

ARRANGEMENT FOR OPTICAL MEASUREMENT

TECHNICAL FIELD

[0001] The present disclosure relates to the field of
5 optics, and more particularly to an arrangement for optical measurements and a method for an optical measurement.

BACKGROUND

10 [0002] In many optical applications, correct alignment between an image source and a waveguide can be important. For example, in augmented reality (AR) applications, such as AR glasses, an image produced by a projector can be guided to the eye of a user using a
15 waveguide with appropriately designed in-coupling and out-coupling structures.

SUMMARY

[0003] This summary is provided to introduce a selection of concepts in a simplified form that are further
20 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 to limit the scope of the claimed
25 subject matter.

[0004] It is an object to provide an arrangement for optical measurements and a method for an optical measurement. The foregoing and other objects are achieved

by the features of the independent claims. Further implementation forms are apparent from the dependent claims, the description and the figures.

[0005] According to a first aspect, an arrangement for
5 optical measurements comprises: an image source; at
least one camera; and a mounting arrangement for a wave-
guide, wherein the waveguide comprises an in-coupling
structure for coupling light into the waveguide and an
out-coupling structure for coupling light out of the
10 waveguide; wherein the image source is configured to
produce light comprising a test image and the image
source is arrangeable to direct the light to the in-
coupling structure of the waveguide; the at least one
camera is arrangeable to receive light out-coupled by
15 the out-coupling structure to a first side of the wave-
guide and to receive light out-coupled by the out-cou-
pling structure to a second side of the waveguide; and
the at least one camera is configured to produce a first
image based on the light out-coupled by the out-coupling
20 structure to the first side of the waveguide and produce
a second image based on the light out-coupled by the
out-coupling structure to the second side of the wave-
guide.

[0006] In an implementation form of the first aspect,
25 the arrangement further comprises a reflector arrange-
able to the second side of the waveguide for receiving
the light out-coupled by the out-coupling structure to
the second side of the waveguide, wherein the reflector
is configured to reflect at least a part of the light

received from the out-coupling structure to the at least one camera and the at least one camera is further configured to produce the second image based on the light received from the reflector.

5 [0007] In another implementation form of the first aspect, the reflector comprises a retroreflector.

[0008] In another implementation form of the first aspect, retroreflector is further configured to rotate the test image by substantially 180 degrees.

10 [0009] In another implementation form of the first aspect, the at least one camera comprises a first camera arrangeable to receive the light out-coupled by the out-coupling structure to the first side of the waveguide and a second camera arrangeable to receive the light
15 out-coupled by the out-coupling structure to the second side of the waveguide, wherein the first camera is configured to produce the first image based on the light out-coupled by the out-coupling structure to the first side of the waveguide and the second camera is configured to produce the second image based on the light out-coupled by the out-coupling structure to the second side
20 of the waveguide.

[0010] In another implementation form of the first aspect, the arrangement further comprises a computing
25 device configured to: obtain the first image and the second image from the at least one camera; and compare a relative position of the first image and the second image.

[0011] In another implementation form of the first aspect, the computing device is further configured to determine an alignment of the image source in relation to the waveguide based on the comparison of the relative position of the first image and the second image.

[0012] In another implementation form of the first aspect, the computing device is further configured to adjust the alignment between the image source and the waveguide by controlling the image source.

10 [0013] In another implementation form of the first aspect, the arrangement further comprises an actuator coupled to the computing device, wherein the computing device is further configured to adjust the alignment between the image source and the waveguide based on the determined alignment between the image source and the waveguide using the actuator.

[0014] In another implementation form of the first aspect, the test image comprises at least one alignment marker.

20 [0015] According to second aspect, a method for an optical measurement comprises: arranging at least one camera on at least a first side of a waveguide; producing light comprising a test image using an image source; directing the light to an in-coupling structure of the waveguide, wherein the in-coupling structure is configured to couple the light into the waveguide and the waveguide comprises an out-coupling structure for coupling light out of the waveguide; receiving light out-coupled by the out-coupling structure to a first side

of the waveguide using the at least one camera thus producing a first image; receiving light out-coupled by the out-coupling structure to a second side of the waveguide using the at least one camera thus producing a
5 second image; and comparing a relative position of the first image and the second image.

[0016] In an implementation form of the second aspect, the method further comprises arranging a reflector on the second side of the waveguide and receiving, using
10 the reflector, the light out-coupled by the out-coupling structure to the second side of the waveguide; and the receiving the light out-coupled by the out-coupling structure to the second side of the waveguide using the at least one camera thus producing the second image
15 comprises: reflecting, using the reflector, at least a part of the light received by the reflector from the out-coupling structure to the at least one camera and producing, using the at least one camera, the second image based on the light received from the reflector.

20 **[0017]** In another implementation form of the second aspect, the reflector comprises a retroreflector.

