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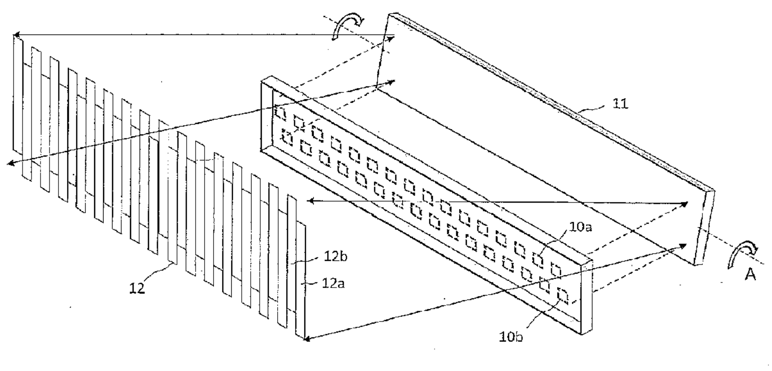

Fig.1

(57) Abstract: A projection display system comprising an array of light emitting diodes comprising at least first and second rows of diodes, the diodes in each row being spaced from each other, the diodes in the second row being offset in a direction parallel to the length of the row relative to the diodes in the first row, a collimator for collimating light emitted from the array of light emitting diodes, a reflector, eg a MEMS minor, arranged to rotate about an axis, the array of light emitting diodes being positioned so that light emitted from the diodes is directed through the collimator and towards the reflector and then reflected to form a display comprising one or more lines of pixels. Imaging optics being provided for receiving the light reflected from the reflector, and positioned so that the reflector (or at least the axis thereof), lies at the focal plane of the imaging optics so as to provide a telecentric arrangement. The display system may be used in a head up display or a helmet mounted display.

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A PROJECTION DISPLAY SYSTEM

FIELD OF THE INVENTION

This invention relates to a projection display system, eg for use in a micro-display or for use in a head up display or head mounted imaging system. The invention also relates to a head up display and head mounted display incorporating such a system.

BACKGROUND ART

Various image projection systems are known which use light emitting diodes (LEDs) as the light source. Some of these systems use a 2D array of LED emitters integrated on a single chip. The individual LED emitters in such an array are separated from each other by electrically isolating boundaries. The LED emitters are thus typically separated by a distance similar to the width of each emitter (eg 5-8 microns) and this limits the display resolution achievable with such arrays. Large area LED arrays are also relatively expensive as the production yield falls as the size of the array increases.

In another arrangement, wavefront correcting micro-mirrors are used to improve the resolution (with one micro-mirror per LED). Such arrangements are however very complex and are difficult to align and assemble (again increasing the cost).
In a further arrangement, single light emitters are used and these are scanned by MEMS micro-mirrors to produce an X-Y matrix for the display. However, in order to provide the required intensity, the single light source is usually a laser diode. The use of these raises eye safety issues. They also tend to suffer from laser speckle.

The present invention seeks to provide a projection display system which overcomes or reduces such problems and is relatively simple and inexpensive to manufacture. The invention also seeks to provide a projection display system with improved resolution.
Some of the features of the present invention are also described in co-pending application No GB1122404.5.

SUMMARY OF THE INVENTION

According to a first aspect of the invention, there is provided a projection display system comprising an array of light emitting diodes comprising at least first and second rows of diodes, the diodes in each row being spaced from each other, the diodes in the second row being offset in a direction parallel to the length of the row relative to the diodes in the first row, a collimator for collimating light emitted from the array of light emitting diodes, a reflector mounted for movement about an axis, and movement means for moving said reflector about said axis, the array of light emitting diodes being positioned such that light emitted therefrom is directed through the collimator and towards the reflector and reflected therefrom to form a display comprising one or more lines of pixels, and imaging optics for receiving the light reflected from the reflector, the imaging optics being positioned so that the reflector, or at least said axis thereof, lies at the focal plane of the imaging optics so as to provide a telecentric arrangement.

It should be noted that the term 'spacing' as used herein refers to the distance between pixels relative to their size rather than the absolute size of the spacing (which will vary according to the magnification of the image compared to the size of the array of light emitting diodes).
The term 'display' as used herein includes an image formed by scanning light over one or more lines, eg in the form of a raster scan, and other arrangements in which light is directed onto an object in one or more lines as if an image was being formed thereon.
According to another aspect of the invention, there is provided a head up display (HUD) comprising a projection display system as detailed above.

According to a further aspect of the invention there is provided a helmet mounted display (HMD) comprising a projection display system as detailed above.
Preferred and optional features of the invention will be apparent from the following description and from the subsidiary claims of the specification.

BRIEF DESCRIPTION OF THE DRAWINGS

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

Figure 1 is a schematic diagram showing a perspective view showing part of a first embodiment of a display system according to the invention using a single LED array;

Figure 2a is a schematic diagram of a square LED emitter array used in Fig 1;

Figure 2b is a schematic diagram illustrating an illumination pattern produced by scanning of the square LED emitter array shown in Fig 2a;

Figure 2c is a schematic diagram of a square LED emitter array having three rows of LED emitters;

Figure 3 is a schematic optical diagram showing the main components of a projection display system according to a first aspect of the invention;

Figure 4 is a schematic diagram similar to Fig 3 but also showing an output lens;

Figure 5 is a schematic diagram from the output lens to an observation plane;

Figure 6 is a schematic diagram similar to Fig 4 illustrating a potential problem if the arrangement is not telecentric; and

Figure 7 is a schematic diagram illustrating a preferred arrangement for enlarging the display provided.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Figure 1 shows a rectangular LED array 10 comprising first and second linear rows of LED emitters formed in a single monolithic chip. Each LED emitter in the array is individually addressable. Other features of the embodiment shown in Fig 1 are described below with reference to Figs 3 to 7 below.

Figure 2a shows a plan view of the LED array 10 with the LED emitters in each row being spaced from each other by a distance D_1 (between adjacent edges of the LEDs), the diodes in the second row being offset from those in the first row in a direction parallel to the length of the rows. Preferably, the distance D_1 corresponds to the width of the diodes and the offset is also by a distance D_1 so that the LED array comprises a two row chequer board pattern of LEDs (as shown in Figures 1 and 2). The first and second row are spaced from each other by a distance D_2 (D_1 and D_2 may be substantially the same, as shown in the Figures).

As shown in Fig 1, light from the LED array 10 is directed towards a rectangular oscillating or rotating reflector 11, such as a micro-electro-mechanical system (MEMS) mirror.

