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(71) Applicant: **TRULIFE OPTICS LIMITED** [GB/GB]; Fittingshop Building, 79 Trinity Buoy Wharf, London E14 0FR (GB).

(72) Inventor: **VOLKOV, Andrii**; Fittingshop Building, 79 Trinity Buoy Wharf, London E14 0FR (GB).

(74) Agent: **CRAWFORD, Andrew**; TRULIFE OPTICS LIMITED, Fittingshop Building, 79 Trinity Buoy Wharf, London E14 0FR (GB).

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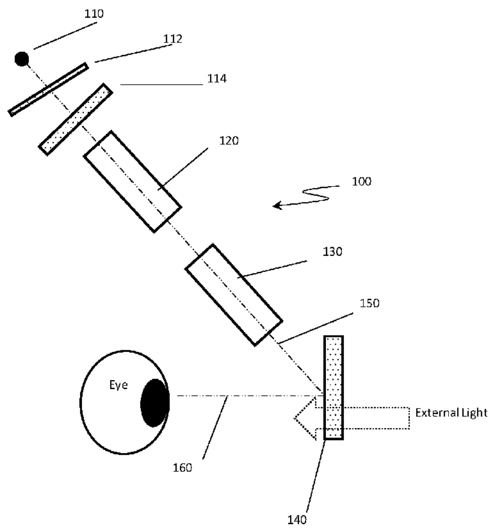


Fig. 1

(57) **Abstract:** The present disclosure relates to an illumination optics system for a wearable AR display system, the illumination optics comprising: a spatial light modulator and a plurality of illumination sources; wherein the illumination sources are arranged to illuminate the spatial light modulator, the spatial light modulator is arranged to modulate light from the illumination sources; and wherein light from each of the plurality of illumination sources is mutually incoherent. The disclosure also relates to a wearable augmented reality display comprising the illumination optics system.

WO 2024/256445 A1

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# ILLUMINATION OPTICS SYSTEM

## FIELD OF THE DISCLOSURE

The present disclosure relates to an illumination optics system for a wearable augmented reality display. The present disclosure also relates to a wearable augmented reality display, and in particular such a display comprising an optical combiner and more particularly a diffractive optical combiner.

## BACKGROUND OF THE DISCLOSURE

Figure 1 is a generalised view of an augmented reality display to superimpose an image from a projector or image source onto a real-world view at for example the eye of a user. The off-axis optical system 100 of Figure 1 generally comprises: a light source or image source 110 with associated beam shaping optics 120; imaging optics 130; and an optical combiner 140. Broadly speaking the combination of the light source 110, beam shaping optics 120 and the imaging optics 130 are termed a projector and when in use provide the image to be viewed at the eye of the user. The function of the optical combiner 140 is to direct light from the projector to a user’s eye while also allowing ambient external environmental light from a real-world view to pass through the optical combiner 140 to the user’s eye such that images from the projector are superimposed on the real-world view. An example of an optical combiner 140 is a holographic optical element (HOE). The HOE directs light from the light source 110 and to a pupil plane of the optical system, which would then be visible by a user’s eye. Whilst not illustrated in Figure 1, a spatial light modulator may be provided between the light source 110 and the optical combiner 140 to modulate light from the light source 110 to provide moving images via the optical combiner 140 to the user’s eye.

An optical combiner 140 has at least two independent optical axes 150, 160 as shown in Figure 1, where the first optical axis 150 is that from the projector to the optical combiner 140 and the second optical axis 160 is that from the optical combiner 140 to the user's eye/pupil plane. Such a system is therefore known as an off-axis optical system. When used in applications such as head-mounted display systems or augmented reality display systems, optical combiner 140 of the type described above are known to advantageously provide high transparency, good efficiency, that is, bright images at low light power and be compatible with ophthalmic glasses lens prescriptions and encapsulation into such lenses.

In addition, a spatial light modulator 112 is typically used as to modulate the light from the light source 110 to create dynamic images. Typically, a diffuser is used to create multiple light rays to illuminate individual pixels of the spatial light modulator 112 across the area of the spatial light modulator. Problematically, where the light source is a coherent light source, light illuminates the diffuser and produces speckle interference due to the diffuser generating multiple rays at each pixel position on the diffuser. The speckle will then propagate through the system and be visible as an unwanted speckle pattern to the user.

