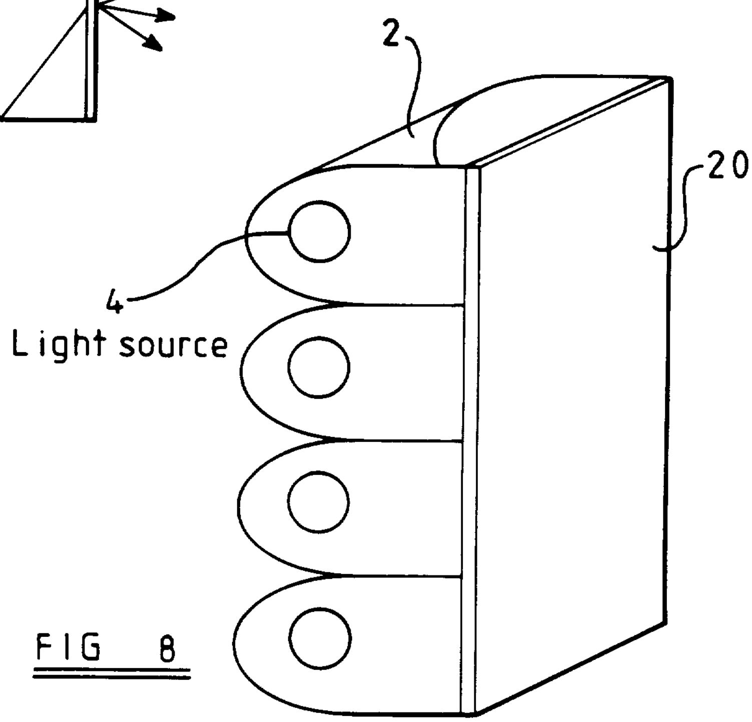


FIG 8

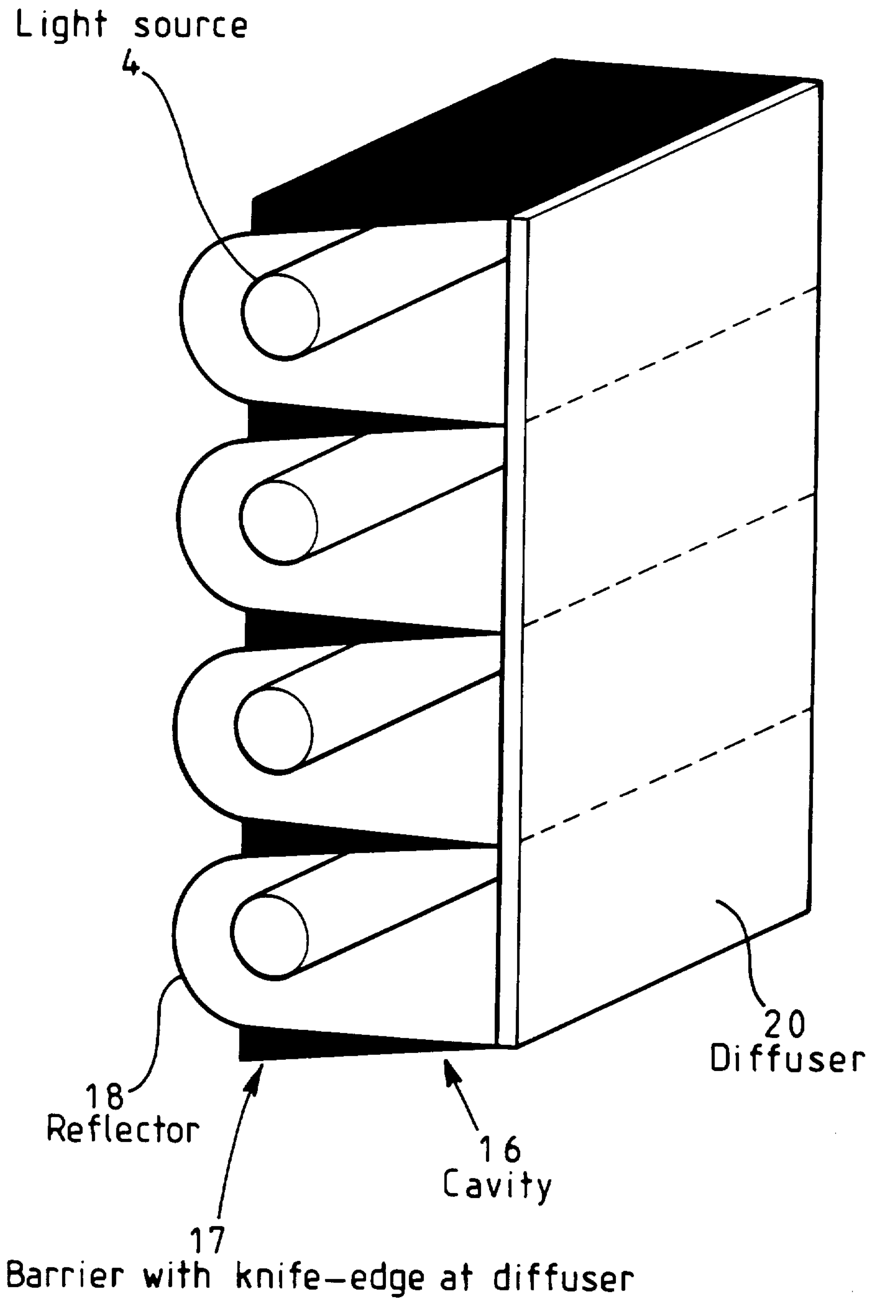

Light source
4
18
Reflector
17
Barrier with knife-edge at diffuser
16
Cavity
20
Diffuser

FIG 9

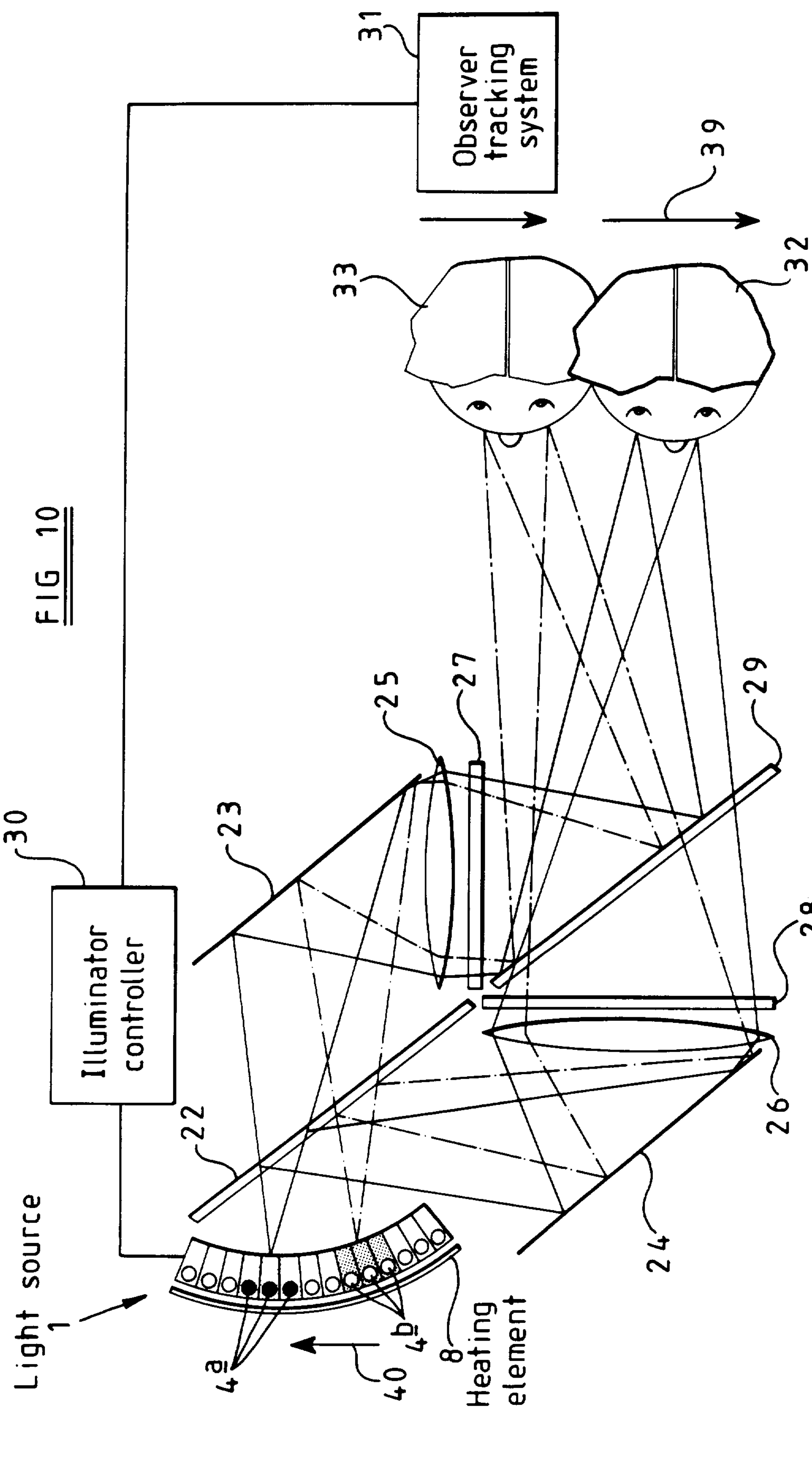
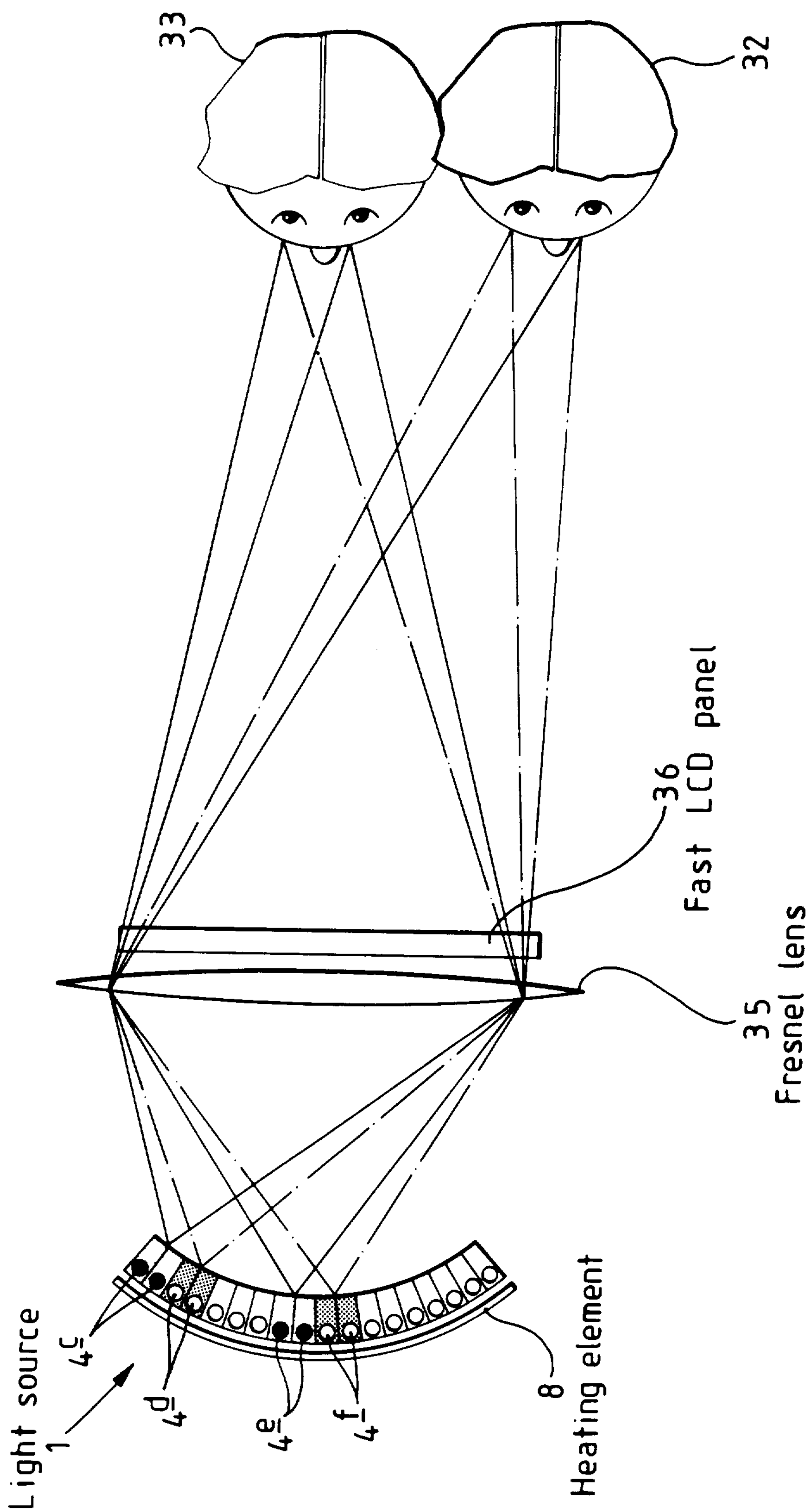

Observer tracking system
31
39
33
32
Illuminator controller
30
23
25
27
29
28
26
22
24
Light source 1
4a
4b
40
8
Heating element

FIG 10



33
32
36
Fast LCD panel
35
Fresnel lens
Light source
1
4c
4d
4e
4f
8
Heating element

FIG 11

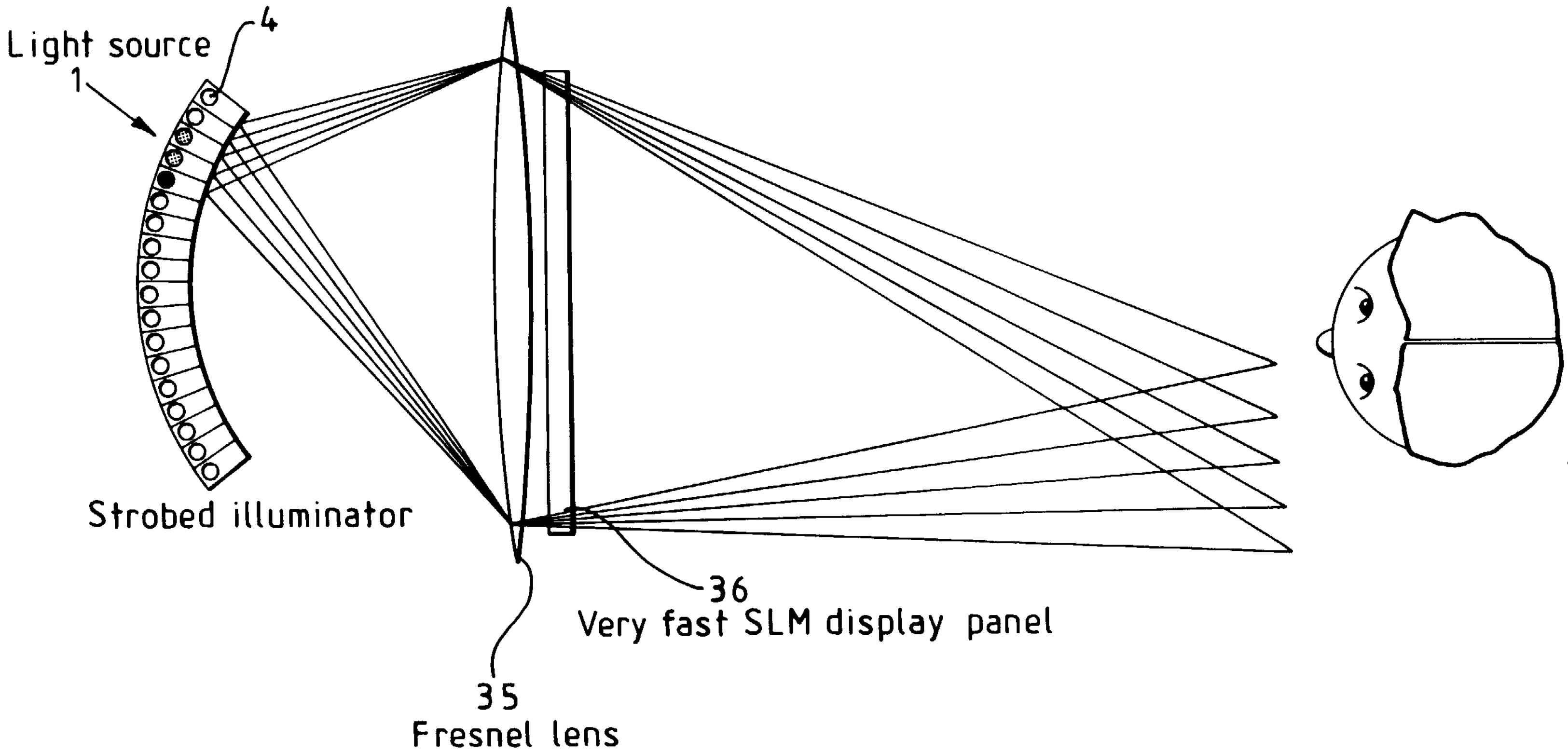

Light source
1
4
Strobed illuminator
36
Very fast SLM display panel
35
Fresnel lens

