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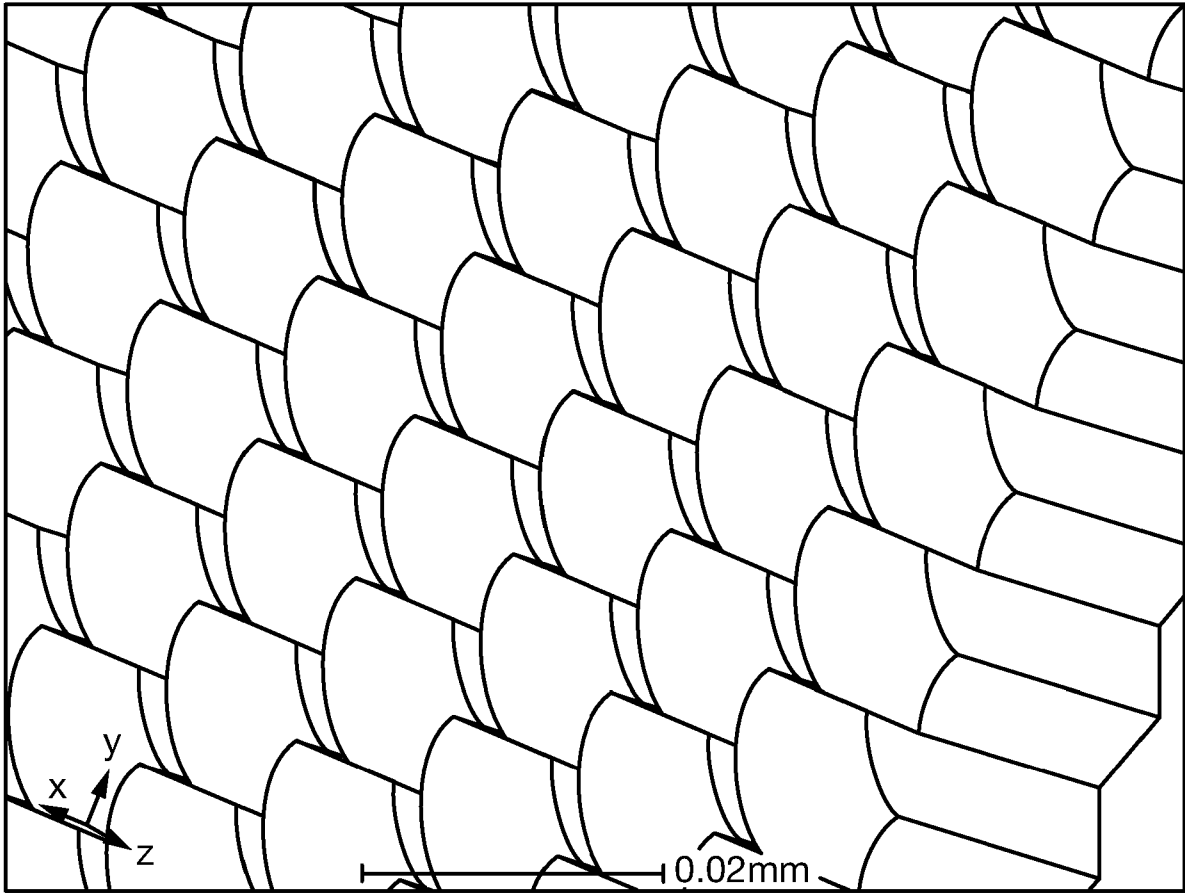   updated as appropriate