A problem with optical combiners 140 and in particular diffractive type optical combiners such as holographic optical elements, surface relief gratings and so on, is the wavelength dependence of diffraction. Therefore, for broadband image sources such as LEDs, the image will be diffracted from the optical combiner to different positions for each component wavelength of the image source light. For example, longer wavelengths will be diffracted from the optical combiner at greater angles than shorter wavelengths. This problem is known as dispersion and results in chromatic aberrations in the image diffracted from the optical combiner. Furthermore, off-axis diffractive systems split different wavelength light rays significantly more than on-axis systems due to the wavelength dependence of diffraction. This effect increases as the deviation of the light by the optical combiners 140 from its diffracted direction increases. Therefore, chromatic dispersion is significantly increased for off-axis systems.

A known solution to the problem of dispersion is to use a very narrow bandwidth image source. One known such narrow bandwidth image source is a laser diode. Laser diodes are advantageous for wearable augmented reality display applications due to their small size and relatively low power consumption. However, it is also known that the narrower the bandwidth of a light source the greater the temporal coherence of the light source, in that if a light source is ideally monochromatic it will ideally have infinite coherence length. One problem with this solution is that where the light source contains two or more such sources (narrow band image sources, such as lasers with a long coherence length) of the same wavelength interference will occur when the narrow bandwidth light sources, such as laser diodes, illuminate a target. For an augmented reality display of the type shown in Figure 1 this interference would propagate through the system to the user eye, where the interference pattern would be visible to the user and degrade the visible image from image source.

## SUMMARY OF INVENTION

It is therefore and object of the embodiments disclosed herein to avoid or mitigate one or more of the disadvantages discussed above.

Against this background, there is provided an illumination optics system for a wearable AR display system and a wearable AR display comprising such an illumination optics system in accordance with the claims. Other preferred and optional features are defined in the other claims and discussed throughout this disclosure.

## BRIEF DESCRIPTION OF THE DRAWINGS

So that the features of the present disclosure can be understood in detail, a more particular description is made with reference to embodiments, some of which are illustrated in the appended figures. It is to be noted, however, that the appended figures illustrate only typical embodiments and are therefore not to be considered limiting of its scope. The figures are for facilitating an understanding of the disclosure and thus are not necessarily drawn to scale. It should be noted that the features as illustrated in the figures have been exaggerated for illustration purposes and no dimensions (unless stated in the text or drawings) should be inferred. Advantages of the embodiments will become apparent to those skilled in the art upon reading this description in conjunction with the accompanying figures, in which like reference numerals have been used to designate like elements, and in which:

Figure 1 shows a generalised arrangement of a known off-axis optical system comprising illumination optics and an optical combiner;

Figure 2 illustrates the illumination optics system according to embodiments and an optical combiner for a wearable augmented reality display;

Figure 3 illustrates the illumination optics system according to embodiments and an optical combiner for a wearable augmented reality display;

Figure 4 illustrates a wearable AR system in the form of a pair of AR glasses comprising the illumination optics system according to embodiments; and

Figures 5a and 5b illustrate the concept of eyebox expansion by increasing eye positions.

## DETAILED DESCRIPTION

Figure 2 illustrates the illumination optics 201 according to embodiments. The illumination optics 201 comprises a plurality of illumination sources 202a, 202b, 202c and a spatial light modulator 204. To aid understanding of the operation of the illumination optics 201 a diffractive optical combiner 206 is also shown illustrating convergence of light rays from the illumination optics 201 to a user's eye 210. Each of the illumination sources 202a, 202b, 202c is disposed to respectively form corresponding eye positions or images of the illumination sources (also known as exit pupils of the illumination sources) 208a, 208b, 208c which are images of the illumination sources 202a, 202b, 202c visible to the user's eye 210 when the combiner 206 is positioned within the field of view of the user's eye. In the context of wearable AR displays optical combiner is used to direct image light from the illumination sources to the user's eye 210.

In the present embodiment the plurality of illumination sources 202a, 202b, 202c may be narrow band light sources. In the context of the present application narrow band lights sources have full width half maximum (FWHM) of no greater than approximately 3.0 nm. The FWHM of an illumination source is the output optical spectrum width, that is the width of the optical power spectral density of the light output in terms of wavelength. The FWHM is measured between the points on the optical spectrum where the power has decayed to one half of its peak value. For example, in wearable AR display applications, the illumination sources 202a, 202b, 202c may be laser diodes which have a FWHM, $\Delta\lambda$ of between approximately 0.1 nm and 3.0 nm. Such laser diodes may have a coherence length of between approximately 0.20 nm and 1.50 nm. Also, laser diodes are advantageous due to their relatively low power consumption, hight power output (compared to LEDs), which allow for relatively brighter images such that image content can be view in daylight conditions. The illumination sources may be configured to operate in the visible spectrum range of 380 nm to 700 nm.