[0018] In another implementation form of the second aspect, the at least one camera comprises a first camera and a second camera and the arranging the at least one
25 camera on at least the first side of the waveguide comprises: arranging the first camera on the first side of the waveguide; arranging the second camera on the second side of the waveguide; the receiving light out-coupled by the out-coupling structure of the waveguide to the

first side of the waveguide using the at least one camera thus producing the first image comprises receiving the light out-coupled by the out-coupling structure to the first side of the waveguide using the first camera thus
5 producing the first image; and the receiving light out-coupled by the out-coupling structure to the second side of the waveguide using the at least one camera thus producing the second image comprises receiving light out-coupled by the out-coupling structure to the second
10 side of the waveguide using the second camera thus producing the second image.

[0019] In another implementation form of the second aspect, the method further comprises determining an alignment between the image source and the waveguide
15 based on the comparison of the relative position of the first image and the second image.

[0020] In another implementation form of the second aspect, the method further comprises adjusting the alignment between the image source and the waveguide
20 based on the determined alignment between the image source and the waveguide.

[0021] In another implementation form of the second aspect, the test image comprises at least one alignment marker.

25 **[0022]** In another implementation form of the second aspect, the in-coupling structure comprises an in-coupling diffraction grating and the out-coupling structure comprises an out-coupling diffraction grating.

[0023] In another implementation form of the second aspect, the image source comprises a projector of a see-through display device and a lens of the see-through display device comprises the waveguide.

5 [0024] Many of the attendant features will be more readily appreciated as they become better understood by reference to the following detailed description considered in connection with the accompanying drawings.

10 DESCRIPTION OF THE DRAWINGS

[0025] In the following, example embodiments are described in more detail with reference to the attached figures and drawings, in which:

15 [0026] Fig. 1 illustrates a schematic representation of an arrangement for optical measurements according to an embodiment;

[0027] Fig. 2 illustrates a schematic representation of an arrangement for optical measurements according to another embodiment;

20 [0028] Fig. 3 illustrates a schematic representation of an arrangement for optical measurements according to another embodiment;

[0029] Fig. 4 illustrates a schematic representation of an arrangement for optical measurements according to
25 another embodiment;

[0030] Fig. 5 illustrates a schematic representation of an arrangement for optical measurements according to another embodiment;

[0031] Fig. 6 illustrates a schematic representation of an image according to an embodiment;

[0032] Fig. 7 illustrates a schematic representation of an image according to another embodiment;

5 [0033] Fig. 8 illustrates a schematic representation of alignment using field of view reduction according to an embodiment;

[0034] Fig. 9 illustrates a flow chart representation of a method according to an embodiment; and

10 [0035] Fig. 10 illustrates a schematic representation of display device according to an embodiment.

[0036] In the following, identical reference signs refer to similar or at least functionally equivalent features.

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DETAILED DESCRIPTION

[0037] In the following description, reference is made to the accompanying drawings, which form part of the disclosure, and in which are shown, by way of illustration, specific aspects in which the present disclosure may be placed. It is understood that other aspects may be utilised, and structural or logical changes may be made without departing from the scope of the present disclosure. The following detailed description, therefore, is not to be taken in a limiting sense, as the scope of the present disclosure is defined by the appended claims.

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[0038] For instance, it is understood that a disclosure in connection with a described method may also hold

true for a corresponding device or system configured to perform the method and vice versa. For example, if a specific method step is described, a corresponding device may include a unit to perform the described method
5 step, even if such unit is not explicitly described or illustrated in the figures. On the other hand, for example, if a specific apparatus is described based on functional units, a corresponding method may include a step performing the described functionality, even if
10 such step is not explicitly described or illustrated in the figures. Further, it is understood that the features of the various example aspects described herein may be combined with each other, unless specifically noted otherwise.

15 **[0039]** Fig. 1 illustrates a schematic representation of an arrangement for optical measurements according to an embodiment.

[0040] According to an embodiment, an arrangement 100 for optical measurements comprises an image source 101,
20 at least one camera 103, and a mounting arrangement 104 for a waveguide 105.

[0041] The mounting 104 arrangement is illustrated in a simplified manner in the embodiment of Fig. 1. The mounting arrangement 104 may comprise, for example, any
25 structure for holding/mounting the waveguide 105. The mounting can be, for example, permanent, semi-permanent, or non-permanent depending on the application.

[0042] The waveguide 105 may comprise an in-coupling structure 111 for coupling light into the waveguide 105

and an out-coupling structure 112 for coupling light out of the waveguide 105.

[0043] The waveguide 105 may comprise, for example, a substantially planar waveguide. Alternatively or additionally, the waveguide 105 may also comprise curved sections. For example, the waveguide 105 may correspond to a lens or a layer of a lens of smart glasses, such as augmented reality (AR) glasses.