FIG 12

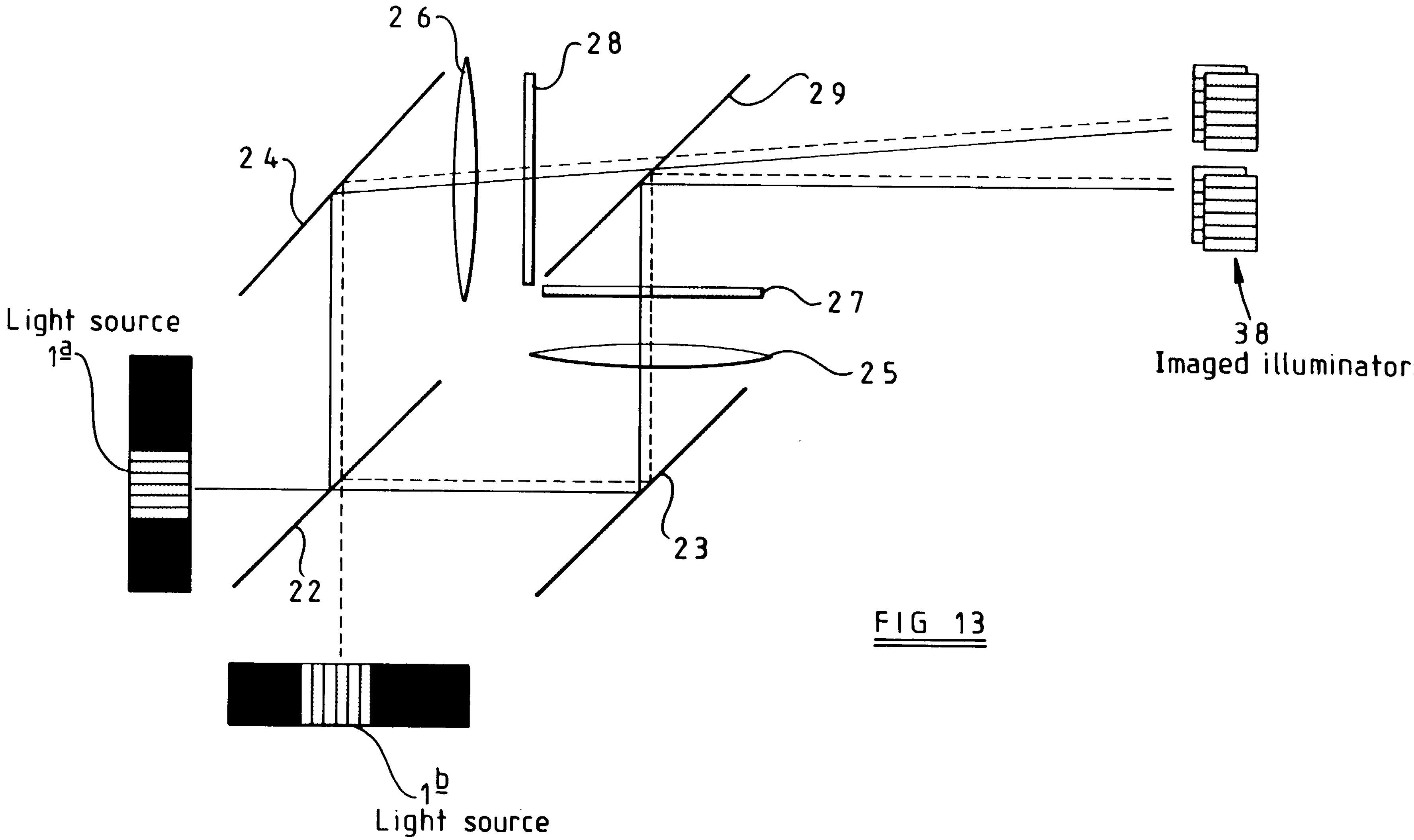

2 6
2 8
2 9
2 4
2 7
Light source
1a
2 5
38
Imaged illuminators
22
23
1b
Light source