Movement means (not shown) are provided so the reflector 11 is arranged to oscillate or rotate about an axis A parallel to the length of the reflector 11 and parallel to the length of the LED array 10. Oscillation means (not shown) in the form of electrostatic or magnetic devices (as commonly used in the art for MEMS scanning mirror devices) may be provided to oscillate the reflector 11, eg by resonant vibration, controlled by an electronic control system (not shown), eg providing a square wave or sinusoidal wave pulsed voltage which to controls the scanning movement of the reflector by maintaining the resonant vibration of the mirror. In another arrangement, the motion of the reflector may be controlled by a different periodic oscillating waveform, for example a linear saw tooth voltage waveform.

In another arrangement, the reflector may be rotated continuously about an axis of a shaft of a miniaturised galvanometric motor (rather than oscillatory rotation in opposite directions as described above). In this case, the reflector may be multi-faceted, eg having a hexagonal or octagonal cross-section (perpendicular to the axis of rotation), so a series of reflective surfaces are used to reflect the light as the reflector is rotated about the axis.

Figure 1 illustrates a display 12 formed by light reflected from the oscillating reflector 11 after passing through other optics described below. The reflector is arranged to scan through an angle sufficient to scan the light reflected therefrom from the top to the bottom of the image 12 to be formed. Thus, as shown in Fig 1, light from LED emitter 10a in the first row of the LED array is scanned up and down the band or column 12a of the image formed. Similarly, light from LED 10b in the second row of the LED array is scanned up and down the band or column 12b of the image formed. The same applies to light from each of the other LED emitters in the array 10. Each of the LED emitters is operated in pulsed mode by the electronic control system referred to above and the timing of each pulse is arranged so that the LED is on (ie emitting light) as the reflected light therefrom passes though each line (or row) of the image to be formed (the lines extending across the width of the image and thus being perpendicular to the columns shown in Figs 1 and 2). Thus, if the image to be formed is made up of 500 lines, each LED is switched on 500 times as the reflected light therefrom is scanned from the top to the bottom of the image 12.

Pixels of the image are thus, in effect, formed at the intersection of the lines and columns in the arrangement shown in Fig 1, all of the pixels in a given column being illuminated by a single LED emitter of the LED array 10.

If scanning of the reflector 11 is controlled by a sinusoidal signal so its speed of rotation varies as it is moved, the timing and/or length of pulses from each LED emitter are controlled to ensure that the LED is on as the reflected light therefrom passes through the respective lines of the image. Preferably, the arrangement is such that the LED pulse timings compensate for the non linear scanning across visible parts of the image, so that the intensity of the illumination pulses of the LEDs across the scanned display can be substantially uniform.

The LED emitters and the oscillation or rotation means are operated so that light from the first row and light from the second row of the LED array 10 is combined in each line of the display 12. Thus, in the arrangement shown, the pixels of each line of the display are alternately formed from light from the first and second rows of the LED array 10. As indicated above, this is achieved by operating the LED array in pulsed mode and synchronising the pulsed period to the scan frequency of the oscillation or rotation of the reflector such that light from two rows of the LED array is combined to form a single line of the display with minimal flicker.

By this means, the resolution of the display 12 can be increased relative to the LED array 10. The inter-pixel separation (relative to the size of the pixels) of the display 12 (along the lines of the image) is a fraction of that (D_1) of the LED emitters in the LED array 10 (and may be zero). The resolution in the direction perpendicular to the lines (ie in the scanning direction) is determined by the illumination pulses of the LEDs, and particularly the rise and fall times of the LEDs as they are turned on and off. LED emitters with rise times of ~10ns are readily available and this is sufficient to provide a spacing (relative the size of the pixels) between lines of the image less than the spacing (D_2) between rows of the LED array 10. It will be appreciated that the absolute size of the spacing between pixels may be larger if the display is magnified relative to the size of the LED array.

The resolution can be further improved in the scanning direction by using additional grey scale variation, ie controlling the rise and fall times of the output of each LED emitter - the limits to resolution achievable being determined by the rise and fall times of the LED turn-on and turn-off characteristics.

In the optimal case, the resolution of the display (in both directions) is limited only by the size of the LED emitters themselves. Preferably, these have a width of 10 microns or less. In the example shown, as the spacing between LED emitters in the LED array corresponds to the width of the LED emitters, adjacent pixels in the display abut one another along the length of each row of the display. The spacing between lines of the display is determined by the movement of the reflector and the timing of the pulses emitted by the LEDs and, in a preferred arrangement, the spacing is zero so pixels in adjacent rows also abut each other. It will be appreciated that other arrangements are possible; the pixels in each row of the display need not abut each other but their spacing is preferably less than the spacing (D_1) of the LEDs in each row of the LED array so as to improve the resolution of the display. Figure 2c shows another form of LED array 13 having three rows of emitters in which the third row is offset by a distance (D_3) which is half of the offset distance (D_1) between the first and second rows of emitters. This results in light from emitters in the third row overlapping with light from emitters in the first and second rows of the LED array in the non-scanned direction (along the lines of the display) and with appropriate pulsing of the emitters the eye then perceives a pixel size smaller than the size of the emitters. This has the advantage of providing a display having a pixel size in the non-scanned direction (ie along the lines of the display) which is half that of the emitter elements themselves. The emitter size does not therefore necessarily determine the pixel size in the non-scanned direction of the display. Other arrangements can be used having a plurality of rows of LED emitters such that the relative pixel size (along the lines of the display) is less than half of the size of the emitters themselves in the non-scanning direction.

In other arrangements the elements of the emitting array may have other shapes, eg they may have a diamond shape, eg so their sides lie at 45 degrees to the length of the row but spaced from each other by a distance (D_1) (between corners of adjacent LED emitters along the length of the row). The spacing D2 between the first and second rows of the diamond shaped emitters may be zero.

In a further embodiment (not shown) of the invention, the LED emitters may be hexagonal in shape. The LEDs may also have other shapes.

The MEMS micro-mirror 11 in the embodiment of Figure 1 may, for example, comprise a rectangular silicon-based MEMS device which is electrostatically or magnetically actuated. The mirror shape may alternatively be ellipsoidal, or the mirror may have some other shape which is able to reflect light from all the LEDs in the LED array.

The MEMs mirror 11 is preferably as large as possible so it can reflect light from large linear LED arrays. For example, an array of 384 emitters could be defined by two rows of 192 stepped emitters, each row being approximately 8 mm long. For this arrangement a MEMS mirror having a length of around 1.2 cm is appropriate to allow for the beam divergence between the LED array and the mirror.