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GB 2553559 B

Fig. 1

Fig. 2
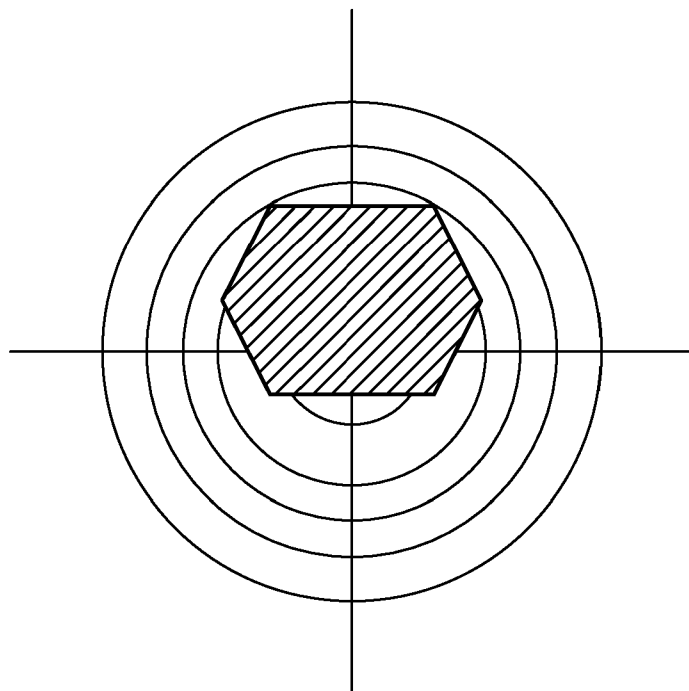
07 12 17

Fig. 3

Fig. 4

07 12 17

0.02mm

z
y
x

Fig. 5
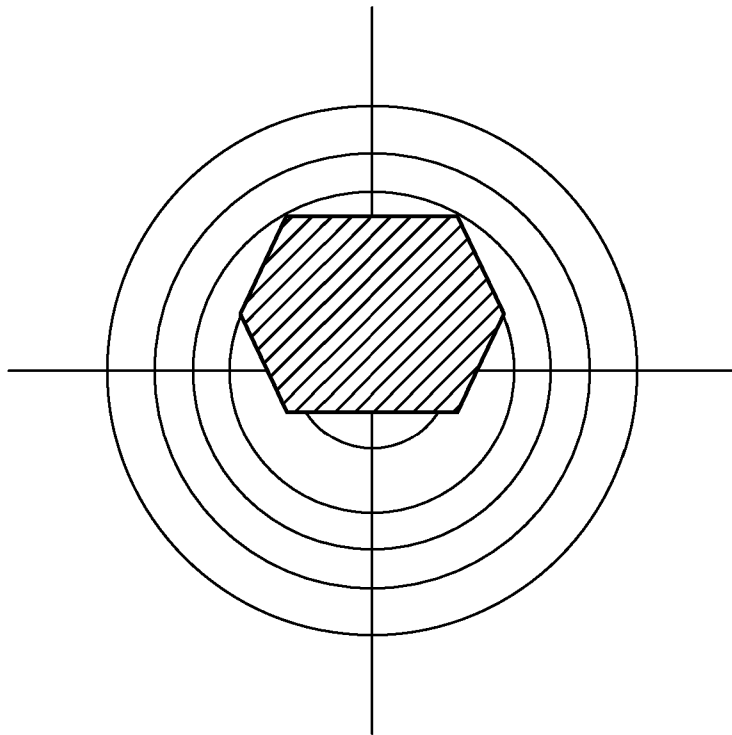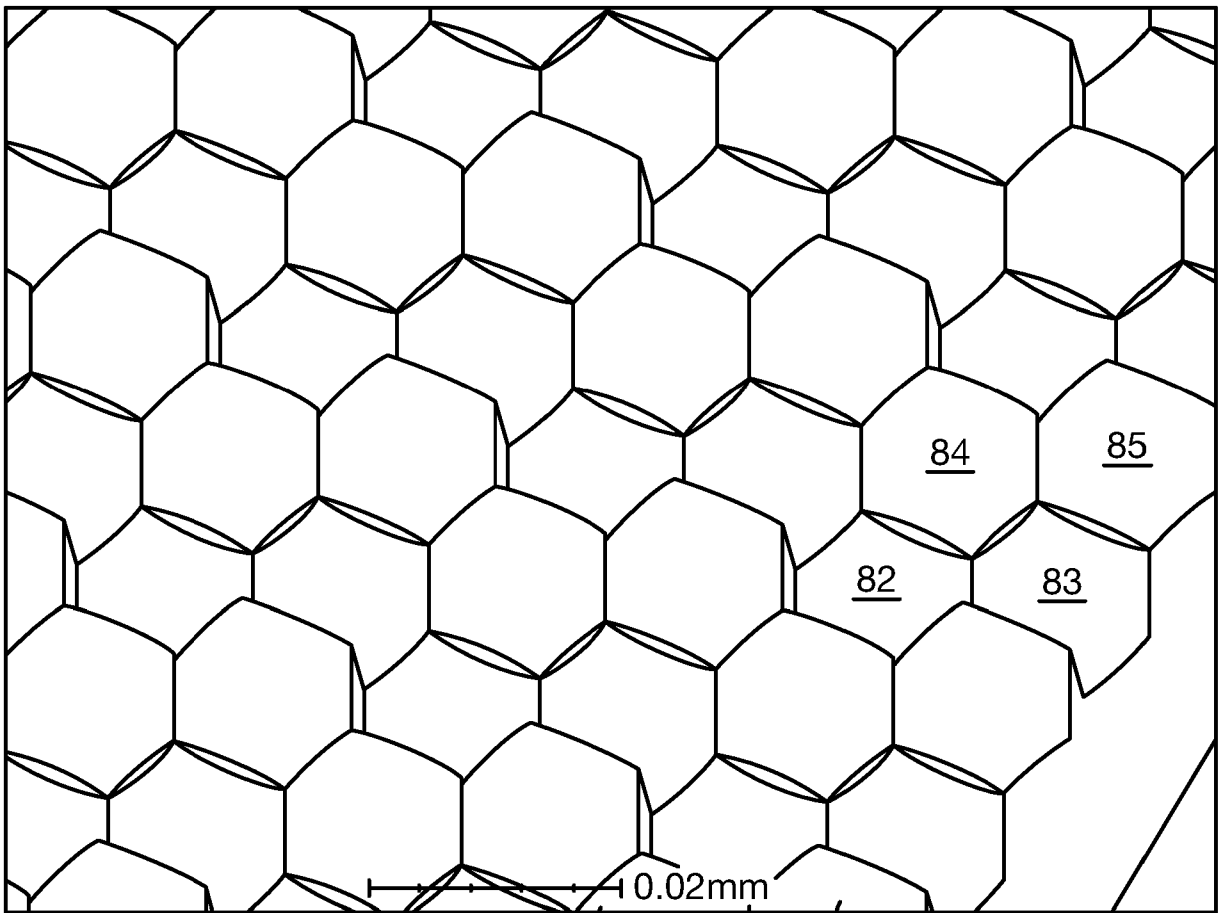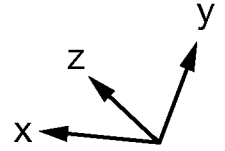