FIG 13

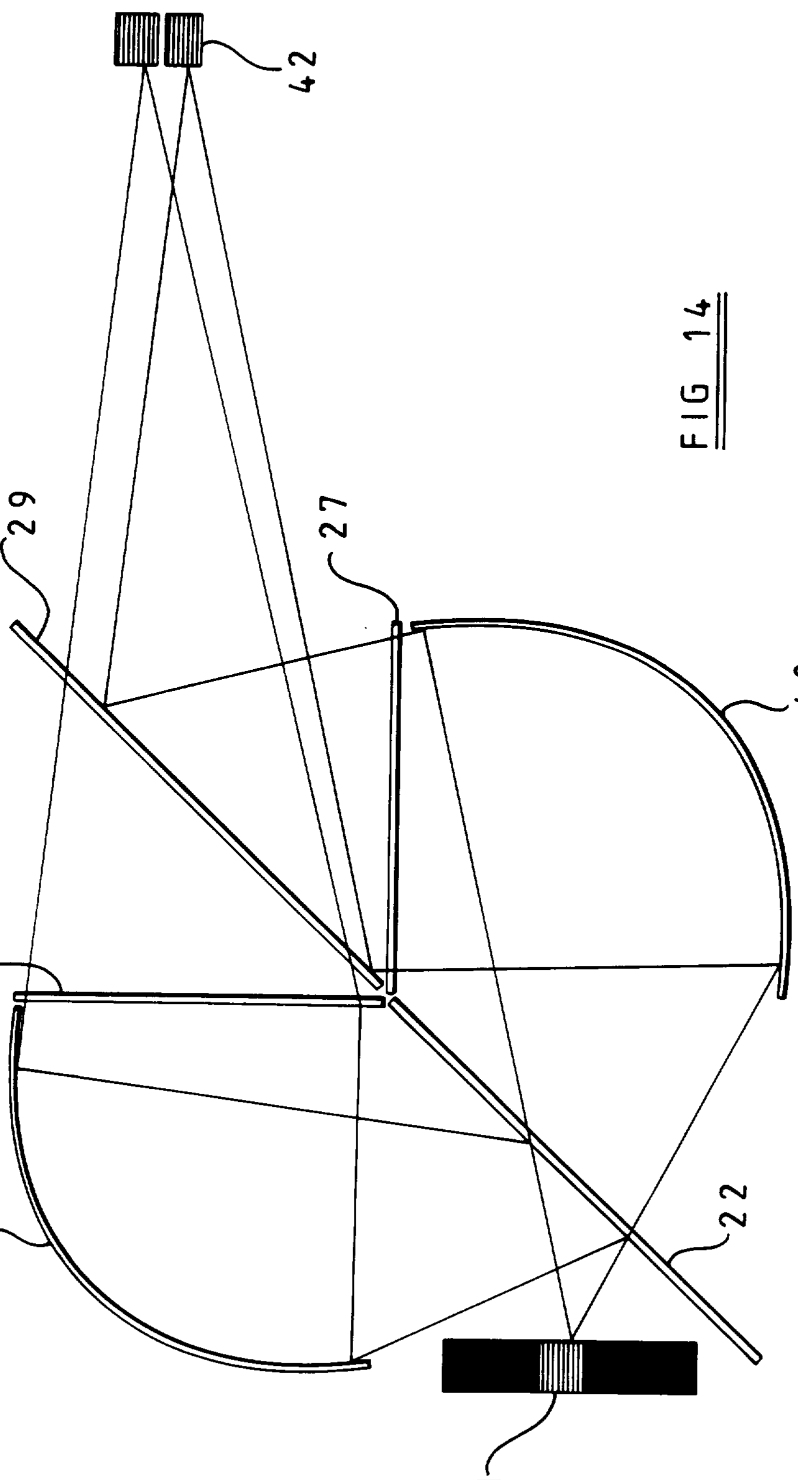


FIG 14

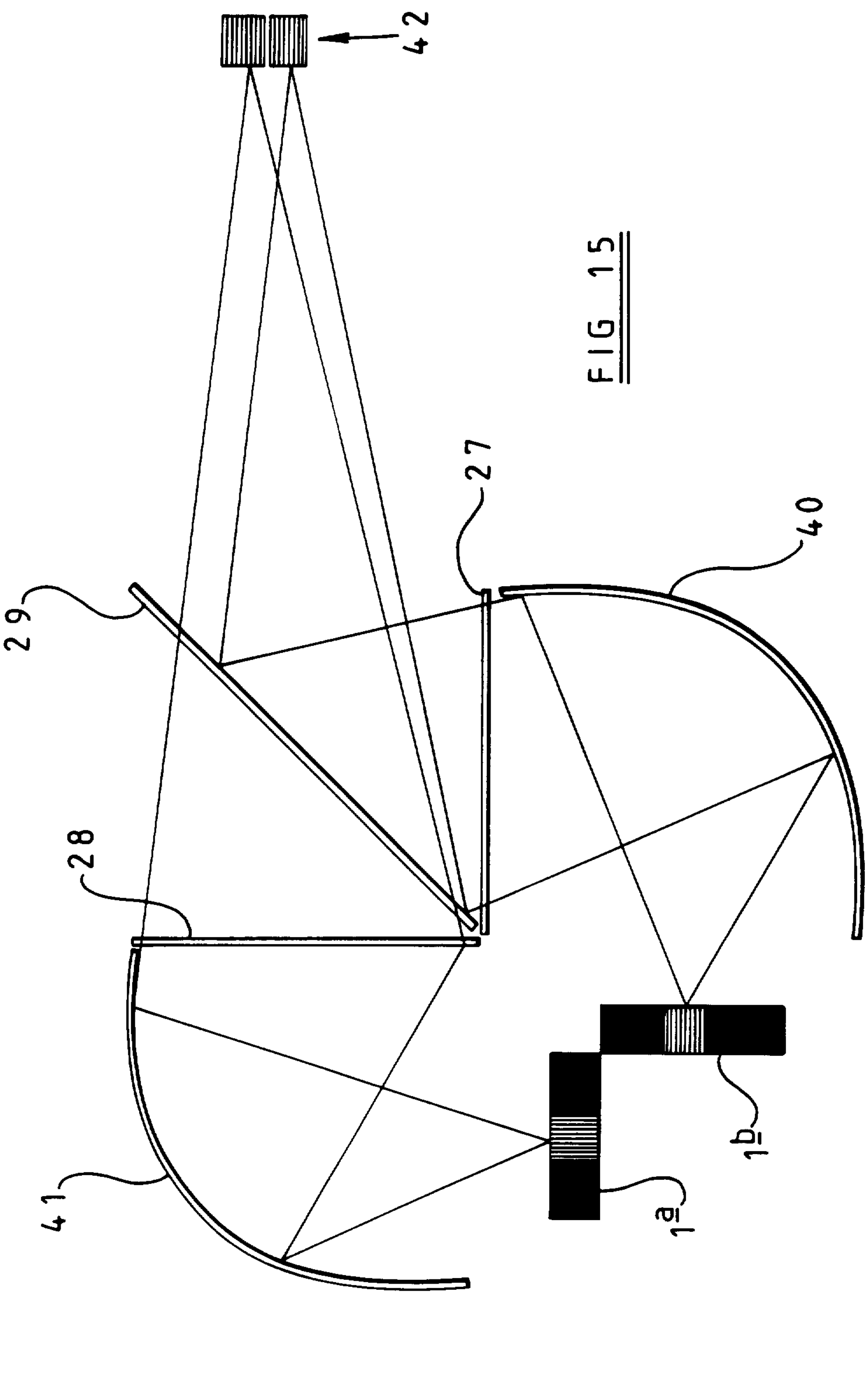


FIG 15

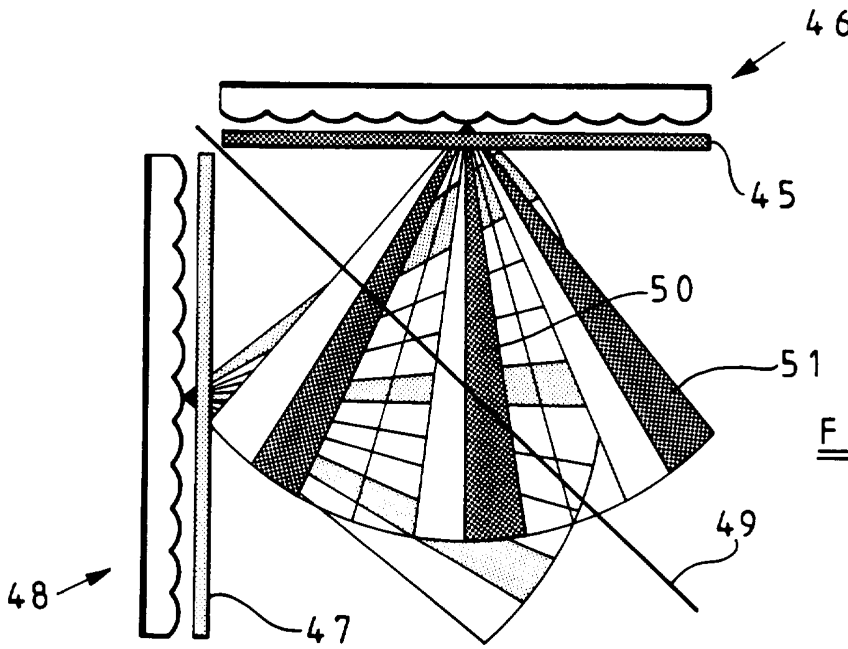

46
45
50
51
49
48
47

FIG 16

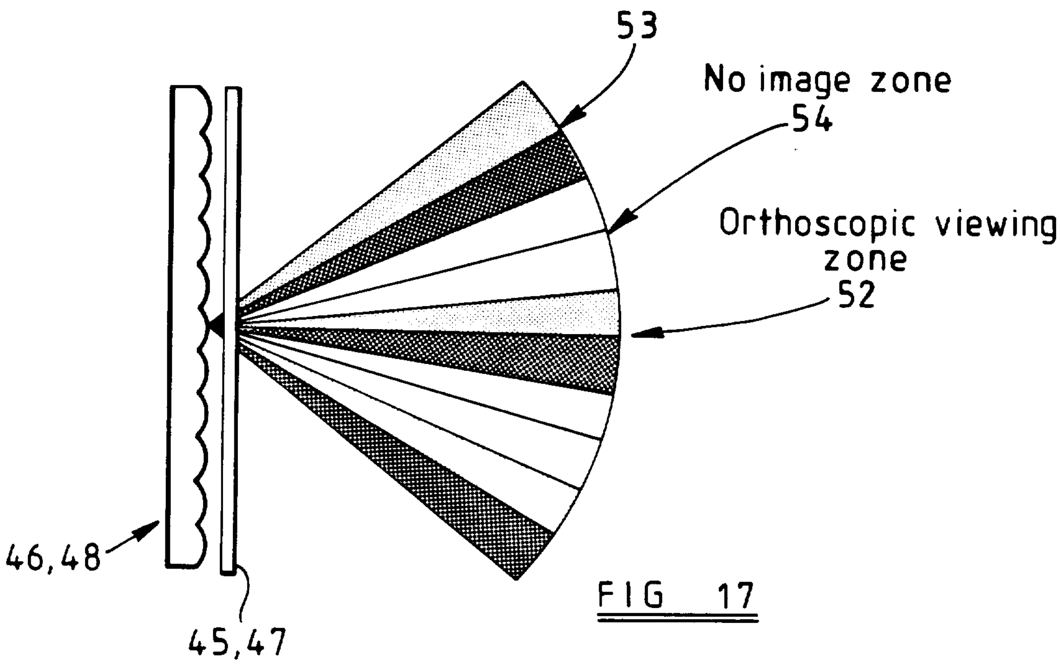

53
No image zone
54
Orthoscopic viewing
zone
52
46,48
45,47

FIG 17

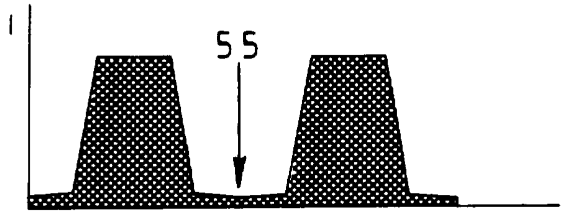


FIG 18a

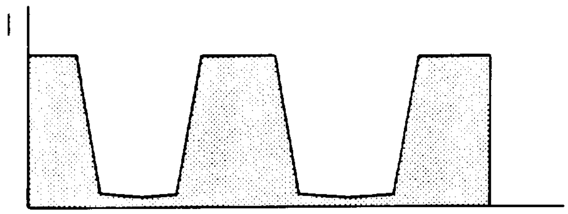


FIG 18b

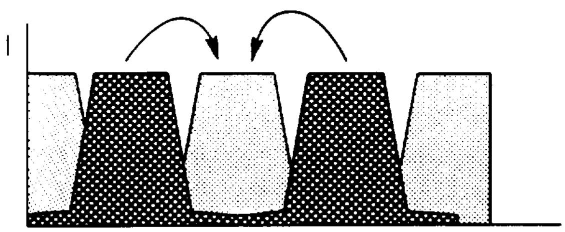


FIG 18c

FIG 19a

FIG 19b

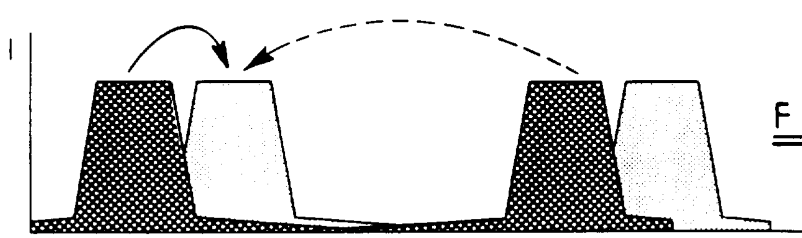


FIG 19c

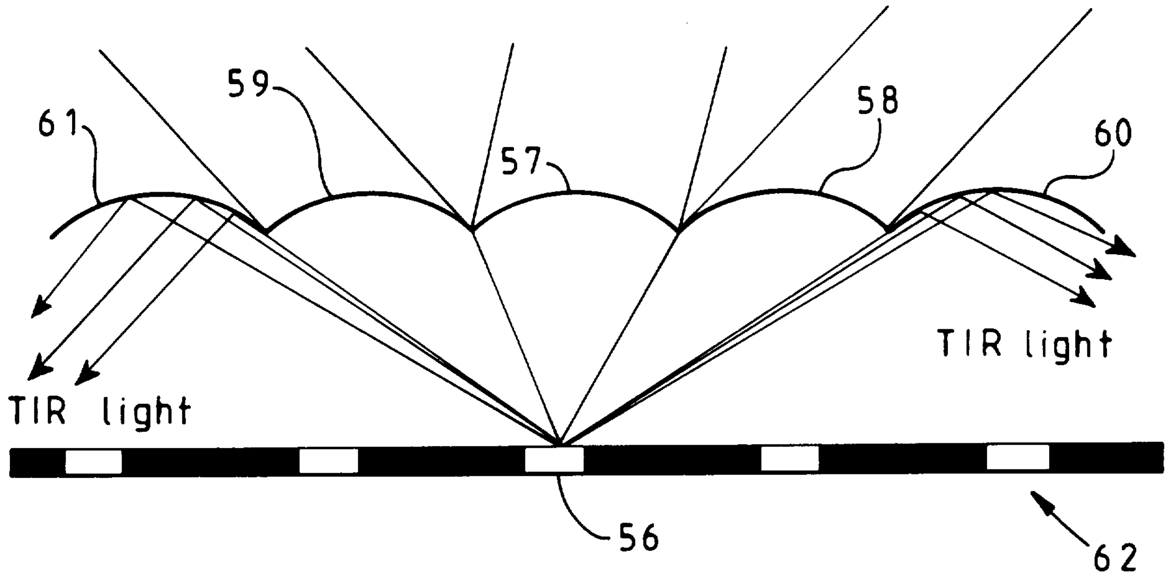

61
59
57
58
60
TIR light
TIR light
56
62

FIG 20

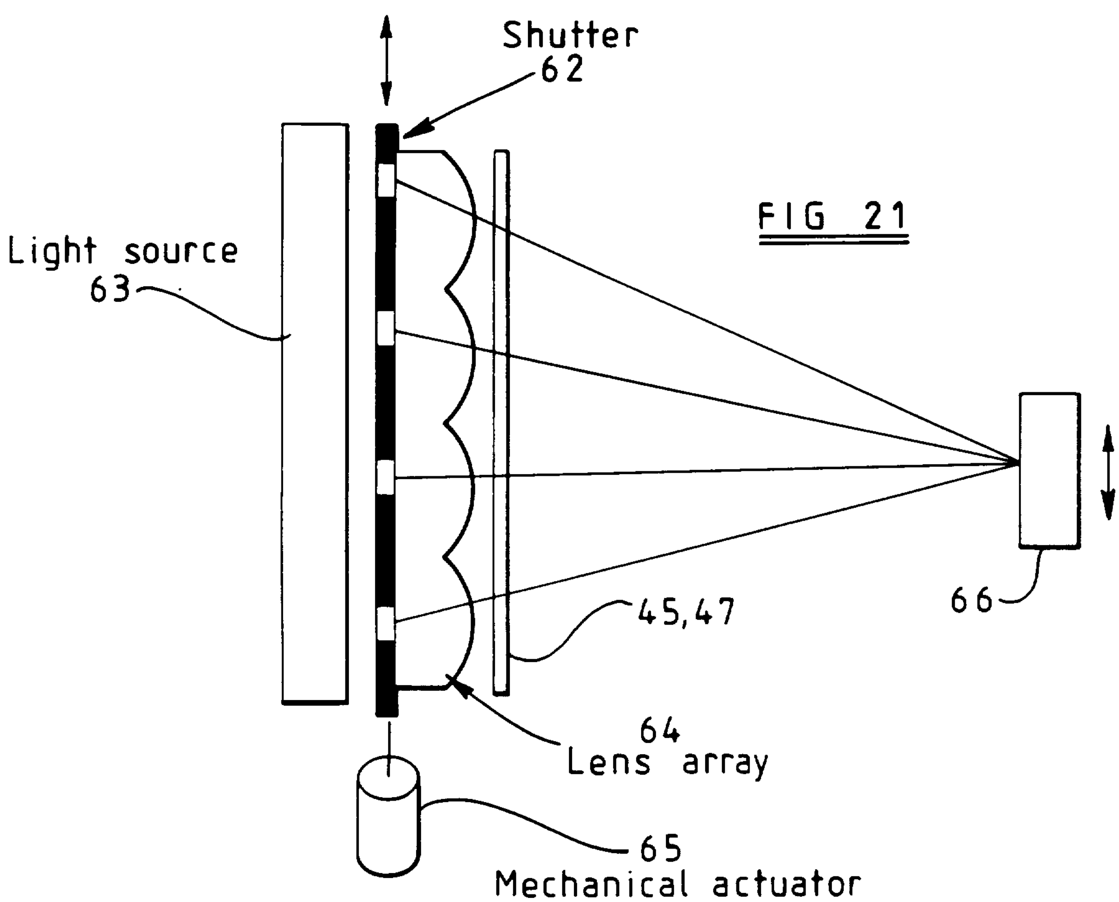

Shutter
62
Light source
63
45,47
66
64
Lens array
65
Mechanical actuator

FIG 21

FIG 22

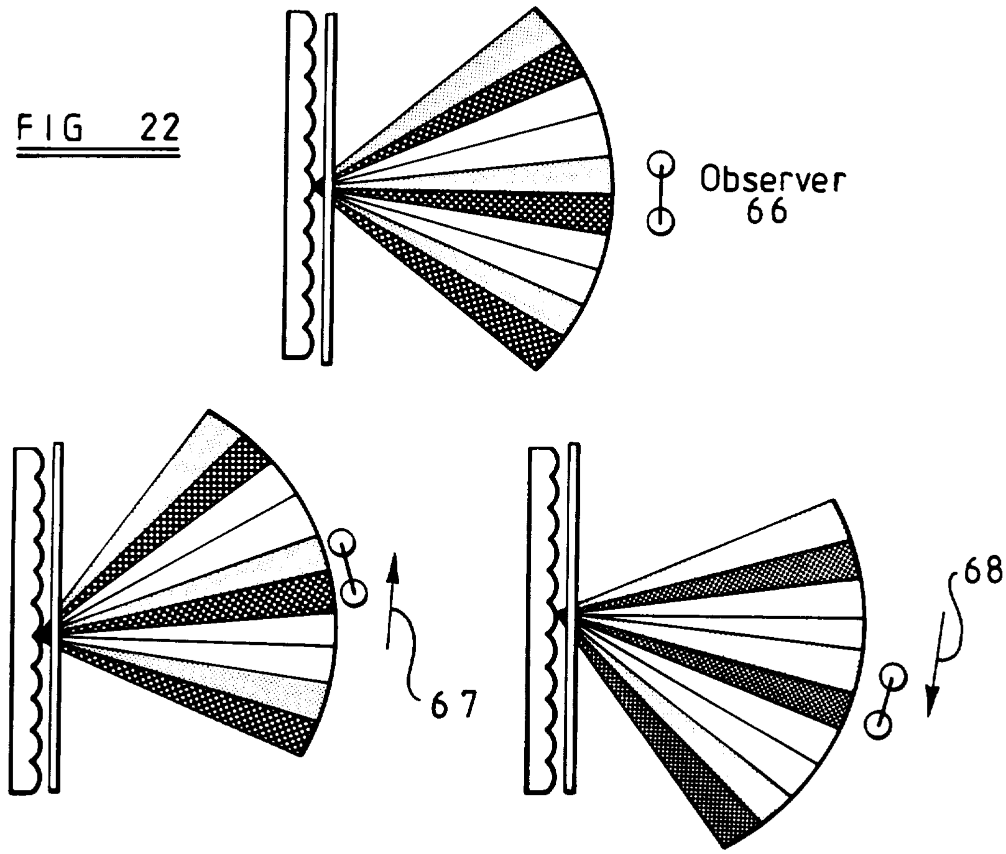
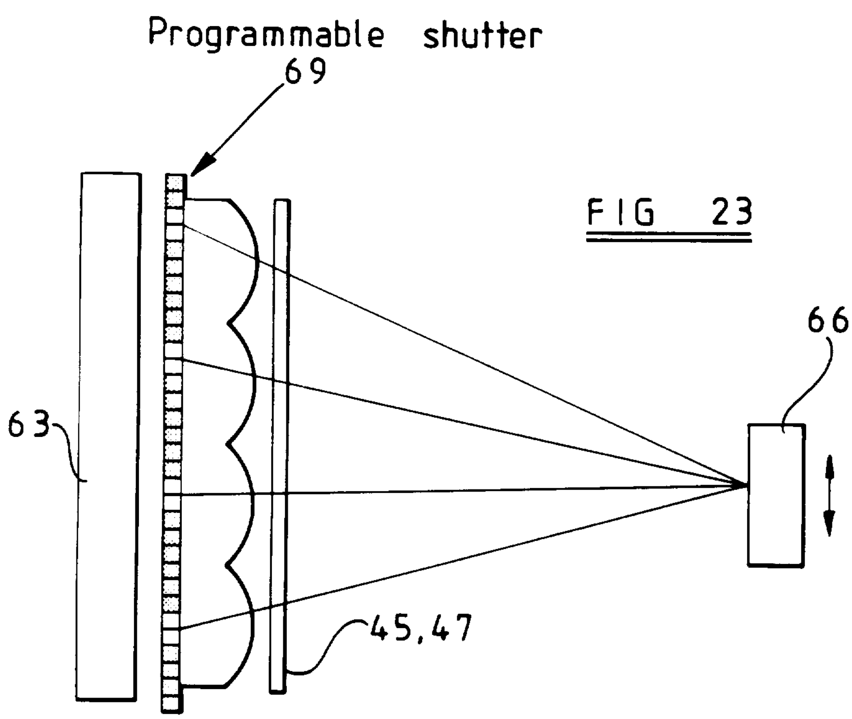


FIG 23



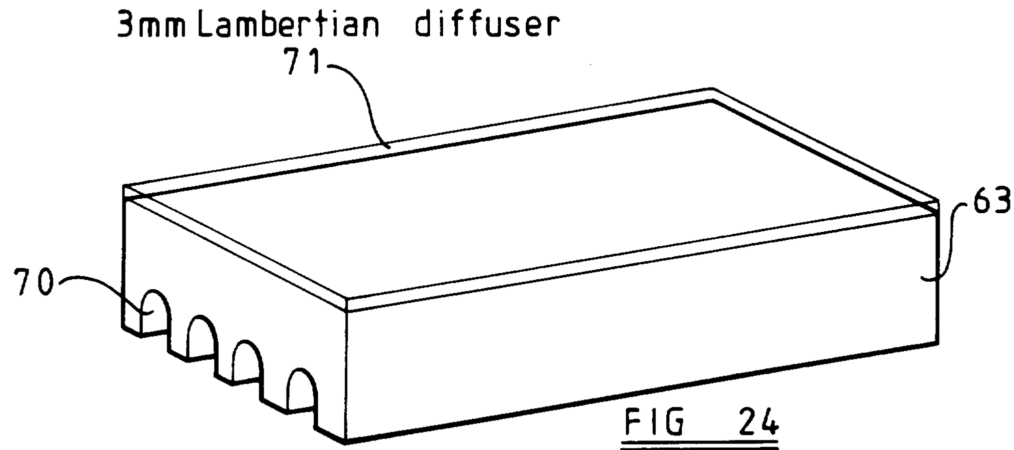


FIG 24

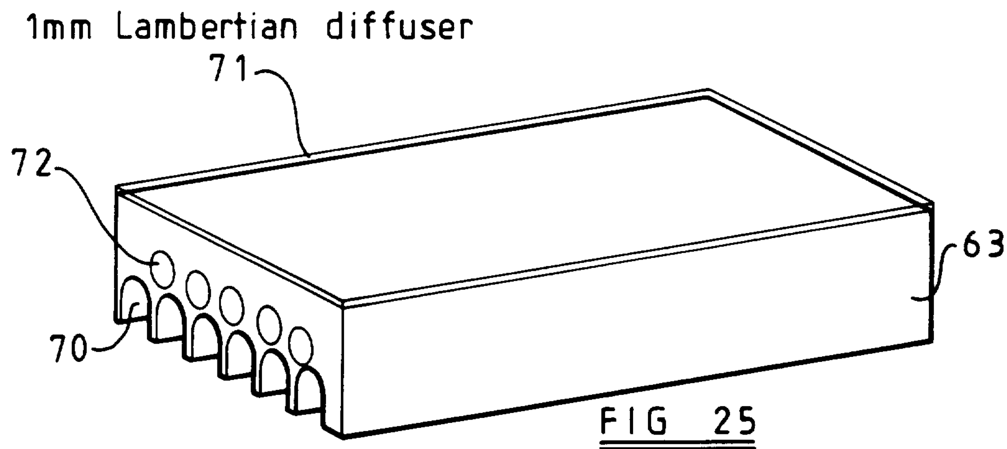


FIG 25

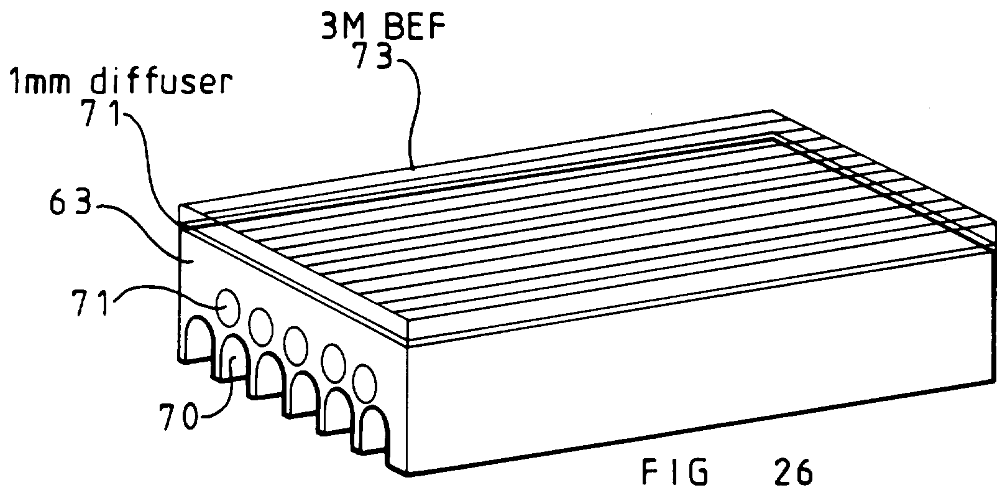


FIG 26

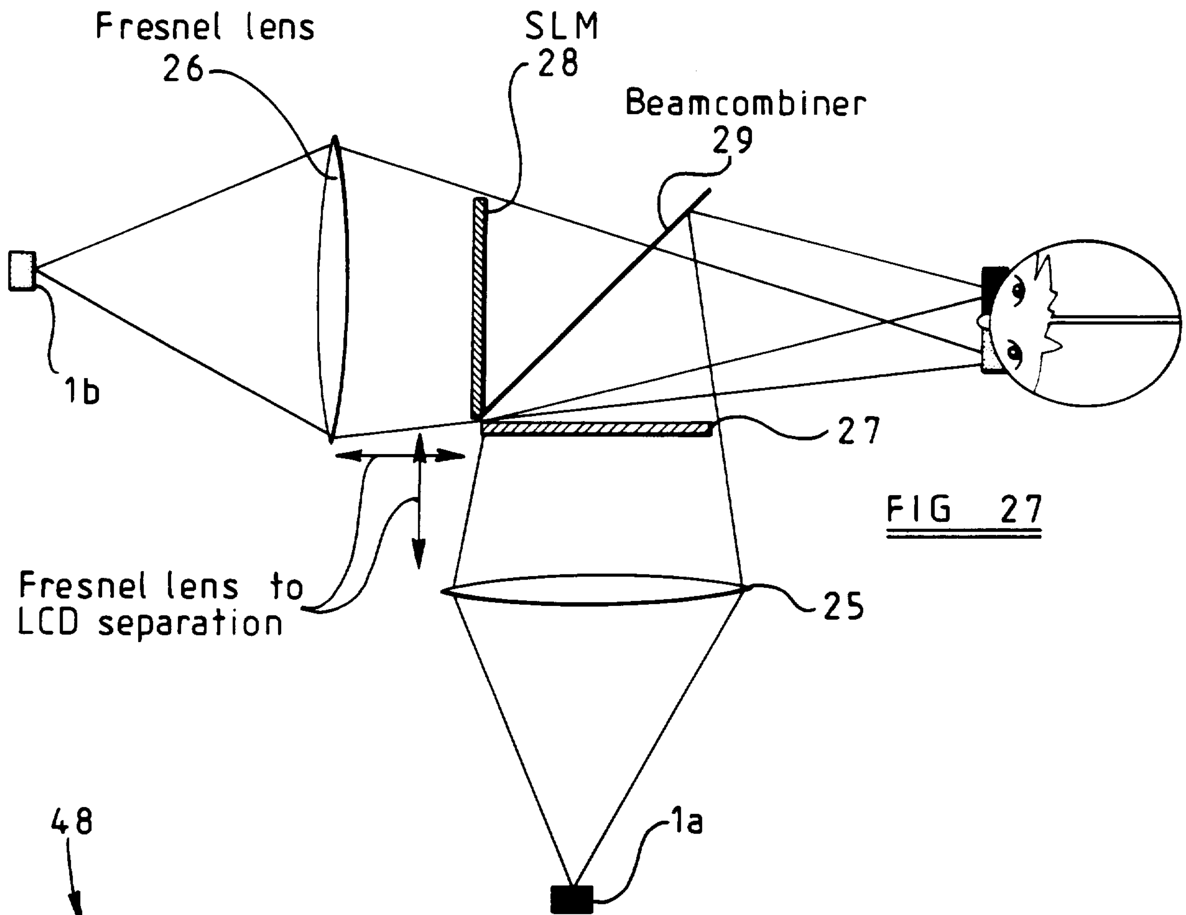

Fresnel lens
26
SLM
28
Beamcombiner
29
1b
27
Fresnel lens to
LCD separation
25
1a