[0044] The in-coupling (IC) structure 111 may be configured to couple light into the waveguide 105 via, for example, diffraction. The IC structure 111 may comprise, for example, an in-coupling diffraction grating.

[0045] The out-coupling (OC) structure 112 may be configured to couple light out of the waveguide 105 via, for example, diffraction. The OC structure 112 may comprise, for example, an out-coupling diffraction grating.

[0046] Herein, a diffraction grating may also be referred to as a surface-relief grating, a grating, a diffractive grating, or similar.

[0047] In other embodiments, the waveguide 105, the IC structure 111, and/or the OC structure 112 may be implemented in other ways. For example, the waveguide 105 may be implemented as a holographic and a reflective waveguide. Alternatively or additionally, the waveguide 105 may comprise any type of lens or other optical component that emits light out of two sides.

[0048] Light coupled into the waveguide 105 by the IC structure 111 can be guided inside the waveguide 105 via total internal reflection (TIR). At least a part of the

light can then be outcoupled from the waveguide 105 by the OC structure 112.

[0049] The waveguide 105 may further comprise any number of other optical components, such as diffraction gratings, that can, for example, manipulate the light propagating in the waveguide 105 in various manners before the light is outcoupled from the waveguide 105.

[0050] The image source 101 may be configured to produce light 131 comprising a test image and the image source 101 may be arrangeable to direct the light 131 to the in-coupling structure 111 of the waveguide 105.

[0051] The image source 101 may comprise, for example, an optical engine, such as a scanner-based optical engine or a projector.

[0052] The light 131 produced by the image source 101 may also be referred to as image-bearing light, image-bearing light rays/beams, image-carrying light rays/beams, and/or similar.

[0053] The at least one camera 103 may be arrangeable to receive light 132 out-coupled by the out-coupling structure 112 to a first side 121 of the waveguide 105 and to receive light 133 out-coupled by the out-coupling structure 112 to a second side 122 of the waveguide 105.

[0054] The second side 122 may be different from the first side 121. The second side 122 may oppose the first side 121.

[0055] The at least one camera 103 may receive the light 133 out-coupled by the out-coupling structure 112 to the second side 122 of the waveguide 105 via any

number of optical components, such as those disclosed herein.

[0056] The at least one camera 103 may be configured to produce a first image based on the light 132 out-coupled by the out-coupling structure 112 to the first side 121 of the waveguide 105 and produce a second image based on the light 133 out-coupled by the out-coupling structure 112 to the second side 122 of the waveguide 105.

[0057] According to an embodiment, the arrangement 100 further comprises a reflector 102 arrangeable to the second side 122 of the waveguide 105 for receiving the light 133 out-coupled by the out-coupling structure 112 to the second side 122 of the waveguide 105, wherein the reflector 102 is configured to reflect at least a part of the light 133 received from the out-coupling structure 112 to the at least one camera 103 and the at least one camera 103 is further configured to produce the second image based on the light 134 received from the reflector 102.

[0058] According to an embodiment, the reflector 102 comprises a retroreflector.

[0059] For example, in the embodiment of Fig. 1, the reflector 102 comprises a retroreflector. In any embodiment disclosed herein, the reflector 102 may comprise any type of reflector, such as a mirror, a plurality of mirrors, a prism, a plurality of prisms, or similar.

[0060] The at least one camera 103 may be arrangeable to a first side 121 of the waveguide 105 for receiving

light from the out-coupling structure 112 of the waveguide 105 and the at least one camera 103 may be configured to produce a first image based on the light received from the out-coupling structure 112.

5 [0061] The at least one camera 103 may be arranged to the first side 121 of the waveguide 105 for receiving light from the out-coupling structure 112 of the waveguide 105.

[0062] The light 132 out-coupled to the first side 121
10 of the waveguide 105 may also be referred to as first out-coupled light or similar.

[0063] The OC structure 112 may out-couple light from the waveguide 105 to the first side 121 of the waveguide 105 and to the second side 122 of the waveguide 105.
15 However, the amount of light outcoupled to each side may be different. For example, in many applications, it can be desirable to minimize the amount of light coupled to one side of the waveguide 105. For example, in smart glasses, it is typically desirable to minimize outcoupling to the outside of the glasses, also referred to
20 as "world-side leakage", while maximizing outcoupling to the eye-side. In such cases, it may be beneficial to use a long exposure time for the at least one camera 103 in order to capture enough light.

25 [0064] For example, the at least one camera 103 can be placed at the eyebow of the waveguide 105 on the transmission side opposite to the image source 101. The tilt angle of the at least one camera 103 can be adjusted

such that the projected field of view (FOV) is in the centre of the camera image.

[0065] The retroreflector may be arrangeable to a second side 122 of the waveguide 105 for receiving light from the out-coupling structure 112 of the waveguide 105 and the retroreflector 102 may be configured to reflect at least a part of the light received from the out-coupling structure 112 to the at least one camera 103. The at least one camera 103 may be further configured to produce a second image based on the light received from the retroreflector 102.