It is not possible to use wide band light sources (that is greater than approximately 3.0 nm), such as LEDs, due to the problem of dispersion effects mentioned above. However high power narrow band LEDs, such as super luminescent diodes (SLEDs) may be used provided that they have a FWHM of no higher than approximately 3.0 nm.

In the present example, the illumination sources 202a, 202b, 202c operate at the same light output wavelength λ. Advantageously, the light output from each of the plurality illumination sources 202a, 202b, 202c are mutually incoherent which reduces the effect of interference between the two or more of the illumination sources 202a, 202b, 202c because light from the illumination sources 202a, 202b, 202c incident on the spatial light modulator 204 will be incoherent at the viewer’s retina. In the context of the present disclosure the skilled person will appreciate that the specific number of illumination sources must be greater than two. Therefore, adjacent illumination sources 202a, 202b, 202c includes any number of light sources that contribute to the viewers perception of images from those light sources, defined below as the eye-box. Illumination sources which are not visible to the user in the eyebox do not need to incoherent.

The illumination sources 202a, 202b, 202c may be single-mode lasers, where a single mode laser is one which provides light output with a bell shaped far field distribution and only one peak. For single mode lasers, the light output can be reshaped to better match the shape of the spatial light modulator 204 (for example square top hat profile). However, the use of multimode lasers will cause multi peak illumination profiles bringing about non-uniformity of the illumination of the spatial light modulator. Multi-mode lasers are also known to produce unwanted patterns or speckle.

The spatial light modulator 204 is dynamic controllable device which can modulate the phase and/or amplitude of incident light from the illumination sources 202a, 202b, 202c. The spatial light modulator 204 modulates light emitted by the illumination sources 202a, 202b, 202c to generate image content at the eye positions 208a, 208b, 208c. The spatial light modulator 204 is controlled by a suitable control processor (not illustrated) to generate image content at eye positions 208a, 208b, 208c. Whilst the spatial light modulator 204 illustrated is a transmissive type, the skilled person will also appreciate the spatial light modulator 204 may be a reflective type without departing from the scope of the present disclosure. In the case of a reflective type, the illumination sources 202a, 202b, 202c would be provided on the same side of the spatial light modulator 204 as illumination sources 202a, 202b, 202c.

Where the images of the illumination sources 202a, 202b, 202c are visible from a wide range of eye positions an optical system is said to have a large eyebox. In the present case, the size of the eyebox size is dependent on the number of illumination sources 202a, 202b, 202c used, where more illumination sources creates more eye positions and therefore a larger eyebox, so in this way the skilled person will recognise that the eyebox in the present application is a combination of the each of the eye positions 208a, 208b, 208c providing a range of continuous eye positions over which images from each of the illumination sources is visible. This concept is discussed in more detail below with reference to Figures 5a and 5b. Whilst the present example shows three illumination sources 202a, 202b, 202c in a 1D linear array, any number of illumination sources 202a, 202b, 202c may be provided in a linear array. Similarly, illumination sources 202a, 202b, 202c may be provided as a 2D rectangular array, or any appropriate shape dependent on the requirements of the wearable AR display system. Adjacent eye positions 208a, 208b, 208c may be discrete and separated from each other as illustrated or they may adjoin each other. Alternatively, adjacent eye positions 208a, 208b, 208c may overlap. Increasing the separation of the eye positions 208a, 208b, 208c will correspondingly increase the field of view, whereas decreasing the separation of the eye positions 208a, 208b, 208c will correspondingly decease the field of view. One advantage of illumination sources 202a, 202b, 202c arranged as a 1D linear array is that it is possible to incorporate or fold the illumination optics into a small volume such that it can be incorporated into a wearable AR display systems such as AR glasses (discussed below with reference to Figure 4) where space is limited, for example the arms of glasses have a flattened cross-section conformal to the human head.

Figure 3 illustrates illumination optics 301 according to a further embodiment. The illumination optics 301 comprises a plurality of illumination sources 314a, 314b, 314c and a spatial light modulator 304. To aid understanding of the operation of the illumination optics 301 a diffractive optical combiner 306 is also shown illustrating convergence of light rays from the illumination optics 301 to a user's eye 310. Each of the illumination sources 314a, 314b, 314c is disposed to respectively form corresponding eye positions (or exit pupils) 308a, 308b, 308c which are images of the illumination sources 314a, 314b, 314c visible to the user's eye 310, when the optical combiner 306 is positioned within the field of view of the user's eye.