Further key features of the invention described herein will now be described. The first feature is that light emitted from the LED array 10 is collimated before being reflected by the mirror 11 and the second feature is that the mirror 11 (or at least the axis A thereof) is placed at the focal plane of imaging optics that are positioned to received light reflected by the mirror 11. This ensures that the beam remains parallel to axis of the imaging optics and so provides a telecentric arrangement. This will be described further below with reference to Figures 3 -7.

Figure 3 shows light passing from an LED array 20, through a collimation lens L1 to a mirror 21 (the rotational axis A of which is perpendicular to the plane of the paper). Figure 3 shows two beams B1, B2 of light (representing two different angular positions of the mirror about axis A) directed towards imaging optics, in this case an imaging lens L2, which forms an intermediate image 14 as shown.

Figure 4 shows a similar arrangement to Fig 3 but also shows an output lens L5 and Figure 5 show the beams as they reach the eye of an observer at an observation plane 15. As mentioned above, it is important that the mirror axis A is located at the focal plane of the imaging lens L2 as this ensures that the intermediate image is telecentric. This means that as the mirror 21 is scanned about axis A, the beams leaving imaging lens L2 remain directed towards the output lens. If the lens L2 is not correctly positioned, the beams from different scan positions will diverge, as illustrated in Fig 6, and by the time they reach the observation plane 15, light at the extremes of the two beams will have diverged beyond the viewing area of the observer's eye.

Another desirable feature is that light reflected by the mirror 11 fills the imaging optics L2 (which is effectively the viewing area of the display to be formed, eg 100mm x 150mm in a HUD). In the arrangement shown in Fig 6, it can be seen that the output lens L2 is only partially filled by light from the beams B1 and B2. This is dictated by the size of the mirror 21: in order to fill of the imaging optics, the mirror 21 must be sufficiently large. However, design constraints mean that is more difficult to increase the mirror width than the length (ie the dimension parallel to the axis A). This can, however, be resolved by the use a cylindrical telescope, to make the mirror appear wider than it is (although this means that the mirror must scan over a larger angle to achieve the same apparent beam deflection). It would also be possible to use a spherical telescope if it is desired to enlarge the mirror in two dimensions but if the length of the mirror is not a problem, a cylindrical telescope is sufficient (and simplifies the optic required).

Figure 7 illustrates a preferred way of providing such a telescope using two convex lenses L3 and L4. This arrangement allows the image formed by lens L4 also to be telecentric. With a conventional form of telescope comprising a concave lens followed by a convex lens (which is the most compact way of producing such a telescope), it is likely to be much more difficult to provide a telecentric arrangement, eg due to the finite thicknesses of the lenses.

As shown in Fig 7, the convex lens L3 is used to collimate the beams passing therethrough and the concave lens L4 then acts to magnify these (in one or two dimensions depending whether it is a cylindrical or spherical lens). As the beams passing between the convex and concave lenses L3 and L4 are collimated, the spacing between these lenses can be adjusted to provide the telecentric arrangement mentioned above without affecting the magnification provided by the telescope. Figure 7 does not show the output lens L5 but it can be seen that the telescope (lenses L3 and L4) widens the beam. The lens separation has also been arranged so that the exiting beams are also both parallel to the optic axis.

The size of the mirror will depend on the application and the size of the viewing area required but it might typically have a length in the range 12 to 17 mm and a width in the range 4 to 8 mm. A typical mirror might, for example have a length of 17mm and a width of 8 mm. By using a cylindrical telescope have a magnification factor of x2, an apparent mirror size, and hence the display size (taking into account the angle of the mirror), of 17 mm long and approximately 12 mm wide can be provided.

It is important to note that the collimation lens L1 between the LED array 20 and mirror 21 is used to image the LED array onto the mirror. The collimation lens L1 is designed to collect sufficient light from the LED array 20 and this is enabled by the mirror 21 being of a substantially similar size to the LED array (or larger).

A mirror having a width of a few mm has a high resonant frequency and this provides some immunity from the vibration spectrum of heavy machinery and vehicles (which is typically in the low 100's of Hz). The mirror may operate in the kHz range if the width is as described above.

In a preferred arrangement, the MEMS mirror 11 would be designed to enable scanning between 100Hz and 10kHz. Preferably, the scan frequency would be in the range 500Hz-2kHz. It is desirable for the scan frequency to be as low as possible to simplify the high speed electronics that drive the LED array.

The lowest possible operating frequency for MEMS mirror and rotating micro-motor structures is commonly higher than 100Hz. For reflector structures with dimensions required for the present invention, stable resonant frequencies typically lie between 1kHz and 20kHz. This is due to the requirement for stable and reliable operation and the subsequent need to minimise coupling of energy into other vibrational modes. For cases where the resonant frequencies are far higher than the response of the eye, there is the advantage of a high modulation bandwidth of the display signal resulting in a high dynamic range as each pixel will be written to many times within the response time of the eye.

Preferably, the mirror scan angle would be in the range 5-30 degrees.

The lenses referred to above may each comprise one or more optical components and in some cases an array of lenses may be used or a diffractive lens (such as a Fresnel lens).

In many applications (such as automotive or construction vehicles), the display to be provided may be in the form of icons or dials, eg for indicating speed, engine temperature, or a graphic showing fill of excavator bucket. These need not be part of the same image so there is no requirement to electronically stitch such images together. Therefore instead of using one large output lens (which impacts on cost and optical quality, as well as size and weight) several smaller lenses can be used. This also allows the effective image area to be of an aspect ratio not normally associated with approximately circularly symmetric optics, such as for example a letterbox shape or a tall column to one side of the driver's main vision.

Due to limitations of integrated circuits used to drive the LED display if a conventional driver chip is used, a wide grey scale dynamic range may not be possible to achieve. Such drivers supports only binary on/off operation for each pixel period so it will be necessary to use field sequential luminance modulation.

With a mirror is oscillating at 500 Hz, there are two scans per cycle and, with a flicker free display frame refresh rate of 100 Hz, this provides ten fields per frame and thus provides a 10:1 luminance dynamic range.

The minimum frame rate for flicker free display is 50 Hz so, in theory, a 20:1 range is possible. However, if the display is for use in hostile environments subject to high levels of vibration, 100 Hz is preferred. A typical arrangement might, for example use 4 bits per pixel for grey scale providing a 16:1 dynamic range which yields a frame refresh rate of 62.5 Hz.

It will be appreciated that it is necessary to determine the position of the mirror as it is rotated about axis A in order to synchronise the display data generation to enable a stable image to be provided.

One way of doing this is to use a photo-detector at one end of the mirror scan field positioned such that it detects the light reflected from the mirror during the scan direction transition period (where no useful image can be generated) and to encode the light pulses to support measurement of scan velocity. Thus, if constant width drive pulses are applied to the LEDs, the detected pulses will increase in frequency up to a maximum when the mirror is stationary and then reduce again as the mirror accelerates in the opposite direction. This feedback is then used to adjust the mirror drive to maintain stable oscillation and to synchronise the display data generator.