y
x

Fig. 6

60   61

07 12 17

Fig. 7

Fig. 8

0.02mm

80

81
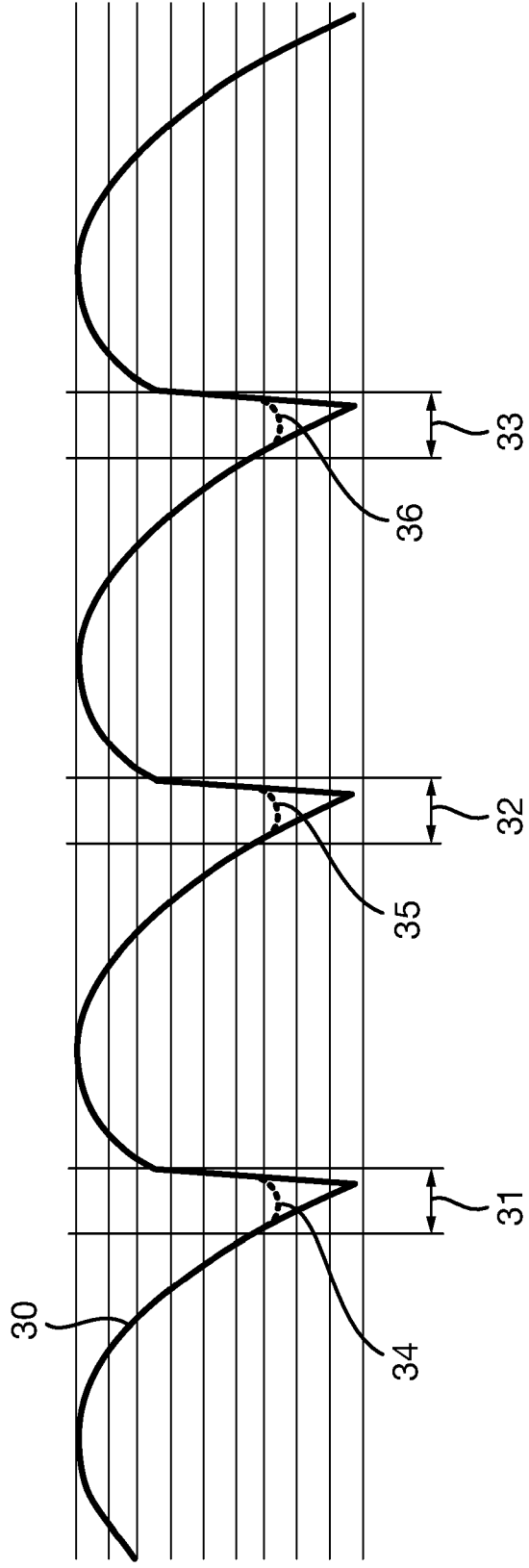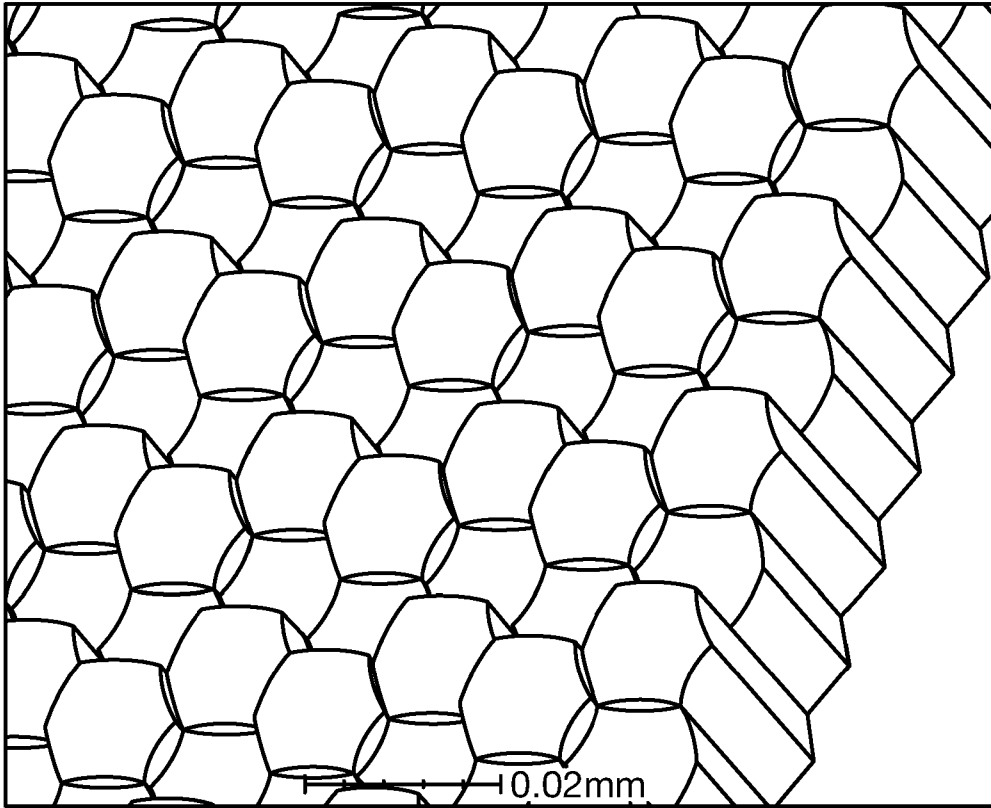