In the arrangement of Figure 3, the plurality of illumination sources 314a, 314b, 314c are the outputs of respective light guiding elements 312a, 312b, 312c. The inputs of the light guiding elements 312a, 312b, 312c are optically coupled, by any suitable light guiding elements in-coupler (not illustrated) to a common light source 302. The length of each of the light guiding elements 312a, 312b, 312c is different which provides a different optical path length (the distance from the output of the light guiding elements 312a, 312b, 312c to the spatial light modulator) for light from the common light source 302 propagating along each optical fibre to the output of each of the light guiding elements 312a, 312b, 312c. This difference in optical path length introduced by the light guiding elements 312a, 312b, 312c results in light output at each of the plurality outputs of the light guiding elements 312a, 312b, 312c will be mutually incoherent, and which reduces the effect of interference between the two or more of the illumination sources 314a, 314b, 314c. The common light source 302 may be a single mode laser diode. In the context of the present disclosure the skilled person will appreciate that the specific number of illumination sources must be greater than two. Therefore, adjacent illumination sources 314a, 314b, 314c includes any number of light sources that contribute to the viewers perception of images from those light sources, defined below as the eye-box. Illumination sources which are not visible to the user in the eyebox do not need to incoherent.

The light guiding elements 312a, 312b, 312c may be any single mode structures and may be any suitable refractive index distribution, that is step or graded index. The skilled person will appreciate that the light guiding elements 312a, 312b, 312c any optical waveguide structure, such as an optical fibre, slab waveguide, planar waveguide, strip waveguide, rib waveguide or laser-inscribed waveguide which operates using total internal reflection that guides electromagnetic waves in the optical spectrum will be suitable, provided that the output of each optical waveguide structure is mutually temporally incoherent. The optical waveguide may also be a light pipe or light guide which guides light by classical reflection.

Furthermore, in the arrangement of Figure 3, the common light source 302 may be a narrow band source. In the context of the present arrangement, narrow band lights sources have a full width half maximum (FWHM) of no greater than 3.0 nm. The FWHM of a light source is the width output optical spectrum width, that is the width of the optical power spectral density of the light output in terms of wavelength, $\lambda$. The FWHM is measured between the points on the optical spectrum where the power has decayed to one half of its peak value. For example, for wearable AR display applications, the common light source 302 may be a laser diode which has a FWHM, $\Delta\lambda$ of between 0.1 nm and 3.0 nm. Also, laser diodes are advantageous due to their relatively hight power output (compared to LEDs), which allow for relatively brighter images such that image content can be view in daylight conditions.

It is not possible to use wide band light sources (that is greater than approximately 3.0 nm), such as LEDs, due to the problem of dispersion effects mentioned above. However high power narrow band LEDs, such as super luminescent diodes (SLEDs) may be used provided that they have a FWHM of no higher than approximately 3.0 nm. The common light source 302 may be configured to operate in the visible spectrum range of 380 nm to 700 nm.

The spatial light modulator 304 modulates light emitted by the illumination sources 314a, 314b, 314c to generate image content at the eye positions 308a, 308b, 308c. The spatial light modulator is controlled by a suitable control processor (not illustrated) to generate image content at eye positions 208a, 208b, 208c. Whilst the spatial light modulator 304 illustrated is a transmissive type, the skilled person will also appreciate the spatial light modulator 304 may be a reflective type without departing from the scope of the present disclosure. In the case of a reflective type, the illumination sources 314a, 314b, 314c would be provided on the same side of the spatial light modulator 304 as the user’s eye 310.

Whilst not illustrated in the arrangements of Figures 2 and 3, the skilled person will appreciate that suitable optics, in the form of a lens or lenses, may be required to couple light from the illumination optics 201, 301 to the spatial light modulator 204, 204 and imaging optics are arranged to couple light from the spatial light modulator 204, 304 to the optical combiner 206, 306. The skilled person will also appreciate that appropriate aberration control optics may also be included.

In terms of operation, image light emitted from the illumination sources 202a, 202b, 202c, and 314a, 314b, 314c is incident on the spatial light modulator 204, 304. The image light is modulated by the spatial light modulator and passes through to the optical combiner 206, 306 where it is diffracted to eye positions 208a, 208b, 208c and 308a, 308b, 308c light passing through or reflected by the spatial light modulator 204, 304 is modulated by amplitude, phase or polarisation modulation (or any combination thereof) by applying an appropriate electrical signal to the spatial light modulator 204, 304. Modulation of the image light creates an appropriate display image at the eye positions 208a, 208b, 208c and 308a, 308b, 308c. With regard to the arrangement of Figure 3, image light from the common light source 302 is coupled into each of the light guiding elements 312a, 312b, 312c and propagates to the end of the light guiding elements 312a, 312b, 312c which correspond to the illumination sources 314a, 314b, 314c. The distance from the common light source 302 through the light guiding elements 312a, 312b, 312c accounting for refractive index, to the combiner 206 and onto the user's eye 310, via a single pixel of the spatial light modulator 304 defines an optical path of the light from the illumination sources. By appropriate selection of the length of the light guiding elements 312a, 312b, 312c the optical path length can be defined so that the light emitted at the illumination sources 314a, 314b, 314c will be incoherent at the user's eye 310. In other words, an optical path difference is introduced such that the light will be incoherent. The skilled person will also understand that an optical path difference may be introduced by introducing a phase shift, for example by providing electro-optic modulation, a piezo-mechanically moving mirror, different refractive indices in each of the light guiding elements or by including an optical element such as a piezoelectric crystal capable of providing an electric-field-induced optical path length change.