The resolution of this method is determined by the speeds of both the LED output pulses and the detector response time. Ideally, the detector will utilise light from the LED array and would need to be shielded from ambient light (although synchronising the detection period with the LED drive pulses will provide some noise immunity). Alternatively, an infra-red (IR) source could be used.

A head up display (HUD) may be used with QVGA (Quarter Video Graphics Array) type resolution to display graphics rather than images, but may also have to accept a diversity of video inputs. This can be achieved by a low cost method of video scaling. For example, with a video input having twice as many pixels in both horizontal and vertical resolution, a simple way of scaling this for a HUD would be to add the four together and take the average. This can be achieved with relatively low cost electronics which are compatible with the low cost drivers of the HUD.

The embodiments described above are for a monochrome display. A full colour display may be provided by using three primary colour LED arrays (red, green and blue), a spectral beam combiner and a single MEMS reflector arranged so as to produce a single multi-colour display. In this arrangement, each LED array would have its own collimator lens and the collimated beams would be combined before being passed to the MEMS reflector.

The examples given above combine light from one or more two-row arrays of LEDs but it would also be possible to combine light from more rows, eg three or four rows, in order to increase the brightness of the displays. In this case, there would be higher brightness areas in regions where light from separate emitters is overlapping. It will be appreciated that LED arrays with only a small number of rows have the advantage of being much smaller than the arrays used in the prior art (in which the number of rows corresponds to the number of lines of pixels making up the display). They are much thus easier and hence less expensive to produce and enable the system to be more compact. And as conventional incoherent LEDs are used (as opposed to laser diodes), there are no eye safety issues.

The reflector is only required to oscillate or rotate about one axis so is also relatively simple (compared to reflectors that oscillate about two or more axes) and are thus also more suitable for use in environments prone to shock and vibration.

In the embodiments described, at least two linear rows of LEDs are scanned by a reflector oscillating or rotating about a single axis to produce a 2D display and the LEDs in the linear rows are stepped such that the pixel density in the scanned display is higher than that of the light source. The size of the LEDs used may typically vary from state of the art emitter sizes of around 10um, up to a more common sizes of 20um or more.

A projection display system such as that described above can be used in a variety of applications., eg in a head up display (HUD) on a window (such as a vehicle windscreen). The imaging optics may be designed such that the display image is projected onto a window, such as a windscreen, without distortion (eg as described in GB2458898). The windscreen or window acts as a reflective optical combiner which combines the projected display with the image of distant objects. In another embodiment, the imaging optics may include multiple optical imaging elements. The image is focussed by the imaging optics such that the focal point is at a virtual image plane more than 2m from the observer's eye so that the display information can be visible while observing distant objects without any perceived need to refocus eyes. In another embodiment, a spherical mirror can be used to image the display instead of such imaging optics.

Another application of the projection display system is for projection in a head-mounted display. This may include a helmet mounted display (HMD) or a near to eye (NTE) display. In this case, the display image is projected onto a helmet visor, optical combiner or the lens surface of a pair of glasses. As in the previous example, the light from the display is imaged by the imaging optics so that it is projected to a point further than 2m from the eye so that it will lie within the same focal plane as distant objects.

In other applications, two such arrangements may be used to project a stereoscopic image for both eyes.

A further embodiment of the invention which uses sinusoidally resonating mirrors may use a retarding or diverging optical element to project a more uniform illumination density across the scanned display without requiring a reduction in optical power from the LED array during non-linear portions of the scan and resulting in a higher display brightness.
As indicated, the projection display system described herein can be used in a wide range of applications including head up displays, head mounted displays, digital printing systems and any other arrangement requiring an optical image or a light signal to be imaged or scanned over a given area or object.

It will also be appreciated that the lines of a display need not necessarily be written in sequence from one side of the display to the other. For example, in the case of a display to be viewed by the eye, the lines can be written in any order such that the eye perceives the desired image. In the case of a printed image, or other arrangement in which a given area is to be exposed to light, the lines may be written in any order such that all of the desired area is exposed as required.

The display may be formed on an object or form a virtual image and the object may be stationary relative to the array of LEDs or may be moving relative thereto.
Embodiments of the invention may also use arrays of LEDs emitting at a variety of wavelengths (depending upon the application) including non-visible wavelengths, such as ultra-violet, infrared and microwave (and combinations thereof) as well as visible wavelengths. Where required, additional apparatus may then be provided for converting an

image to one capable of being seen by the human eye, eg as used in known night vision apparatus.

It will of course be understood that many variations may be made to the above-described embodiment without departing from the scope of the present invention.

CLAIMS

1. A projection display system comprising an array of light emitting diodes comprising at least first and second rows of diodes, the diodes in each row being spaced from each other, the diodes in the second row being offset in a direction parallel to the length of the row relative to the diodes in the first row, a collimator for collimating light emitted from the array of light emitting diodes, a reflector mounted for movement about an axis, and movement means for moving said reflector about said axis, the array of light emitting diodes being positioned such that light emitted therefrom is directed through the collimator and towards the reflector and reflected therefrom to form a display comprising one or more lines of pixels, and imaging optics for receiving the light reflected from the reflector, the imaging optics being positioned so that the reflector, or at least said axis thereof, lies at the focal plane of the imaging optics so as to provide a telecentric arrangement.

2. A display system as claimed in claim 1 comprising control means for operating the diodes in a pulsed mode as the light therefrom is scanned across the display by the reflector.

3. A display system as claimed in claim 1 or 2 in which the movement means is arranged such that light from said first row of diodes and light from said second row of diodes is used to form each line of the display so the spacing between pixels along each line of the display is reduced compared to the spacing of the diodes in the rows of the array.

4. A display system as claimed in claim 2 in which the timing of pulses of light from the diodes determines the spacing between pixels of the display in a direction perpendicular to the lines of the display such that said spacing is reduced compared to the spacing between the first and second rows of diodes in the array.

5. A display system as claimed in claim 1, 2 or 3 in which the reflector is a micro-electro-mechanical system (MEMs) scanning mirror.

6. A display system as claimed in any preceding claim in which the reflector is of a size such that light from substantially all the light emitting diodes in the array is incident upon the reflector.

7. A display system as claimed in claim 6 in which the reflector is as large as or larger than the LED array.

8. A display system as claimed in any preceding claim in which the mirror is magnified in one direction by a telescope of cylindrical lenses so that it appears wider than it is so as to provide a larger viewing area.