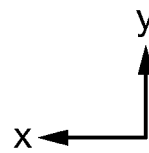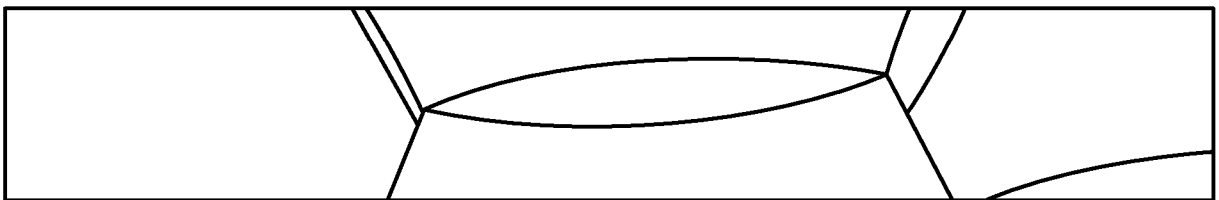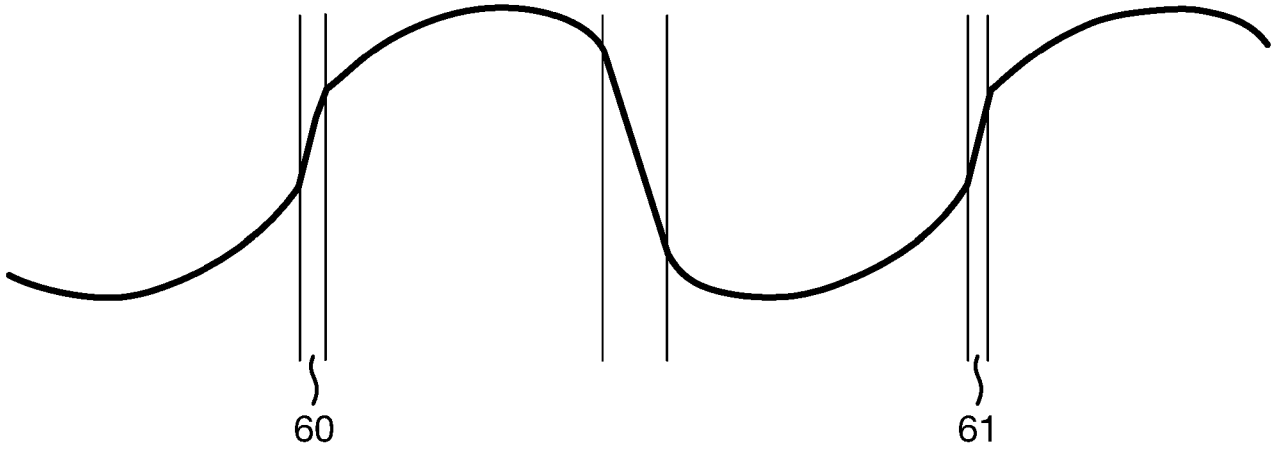
84   85