[0066] The retroreflector may be arranged to the second side 122 of the waveguide 105 for receiving light from the out-coupling structure 112 of the waveguide 105.

[0067] The light 133 out-coupled to the second side 122 of the waveguide 105 may also be referred to as second out-coupled light or similar.

[0068] The light 134 reflected by the retroreflector 102 may also be referred to as reflected light or similar.

[0069] For example, the retroreflector 102 can be put on the reflection side of the waveguide 105, i.e. the same side as the image source 101, close to the OC structure 112.

[0070] The retroreflector 102 may be configured to reflect the light 134 in such a way that the reflected light 134 is in the same angle as the second out-coupled light 133.

[0071] It should be understood that the geometry of the arrangement 100 illustrated in the embodiment of Fig. 1 is only exemplary and the arrangement 100 may be implemented in various other ways.

5 [0072] Although the various light paths are illustrated in a simplified manner in the embodiments disclosed herein, the image source 101 may produce a full, wide-angle image. The light paths illustrated in the embodiments may correspond to, for example, a centre of
10 the FOV of such an image. Alternatively, the image source 101 may comprise, for example, a laser pointer or any other laser source that produces only a small dot that can be used for the alignment.

[0073] According to an embodiment, retroreflector 102
15 is further configured to rotate the test image by substantially 180 degrees.

[0074] Herein, the rotation of the test image by substantially 180 degrees may refer to a rotation around the vertical axis. The vertical axis may be oriented
20 orthogonally with the propagation direction of the light 132 out-coupled by the out-coupling structure 112 and orthogonally with the propagation direction of the light 133 out-coupled by the out-coupling structure 112. Thus, the vertical axis may be oriented orthogonally with a
25 plane defined by the propagation direction of the light 132 out-coupled by the out-coupling structure 112 and the propagation direction of the light 133 out-coupled by the out-coupling structure 112. For example, in Fig.

1 the vertical axis may be oriented in the in-out direction of the figure.

[0075] Herein, when the retroreflector 102 is configured to rotate the test image by substantially 180 degrees, the retroreflector 102 may rotate the test image
5 by, for example, 175 - 185 degrees, 177.5 - 182.5 degrees, 179 - 181 degrees 179.9 - 180.1 degrees, or 179.99 - 180.01 degrees.

[0076] Although the retroreflector 102 is illustrated
10 in the embodiment of Fig. 1 in a simplified manner, the retroreflector 102 may comprise any type of retroreflector. For example, in some embodiments, the retroreflector 102 may comprise a corner reflector, a corner cube, a cube corner, or a plurality thereof. Alternatively, the retroreflector 102 may comprise, for exam-
15 ple, a retroreflective grating or a retroreflective metasurface.

[0077] With at least some embodiments disclosed herein, the tilt angle of the image source 101 can be
20 accurately aligned to the waveguide 105. The tilt angle may refer to an angle between the light emitted by the image source 101 and the normal direction of the surface of the waveguide 105. Typically, the light emitted by the image source 101 forms a beam and the tilt angle may
25 be measured between the centre of the beam and the normal direction of the surface of the waveguide 105.

[0078] Since the light 133 out-couple to the second side 122 is reflected back with the retroreflector 102,

the at least one camera 103 can detect both the transmission mode emission and reflection mode emission of the waveguide 105. The reflected image is shifted in the field of view (FOV) based on the tilt of the image source
5 101. The difference between the transmission mode image and the reflection mode image can be, for example, equal to two times the image source tilt angle.

[0079] At least some embodiments disclosed herein can make determining the alignment between the image source
10 101 and the waveguide 105 easier and simpler.

[0080] At least some embodiments disclosed herein can make determining the alignment between the image source 101 and the waveguide 105 more accurate and reliable, because the relative position of the first and second
15 image is not affected by the alignment of other components.

[0081] For metrology of waveguides or their integration into a system, it can be important to have the image source 101 set at the correct Pantoscopic tilt and
20 face wrap angle, as defined by the design. In the case of aligning an augmented reality headset, for example, one of the main goals may be to ensure that the left and right side images overlap. This could mean that the projector angle alignment to the waveguide is not as
25 intended by the designers. The embodiments disclosed herein can improve the alignment process, for example, in such applications.

[0082] At least some embodiments disclosed herein can be used in alignment of a sample in waveguide metrology tools.

5 [0083] At least some embodiments disclosed herein can be used in measurement of a projector angle in systems where the waveguide is integrated into a system, such as quality control for AR glasses or AR headsets.

[0084] At least some embodiments disclosed herein can be used in applications where a large angle alignment
10 is needed, and an autocollimator cannot be used. Even in application where a waveguide is not used, a simple waveguide could be integrated into any flat and transparent glass or plastic structure for alignment purposes.