9. A display system as claimed in claim 8 in which the cylindrical telescope comprises a pair of convex lenses.

10. A display system as claimed in any preceding claim in which the reflector is arranged to be rotated by a rotating motor shaft.

11. A display system as claimed in any preceding claim having two or more arrays of light emitting diodes, each comprising at least first and second rows of diodes and optical combining means for combining the light from the two or more arrays prior to or as the light is directed to said reflector.

12. A display system as claimed in claim 11 in having three arrays of light emitting diodes arranged to provide light of three different colours so as to provide a multi-colour display.

13. A display system as claimed in claim 12 having three arrays of light emitting diodes emitting red, green and blue light respectively.

14. A display system as claimed in claim 11 in which the diodes of the respective arrays emit white or multi-wavelength light and wavelength selector means are provided to direct a selected wavelength from each of the arrays to the reflector.

15. A display system as claimed in any preceding claim in which the collimator comprises a collimating lens or an array of collimating lenses arranged to collimate light emitted from the array of light emitting diodes.

16. A display system as claimed in any preceding claim in which the array of light emitting diodes is formed as an integrated device.

17. A display system as claimed in any preceding claim in which the spacing between the diodes in each row is substantially similar to the width of each diode.

18. A display system as claimed in any preceding claim in which the offset between diodes in the first and second rows is substantially similar to the width of each diode.

19. A display system as claimed in any preceding claim in which each diode has a width of 20 microns or less.

20. A display as claimed in any preceding claim having one or more output lenses for receiving light from the imaging optics, each output lens being arranged to form part of a display.

21. A display system as claimed in any preceding claim arranged to use field sequential luminance modulation to provide grey scale modulation of the display.

22. A display system as claimed in any preceding claim having a photo-detector for detecting light reflected from the reflector during a scan direction transition period and arranged to determine the position of the mirror therefrom.

23. A display system substantially as hereinbefore described with reference to and/or as shown in one or more of the accompanying drawings.