82   83

DIFFUSERS FOR HEAD UP DISPLAYS

This disclosure relates to optical systems for the projection of light into a head up display.

Head up displays utilise a transparent component, which the user looks through, to overlay an image on the user's actual view of the surroundings. The user's eye receives light from those surroundings in the normal way, and the user's eye also receives light from the head up display system. An image from the head up display is thus overlaid on the actual surroundings.

The transparent component of a head up display (HUD) may be either mounted in a fixed position on equipment being used by a user (for example the cockpit of an aircraft), or on the head of the user (for example as a pair of spectacles, or on a helmet) such that the component moves with the user's head and thus remains at a fixed location in relation to the user's eye.

A fundamental requirement of a HUD is to couple light from an image source to the location required for viewing by the user, known as the output pupil. This is typically achieved using a waveguide system. Conventional HUDs utilise a Cathode Ray Tube (CRT) as an image source. The CRT output is coupled into the HUD optics for guidance to the required output pupil.

CRT displays utilise phosphor light sources which emit a narrow spectrum of light into a near-hemispherical output field. However, CRT displays are becoming outdated and are no longer the preferred choice of light source for HUDs. LEDs are a preferable choice of light source, but their optical output has significantly different properties to CRT displays. Firstly, the optical spectrum is broader than a CRT, and secondly the output is more directional than a CRT output.

HUD optical systems are often optimised for a narrow optical bandwidth, particularly where diffractive optics are utilised to guide light and expand the image. The broader spectrum of LEDs can lead to a degradation of image quality, leading to a need for the light to be filtered to reduce the optical bandwidth prior to transmission through the HUD optics. However, this filtering

reduces the optical intensity, thereby reducing the brightness that can be achieved by the HUD, which may lead to inferior system performance. The optical attenuation of the overall optical system must therefore be optimised to avoid further degradation in performance.

5   There is therefore a requirement for an efficient system to couple image light into the HUD optics.

The embodiments described below are not limited to implementations which solve any or all of the disadvantages of known systems.

10 SUMMARY

This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining
15   the scope of the claimed subject matter.