FIG 27

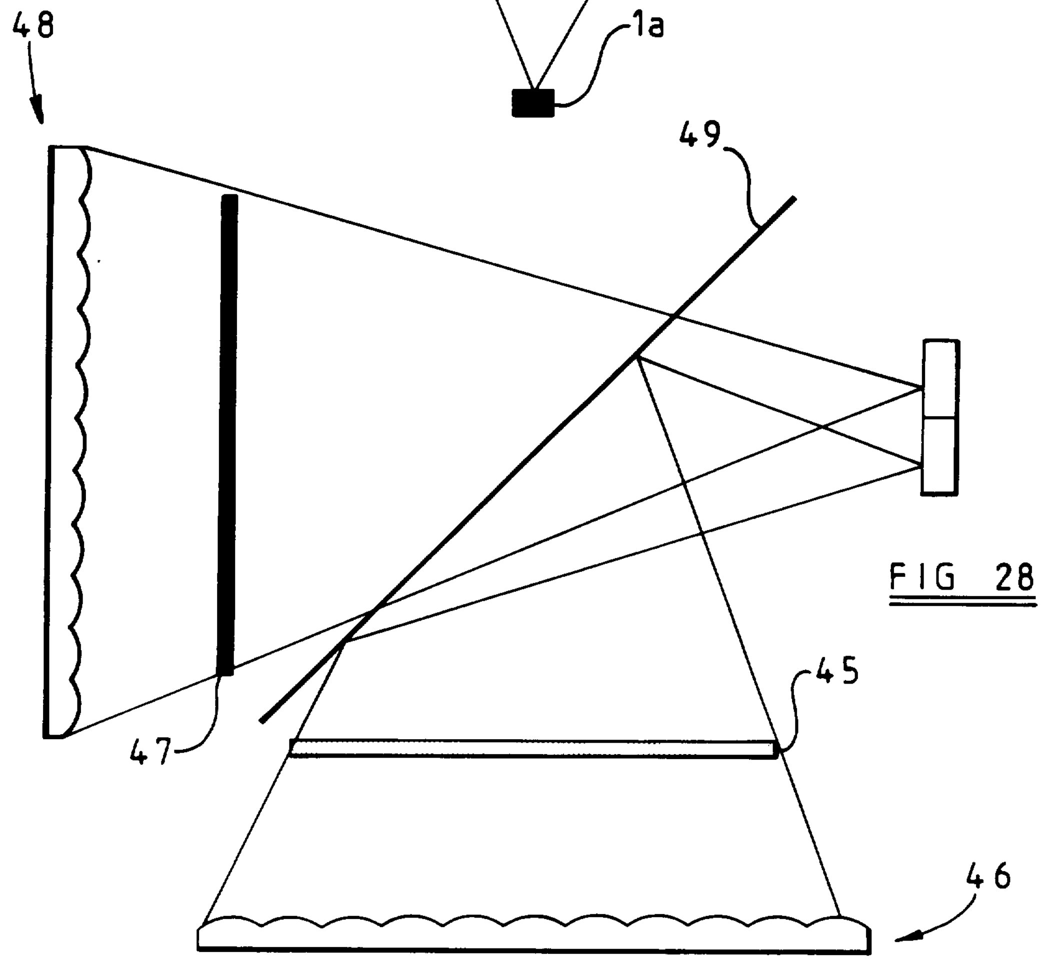

48
49
47
45
46

FIG 28

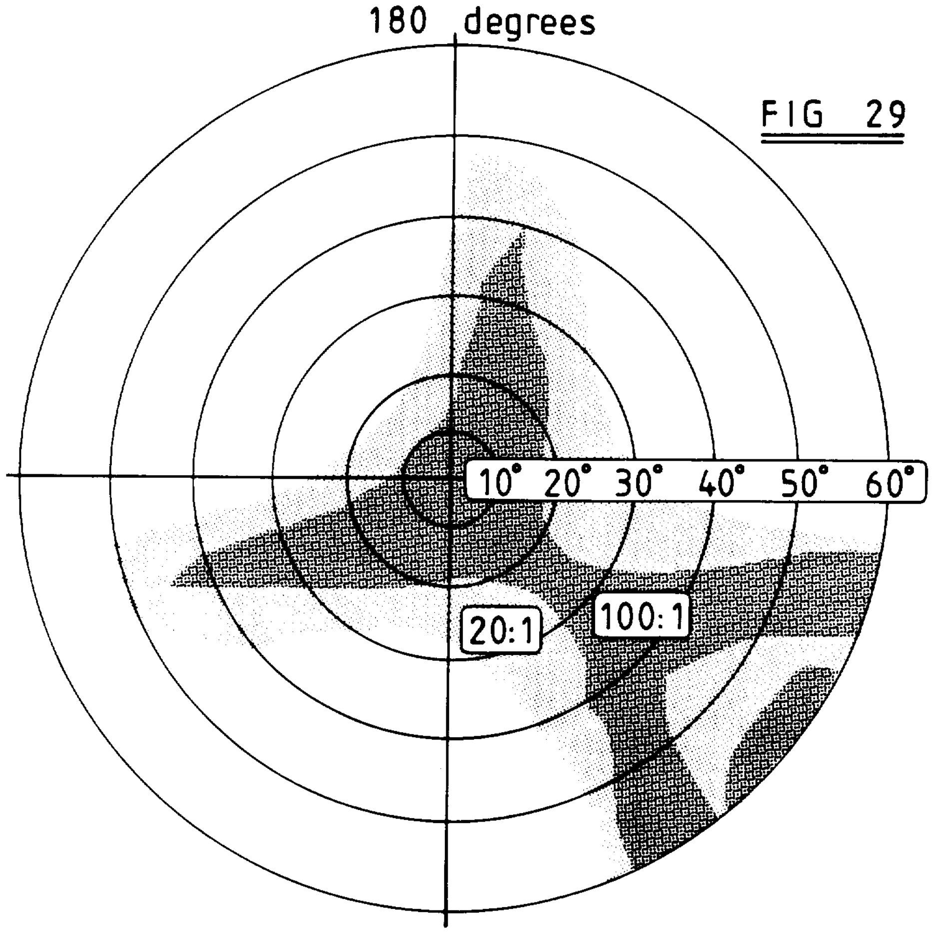


FIG 29

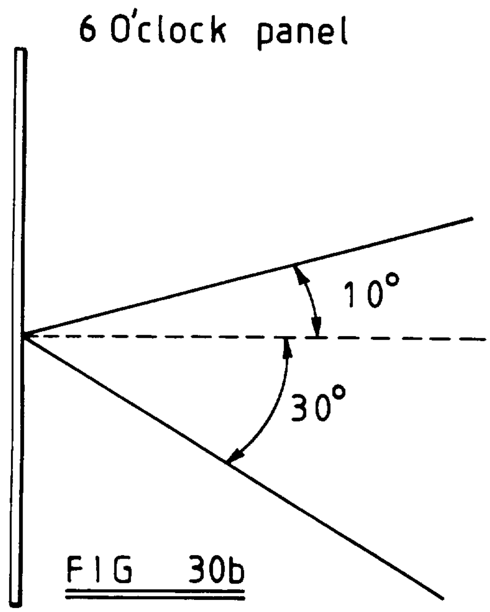


FIG 30b

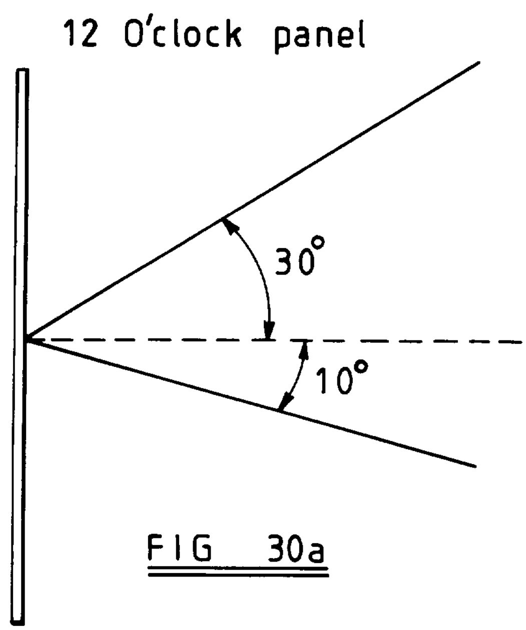


FIG 30a

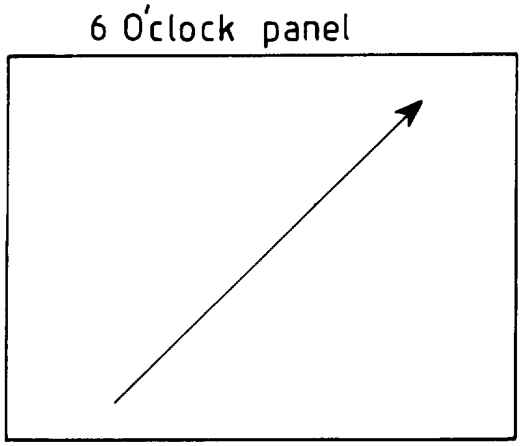


FIG 31b

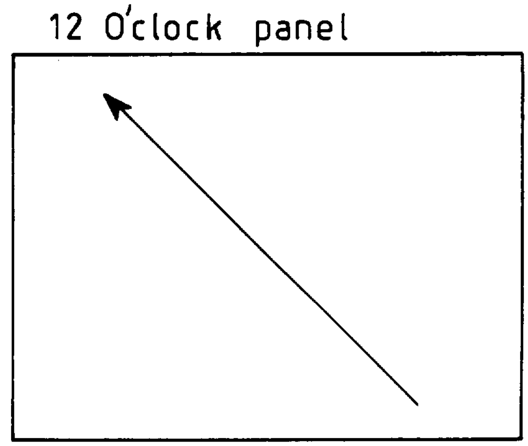


FIG 31a

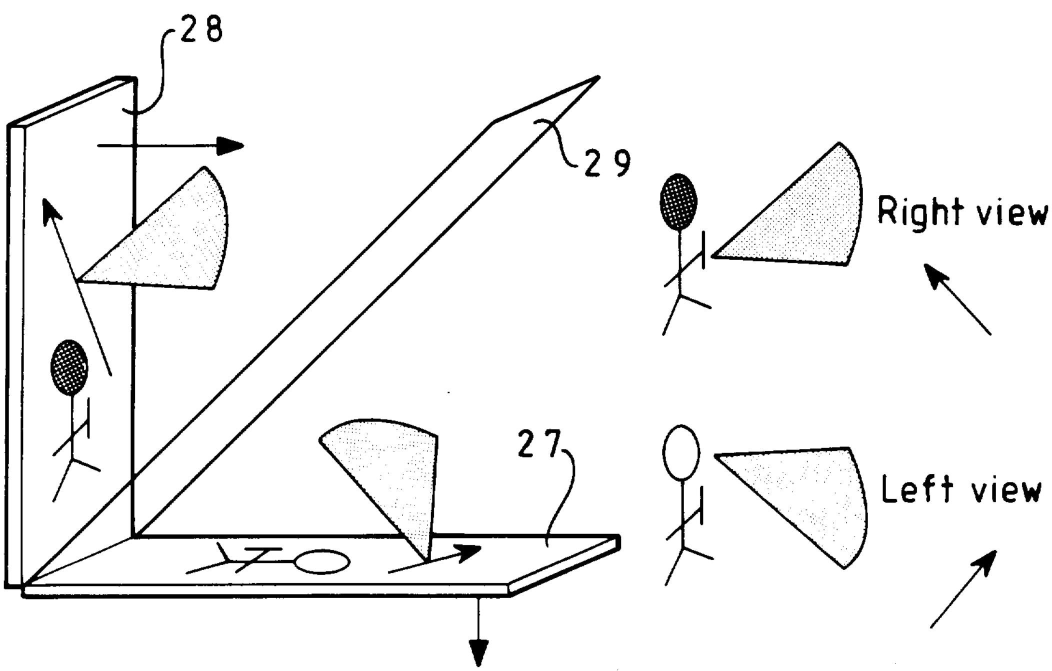
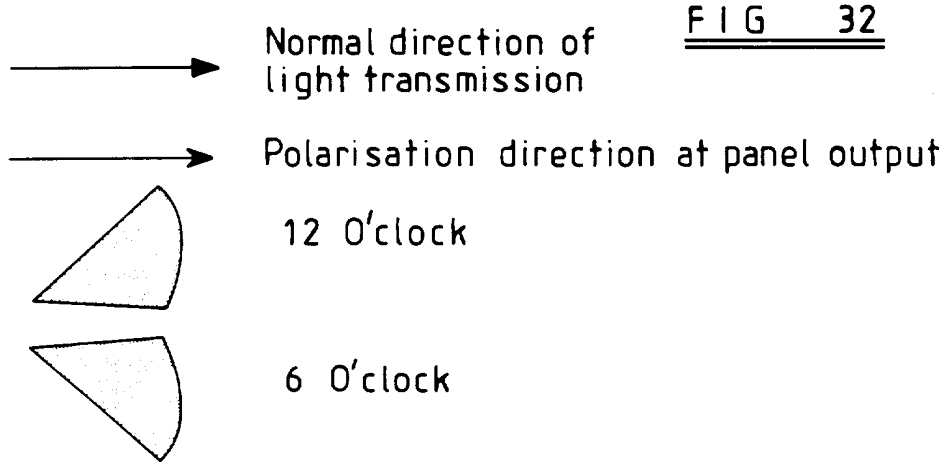