The optical combiner 206, 306, according to embodiments is arranged to allow external or environmental light to pass through the to the user's eye 210, 310, while also redirecting the light rays from the illumination sources 202a, 202b, 202c, 314a, 314b, 314c to the user's eye 210, 310 such that the external light and light ray are both are visible to a user. The optical combiner 206, 306 may include at least one diffractive element such as holographic optical element, volume diffraction grating, surface relief diffraction grating or a reflection grating. The optical combiner may be provided on or in a transparent substrate such as an ophthalmic lens.

As understood by the skilled person the spatial light modulator 204, 304 may be of any appropriate type such as Liquid Crystal on Silicon (LCoS which is an example of a reflective type spatial light modulator), Liquid Crystal Display (LCD which is an example of a transmission type spatial light modulator), Digital Light Processor (DLP) or a Digital Micromirror Device (DMD). The spatial light modulator 204, 304 and the common 302 or plurality of illumination sources 202a, 202b, 202c may be controlled by any suitable control processor (not illustrated), the specific details of which are outside the scope of the present disclosure.

The common light source 302 or illumination sources 202a, 202b, 202c may provide a single wavelength of light, that is they may provide one of red, green, or blue wavelength light. Alternatively, the common light source 302 or illumination sources 202a, 202b, 202c may be so called tri-colour laser diode modules, which typically consist of red, green and blue (RGB) laser diodes integrated into a single device package.

Figure 4 illustrates a wearable augmented reality display 400 comprising at least one of the illumination optics 201, 301 (not illustrated in Figure 4) described above. This wearable augmented reality display takes the form of a wearable heads-up display, such as for example, a pair of glasses. As with known types of glasses, wearable augmented reality display 400 includes a frame 402. The frame 402 includes arms 404, and lens mounting portions 406 connected by a bridge portion 408. One of the arms 404 includes a mounting portion 410 in which the illumination optics 201, 301 is fixedly mounted such that the light from the illumination optics 201, 301 will be incident on an eyeglass lens 412 including an optical combiner 206, 306 as described above.

The skilled person will appreciate that the illumination optics 201, 301 will be mounted on the arm 404 adjacent the lens mounting portion 406 holding the eyeglass lens 412 and optical combiner 206, 306. The other lens mounting portion may have a standard ophthalmic lens inserted therein. Alternatively, an eyeglass lens including the optical combiner may be mounted in the other lens mounting portion and there may be an additional illumination optics 201, 301 mounted on a corresponding mounting portion on second arm 404.

One or both of the arms 404 may also be adapted to house a battery (not illustrated) to power the illumination optics 201, 301. In addition, one or both of the arms 404 may also include control electronics (not illustrated) for controlling the operation of the illumination optics 201, 301.

In the context of wearable AR display systems, and more generally near eye optical devices such as telescopes and binoculars, the concept of an eyebox is the range of eye positions over which an image provided by the device or display can be viewed by the user. This concept is well known in the field of augmented reality displays. The size and shape of the eyebox affect a user’s experience of a wearable AR display system. If the wearable AR display system has a small eyebox that is arranged to be centred on the that user's pupil looking directly ahead, some or all content displayed may not be visible when the user gazes off-centre. Furthermore, if the display has a small eyebox and is configured to align the eyebox on a specific user’s pupil, then for a different user the eyebox may be misaligned due to variations in for example, interpupillary distance (IPD) from one user to the next. To overcome issues with eyebox misalignment, AR display systems are generally designed to have a large eyebox so that they are suitable for use by a wide range of users. According to the present disclosure, as illustrated by a comparison of Figures 5a and 5b, eyebox expansion can be achieved by increasing the number of eye positions from one eye position 208a in Figure 5a to three eye positions 208a, 208b, 208c in Figure 5b. Whilst, the eyebox expansion in Figure 5b is in the horizonal direction the skilled person will recognise that the eyebox expansion may be in the vertical direction and/or the horizontal direction. The eyebox expansion is achieved by increasing the number of illumination sources 202a, 202b, 202c or 314a, 314b, 314c of the illumination optics 201, 301 described above. The size of the eye positions is determined by the size of the exit pupils of the illumination sources 202a, 202b, 202c or 314a, 314b, 314c. It should be noted that whilst the eye positions 208a, 208b, 208c of Figure 5b are shown as spaced apart, they may be adjoined or overlapped, and this will decrease the size of the eyebox in the horizontal and/or vertical dimensions.