There is provided a microlens array for use in a head up display, the microlens array comprising a plurality of microlenses arranged in an array and forming a contiguous structure, wherein a first face of the microlens array comprises a plurality of microlens surfaces arranged in a regular pattern, each
20   microlens surface corresponding to a microlens in the array of microlenses; and wherein the microlens surfaces alternate between concave and convex along at least one dimension of the array, and wherein each microlens is decentred parallel to the dimension in which the microlens surfaces alternate between concave and convex.

25   The array may be a 1 dimensional array.

The array may be a 2 dimensional array.

Each microlens surface may be hexagonal, rectangular, or square in plan view.

The surface height of the centre of each microlens may be different to the surface height of the centre of an adjacent microlens of the same type, such that the surface height difference at the joint between the two lenses is reduced compared to if the surface height at the centre of the microlenses was the same.

The disclosure provided here may provide waveguides which are smaller and lighter than other waveguide designs, but which do not produce stray light paths.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will be described, by way of example, with reference to the following drawings, in which:

Figure 1 shows a decentred microlens array;

Figure 2 shows a plot of angular output for the array of Figure 1;

Figure 3 shows a surface of the array of Figure 1;

Figure 4 shows a decentred microlens array with alternating microlens types;

Figure 5 shows a magnification of part of Figure 4;

Figure 6 shows a surface of the array of Figure 4;

Figure 7 shows a plot of angular output for the array of Figure 4; and

Figure 8 shows a decentred microlens array with alternating microlens types.

DETAILED DESCRIPTION

Further details, aspects and embodiments of the invention will now be described, by way of example only, with reference to the drawings. Elements in the figures are illustrated for simplicity and clarity and have not necessarily been

drawn to scale. Like reference numerals have been included in the respective drawings to ease understanding.

As discussed above, LED image sources typically have a more directional output than a CRT source. To improve coupling of this image source into HUD optics, which may be optimised for a CRT source, a diffuser screen may be utilised between the image source and HUD optics. Such a diffuser screen may be formed by a microlens array, as shown in Figure 1. The array of Figure 1 comprises a set of hexagonal shaped microlenses packed into an array. Each microlens has a convex shape and is decentred. The microlenses are plano-convex such that the opposite face of the array to that seen in Figure 1 is planar. That face is aligned at the focal plane of the image projector.

Figure 2 shows the angular output from the array of Figure 1. The angular output is hexagonal in shape (due to each microlens being hexagonal) and off-centre (provided by the decentred microlenses) which gives an efficient coupling into HUD optics.

Figure 3 shows the surface profile of a cross-section through the microlens array of Figure 1. The solid line 30 indicates the designed profile of the surface. Due to the decentration of the microlenses a sharp intersection occurs in regions 31, 32, 33 between microlenses. However, fabrication techniques cannot reproduce such a sharp, narrow, shape and there is a minimum radius of curvature of the surface, as shown by dashed lines 34, 35, 36.

Due to the errors in surface profile in the regions 34, 35, 36 light propagating through the microlens surface in those regions will not be directed as intended by the optical design and will thus not be directed into the desired output angular range. The light passing through these regions is therefore lost, thus reducing the efficiency of the optical system. Even with perfect reproduction of the design shape, there are still losses in this region due to the need to transition the surface between the different surface heights of the two adjacent microlenses.

Figure 4 shows a microlens array which addresses the difficulties of fabricating the sharp direction changes in the microlens array of Figure 1. The microlens array of Figure 4 uses alternating convex and concave microlenses in the y axis, with each microlens decentred along that of the array.

The use of alternating microlens types provides a reduction in the surface discontinuities at the edges of the microlenses. Figure 5 shows an enlarged view of the edge region between a concave and convex microlens, which shows a much a smaller step between those microlenses compared to the previous design.

Figure 6 shows the surface profile of a cross-section through the microlens array of Figure 4 corresponding to the cross-section shown in Figure 3. Compared to Figure 3 the surface profile is much smoother and points of inflection are removed. The manufactured microlens array can thus match the design profile more accurately. Furthermore, two of the lossy regions 60, 61 are reduced in size due to the proximity of the microlens surface heights in those regions leading to a reduced transition area. The loss in those regions is therefore expected to decrease compared to the microlens array of Figure 1. The lossy region 62 may be wider than that of Figure 3, but it is expected that the reduction in size of the other regions will have a greater effect than this increase.