FIG 32



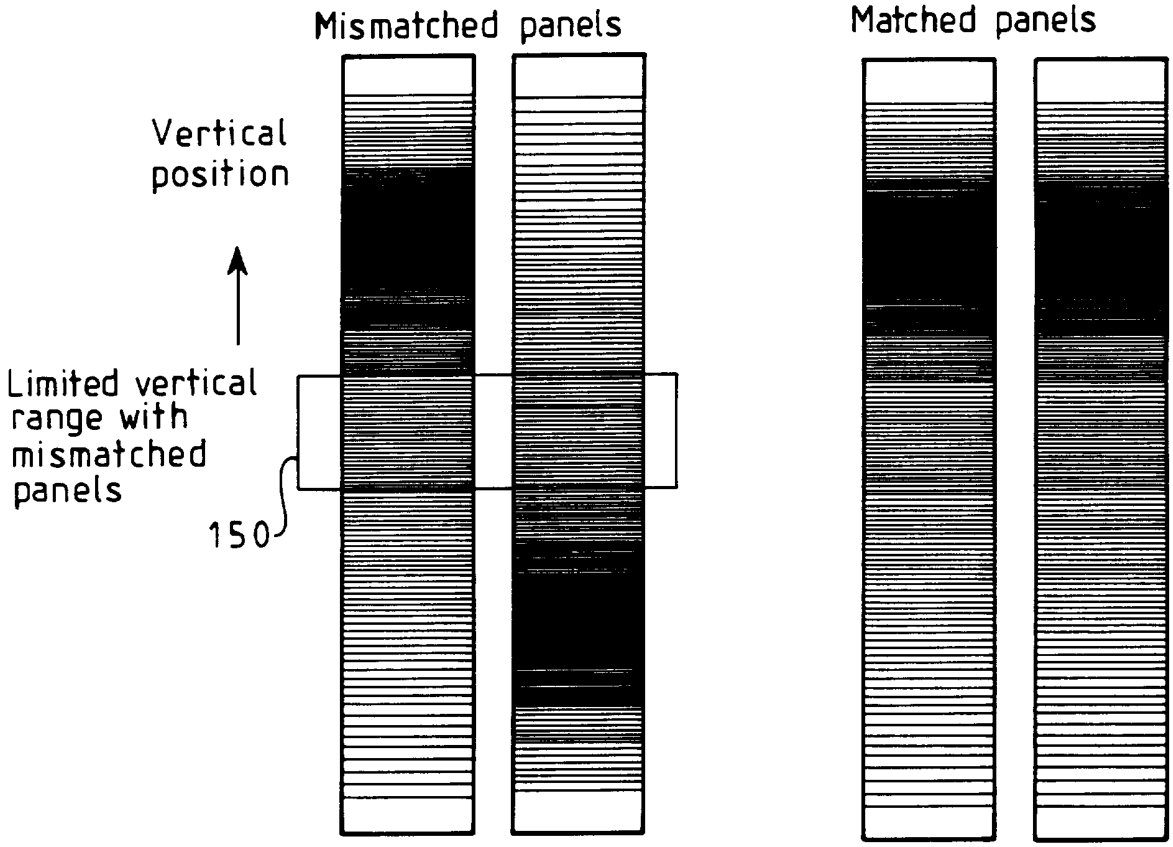


FIG 33a

FIG 33b

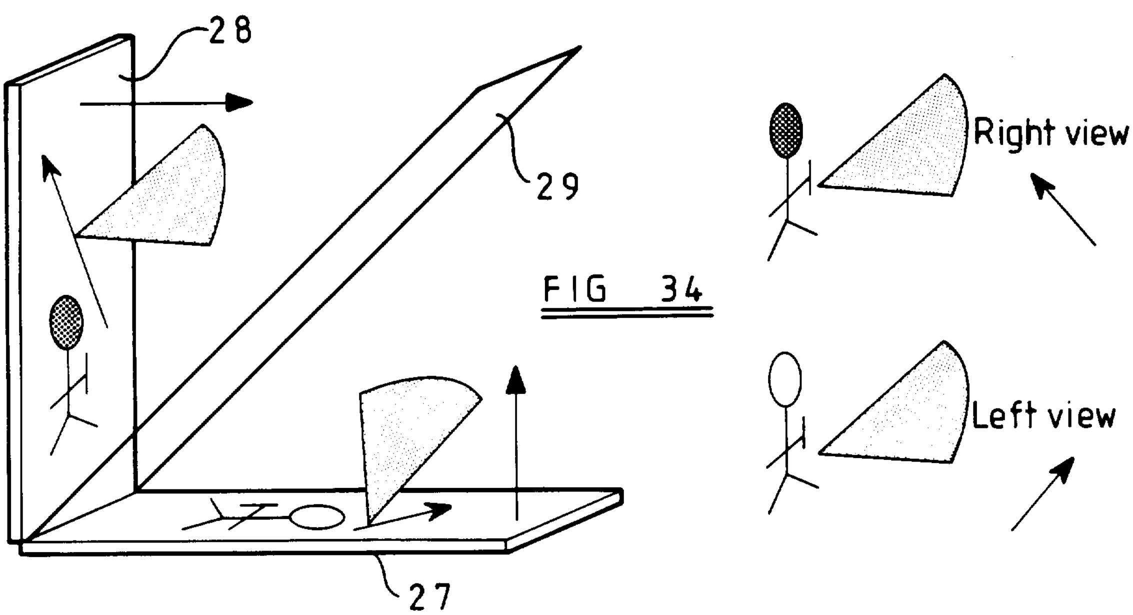


FIG 34

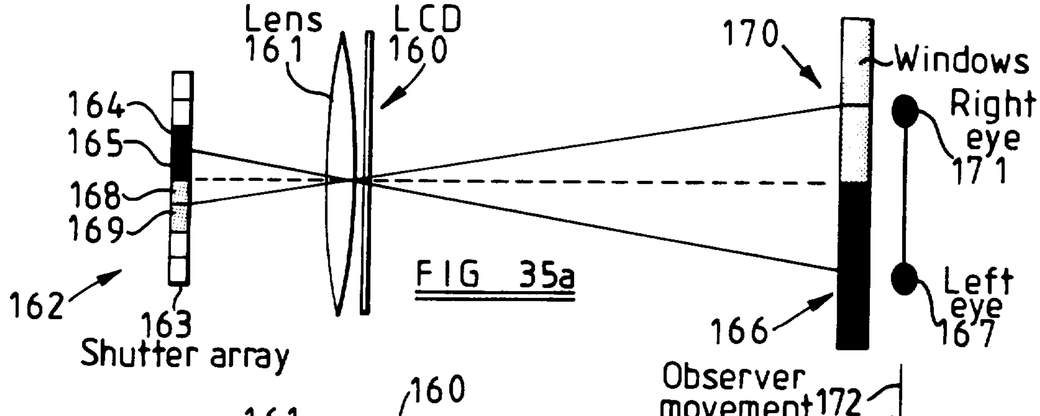


FIG 35a

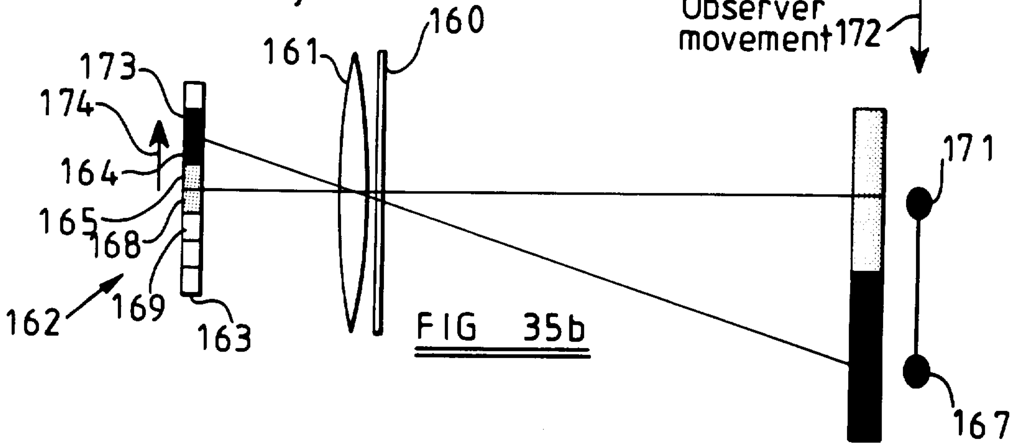


FIG 35b

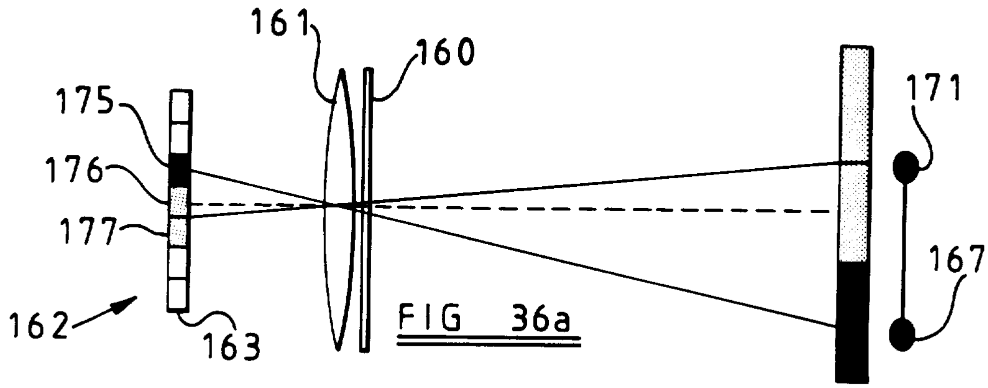


FIG 36a

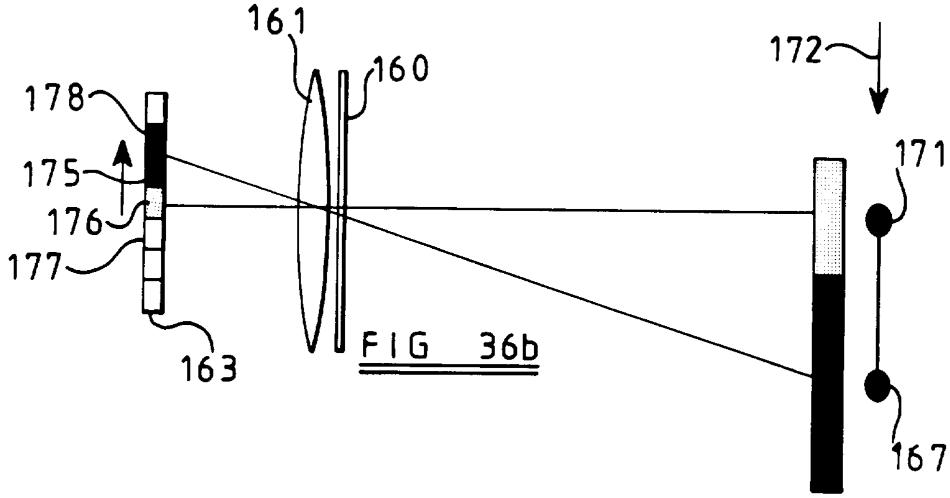


FIG 36b

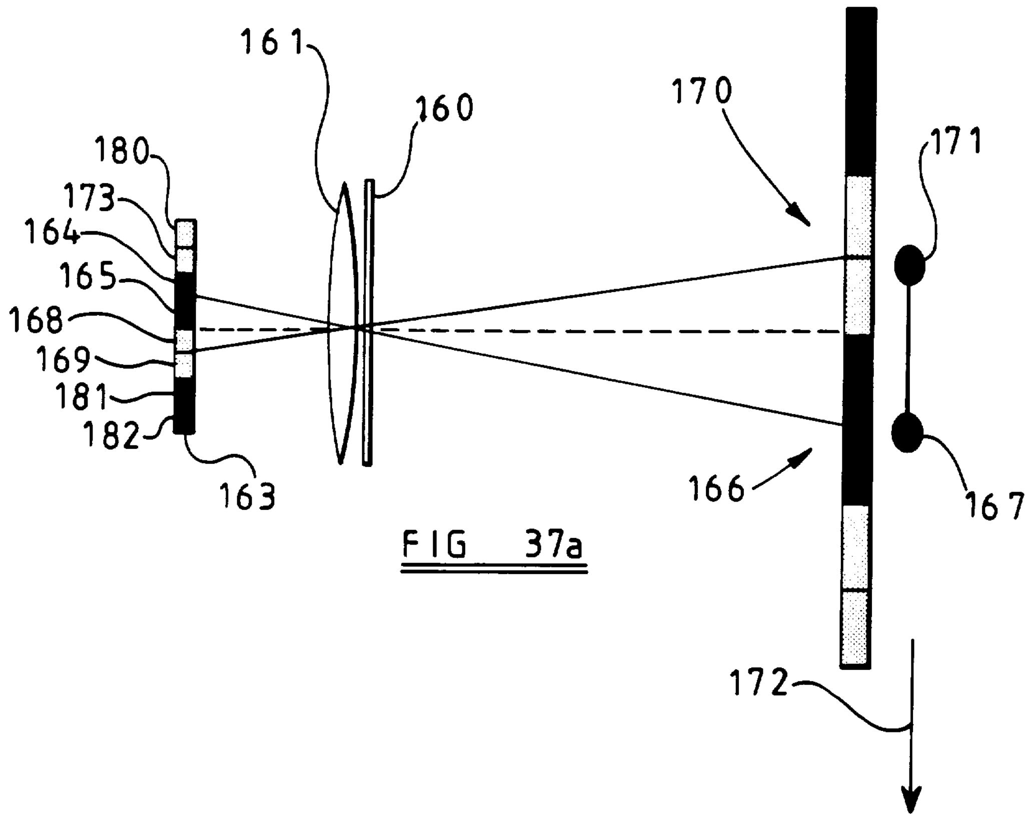


FIG 37a

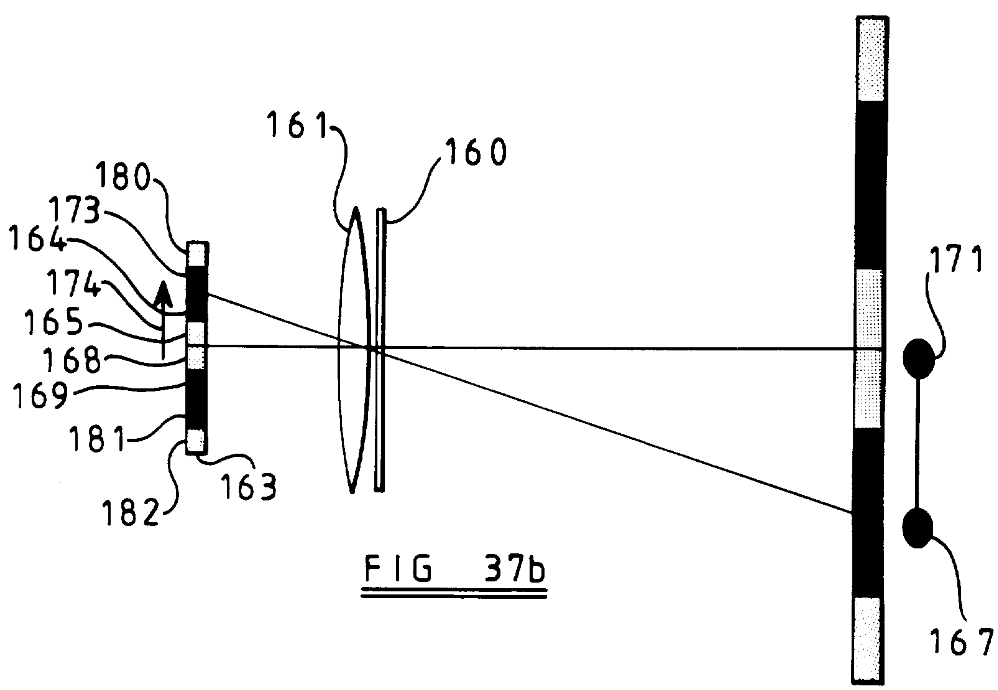


FIG 37b

FIG 38a

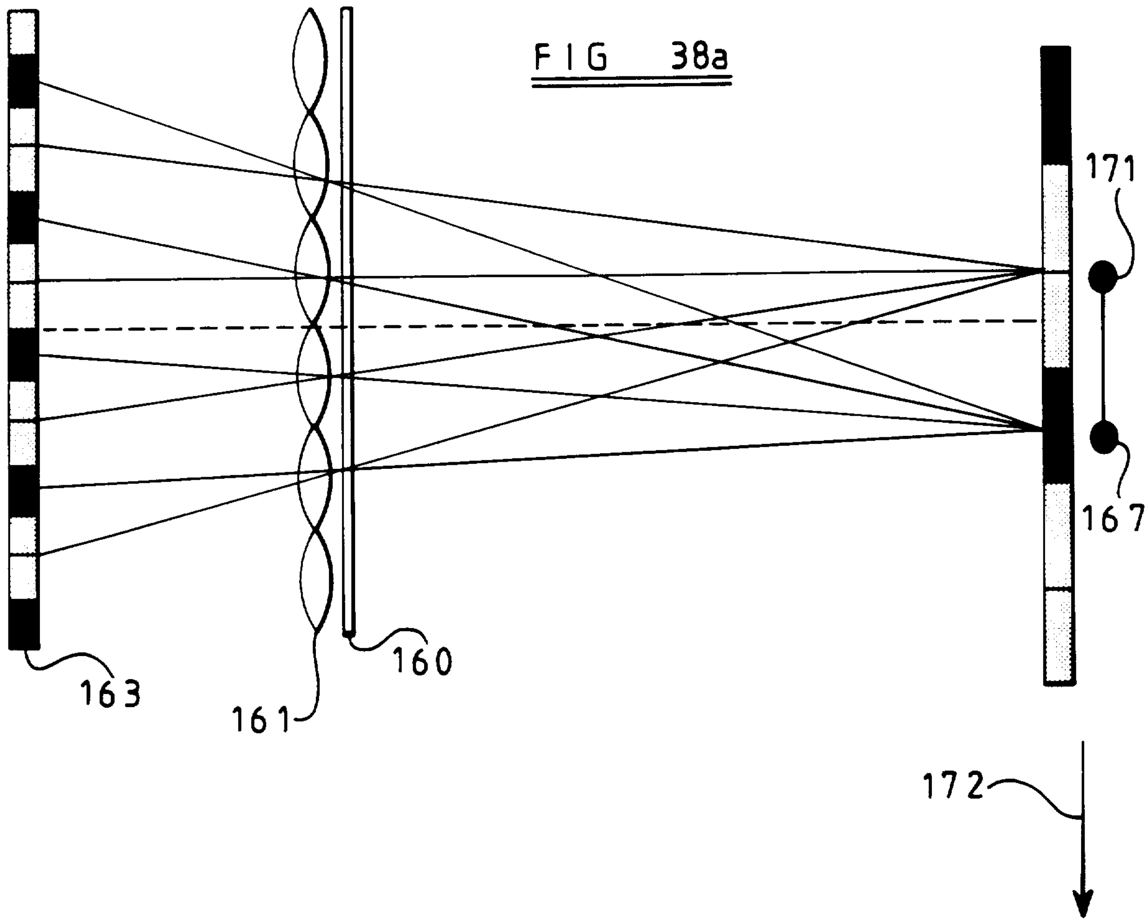
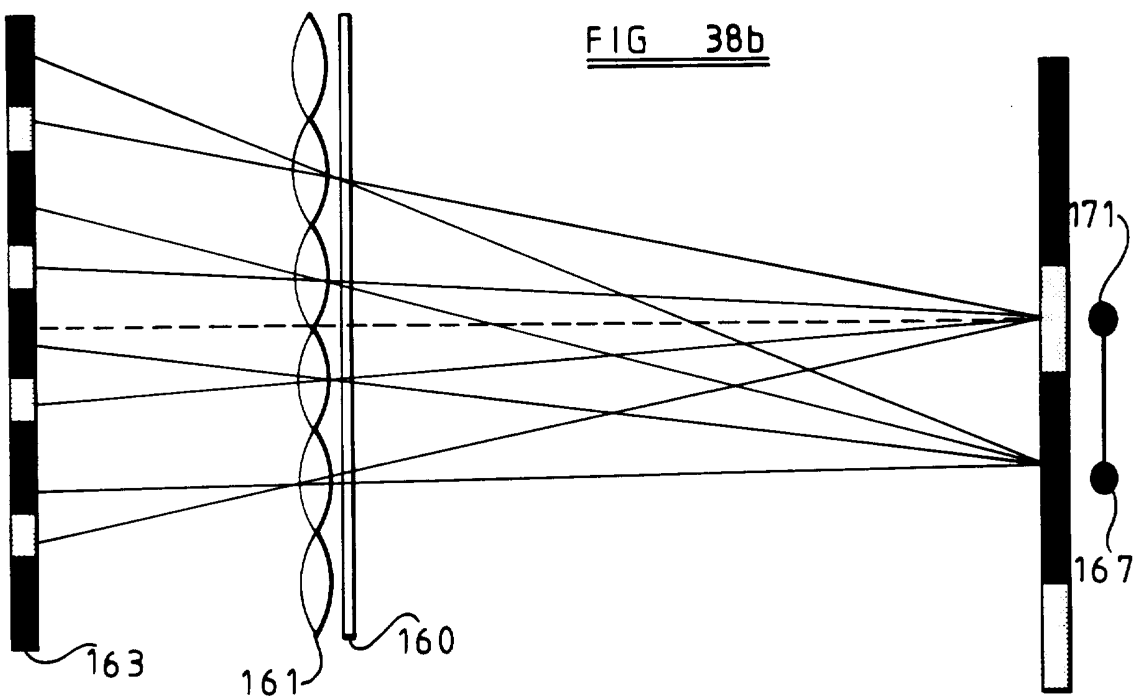