A further advantage of having multiple illumination sources 202a, 202b, 202c or 314a, 314b, 314c according to embodiments is that there is no need for a diffuser (as discussed in relation to Figure 1 above) because multiple light rays from the multiple illumination sources 202a, 202b, 202c or 314a, 314b illuminate pixels of the spatial light modulator 206, 306 thus reducing speckle.

As mentioned above one advantage of illumination sources 202a, 202b, 202c arranged as a 1D linear array is that it is possible to incorporate or fold the illumination optics into a small volume. A further effect is that where the 1D array is arranged horizontally with respect to the user's eye, the eyebox as shown in Figure 5b, will also be orientated horizontally with respect to the user's eye. This has the advantage that the eyebox is longest in the direction of IPD and therefore an increased number of eye positions accommodates a wider range of IPDs and therefore a wider range of users of a wearable AR display. The skilled person will also understand that introduction of mirrors allows physical reorientation of the array of illumination sources relative to the spatial light modulator and or optical combiner.

Particular and preferred aspects of the disclosure are set out in the accompanying independent claims. Combinations of features from the dependent and/or independent claims may be combined as appropriate and not merely as set out in the claims.

The scope of the present disclosure includes any novel feature or combination of features disclosed therein either explicitly or implicitly or any generalisation thereof irrespective of whether or not it relates to the claimed disclosure or mitigate against any or all of the problems addressed by the present disclosure. The applicant hereby gives notice that new claims may be formulated to such features during prosecution of this application or of any such further application derived therefrom. In particular, with reference to the appended claims, features from dependent claims may be combined with those of the independent claims and features from respective independent claims may be combined in any appropriate manner and not merely in specific combinations enumerated in the claims.

Features which are described in the context of separate embodiments may also be provided in combination in a single embodiment. Conversely, various features which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable sub combination.

The term “comprising” does not exclude other elements or steps, the term “a” or “an” does not exclude a plurality. Reference signs in the claims shall not be construed as limiting the scope of the claims.

CLAIMS

1. An illumination optics system for a wearable AR display system, the illumination optics comprising: a spatial light modulator and a plurality of illumination sources;

wherein the plurality of illumination sources is arranged to illuminate the spatial light modulator and the spatial light modulator is arranged to modulate light from the plurality illumination sources; and

wherein light from adjacent illumination sources is mutually incoherent.

2. The illumination optics system of claim 1, wherein light from each of the plurality of illumination sources is mutually temporally incoherent.

3. Wherein each of the plurality of illumination sources generates a corresponding plurality of eye positions.

4. The illumination optics system of claims 1 to 3, wherein the each of the plurality of illumination sources are narrowband light sources.

5. The illumination optics system of claim 4, wherein each of the plurality of narrowband light sources has a FWHM of between 0.1nm and 3.0nm.

6. The illumination optics system of claims 4 or 5, wherein the each of the plurality of narrowband light sources has a coherence length of between approximately 0.20 nm and 1.50 nm.

7. The illumination optics of claim 4, wherein the each of the narrowband light sources are laser diodes.

8. The illumination optics of claims 7, wherein the laser diodes are configured to operate at the same emission wavelength.

9. The illumination optics of claim 7, wherein the laser diodes are configured to operate in the range of 380 nm to 700 nm.

10. The illumination optics of claim 1, wherein the illumination sources each comprise a light guiding element and each of the light guiding elements is optically coupled to a common light source.

11. The illumination optics of claim 10, wherein the common light source comprises a narrow band light source and the narrow band light source is a laser diode.

12. The illumination optics of claim 3, wherein an optical path length from the common light source to eye positions is different.

13. The illumination optics of any preceding claim, wherein the spatial light modulator is a transmissive spatial light modulator or a reflection spatial light modulator.

14. The illumination optics of any preceding claim 7 wherein the laser diode is an a RGB laser diode module.

15. A wearable AR display, comprising: the illumination optics of claims 1 to 14.

16. The wearable AR display of claim 15, further comprising a diffractive optical combiner configured to direct light from the illumination optics to an eye position, where the number of illumination sources corresponds to the number of eye positions.