In an example array each microlens may have a diameter of 10 – 15μm. The diameter of the microlenses is selected to provide appropriate optical performance; in particular as a trade-off between a larger diameter which gives reduced losses at the joints between microlenses but may lead to visibility of the microlenses by the user, and a smaller diameter which gives increases losses but potentially improves image quality. When a DMD or other electromechanical imaging device is set up to display a line which is 2 pixels wide, there are preferably at least 5 microlenses across the width of that line.

The microlens array of Figure 4 can be described as a set of microlenses arranged in a regular repeating two dimensional array. The surface of each microlens is decentred in a first dimension of the array, and the microlens

surfaces alternate between concave and convex in that first dimension. The example of Figure 4 uses hexagonal microlenses, but the same principles apply to other shapes, such as square or rectangular. Where different shaped microlenses are utilised the angular output will match the microlens shape.

5   The microlenses of the array form a contiguous structure in which the optical axes of the microlenses are parallel to one another.

Figure 7 shows a chart of the angular output profile of the microlens array of Figure 3, which is a good match for the angular profile of the all-convex design of Figure 1. Due to the improvement in manufacturing tolerance to the design profile, the efficiency of the microlens array of Figure 3 is expected to be significantly improved.

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Figure 8 shows a schematic diagram of a further microlens array. The microlens array of Figure 8 is similar to that of Figure 4, but the surface heights of the microlenses are adjusted to reduce the difference in surface heights at the borders between adjacent microlenses. In particular, the surface height at the centre of each microlens is different to the surface height at the centre of an adjacent microlens of the same type (concave or convex). Expressed differently, the height of the microlenses forming the second column 80 in the y-direction have been lowered relative to the first column 81, such that the edges of adjacent lenses of the same type (for example 82, 83 and 84, 85) are aligned. This adjustment of heights reduces discontinuities between microlenses in many of the borders, thus reducing losses. The adjustment is continued across the array, such that the centres of microlenses in the first, third, fifth, etc columns are higher than microlenses of the same type in the second, fourth, sixth etc columns.

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The microlens arrays described hereinbefore may be formed as a single piece of material with appropriate shaping of the surfaces, or could be formed from a set of individual microlenses joined together.

The arrays shown above are 2 dimensional arrays but the same principles may be applied to 1 dimensional arrays.

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Although the present invention has been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present invention is limited only by the accompanying claims. Additionally, although a feature may appear to be described in connection with particular embodiments, one skilled in the art would recognize that various features of the described embodiments may be combined in accordance with the invention. In the claims, the term 'comprising' does not exclude the presence of other elements or steps.

Furthermore, the order of features in the claims does not imply any specific order in which the features must be performed and in particular the order of individual steps in a method claim does not imply that the steps must be performed in this order. Rather, the steps may be performed in any suitable order. In addition, singular references do not exclude a plurality. Thus, references to 'a', 'an', 'first', 'second', etc. do not preclude a plurality. In the claims, the term 'comprising' or "including" does not exclude the presence of other elements.

CLAIMS

1.   A microlens array for use in a head up display, the microlens array comprising

5   a plurality of microlenses arranged in an array and forming a contiguous structure, wherein

a first face of the microlens array comprises a plurality of microlens surfaces arranged in a regular pattern, each microlens surface corresponding to a microlens in the array of microlenses; and wherein

10   the microlens surfaces alternate between concave and convex along at least one dimension of the array,

wherein each microlens is decentred parallel to the dimension in which the microlens surfaces alternate between concave and convex.

15   2.   A microlens array according to claim 1, wherein the array is a 1 dimensional array.

3.   A microlens array according to claim 1, wherein the array is a 2 dimensional array.

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4.   A microlens array according to any preceding claim, wherein each microlens surface is hexagonal, rectangular, or square in plan view.

5.   A microlens array according to any preceding claim, where the surface
25   height of the centre of each microlens is different to the surface height of the centre of an adjacent microlens of the same type, such that the surface height difference at the joint between the two lenses is reduced compared to if the

surface height at the centre of the microlenses was the same.

6.   A head up display (HUD) comprising a microlens array according to any of claims 1 to 5.

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7.   A head up display according to claim 6 further comprising an LED image source.

8.   A head up display according to claim 6 or claim 7 further comprising a

10   diffuser screen, formed by the microlens array.

9.   A head up display according to claim 8 when dependent on claim 8, further comprising HUD optics, wherein the diffuser screen is utilised between the LED image source and the HUD optics.