24. A head up display comprising a projection display system as claimed in any preceding claim.

25. A head up display as claimed in claim 24 arranged to form a virtual image on a vehicle window.

26. A helmet mounted display comprising a projection display system as claimed in any of claims 1 – 23.

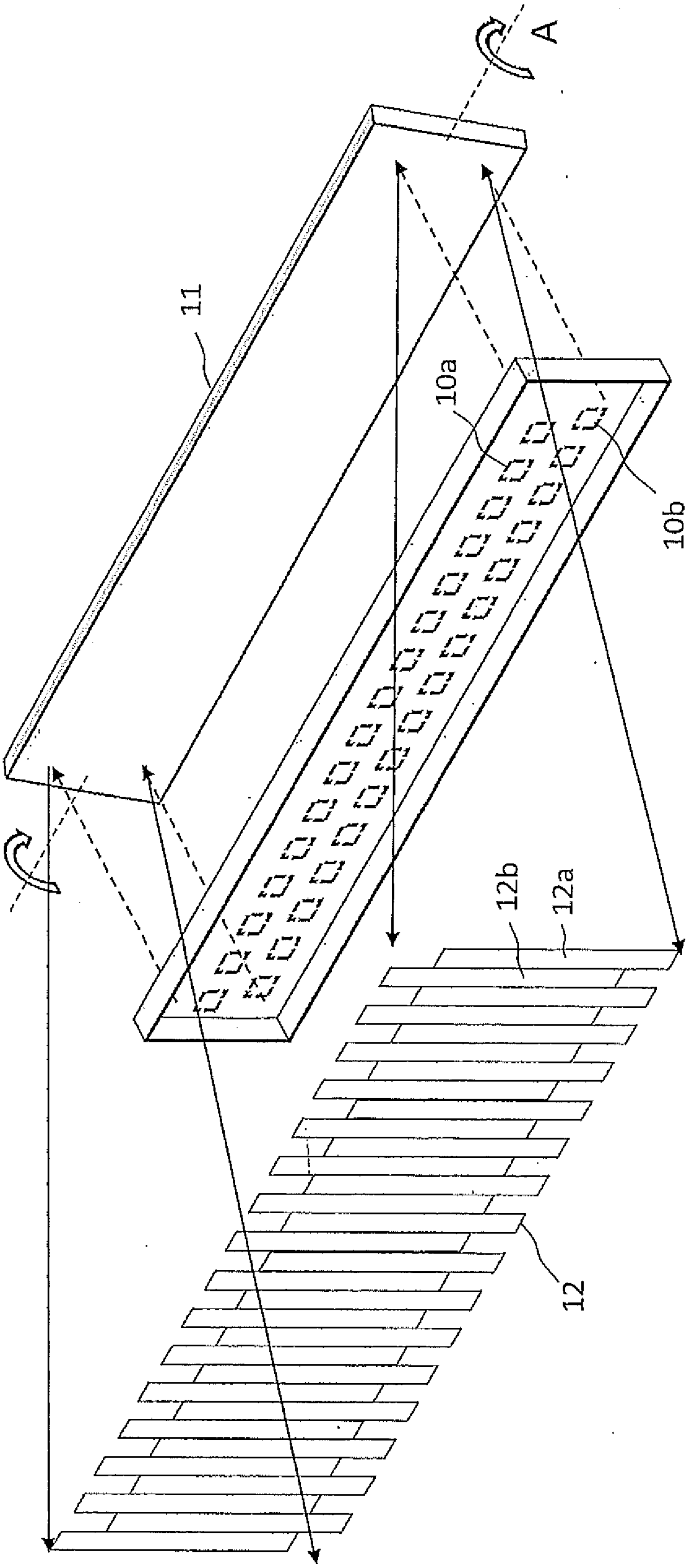

Fig.1

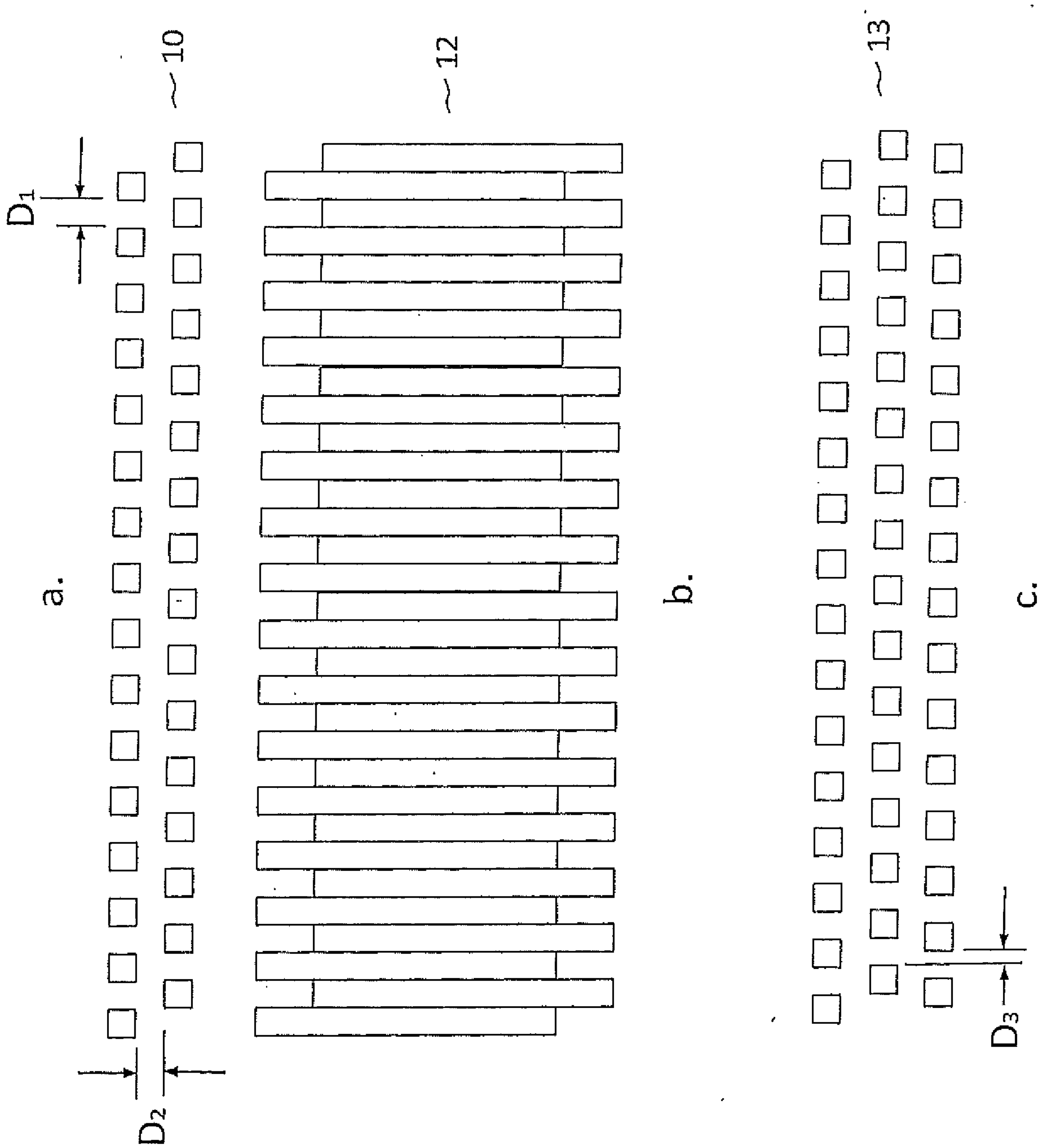

Fig.2

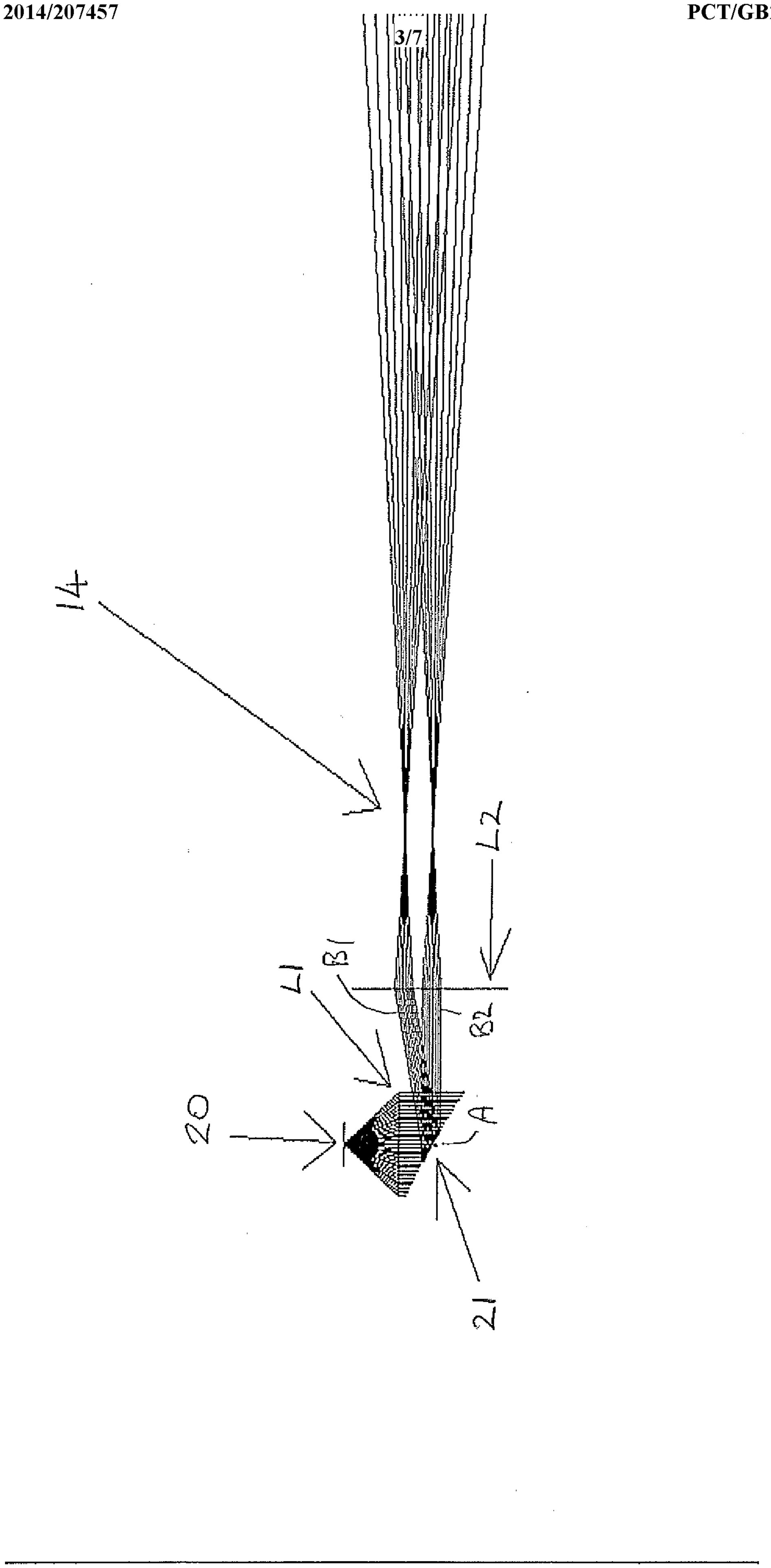

Fig. 3

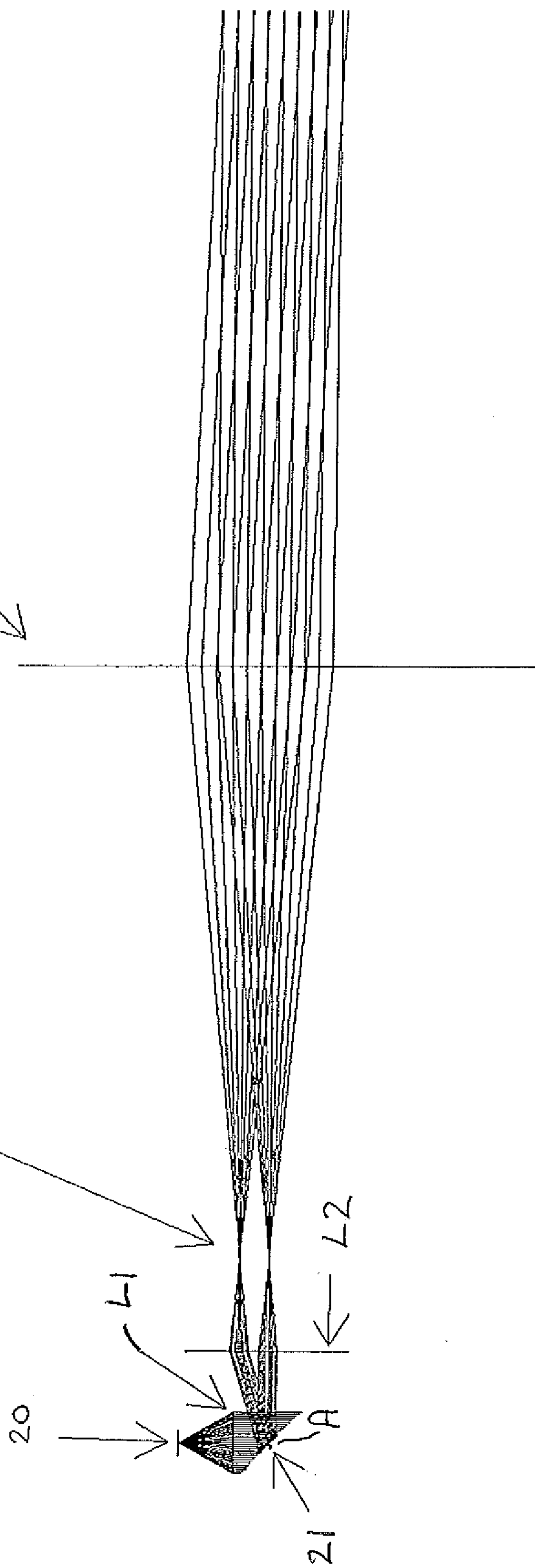

Fig. 4

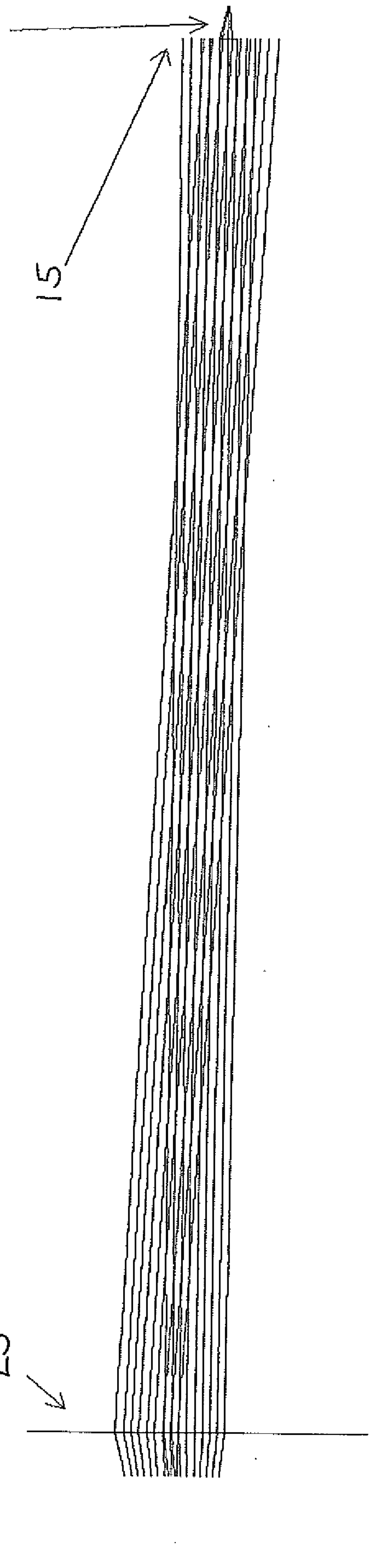

Fig. 5

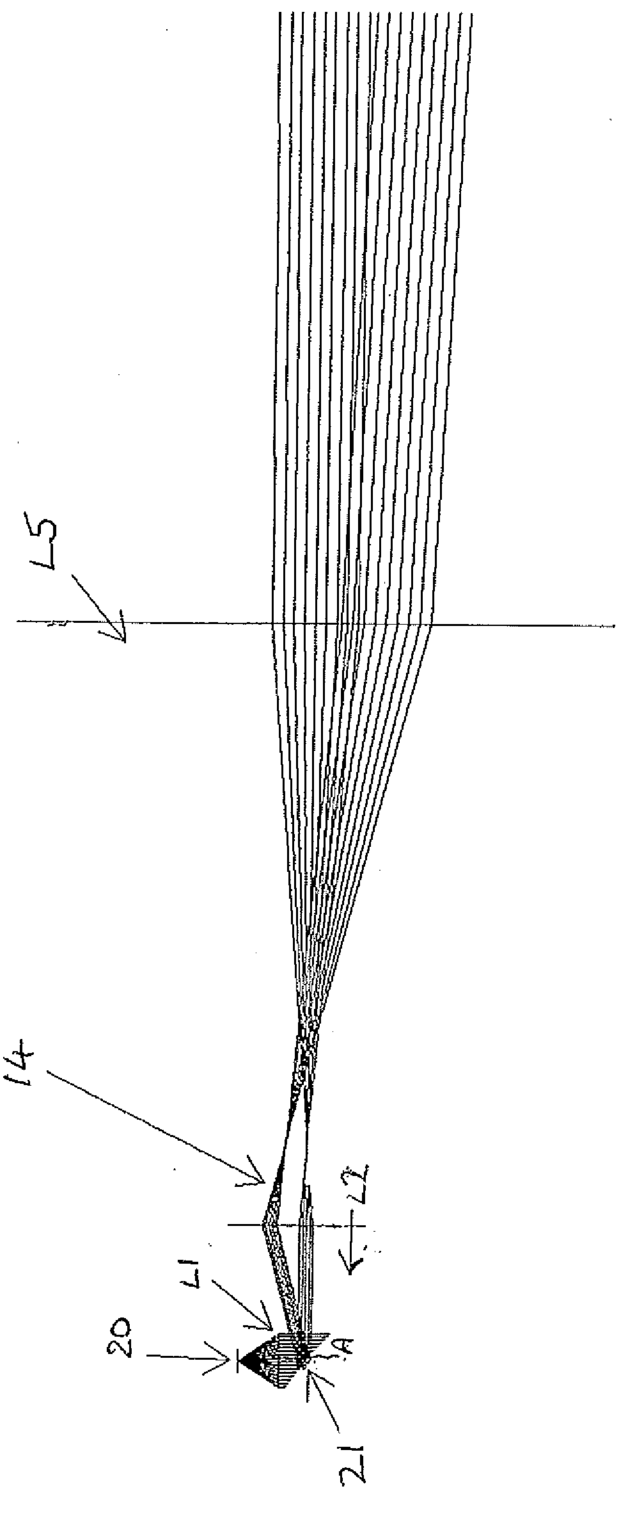

Fig. 6

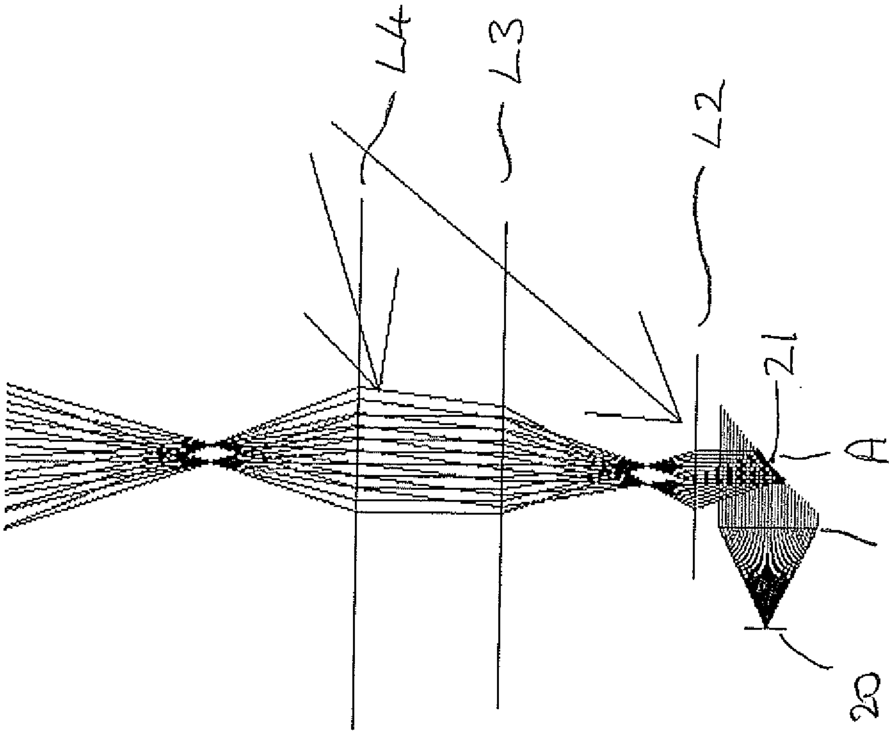

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2014/051935

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B26/10 G02B27/01
ADD.

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)
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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2006/007058 A1 (YAMAMOTO AKIRA [JP] ET AL) 12 January 2006 (2006-01-12) figures 1-11 paragraph [0062] - paragraph [0074] -----	1-22, 24-26