FIG 38b



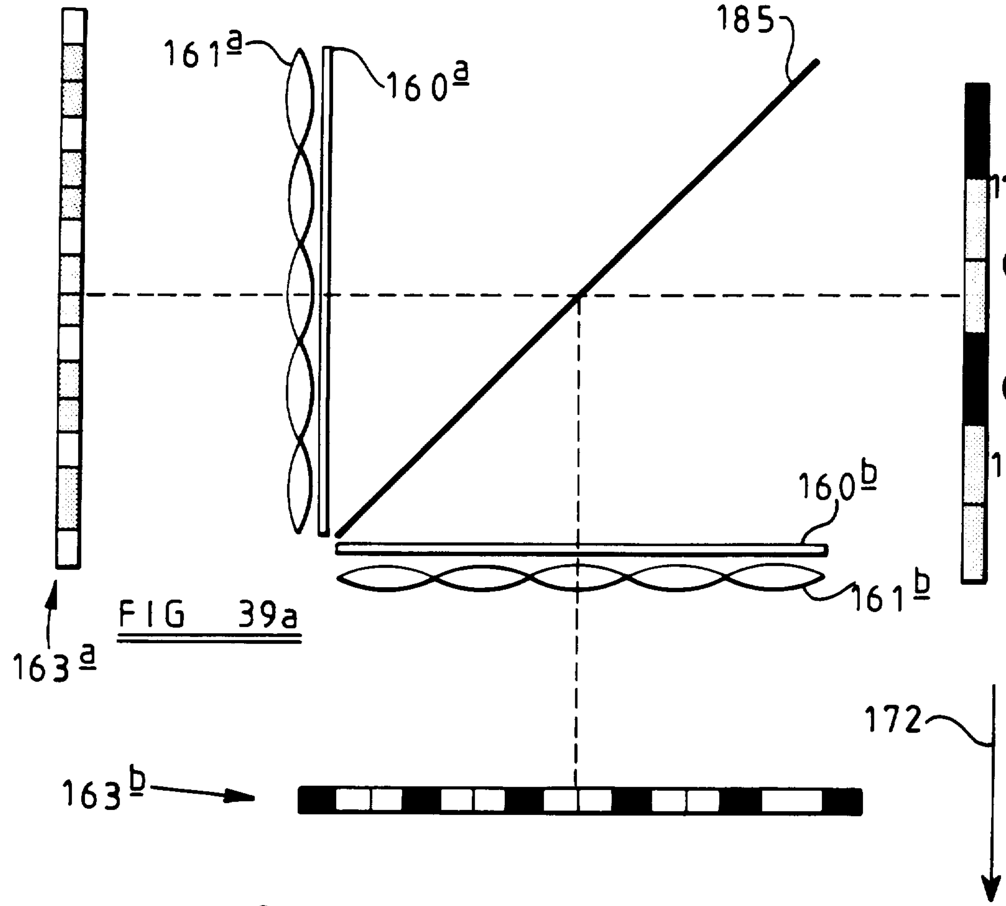


FIG 39a

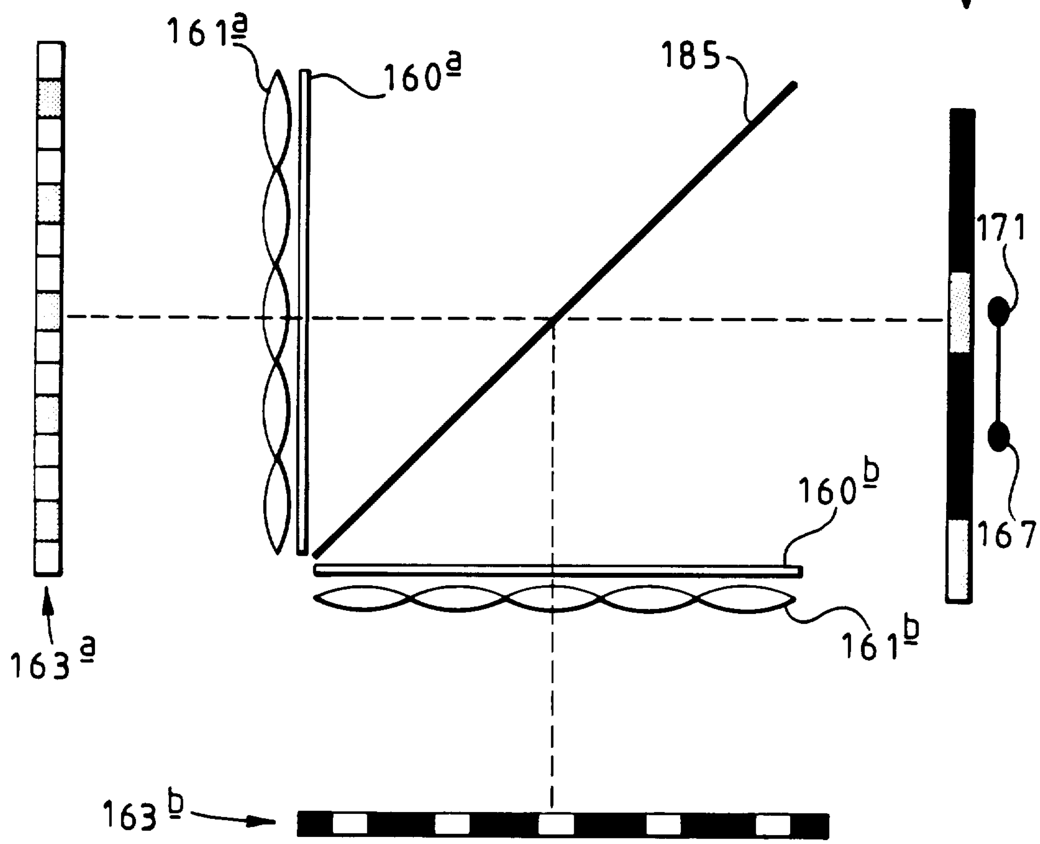


FIG 39b

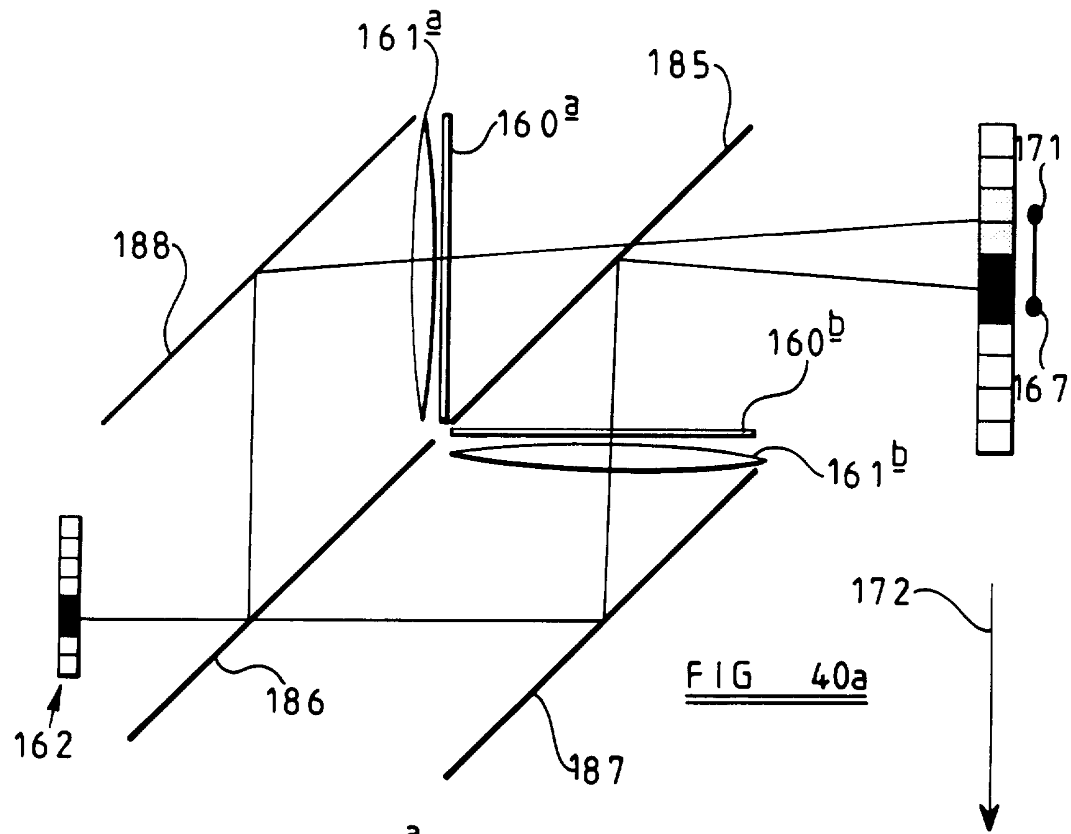


FIG 40a

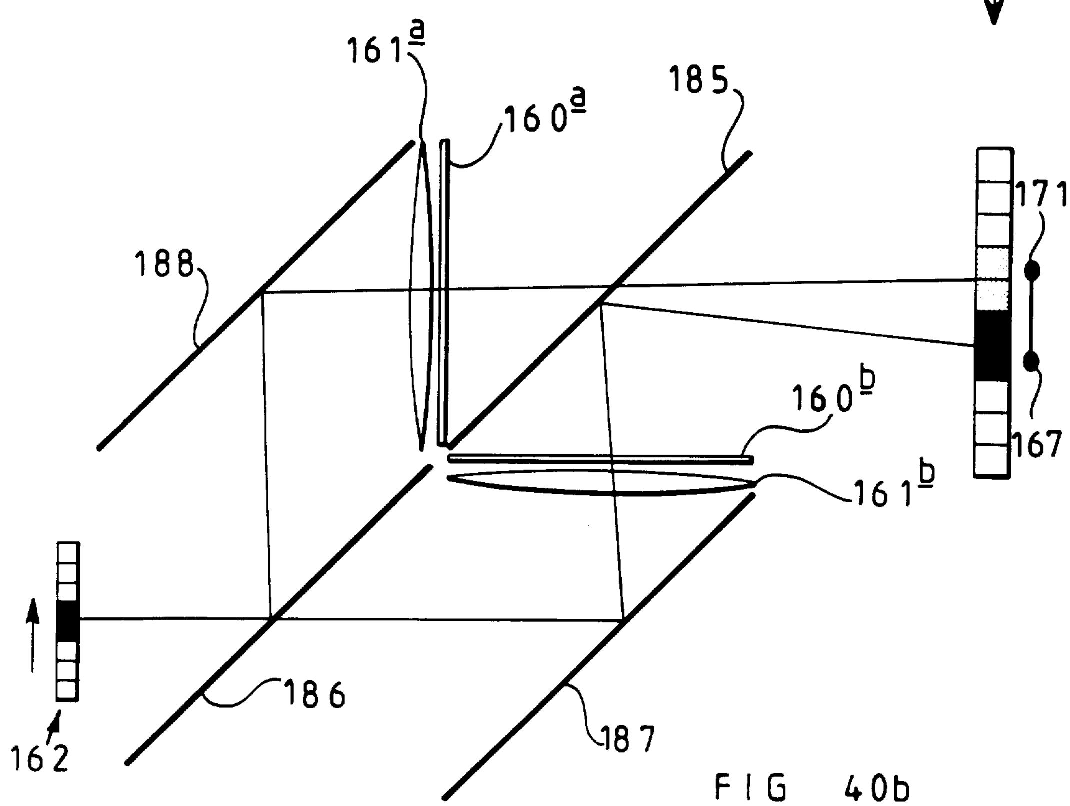


FIG 40b

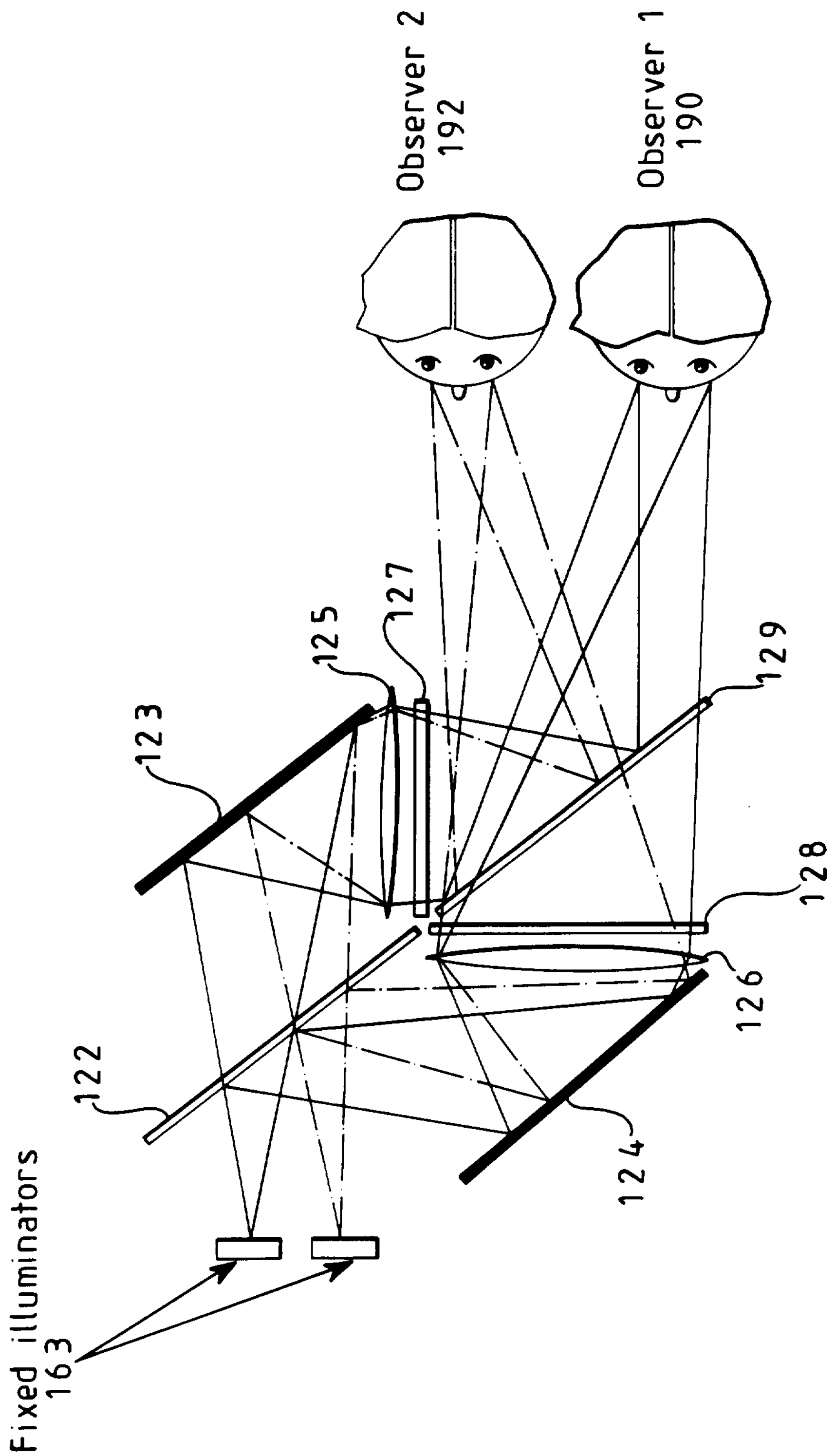

Observer 2
192
Observer 1
190
127
125
123
129
128
126
122
124
Fixed illuminators
163

FIG 41

2294350

LIGHT SOURCE AND DISPLAY.

The present invention relates to light sources and displays.

According to a first aspect of the invention, there is provided a light source as defined in the appended Claim 1.

According to a second aspect of the invention, there is provided a display as defined in the appended Claim 15.

According to a third aspect of the invention, there is provided a display as defined in the appended Claim 22.

According to a fourth aspect of the invention, there is provided a display as defined in the appended Claim 27.

According to a fifth aspect of the invention, there is provided a display as defined in the appended Claim 34.

According to a sixth aspect of the invention, there is provided a display as defined in the appended Claim 36.

Preferred embodiments of the invention are defined in the other appended claims.

The invention will be further described by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a light source constituting a first embodiment of the invention;

Figure 2 shows part of the light source of Figure 1 in more detail;

Figure 3 shows a light source constituting a second embodiment of the invention;

Figure 4 shows part of the light source of Figure 3 in more detail;

Figure 5 shows part of the light source of Figure 1 with the addition of an optical diffuser;

Figure 6 shows a light source constituting a third embodiment of the invention;

Figure 7 shows part of a light source, for instance of the type shown in Figure 6;

Figure 8 shows a light source constituting a fourth embodiment of the invention;

Figure 9 shows a light source constituting a fifth embodiment of the invention;

Figure 10 is a diagram showing a 3D display constituting a sixth embodiment of the invention and including a light source as shown in Figure 3;

Figure 11 is a diagram showing a 3D display constituting a seventh embodiment of the invention and including a light source as shown in Figure 3;

Figure 12 is a diagram showing a 3D display constituting an eighth embodiment of the invention and including a light source as shown in Figure 3;

Figure 13 is a diagram showing a 3D display constituting a ninth embodiment of the invention and including two light sources as shown in Figure 1;

Figure 14 is a diagram showing a 3D display constituting a tenth embodiment of the invention and including a light source as shown in Figure 1;

Figure 15 is a diagram showing a 3D display constituting an eleventh embodiment of the invention and including two light sources as shown in Figure 1;

Figure 16 is a diagram showing a 3D display constituting a twelfth embodiment of the invention;

Figure 17 is a diagram illustrating operation of the display of Figure 16;

Figures 18a to 18c are graphs of light intensity against position illustrating operation of an earlier type of 3D display;

Figures 19a to 19c are graphs of light intensity against position illustrating operation of the display of Figure 16;

Figure 20 illustrates a mechanism believed to be at least partly responsible for cross talk in 3D displays;

Figure 21 is a diagram showing part of a 3D display constituting a thirteenth embodiment of the invention;

Figure 22 illustrates operation of the display of Figure 21 for tracking an observer;

Figure 23 is a diagram showing part of a 3D display constituting a fourteenth embodiment of the invention;

Figures 24 to 26 shows examples of extended light sources suitable for use in displays of the types illustrated in Figures 16, 17, and 21 to 23;

Figure 27 is a diagram showing a 3D display constituting a fifteenth embodiment of the invention and including two light sources as shown in Figure 1;

Figure 28 is diagram showing a 3D display constituting a sixteenth embodiment of the invention;

Figure 29 is an iso contrast viewing diagram for a "normally white" mode of a twisted nematic liquid crystal display;

Figures 30a and 30b illustrate vertical viewing angles for 12 o'clock and 6 o'clock liquid crystal display panels, respectively;

Figures 31a and 31b illustrate output polariser configurations for 12 o'clock and 6 o'clock liquid crystal display panels, respectively;

Figure 32 is a diagram showing a 3D display having mismatched display panels;

Figures 33a and 33b illustrate contrast against vertical viewing angle for mismatched display panels, as shown in Figure 32, and for matched panels, respectively;

Figure 34 is a diagram showing a 3D display constituting a seventeenth embodiment of the invention;

Figures 35a and 35b are diagrams showing a 3D display constituting an eighteenth embodiment of the invention and illustrating observer tracking;

Figures 36a and 36b are diagrams showing a 3D display constituting a nineteenth embodiment of the invention and illustrating observer tracking;

Figures 37a and 37b are diagrams showing a 3D display constituting a twentieth embodiment of the invention and illustrating observer tracking;

Figures 38a and 38b are diagrams showing a 3D display constituting a twenty first embodiment of the invention and illustrating observer tracking;

Figures 39a and 39b are diagrams showing a 3D display constituting a twenty second embodiment of the invention and illustrating observer tracking;

Figures 40a and 40b are diagrams showing a 3D display constituting a twenty third embodiment of the invention and illustrating observer tracking; and

Figure 41 is a diagram showing a 3D display constituting a twenty fourth embodiment of the invention.

Figure 1 shows a light source which may be used as part of a three dimensional (3D) display, for instance of the autostereoscopic type. The light source 1 comprises a plurality of optical waveguides 2, one of which is shown in more detail in Figure 2. Each optical waveguide 2 comprises a cuboidal block of optically transmissive material. The material may comprise glass or a transparent plastics, such as perspex (RTM). Each block 2 has formed therein by drilling or moulding a cylindrical cavity 3 which contains an elongate light source 4, such as a cold cathode fluorescent tube. Other possible light sources include light emitting diodes, lasers such as laser diodes and incandescent light sources, light emitting polymers, luminescence and plasma sources.

Each block 2 has a light-emitting surface 5 shown as an optically diffusing surface formed by roughening the block surface, for instance by sand blasting, although it may comprise a smooth surface covered by a thin optical diffusing layer. The remaining surfaces 6 of the block 2 are optically reflective, for instance as a result of being coated with a thin film of reflective material. The film is preferably less than 100 micrometers thick so that, as shown in Figure 1, the blocks 2 can be arranged as a linear array with adjacent pairs of blocks abutting against each other with a minimal gap between the surfaces 5 thereof. Thus, the light source 1 comprises a linear array of contiguous light-emitting surfaces.

The arrows 7 in Figure 1 illustrate various light paths for light generated by the florescent tubes 4 in two of the blocks 2. The reflective surfaces 6 contain the light within each block 2 so that it acts as a waveguide, the light being emitted only from the surface 5. The reflective surfaces 6 therefore cause the light output from each block to be maximised and to prevent light from passing from each block 2 to an adjacent block so as to prevent "optical cross talk" which would be disadvantageous, for instance when the light source 1 is used in an autostereoscopic 3D display.

It is desirable for variations in light output from the blocks 2 to be minimised. Cold cathode florescent tubes provide high brightness and efficiency with fast switching speeds but exhibit brightness variations because of their long warm-up time, which can amount to several minutes. As a result, there will be brightness differences between those tubes which have recently been switched on and those tubes which have been recently switched off. A heater pad 8 provided with a suitable temperature controller (not shown) is therefore disposed adjacent the florescent tubes 4 so as to maintain the temperatures of all of the tubes 4 at their normal operating temperature, which is typically about 55°C. Thus, tubes which have been switched off for a substantial time will emit substantially their full intensity immediately on being switched on.

Figures 3 and 4 show a modified form of light source 1 in which the cuboidal blocks 2 are replaced by wedge-shaped blocks 12. The surfaces 15 correspond to the diffusing surfaces 5 of the blocks 2 and provide the light output of the blocks 12. The remaining surfaces are coated with reflective material as in the case of the blocks 2. It is thus possible to provide a curved one dimensional light source in which the surfaces 15 of the wedge blocks 12 form or approximate part of a cylindrical or spherical surface. The surfaces 15 may be narrower than the width of the tubes 4 so as to increase the spatial resolution of the light source. Such a curved light source may be useful in overcoming field curvature aberration, for instance associated with off-axis performance of Fresnel lenses used in 3D display systems, thus increasing the field of view of such a display.

In many applications such as autostereoscopic 3D displays, it is important for any residual gap between adjacent surfaces 5 or 15 of the blocks to be substantially invisible to the viewer. This may be at least partly achieved by carefully machining the blocks to have sharp edges at the surfaces 5 and 15 which are pressed together with only a thin reflective film separating adjacent blocks. However, in order to reduce the visibility of the gaps still further, an additional thin diffuser 20 may be disposed across the surfaces 5 of the blocks so as to allow a small amount of controlled cross-diffusion of light between adjacent blocks, as shown in Figure 5. In addition, a layer of 3M Brightness Enhancing Film

(BEF) may be used on the surface of the diffuser 20 to enhance the brightness of the source in the normal direction.

Figure 6 shows a two dimensional light source 1 comprising a plurality of blocks 2 arranged as a two dimensional contiguous array. The light sources of the individual blocks are independently controllable so as to permit any pattern of illumination to be provided. For instance, associated control circuitry may be arranged to illuminate one block at a time so that all of the blocks are illuminated in a repeating sequence. Such a light source may, for instance, be used in a 3D display to provide both vertical and horizontal parallax.

Figure 7 illustrates a modified type of block 2 in which the fluorescent tube 4 is located within a slot 3', extending inwardly from the rear surface of the block 2, instead of in the cylindrical cavity 3 shown in Figure 2. The surface defining the slot 3' is optically transmissive so that light from the fluorescent tube 4 is coupled into the waveguide formed by the block 2.

Figure 8 illustrates a light source formed from blocks 2 which differ from the type shown in Figure 2 in that the rear surface of each block is curved. Such an arrangement may be used to improve the uniformity of output brightness of the waveguide element.

The light source shown in Figure 9 is of a similar configuration to that shown in Figure 8 but differs in that the essentially solid perspex (RTM) blocks 2 are replaced by "air filled waveguides" enclosing cavities 16. The cavities are defined by opaque barriers 17 having knife-edges at the diffuser 20 and by opaque end barriers (not shown). The barriers have reflective surfaces and the rear of each cavity 16 is defined by a cylindrically or parabolically curved reflector 18.

The perspex blocks 2 and 12 shown in Figures 1 to 5 may likewise be replaced by air filled waveguides.