15 [0085] When a waveguide and the optical components, such as the IC structure and the OC structure, are designed for, for example, smart glasses, a specific tilt angles are typically assumed for the image source and the eye of the user. Therefore, when the optical prop-
20 erties of the waveguide and the optical components are measured, it is typically beneficial to be able to set the tilt angles accurately.

[0086] If the tilt angle of the image source is not correct, various issue may arise. For example, the FOV
25 may be misaligned compared to the eye of the user of smart glasses and the image uniformity may be reduced.

[0087] Fig. 2 illustrates a schematic representation of an arrangement for optical measurements according to another embodiment.

[0088] In the embodiment of Fig. 2, the image source 101 and the in-coupling structure 111 are arranged onto the first side 121 of the waveguide 105. In any embodiment disclosed herein, the image source 101 and/or the
5 in-coupling structure 111 can be arranged onto the first side 121 or the second side 122 of the waveguide 105. In some embodiments, the image source 101 and the in-coupling structure 111 can be arranged onto different sides of the waveguide 105.

10 [0089] In other embodiments, the arrangement 100 can be modified in various ways. For example, the at least one camera 103 and the retroreflector 102 can be on any side of the waveguide 105 and/or the in-coupling structure 111 and/or the out-coupling structure 112 can com-
15 prise transmissive or reflective diffraction gratings. The at least one camera 103 and the retroreflector 102 can be on the transmissive or the reflective side of the waveguide 105 regardless of whether the waveguide 105 is designed to function as a reflective or transmissive
20 waveguide.

[0090] Fig. 3 illustrates a schematic representation of an arrangement for optical measurements according to another embodiment.

[0091] According to an embodiment, the arrangement 100
25 further comprises a computing device 301 configured to obtain the first image and the second image from the at least one camera 103 and compare a relative position of the first image and the second image.

[0092] In some embodiments, the at least one camera 103 may comprise, for example, one camera or a plurality of cameras, such as two cameras, taking two different pictures. For example, if the FOV of one camera is too small to measure a large alignment angle, a plurality of cameras can be arranged next to each other to effectively increase the FOV.

[0093] The computing device 301 may comprise at least one processor. The at least one processor may comprise, for example, one or more of various processing devices, such as a co-processor, a microprocessor, a digital signal processor (DSP), a processing circuitry with or without an accompanying DSP, or various other processing devices including integrated circuits such as, for example, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), a microprocessor unit (MCU), a hardware accelerator, a special-purpose computer chip, or the like.

[0094] The computing device 301 may further comprise a memory. The memory may be configured to store, for example, computer programs and the like. The memory may comprise one or more volatile memory devices, one or more non-volatile memory devices, and/or a combination of one or more volatile memory devices and non-volatile memory devices. For example, the memory may be embodied as magnetic storage devices (such as hard disk drives, floppy disks, magnetic tapes, etc.), optical magnetic storage devices, and semiconductor memories (such as

mask ROM, PROM (programmable ROM), EPROM (erasable PROM), flash ROM, RAM (random access memory), etc.).

[0095] The computing device 301 may further comprise other components. The computing device 301 may comprise,
5 for example, an input/output bus for connecting the computing device 301 to the at least one camera 103 and/or other devices. Further, a user may control the computing device 301 via the input/output bus.

[0096] When the computing device 301 is configured to
10 implement some functionality, some component and/or components of the computing device 301, such as the at least one processor and/or the memory, may be configured to implement this functionality. Furthermore, when the at least one processor is configured to implement some
15 functionality, this functionality may be implemented using program code comprised, for example, in the memory.

[0097] The computing device 301 may be implemented using, for example, a computer, some other computing
20 device, or similar.

[0098] The computing device 301 can be, for example, electrically and/or functionally coupled to the at least one camera 103. For example, there may be any type of data connection between the computing device 301 and the
25 at least one camera 103 that enables the computing device 301 to obtain the first image and the second image from the at least one camera 103. Such a data connection can be implemented, for example, using a wired connection, such as a universal serial bus (USB) connection

and/or an ethernet connection or using a wireless connection, such as Bluetooth and/or Wi-Fi.

[0099] The computing device 301 may be configured to compare the relative position of the first image and the second image using, for example, machine vision or any other applicable method and/or algorithm.

[0100] According to an embodiment, the computing device 301 is further configured to determine an alignment of the image source 101 in relation to the waveguide 105 based on the comparison of the relative position of the first image and the second image.

[0101] The computing device 301 may be configured to, for example, compute the alignment of the image source 101 in relation to the waveguide 105 based on the relative position of the first image and the second image. For example, in some embodiments, there can be a linear relation between the tilt angle of the image source 101 and the distance between the first image and the second image. Alternatively, there may be some other relation and the computing device 301 can be configured to compute the alignment based on such a relation.