17. The wearable AR display of claim 15, wherein the diffractive optical combiner is one of a holographic optical element, a volume diffraction grating, a surface relief diffraction grating or a reflection grating.

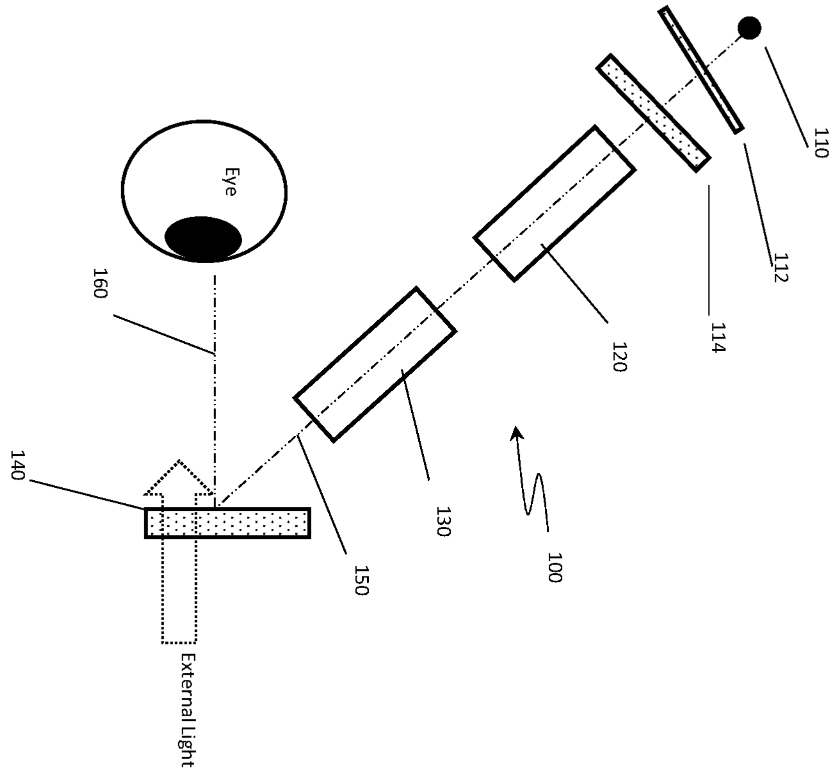
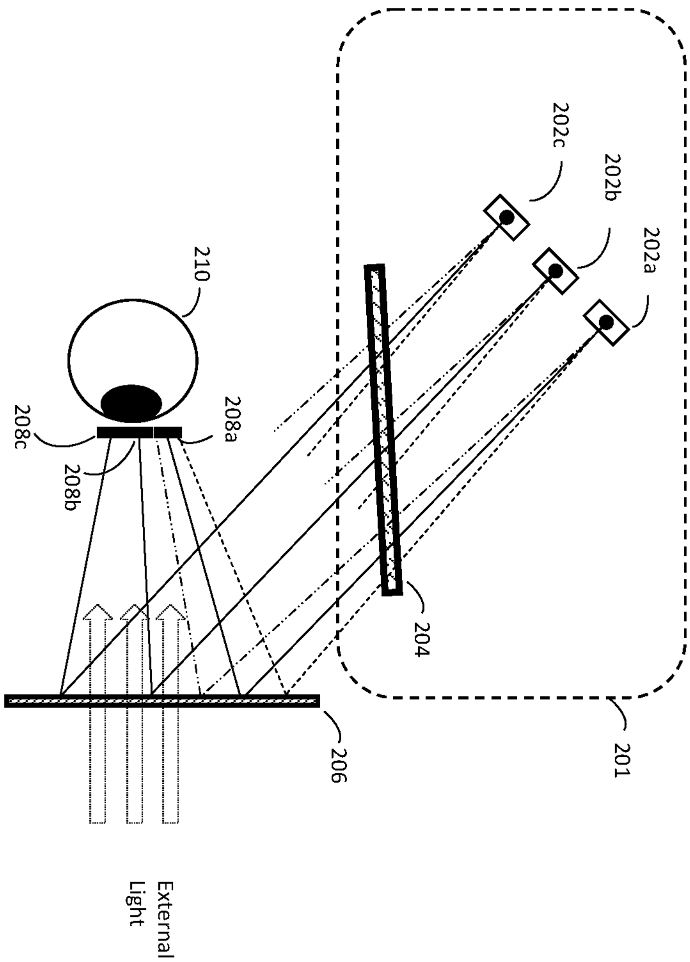
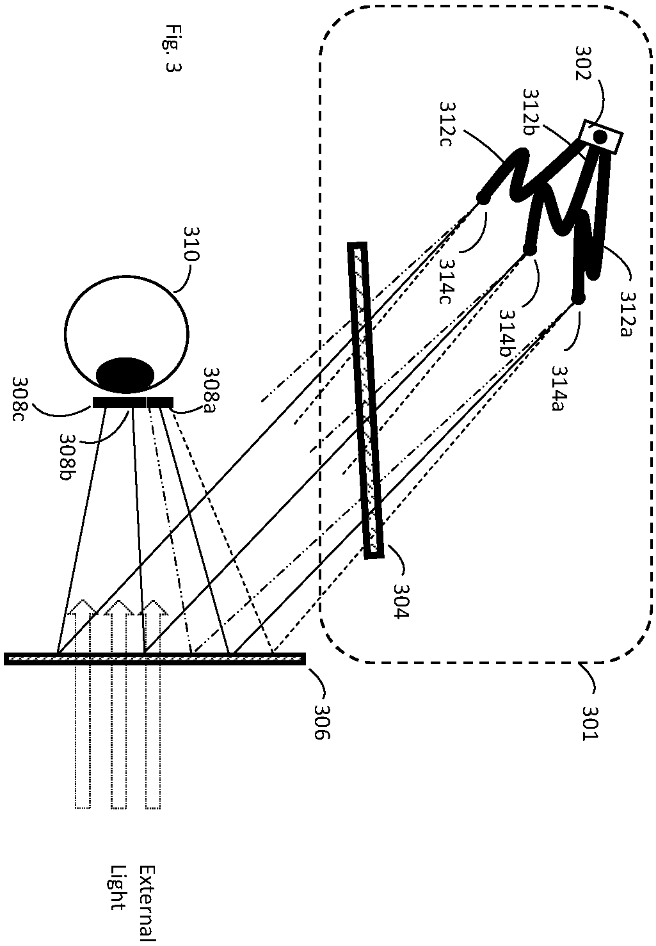