Figure 10 shows an application of the light source 1 of Figures 3 and 4 in a 3D autostereoscopic display of the type disclosed in Figure 3 of British Patent Application No.9324703.9. The light source 1 supplies light to a beam splitter 22 which transmits substantially half of the light to a mirror 23 and reflects substantially half of the light to a mirror 24. The mirrors 23 and 24 reflect the light through Fresnel lenses 25 and 26 and spatial light modulators 27 and 28, respectively. The light rays modulated by the spatial light modulators 27 and 28 are then combined by a beam combiner 29 such that an image formed on the spatial light modulator 27 is visible to the right eye of an observer and an image formed on the modulator 28 is visible to a left eye of the observer. The Fresnel lenses 25 and 26 form images of the light source 1 at the right and left eye positions, respectively, of the observer.

The individual florescent tubes of the light source 1 are controlled by an illuminator controller 30 which in turn is controlled by an observer tracking system 31. The observer tracking system 31 is arranged to track the position of the observer and to cause the illuminator controller 30 to switch on those florescent tubes which result in images of the surfaces 15 of the corresponding blocks 12 being formed at the positions of the eyes of the observer. For instance, with the observer located at the position 32, the florescent tubes 4a are illuminated and typical ray paths for the light from the corresponding blocks is shown by the continuous lines. When the observer moves to position 33, the observer tracking system 31 detects the change in position and causes the illuminator controller 30 to extinguish the tubes 4a and to light the tubes 4b. Typical ray paths are illustrated by the chain dot lines in Figure 10.

Alternatively, in order to allow two observers to see autostereoscopic images simultaneously, for instance at the positions 32 and 33, both sets of tubes 4a and 4b may be illuminated simultaneously. The observer tracking system 31 may further be arranged to track the positions of both observers and to cause the illuminator controller 30 to illuminate those tubes 4 which cause autostereoscopic images to be observable by both observers within the range of movement permitted by the display.

Figure 11 shows another autostereoscopic 3D display which differs from the display shown in Figure 10 in that the two views making up the autostereoscopic image are provided by temporal multiplexing. With the observer at the position 32, light from the tubes 4c is imaged by a Fresnel lens 35 through a spatial light modulator in the form of a fast liquid crystal device panel 36 at the left eye of the observer (as shown by continuous lines) whereas light from the tubes 4d is imaged at the right eye (as shown by the chain dot lines). When the observer is at the position 33, the tubes 4e and 4f are illuminated. With the observer at the position 32, the tubes 4c are first illuminated and other tubes are switched off. A left eye image is presented to the LCD panel 36 and is seen by the left eye of the observer. The tubes 4c are then extinguished and the tubes 4d are illuminated while the image data have been changed to represent a right eye image which is seen by the right eye of the observer at the position 32. This sequence is repeated with a repetition rate sufficiently high to prevent the visibility of flicker so that the observer sees an autostereoscopic 3D image.

As the observer moves, for the instance from the position 32 to the position 33, the active tubes 4 change from 4c and 4d to 4e and 4f continuously so that, within the range of permissible viewing positions, the observer sees the same autostereoscopic 3D image.

Alternatively, as in the case of Figure 10, two sets of tubes 4c, 4d and 4e, 4f may be active simultaneously so as to permit two observers to see the same autostereoscopic 3D image at different observer locations. For instance, when the observers are at the positions 32 and 33, the tubes 4c and 4e are switched in synchronism and the tubes 4d and 4f are switched in synchronism. Both observers can be independently tracked and the appropriate tubes 4 activated in synchronism with the image data presented to the LCD panel 36.

Figure 12 shows an autostereoscopic 3D display of a type similar to Figure 11 but in which no tracking of an observer is necessary. In the display of Figure 12, the panel 36 is a very fast spatial light modulator (SLM) display panel capable of being updated with fresh image data at a very high repetition rate. The individual tubes 4 of the light source 1 are illuminated one at a time in sequence with image data corresponding to a different view being presented to the panel 36 in synchronism with illumination of each respective tube 4. The display therefore provides a large number of views in different directions at a rate sufficient for flicker to be invisible to an observer, so that the observer has a substantial degree of lateral movement within which an autostereoscopic 3D image is visible.

Figure 13 shows an autostereoscopic 3D display of a type similar to that shown in Figure 10 but in which two light sources 1a and 1b are provided. The light from the light sources 1a and 1b is divided by the beam splitter 22 with the path of light from the source 1a being shown by continuous lines and that from the source 1b shown by broken lines. The light sources 1a and 1b are disposed in positions such that the images, shown at 38, overlap each other by half the pitch of the blocks 2 or 12 of the light sources. Thus, such an arrangement provides a higher light intensity for the display and doubles the effective resolution of the individually illuminatable elements of the light source. Further, any gap between adjacent surfaces 2 or 12 of one light source will be covered by the light from one of the surfaces 2 or 12 of the other light source so that such gaps are less visible.

The tubes 4 of the light sources are individually controllable and may be switched on and off in order to represent any desired type of light source. In the case of a single tracked observer, there are always several tubes 4 in adjacent blocks which are simultaneously illuminated. As an observer moves, for instance to the left as shown by an arrow 39 in Figure 10, it is necessary for the light source effectively to move in the direction of the arrow 40. This is achieved by switching off the tube at one end of the group of illuminated tubes and switching on the tube adjacent the other end. Thus, as an observer moves, an autostereoscopic 3D image is continuously visible. The light source 1 therefore effectively simulates a movable light source but requires no moving parts. As described hereinbefore, in order for two or more observers to see simultaneously the 3D image, two or more groups of tubes 4 may be simultaneously illuminated or controlled with the illuminated groups tracking the observers independently of each other.

In a typical example of a light source of the type shown in Figure 1, the fluorescent tubes 4 are 4mm in diameter and the blocks 2 are 8mm wide. An array of 24 blocks therefore provides a light source having a total width of 192mm. When used in a beam combiner display of the type shown in Figure 10, it is required to produce two images of the light source 64mm wide separated by 64mm at the observer. For Fresnel lenses 25 and 26 arranged to provide a magnification of 2:1, four tubes can be illuminated so that the illumination width at the light source is 32mm. The maximum range of movement of the observer is then 384mm and the tubes must be switched progressively for approximately each 16mm of movement of the observer in order to obtain smooth viewing freedom of movement of the observer.

Figure 14 shows an autostereoscopic 3D display of a type similar to that shown in Figure 10. However, the mirrors 23 and 24 and the lenses 25 and 26 are replaced by mirrors 40 and 41. Each of the mirrors 40 and 41 comprises a spherical or aspherical mirror which deflects the light from the light source 1 through the corresponding SLM 27 or 28 and forms an image of the light source 1 at an observer location 42. The reflecting surfaces of the mirrors 40 and 41 may additionally incorporate a diffractive pattern so as to produce a hybrid reflective/diffractive element with the focusing power shared between the reflection and the diffraction. This allows an improved optical performance to be obtained together with a larger effective aperture. In addition, the back working distance of the display may be reduced so as to make the display more compact.

Figure 15 shows an autostereoscopic 3D display similar to that shown in Figure 14 but in which the light source 1 and the beam splitter 22 are replaced by two light sources 1a and 1b.

Figure 16 shows an autostereoscopic 3D display of a type similar to that shown in Figure 14 of European Patent Application No.93310071.1. The display comprises a liquid crystal spatial light modulator 45 for modulating light from a light source 46 with an image to be viewed by the left eye of an observer. Similarly, a liquid crystal spatial light modulator 47 is illuminated by a light source 48 and displays an image for viewing by a right eye of the observer. The images are combined by means of a beam combiner 49 such that light from the light source 46 and the spatial light modulator 45 is reflected by the beam combiner 49 whereas light from the light source 48 and the spatial light modulator 47 is transmitted by the beam combiner 49.

Each of the light sources 46 and 48 comprises a lenticular screen behind which is disposed an array of slits and an extended source of illumination. The lenticular screen may alternatively be replaced by a parallax barrier. Each lenticule of each lenticular screen is aligned with a respective slit so as to control the direction of illumination of the spatial light modulator 45 or 47 so that the left and right images are viewable by the left and right eyes, respectively, of an observer located at a viewing region of the display. This region is referred to as the orthoscopic viewing zone.

In order to prevent the generation of pseudoscopic viewing zones i.e. regions in which an observer would see the right image with the left eye and the left image with the right eye, the pitch of the slits may be made greater than twice the width of the slits, i.e. the slit width is less than one third of the lenticular pitch. In a preferred embodiment as shown in Figure 12, the width of each slit is substantially equal to a quarter of the pitch of the slits. Each lenticule is aligned with a respective slit so that the left image is viewable within a main beam fan 50 whereas the spaces between the slits give rise to a dark region equal to three times the angular extent of the beam fan 50 on either side thereof. On either side of these dark zones, secondary beam fans such as 51 are produced.

Figure 17 illustrates the resultant output of the display shown in Figure 16 after the beams have been combined by the beam combiner 49. There is a main orthoscopic viewing zone 52 in front of the display separated from subsidiary orthoscopic viewing zones such as 53 by dark or "no image" zones 54. Thus, irrespective of the position of an observer, no pseudoscopic viewing zones are generated by the display shown in Figure 16.

The display shown in Figure 16 has the further advantage that "cross talk" within the display is reduced. Figures 18a to 18c illustrate the effects of cross talk in a display of the type shown in Figure 14 of European Application No.93310071.1, which is similar to that shown in Figure 16 of the accompanying drawings but in which the width of the slits is substantially equal to half the pitch of the slits i.e. the width of the slits is substantially equal to the space between the slits. Figures 18a and 18b show the intensity profiles of light from the left and right spatial light modulators, respectively. As shown in each of Figures 18a and 18b, there is a substantial amount of light spill, for instance as shown at 55 in Figure 18a. Figure 18c shows the combined outputs, so that there is substantial light spill and therefore cross talk between the left and right images as seen by the observer.

Figure 19a to 19c correspond to Figures 18a to 18c, respectively, for the display of Figure 16 in which the pitch of the slits is substantially equal to four times the width of the slits. Because of the effectively greater separation of the slits and the light lobes produced thereby, the amount of light spill is greatly reduced. In particular, whereas as shown in Figure 18c light spills from both sides into each window, light spills from only one side into each window as shown in Figure 19c. Cross talk between images is therefore greatly reduced.

It is believed that an important mechanism for creating this cross talk is total internal reflection (TIR) of off axis light from the lens surfaces, as shown in Figure 20. Light from the slit 56 passes through the aligned lenticule 57 and the adjacent lenticules 58 and 59. However, light from the slit 56 directed to the next lenticules 60 and 61 is totally internally reflected from the surfaces of the lenticules back towards the shutter 62 defining the slits. The light is then partially reflected from the opaque areas of the shutter and thus results in the light spill as illustrated in Figures 18 and 19.

The effects of TIR may be reduced by various techniques. For instance, the opaque areas of the shutter 62 may be made less reflective. Also, the angular spread of light incident on the shutter 62 may be reduced so as to prevent or reduce the off axis light. This may be achieved, for instance, by using a brightness enhancing film (available from 3M) which converts a Lambertian diffuser output into a more angularly peaked output. Alternatively, venetian blind material may be used.

Another technique for reducing TIR is to arrange a neutral density filter between the lens surfaces and the shutter 62. The required transmitted light will then make a single pass through the neutral density filter whereas the unwanted light will have to make more than one pass and will therefore suffer much greater attenuation. The neutral density filter may comprise a single layer or may be distributed, for instance in the lenticular sheet. Further, an anti-reflection coating may be provided on the surface of the lenticules so as to reduce the range of angles at which TIR occurs.

Figure 21 illustrates a modification to the type of display shown in Figure 16 to allow the viewing position of an observer to be tracked. Figure 21 illustrates one "arm" of the display, the other arm being substantially identical. The shutter 62 is disposed between an extended light source 63 and the lens array 64 and is connected to a mechanical actuator 65. Means (not shown) are provided for tracking the position of an observer 66 and, from this, control signals are supplied to the actuator 65 so as to position the shutter 62 with respect to the lens array 64 so that the observer can see the 3D image.

Figure 22 illustrates the effects of moving the shutter 62 so as to track an observer in the directions of the arrows 67 and 68.

Figure 23 illustrates an alternative arrangement for tracking an observer and shows one arm of the display, the other arm being substantially identical. In this display, the mechanically movable shutter 62 and the actuator 65 are replaced by a programmable shutter 69. The programmable shutter 69 may, for instance, comprise a liquid crystal spatial light modulator which is controlled so as to provide transparent slits whose positions are movable so as to track movement of the observer 66.

Figure 24 shows an example of an extended light source 63 made of a transparent glass or plastics material such as perspex (RTM). Grooves 70 are formed in the block for receiving, for example, 4mm diameter cold cathode fluorescent tubes. The upper surface of the block 63 is covered with a Lambertian diffuser 71, for instance which is 3mm thick. The remaining surfaces of the block 63 are made optically reflective, for instance by coating with an optically reflective material, so that the block acts as a light waveguide.

The extended light source shown in Figure 25 differs from that shown in Figure 24 in that cylindrical bores 72 are formed therein so as to increase the number of fluorescent tubes. Further, the diffuser 71 is reduced in thickness to 1mm. Thus, the light output of the light source may be increased. As shown in Figure 26, the light output of the light source may be increased further by disposing a 3M BEF (brightness enhancing film) 73 over the diffuser 71. Optical gain is provided by the film 73 in one axis only and this can result in changes in brightness with changes in viewing angle. However, the optical gain can be provided in the horizontal axis, where the angular freedom of movement of an observer is relatively small so that brightness variations with movement will not be substantially observable.

The 3D autostereoscopic display shown in Figure 41 makes use of the illuminators 63 of the type shown in Figures 24 to 26 in a display arrangement similar to that shown in Figure 10. Thus, the observer tracking system, the illuminator controller, and the light source of Figure

10 are replaced by two fixed illuminators 63 which are illuminated continuously so that two observers 90 and 92 can view the display simultaneously. Similar, a third fixed light source could be added so as to permit a third observer to view the display. Further light sources may be provided, the total number of which is limited by considerations such as compactness, geometry, and optical performance.

Although the fixed illuminators 63 may be continuously illuminated, it is also possible to control which of the fixed illuminators is or are illuminated, for instance by a manually operated switch. Thus, the display may be switchable for the position from which it is viewable or for the number of viewers who may simultaneously view the display.

Although a programmable light source, for instance of the type shown at 1 in Figure 10, could be used to provide the fixed illuminators 63, problems of light leakage and reflection can result in undesirable visual artifacts. The use of discrete fixed illuminators 63 allows effective screening to be used to separate the illuminators optically so as to avoid or reduce such problems.

In order to reduce the loss of contrast caused by light reflected from the spatial modulators in displays, a neutral density filter may be disposed in front of the spatial light modulator. Light emitted by the display makes a single pass through the filter whereas reflected light makes two passes, namely from the exterior through the filter to the spatial light modulator and back through the filter. Thus, whereas light from the display is attenuated by the filter, reflected light is attenuated twice by the filter and once by reflection at the spatial light modulator. For applications where background levels of lighting are relatively low, the neutral density filter may be movable out of the optical path so that the display may be viewed directly.

The range of eye separation for human observers may vary between approximately 48mm and approximately 78mm. 3D displays may need some interocular adjustment in order to compensate for this. For instance, in the case of the display shown in Figure 10, either or both of the mirrors 23 and 24 may be tilted so as to adjust the interocular distance. In the case of displays where two or more light sources are provided, the size and position of the light sources may be varied so as to provide interocular adjustment. In the case of displays using extended light sources and programmable shutters, for instance as shown in Figure 23, interocular adjustment may be provided by adjusting the positions of the slits in the programmable shutter of one light source with respect to the other light source.

In general, any technique which alters the angles at which the left and right views are visible may be employed in order to provide interocular adjustment.

3D displays generally contain lenses for focusing or directing light through one or more spatial light modulators. Such lenses may be Fresnel refractive lenses because of their ability to provide large size, light weight, low cost, high numerical aperture, and a degree of compensation for off axis aberrations. Alternatively, lens arrays or lenticular screens may be used for this purpose. Devices of these types may be referred to as "repetitive optical structures".

A typical repetitive optical structure may have a pitch of the same order as that of the picture elements of a liquid crystal device forming the spatial light modulator. When such a repetitive optical structure is disposed adjacent the surface of the SLM, Moire fringes may be observed at a variety of angles corresponding to the lens grooves beating with the regular pixel arrangement. This can cause unwanted visual artifacts in the display.

A Fresnel lens comprises a substrate having formed therein a pattern of grooves. Scattering and non-continuous refraction variations take place at the boundaries of the grooves, resulting in intensity variations across the lens from a particular viewing direction. Such variations generally have a size below the limit of resolution of an observer at a normal viewing distance. However, when such a lens is in close proximity to a SLM such as a liquid crystal device LCD which may have a black mask structure, Moire beating may occur at observable spatial frequencies. In the case of 3D displays provided with observer tracking, it is important to remove the Moire effects because movement of an observer and the consequent tracking can result in a change of the appearance of the fringing, thus highlighting its presence.

Figure 27 shows an autostereoscopic 3D display in which views provided by spatial light modulators 27 and 28 are combined by a beam combiner 29 to provide an observer with a 3D image. Light sources, for instance of the types 1a and 1b shown in Figure 13, illuminate the SLMs via Fresnel lenses 25 and 26.

In order to reduce or eliminate Moire fringing effects, the lenses 25 and 26 are separated from the SLMs 27 and 28, respectively, by a distance sufficient to reduce or eliminate the intensity variations caused by the Fresnel lens with respect to the SLM. In particular, the separation is such that several lens grooves are resolved through each pixel of the respective SLM. The lenses 25 and 26 are larger than the SLMs 27 and 28 so that, as an observer moves off axis, some parts of each lens are still visible through the respective SLM.

Figure 28 illustrates an autostereoscopic 3D display of the type shown in Figure 16. In this case, the lens arrays or lenticular screens of the light sources 46 and 48 are spaced from the SLMs 45 and 47, respectively, by an amount sufficient to reduce or eliminate Moire fringing effects.

Other means for reducing or eliminating Moire fringing effects may be provided. For instance, there may be provided a large difference between the pitch of the pixels of the SLMs and the groove pitches of the Fresnel lenses. However, this may be difficult to achieve, for instance in spherical type lenses where Moire fringing has to be removed at a number of angles.

Alternatively, a cylindrical Fresnel lens may be used having substantially the same horizontal groove pitch as the pixel pitch of the SLMs. However, this may be difficult to implement because of the pitch tolerances required for manufacture of the lens.

A further possibility is to vibrate the respective optical structure with respect to the corresponding SLM so that the fringes are temporally blurred so as to be substantially invisible. However, this may be difficult to implement and may cause degradation in the cross talk seen by an observer.