[0102] Herein, alignment of the image source 101 in relation to the waveguide 105 may refer to any degree of freedom between image source 101 in relation to the waveguide 105. In some embodiments, the alignment of the image source 101 in relation to the waveguide 105 may comprise a plurality of degrees of freedom. For example, in many applications, alignment of the image source 101 in relation to the waveguide 105 may refer to the tilt

angle between the light emitted by the image source 101 and the normal vector of the surface of the waveguide 105. Alternatively or additionally, the alignment may also comprise, for example, the displacement of the image source 101 in the plane of the waveguide 105 in relation to the IC structure 111.

[0103] Fig. 4 illustrates a schematic representation of an arrangement for optical measurements according to another embodiment.

10 **[0104]** According to an embodiment, the arrangement further comprises an actuator 401 coupled to the computing device 301, wherein the computing device 301 is further configured to adjust the alignment between the image source 101 and the waveguide 105 based on the
15 determined alignment between the image source 101 and the waveguide 105 using the actuator 401.

[0105] The computing device 301 may configured to, for example, compute the alignment of the image source 101 in relation to the waveguide 105 and then move the image
20 source 101 and/or the waveguide 105 to adjust the alignment. For example, a desired alignment, such as the tilt angle of the image source 101, may be preconfigured to the computing device 301. The computing device 301 can adjust the alignment until the desired alignment is
25 achieved.

[0106] The actuator may be, for example, mechanically coupled to the image source 101 and/or to the waveguide 105. Thus, the actuator may move the image source 101

and/or to the waveguide 105 and change the alignment between the image source 101 and the waveguide 105.

[0107] The actuator 401 may comprise, for example, at least one electrical motor, such as a stepper motor, 5 that can be controlled via the computing device 301 for adjusting the alignment between the image source and the waveguide.

[0108] The actuator 401 may also be referred to as a mechanical actuator or similar.

10 [0109] The computing device 301 can be, for example, electrically coupled to the actuator. For example, there may be any type of electrical and/or data connection between the computing device 301 and the actuator that enables the computing device 301 to control the actua-
15 tor. Such a data connection can be implemented, for example, using a wired connection, such as a USB connection and/or an ethernet connection or using a wireless connection, such as Bluetooth and/or Wi-Fi. Alternatively or additionally, the actuator may comprise, for
20 example, at least one electrical motor and the computing device 301 may be electrically coupled to the at least one electrical motor enabling the computing device 301 to control the at least one electrical motor.

[0110] For example, in the embodiment of Fig. 4, the 25 actuator 401 is mechanically coupled to the image source 101 thus enabling the actuator 401 to move the image source 101 and change the alignment between the image source 101 and the waveguide 105. In other embodiments,

the actuator can be mechanically coupled to the waveguide 105. For example, the actuator can be mechanically coupled to the mounting arrangement 104 thus enabling movement of the waveguide 105. In other embodiments, the
5 arrangement 100 may comprise a first actuator for moving the image source 101 and a second actuator for moving the waveguide 105.

[0111] Although the computing device 301 and the actuator 401 are illustrated as being arranged onto the
10 first side 121 of the waveguide 105 in the embodiment of Fig. 4, this is only for illustrative purposes. In other embodiments, the computing device 301 and the actuator 401 can be arranged in various other ways.

[0112] Fig. 5 illustrates a schematic representation
15 of an arrangement for optical measurements according to another embodiment.

[0113] According to an embodiment, the at least one camera 103 comprises a first camera 103_1 arrangeable to receive the light 132 out-coupled by the out-coupling
20 structure 112 to the first side 121 of the waveguide 105 and a second camera 103_2 arrangeable to receive the light 133 out-coupled by the out-coupling structure 112 to the second side 122 of the waveguide 105. The first camera 103_1 can be configured to produce the first
25 image based on the light 132 out-coupled by the out-coupling structure 112 to the first side 121 of the waveguide 105 and the second camera 103_2 can be configured to produce the second image based on the light

133 out-coupled by the out-coupling structure 112 to the second side 122 of the waveguide 105.

[0114] The first camera 103_1 may be configured to receive the light 132 out-coupled by the out-coupling structure 112 to the first side 121 of the waveguide 105 and the second camera 103_2 may be configured to receive the light 133 out-coupled by the out-coupling structure 112 to the second side 122 of the waveguide 105.

[0115] In embodiments, where the first camera 103_1 and the second camera 103_2 are used, an alignment between the first camera 103_1 and the second camera 103_2 may need to be taken into account when determining the alignment between the image source 101 and the waveguide 105, since the alignment between the first camera 103_1 and the second camera 103_2 can also affect the relative position of the first image and the second image.

[0116] In any embodiments disclosed herein, such as in the embodiments illustrated in Figs. 1 - 4, two cameras 103_1, 103_2 can be used, instead of a camera 103 and a reflector 102, in a similar fashion to the embodiment of Fig. 5.