Y A	US 5 612 708 A (ANSLEY DAVID A [US] ET AL) 18 March 1997 (1997-03-18) figures 1-4 column 2 - column 4 -----	1-22, 24-26 23
A	US 2004/057138 A1 (TANIJIRI YASUSHI [JP] ET AL) 25 March 2004 (2004-03-25) paragraph [0088] -----	21
A	US 2002/196377 A1 (FURUKAWA YUKIO [JP] ET AL) 26 December 2002 (2002-12-26) the whole document ----- -/--	1

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search

23 September 2014

Date of mailing of the international search report

01/10/2014

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Beutter, Matthias

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011/211242 A1 (NAKAMURA AKIRA [JP]) 1 September 2011 (2011-09-01) the whole document -----	1
A	US 5 982 553 A (BLOOM DAVID M [US] ET AL) 9 November 1999 (1999-11-09) the whole document -----	1

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2014/051935

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2006007058 A1	12-01-2006	JP 4681825 B2	11-05-2011
		JP 2005351990 A	22-12-2005
		US 2006007058 A1	12-01-2006
US 5612708 A	18-03-1997	CA 2149565 A1	18-12-1995
		EP 0687933 A2	20-12-1995
		IL 113758 A	30-10-1998
		JP 2650878 B2	10-09-1997
		JP H08171072 A	02-07-1996
		US 5612708 A	18-03-1997
US 2004057138 A1	25-03-2004	JP 3994896 B2	24-10-2007
		JP 2004163858 A	10-06-2004
		US 2004057138 A1	25-03-2004
		US 2006274440 A1	07-12-2006
US 2002196377 A1	26-12-2002	JP 4174195 B2	29-10-2008
		JP 2002350757 A	04-12-2002
		US 2002196377 A1	26-12-2002
		US 2006044297 A1	02-03-2006
US 2011211242 A1	01-09-2011	EP 2172800 A1	07-04-2010
		JP 2009037172 A	19-02-2009
		KR 20100066444 A	17-06-2010
		TW 200918942 A	01-05-2009
		US 2011211242 A1	01-09-2011
		WO 2009019934 A1	12-02-2009
US 5982553 A	09-11-1999	AU 6569098 A	12-10-1998
		CN 1251178 A	19-04-2000
		DE 69803656 D1	14-03-2002
		DE 69803656 T2	13-06-2002
		DK 0968453 T3	25-03-2002
		EP 0968453 A1	05-01-2000
		JP 3489841 B2	26-01-2004
		JP 2000513114 A	03-10-2000
		NO 994515 A	17-09-1999
		US 5982553 A	09-11-1999
		WO 9841893 A1	24-09-1998