Many spatial light modulators have a contrast performance which varies asymmetrically with respect to viewing angle about the normal to the plane of the modulator. For instance, spatial light modulators in the form of twisted nematic liquid crystal displays exhibit asymmetric contrast performance with respect to vertical viewing angle. This is illustrated in Figure 29, which is an iso contrast viewing diagram for the normally white mode of a twisted nematic liquid crystal device and which is based on a diagram in "Liquid Crystals, Applications and Uses", volume 1, chapter 10 "Twisted Nematic and Supertwisted Nematic Mode LCDs", by T. Scheffer and J. Nehring, Ed. B. Brahadur, Pub. World Scientific 1990. The darker shaded area represents those viewing angles for which the maximum contrast is greater than or equal to 100:1 whereas the intermediate shaded areas represent those viewing angles where the contrast is between 20:1 and 100:1. If the best vertical viewing angle zone is above the normal or horizontal axis, the panel is described as a "twelve o'clock panel" as shown in Figure 30a whereas, if the best viewing zone is below the horizontal axis, the device is described as a "six o'clock panel" as illustrated in Figure 30b. In general, this corresponds to the direction of the output polariser of the device as illustrated in Figure 31a for a twelve o'clock panel and in Figure 31b for a six o'clock panel.

Part of a beam combining display, for instance of the type shown in Figure 10, is shown in Figure 32. The outputs of the liquid crystal spatial light modulators 27 and 28 are combined by means of a beam combiner 29. The SLM 28 provides a right view and the SLM 27 provides a left view of a 3D image. Figure 32 illustrates the directions of polarisation of the polarisers of the SLMs 27 and 28 facing the beam combiner 29. The orientations of the images on the SLMs is the same as for normal operation of the liquid crystal devices but, whereas light is transmitted through the SLM 28 in the usual direction, light is transmitted in a direction opposite the usual direction in the SLM 27. As a result of this, the SLM 28 behaves as a twelve o'clock panel whereas the SLM 27 behaves as a six o'clock panel.

Figure 33a illustrates the contrast performances of the SLMs 27 and 28 where the grey levels shown in the vertical columns represent contrast levels against vertical position of an observer. The contrast levels thus have a similar value throughout a relatively limited vertical range as indicated at 150. This can cause visual stress and induced Pulfrich effects to an incorrectly positioned observer and is therefore disadvantageous.

Because light from the SLM 27 is reflected by the beam combiner 29, the image it carries is required to be laterally inverted with respect to the image carried by the SLM 28. In the arrangement of Figure 32, this is achieved by illuminating the SLM 27 in the reverse direction, which gives rise to the mismatched contrast performances.

Figure 34 shows a display of the type illustrated in Figure 32 but in which the SLM 27 is illuminated in the usual direction. The image presented by the SLM 27 is electronically laterally inverted so that both SLMs 27 and 28 behave as twelve o'clock panels to a viewer. As shown in Figure 33b, the contrast performances of the panels with respect to vertical viewing angle are substantially matched so that the disadvantages of the arrangement shown in Figure 32 are overcome.

As described in British Patent Application No.9324703.9, in which the position of an observer is tracked and the display is adjusted so as to present an autostereoscopic 3D image to the observer within the range of permissible positions, the relative positions of one or more sources of illumination and an imaging device such as a lens are varied so as to track the observer. It is believed desirable to limit the fluctuations of brightness as the observer moves to less than 5%. It is possible to achieve this by providing a source of illumination which is effectively movable and various techniques exist for achieving this. For instance, a light source may be mechanically moved with respect to the lens or lenses. However, such an arrangement may suffer from problems of response speed and may be difficult to implement for relatively large illumination sources.

Another possible technique is the use of a cathode ray tube controlled so as to provide at its screen a movable light emitting region. However, such an arrangement would have to be relatively large particularly for high brightness cathode ray tubes. Further, such tubes generally have a curved output screen which could affect the optical performance.

Figures 35a and 35b show an autostereoscopic 3D observer tracking display of the type shown in Figure 5 of British Patent Application No.9324703.9. The display comprises a SLM in the form of a liquid crystal device 160 associated with a lens 161, such as a converging Fresnel lens. An illumination source 162 comprises an extended light source (not shown) in the form of a back light in front of which is disposed a shutter array 163 in the form of a low resolution liquid crystal spatial light modulator. The shutter array 163 is controlled by means for tracking the position of an observer (not shown).

In use, the shutter array 163 is controlled so that elements 164 and 165 are transparent whereas the other elements of the array 163 are opaque. Thus, the transparent elements 164 and 165 together with the back light comprise a light source which is imaged by the lens 161 to a region 166 at which the left eye 167 of an observer is located. The light from the elements 164 and 165 is modulated by the liquid crystal device 160 so as to present a left image of a 3D image to the left eye 167 of the observer.

The elements 164 and 165 are then controlled so as to be opaque and the elements 168 and 169 are made transparent so as to act as another light source. Light from the elements 168 and 169 is imaged by the lens 161 to a region 170 at which the right eye 171 of the observer is located. The light is modulated by the liquid crystal device 160 in accordance with a second image of the 3D image to be viewed by the right eye 171. This cycle of events is then repeated at a sufficiently rapid rate to make flicker imperceptible to the observer so that the display provides an autostereoscopic 3D image by temporal multiplexing.

Figure 35b illustrates operation of the display when the observer has moved in the direction of arrow 172. In order to track the observer smoothly and ensure that the observer continues to see an autostereoscopic 3D image, the shutter array elements 173 and 164 are imaged to the left eye 167 whereas the shutter elements 165 and 168 are imaged at the right eye 171. Thus, light from the shutter elements 173 and 164 is modulated by the device 160 with the left image whereas light from the shutter elements 165 and 168 is modulated by the device 160 with the right image. The shutter array 163 and back light thus simulate movement of the source of illumination in the direction of arrow 174 so as to track movement of the observer.

The display shown in Figures 36a and 36b is similar to that shown in Figures 35a and 35b but using a shutter array 163 of lower resolution. In this case, in Figure 36a with the eyes 167 and 171 of the observer in the position shown, only the shutter element 175 is imaged by the lens 161 at the left eye 167 whereas the shutter elements 176 and 177 are imaged at the right eye 171. When the observer moves in the direction of the arrow 172 as shown in Figure 36b, the shutter elements 176 and 178 are controlled so as to provide light imaged at the left eye 167 whereas only the element 176 is controlled to provide light imaged at the right eye 171.

Figures 37a and 37b show a display of the type shown in Figures 35a and 35b but with the shutter array 163 operated differently such that all of the shutter elements are strobed continuously. In particular, with the observer in the position shown in Figure 37a, the shutter elements 173 and 180 are operated in synchronism with the shutter elements 168 and 169 whereas the shutter elements 181 and 182 are operated in synchronism with the shutter elements 164 and 165. Such an arrangement helps to reduce storage effects which may be present in certain types of liquid crystal device if switched to one state for a long time, as is likely for shutter elements disposed further away from the axis of the display. In displays where the light sources are themselves switched, such as the sources illustrated in Figures 1 to 5, continuous switched operation of all the light sources helps to reduce the effects of lifetime degradation of the brightness of the sources. If more than one observer is present, then different parts of the shutter array 163 may be controlled in the same way for each observer.

Figure 37b illustrates operation when the observer has moved in the direction of the arrow 172. In this case, the shutter elements 180, 165, 168, and 182 are controlled in synchronism and the remaining shutter elements 173, 164, 169, and 181 are operated in synchronism.

Figures 38a and 38b illustrate the mode of operation as illustrated in Figures 37a and 37b in the case of a lower resolution shutter array 163 of the type illustrated in Figures 36a and 36b. In particular Figures 38a and 38b show a compact type time multiplexed display using an array of lenses and using higher resolution shutter elements than those shown in Figures 35a to 37b, with a respective group of "illuminators" for each lens. As in the display shown in Figures 36a and 36b, the effective illumination elements are of different sizes for the left and right eyes 167 and 161.

Figures 39a and 39b show an autostereoscopic 3D display of a type similar to that shown in Figure 1 of British Patent Application No.9324703.9 but including illumination sources of the type shown in Figures 38a and 38b comprising extended light sources (not shown) and shutters 163a and 163b. In this case, light passes through the shutter 163a for the right image whereas light passes through the shutter 163b for the left image. Light is supplied continuously through the shutters 163a and 163b so that the light paths therefrom are modulated by right and left images supplied to liquid crystal spatial light modulators 160a and 160b, respectively. Two converging lens arrays 161a and 161b are provided for imaging the effective light sources at the right and left eyes

171 and 167, respectively. The left and right images are combined by means of a beam combiner 185.

Figure 39b illustrates the change in operation of the shutters 163a and 163b in response to movement of the observer in the direction of the arrow 172 so that the display tracks the observer movement.

Figures 40a and 40b illustrate an autostereoscopic 3D display of the type shown in Figure 3 of British Patent Application No.9324703.9. This display differs from that shown in Figures 39a and 39b in that the two light sources are replaced by a single light source 162 of the type shown in Figures 35a and 35b together with a light dividing arrangement comprising a beam splitter 186 and reflectors 187 and 188. Light from the illumination source 162 is divided so as to simulate two light sources imaged at the positions of the left and right eyes 167 and 171, respectively. Again, Figure 40b illustrates operation as a result of movement of the observer in the direction of the arrow 172.

In displays of the type shown in Figures 39a and 39b, light from the light source, and the shutter 163a is transmitted by the beam combiner 185 whereas light from the light source and the shutter 163b is reflected by the beam combiner 185. This can give rise to disturbing colour differences because the reflection and transmission characteristics of the beam combiner 185 may vary in different ways with respect to colour. However, displays of the type shown in Figures 40a and 40b do not exhibit this phenomenon. In particular, by making the beam splitter 186 and the beam combiner 185 substantially identical, the light path through the beam splitter 186, via the mirror 187, and reflected by the beam combiner 185 undergoes one transmission and two reflections whereas light reflected by the beam splitter 186 is reflected by the mirror 188 and transmitted by the beam combiner 185 and therefore also undergoes two reflections and one transmission. Thus, light passing along the two optical paths undergoes the same colour mapping and colour differences are therefore reduced or eliminated.

The illumination sources of the embodiments shown in Figures 35a to 40b may comprise extended light sources associated with shutters, as described, or contiguous arrays of discrete light sources. In either case, these embodiments allow shutters or light source arrays of relatively low spatial resolution to be used in arrangements which provide observer tracking. For instance light sources of the type shown in Figure 1 to 5 having a resolution limited by the size of the fluorescent tubes may nevertheless be used in observer tracking displays.

CLAIMS.

1. A light source comprising a plurality of individually controllable light emitting means and a plurality of optical waveguides, each of which is arranged to receive light from a respective one of the light emitting means, the optical waveguides having light outputs arranged as an array with adjacent light outputs being contiguous with each other, each of the light emitting means comprising at least one light emitter.

2. A light source as claimed in Claim 1, in which the light outputs are arranged as a one or two dimensional array.

3. A light source as claimed in Claim 1 or 2, in which each of the optical waveguides comprises a block of optically transparent material having a cavity containing the respective one of the light emitters.

4. A light source as claimed in Claim 3, in which each of the blocks has a first face constituting the light output and at least one further face, the or each further face being optically internally reflective or optically absorptive.

5. A light source as claimed in Claim 4, in which the or each further face is coated with a reflective layer.

6. A light source as claimed in Claim 4 or 5, in which the first face is optically diffusing.

7. A light source as claimed in any one of Claims 4 to 6, in which each of the blocks is cuboidal and the first faces of the blocks are disposed in a common plane.

8. A light source as claimed in any one of Claims 4 to 6, in which each of the blocks is wedged-shaped and the first faces of the blocks are disposed in a substantially arcuate surface.

9. A light source as claimed in Claim 1 or 2, in which each of the optical waveguides comprises a cavity defined by at least one opaque barrier.

10. A light source as claimed in Claim 9, in which the or each barrier is optically reflective.

11. A light source as claimed in any one of the preceding claims, in which a diffuser is disposed in front of the light outputs.

12. A light source as claimed in any one of the preceding claims, in which the light emitters comprise fluorescent light tubes.

13. A light source as claimed in Claim 12, comprising a heater for maintaining the fluorescent tubes substantially at normal operating temperature.

14. A three dimensional display including a light source as claimed in any one of the preceding claims.

15. A directional display comprising at least one light source, at least one spatial light modulator, and at least one curved reflector arranged to deflect light from the light source through the at least one spatial light modulator and to form an image of the at least one light source at a viewer location.

16. A display as claimed in Claim 15, in which the light source comprises a plurality independently controllable light emitters.

17. A display as claimed in Claim 16, in which the or each light source comprises a light source as claimed in any one of Claims 1 to 13.

18. A display as claimed in any one of Claims 15 to 17, in which the at least one spatial light modulator comprises first and second spatial light modulators, the at least one curved reflector comprises first and second curved reflectors for deflecting light through the first and second spatial light modulators, respectively, and there is provided a beam combiner for combining light from the first and second spatial light modulators.

19. A display as claimed in Claim 18, in which the at least one light source comprises a single light source and a beam splitter for directing light to the first and second curved reflectors from the single light source.

20. A display as claimed in Claim 18, in which the at least one light source comprises first and second light sources for directing light to the first and second curved reflectors, respectively.

21. A display as claimed in any one of Claims 15 to 20, in which the or each curved reflector has a diffractive pattern formed thereon for focusing light from the at least one light source.

22. A directional display comprising first and second display means and an optical combiner for combining light from the first and second display means, each of the first and second display means comprising a spatial light modulator, an extended light source, an array of apertures in which the pitch of the apertures is greater than twice the aperture width, and a parallax screen for controlling the direction of illumination of the spatial light modulator by light from the apertures.

23. A display as claimed in Claim 22, in which the parallax screen comprises an array of lenses.

24. A display as claimed in Claim 22 or 23, in which the pitch of the apertures is greater than three times the aperture width.

25. A display as claimed in Claim 24, in which the pitch of the apertures is substantially equal to four times the aperture width.

26. A display as claimed in any one of Claims 22 to 25, in which the array of apertures is movable with respect to the parallax screen for tracking an observer position.

27. A directional display comprising at least one spatial light modulator arranged to be illuminated via a repetitive optical structure, characterised by means for reducing visibility of Moire fringes.

28. A display as claimed in Claim 27, in which the or each spatial light modulator is spaced from the structure by a distance sufficient for a plurality of elements of the structure to be resolved through each spatial light modulator picture element.

29. A display as claimed in Claim 27, in which the pitch of picture elements of the or each spatial light modulator is substantially different from the pitch of the elements of the structure.

30. A display as claimed in Claim 27, in which the reducing means comprises means for producing relative vibration between the or each spatial light modulator and the structure.

31. A display as claimed in any one of Claims 27 to 30, in which the structure comprises a Fresnel lens.

32. A display as claimed in any one of Claims 27 to 30, in which the structure comprises a lens array.

33. A display as claimed in Claim 33, in which the lens array comprises a lenticular screen.

34. A directional display comprising first and second spatial light modulators for modulating light with first and second image views, respectively, and means for permitting the first and second image views to be visible in first and second directions, respectively, each of the first and second spatial light modulators having a contrast which varies asymmetrically with vertical viewing angle and co-operating with the

permitting means to provide contrasts which vary similarly in the first and second directions with respect to vertical viewing angle.

35. A display as claimed in Claim 34, in which the permitting means comprises a beam combiner for transmitting light from the first spatial light modulator and for reflecting light from the second spatial light modulator, the first and second spatial light modulators are of the same type, and the second spatial light modulator is arranged to present the second image view with an orientation which is inverted with respect to that of the first spatial light modulator.

36. A display for displaying three dimensional images, comprising adapting means for adapting the relative positions of at least one imaging means associated with at least one spatial light modulator and at least one source of illumination so as to dynamically control the position of a first viewing region in which an autostereoscopic three dimensional image is perceptible to a first observer.

37. A display as claimed in Claim 36, in which the or each source of illumination comprises an extended light source and a movable shutter.

38. A display as claimed in Claim 37, in which the movable shutter comprises a further spatial light modulator arranged to provide at least one shutter aperture whose position is responsive to the adapting means.

39. An apparatus comprising a set of features as claimed in any combination of the preceding claims.

Patents Act 1977 **Examiner's report to the Comptroller under Section 17** **(The Search report)**	Application number GB 9421278.4
Relevant Technical Fields (i) UK Cl (Ed.N) G5C (CHX) (ii) Int Cl (Ed.6) G02F 1/1335	Search Examiner MR G M PITCHMAN Date of completion of Search 24 JANUARY 1995
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE: EPODOC WPI JAPIO	Documents considered relevant following a search in respect of Claims :- 1 TO 14

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	EP 0540140 A1	(LITTON) see Figures 8 and 9	1 to 4, 12
X	EP 0491662 A2	(OIS) see Figure 4	1, 12
Y	EP 0316465 A1	(DIMENSION TECHNOLOGIES) see column 6 lines 15 to 41	14
X	US 5057974	(MIZOBE) see column 4 line 3 to column 5 line 2	1 to 7, 12
X	US 4954891	(BURK) see column 4 lines 41 to 66	1, 12
X	US 4948214	(HAMBLES) see column 49 to 55	1

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

The Patent Office

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Application No: GB 9421278.4
Claims searched: 15 to 21

Examiner: Mr.G.M Pitchman
Date of search: 30 August 1995

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.N): G5C(CHA) G2J(JX15) H4F(FCW FDD)

Int Cl (Ed.6): H04N 13/00 13/04

Other: ONLINE: EDOC WPI JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	EP 0372568 (HOSIDEN)-see figures 2 and 3	15
X	US 5121983 (GOLDSTAR)-see figures 1, 3, 4, and 5	15

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
& Member of the same patent family
A Document indicating technological background and/or state of the art.
P Document published on or after the declared priority date but before the filing date of this invention.
E Patent document published on or after, but with priority date earlier than, the filing date of this application.

Application No:	GB 9421278.4	**Examiner:**	Mr.G.M Pitchman
Claims searched:	22 to 26	**Date of search:**	30 August 1995

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.N): G5C(CHA) G2J(JX15) H4F(FCW FDD)

Int Cl (Ed.6): H04N 13/00 13/04

Other: ONLINE: EDOC WPI JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2284487 (SHARP)-see page 9	22
A	GB 2273577 (SHARP)-see page 6	22

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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&	Member of the same patent family		

The Patent Office

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Application No: GB 9421278.4
Claims searched: 27 to 33
Examiner: Mr.G.M Pitchman
Date of search: 30 August 1995

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.N): G5C(CHA) G2J(JX15) H4F(FCW FDD)

Int Cl (Ed.6): H04N 13/00 13/04

Other: ONLINE: EDOC WPI JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
	NONE	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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Application No: GB 9421278.4
Claims searched: 36

Examiner: Mr.G.M Pitchman
Date of search: 30 August 1995

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.N): G5C(CHA) G2J(JX15) H4F(FCW FDD)

Int Cl (Ed.6): H04N 13/00 13/04

Other: ONLINE: EDOC WPI JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB2284487 (SHARP)-abstract	36

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		

Application No: GB 9421278.4
Claims searched: 34 and 35

Examiner: Mr.G.M Pitchman
Date of search: 30 August 1995

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.N): G5C(CHA) G2J(JX15) H4F(FCW FDD)

Int Cl (Ed.6): H04N 13/00 13/04

Other: ONLINE: EDOC WPI JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2273577 (SHARP)-see page 6	34

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		