[0117] Fig. 6 illustrates a schematic representation of an image according to an embodiment.

[0118] According to an embodiment, the test image comprises at least one alignment marker.

[0119] For example, in the embodiment of Fig. 6, an image 500 obtained by the at least one camera 103 comprises the first image 501_1 and the second image 501_2.

Each of the first image 501_1 and the second image 501_2 comprises an alignment marker 502 from the test image.

[0120] It should be appreciated that the at least one camera 103 can obtain the first image 501_1 and the second image 501_2 separately or using a single image. For example, in some embodiments, the at least one camera 103 may capture one image and the captured image may comprise the first image 501_1 and the second image 501_2 due to the light from the OC structure 112 and from the retroreflector 102. In such embodiments, the first image 501_1 may refer to parts of the captured image that are due to light from the OC structure 112 and the second image 501_2 may refer to parts of the captured image that are due to light from the retroreflector 102. In other embodiments, the at least one camera 103 may capture the first image 501_1 and the second image 501_2 as separate images.

[0121] Fig. 7 illustrates a schematic representation of an image according to another embodiment.

[0122] In the embodiment of Fig. 7, an image 500 obtained by the at least one camera 103 comprises the first image 501_1 and the second image 501_2. Each of the first image 501_1 and the second image 501_2 comprises an alignment marker 502 from the test image.

[0123] According to an embodiment, the alignment marker 502 comprises at least one alignment indicator for determining the alignment between the image source 101 and the waveguide 105.

[0124] For example, in the embodiment of Fig. 7, the alignment marker 502 comprise a cross with a plurality of dashes as the at least one alignment indicator. Each interval between two consecutive dashes may correspond to, for example, specific amount of misalignment between the image source 101 and the waveguide 105. For example, each interval can correspond to a predetermined number of degrees of tilt angle of the image source 101. Using such an alignment marker, the alignment between the image source 101 and the waveguide 105 can be determined more easily, since based on the dashes, the required amount of adjustment to achieve the desired alignment can be determined with at least some degree of accuracy.

[0125] In other embodiments, the alignment marker may be different from what is illustrated in the embodiments of Figs. 5 and 6. For example, in some embodiments, the alignment marker may comprise a simple dot. In other embodiments, the alignment marker may comprise more markings that can enable easier determination of the alignment similarly to the dashes in the embodiment of Fig. 7.

[0126] Fig. 8 illustrates a schematic representation of alignment using field of view reduction according to an embodiment.

[0127] According to an embodiment, the computing device 301 is further configured to adjust the alignment between the image source 101 and the waveguide 105 by controlling the image source 101.

[0128] The computing device 301 can be, for example, electrically and/or functionally coupled to the image source 101. For example, there may be any type of data connection between the computing device 301 and image source 101 that enables the computing device 301 to control the image source 101. Such a data connection can be implemented, for example, using a wired connection, such as a universal serial bus (USB) connection and/or an ethernet connection or using a wireless connection, such as Bluetooth and/or Wi-Fi.

[0129] According to an embodiment, the computing device 301 is further configured to adjust the alignment between the image source 101 and the waveguide 105 by reducing and shifting a field of view of the image source 101.

[0130] In some embodiments, the alignment of the image source 101 may not be performed physically/mechanically. For example, available FOV of image source 101 can be reduced/cut and shifting the reduced FOV such that the centre of the reduced FOV moves in order to perform the alignment. An example of this is illustrated in the embodiment of Fig. 8, where a centre 611 of the full/original FOV 601 and a centre 612 of a reduced/cut FOV 602 (dashed rectangle) are illustrated. This procedure can be used, for example, for aligning the image source 101 in a final product, where the image source 101 may not be a mechanically adjustable.

[0131] Fig. 9 illustrates a flow chart representation of a method according to an embodiment.

[0132] According to an embodiment, a method 700 for an optical measurement comprises arranging 701 at least one camera on at least a first side of a waveguide.

5 [0133] The method 700 may further comprise producing 703 light comprising a test image using an image source.

[0134] The method 700 may further comprise directing 704 the light to an in-coupling structure of a waveguide, wherein the in-coupling structure is configured to couple the light into the waveguide and the waveguide
10 comprises an out-coupling structure for coupling light out of the waveguide.

[0135] The method 700 may further comprise receiving 705 light out-coupled by the out-coupling structure to a first side of the waveguide using the at least one
15 camera thus producing a first image.

[0136] The method 700 may further comprise receiving 707 light out-coupled by the out-coupling structure to a second side of the waveguide using the at least one camera thus producing a second image.

20 [0137] The method 700 may further comprise comparing 708 a relative position of the first image and the second image.