Fig. 1

Fig. 2




301
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308a
308b
308c
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312a
312b
312c
314a
314b
314c
External
Light

Fig. 3

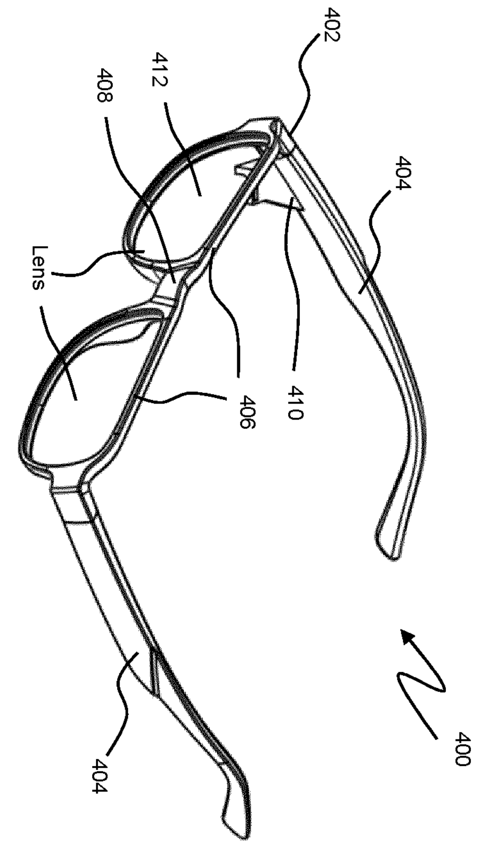


Fig. 4

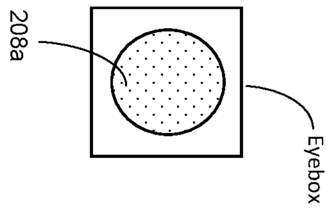


Fig. 5a

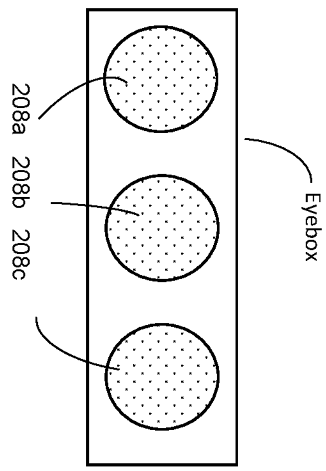


Fig. 5b

# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/066190

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. G02B27/01 G02B27/48
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

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 23 September 2024 | 08/10/2024 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Stemmer, Michael |

2

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