[0138] According to an embodiment, the method 700 further comprises arranging a reflector on the second side
25 of the waveguide and receiving, using the reflector, the light out-coupled by the out-coupling structure to the second side of the waveguide, and the receiving 707 the light out-coupled by the out-coupling structure to the second side of the waveguide using the at least one

camera thus producing the second image comprises: reflecting, using the reflector, at least a part of the light received by the reflector from the out-coupling structure to the at least one camera and producing,
5 using the at least one camera, the second image based on the light received from the reflector.

[0139] According to an embodiment, the reflector comprises a retroreflector.

[0140] According to an embodiment, the at least one
10 camera comprises a first camera and a second camera and the arranging 701 the at least one camera on at least the first side of the waveguide comprises: arranging the first camera on the first side of the waveguide; arranging the second camera on the second side of the
15 waveguide; the receiving 705 light out-coupled by the out-coupling structure of the waveguide to the first side of the waveguide using the at least one camera thus producing the first image comprises receiving the light out-coupled by the out-coupling structure to the first
20 side of the waveguide using the first camera thus producing the first image; and the receiving 707 light out-coupled by the out-coupling structure to the second side of the waveguide using the at least one camera thus producing the second image comprises receiving light
25 out-coupled by the out-coupling structure to the second side of the waveguide using the second camera thus producing the second image.

[0141] The operations of the method 700 can be performed using, for example, the arrangement 100.

[0142] In some embodiments, a user may perform the method 700 using, for example, the arrangement 100. In other embodiments, the method 700 can be performed, at least partially, in an automated fashion by, for example, the computing device 301.

[0143] According to an embodiment, the method 700 further comprises determining 709 an alignment between the image source and the waveguide based on the comparison of the relative position of the first image and the second image.

[0144] In some embodiments, a user can compare the relative position of the first image and the second image and determining the alignment between the image source and the waveguide based on the comparison of the relative position of the first image and the second image. In other embodiments, these can be performed by, for example, the computing device 301 or some other data processing device as disclosed herein.

[0145] According to an embodiment, the method 700 further comprises adjusting 710 the alignment between the image source and the waveguide based on the determined alignment between the image source and the waveguide.

[0146] The adjusting 710 the alignment between the image source and the waveguide may comprise, for example, adjusting the alignment until a desired alignment, such as a desired tilt angle of the image source, is achieved. In some embodiments, the adjusting may be performed in an iterative fashion by repeatedly performing an adjustment and determining a new alignment after the

adjustment until a desired alignment is achieved. In other embodiments, such as when the alignment marker comprises the at least one alignment indicator, it may be possible to achieve the desired alignment using one
5 adjustment. This can be confirmed by determining the alignment again after the adjustment.

[0147] In some embodiments, a user can adjust the alignment between the image source and the waveguide based on the determined alignment between the image
10 source and the waveguide. In other embodiments, these can be performed by, for example, the computing device 301 or some other data processing device as disclosed herein.

[0148] It should be appreciated that the operations
15 of the method 700 may be performed in various orders and some operations may be performed substantially simultaneously. For example, the arranging 701 the at least one camera and the arranging the reflector may be performed in any order. Further, when the image source is produc-
20 ing 703 light, at least operations 704 - 708 may be performed substantially simultaneously and continuously.

[0149] Fig. 10 illustrates a schematic representation of display device according to an embodiment.

25 **[0150]** According to an embodiment, the image source 101 comprises a projector of a see-through display device and a lens of the see-through display device comprises the waveguide 105.

[0151] The display device 800 may be implemented as, for example, a see-through display device.

[0152] The display device 800 may be implemented as, for example, a head-mounted display device.

5 [0153] For example, in the embodiment of Fig. 10, the display device 800 is implemented as smart glasses. The waveguide 105 can correspond to a lens or a layer of a lens of such smart glasses. Such smart glasses may be used to, for example, implement augmented reality (AR),
10 virtual reality (VR), and/or extended reality (XR) functionality.

[0154] In the embodiment of Fig. 10, the display device 800 comprises an optical engine, such as a light-emitting diode (LED) optical engine, a scanner-based
15 optical engine, and/or a laser-scanning optical engine as the image source 101.

[0155] The arrangement 100 and/or the method 700 can be used in, for example, quality control of display devices 800, such as smart glasses. For example, the
20 arrangement and/or the method 700 can be used to ensure that the image source 101 is correctly aligned with the waveguide 105. If the structure of the display device 800 enables realignment, the arrangement 100 and/or the method 700 can be used to correct the alignment or if
25 the structure of the display device 800 does not enable realignment, the alignment can be performed, for example, in a manner illustrated in the embodiment of Fig. 8 or the display device 800 may be discarded as a part

of quality control if the alignment is not satisfactory, such as within predetermined tolerances.

[0156] Any range or device value given herein may be extended or altered without losing the effect sought.

5 Also any embodiment may be combined with another embodiment unless explicitly disallowed.

[0157] Although the subject matter has been described in language specific to structural features and/or acts, it is to be understood that the subject matter defined
10 in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as examples of implementing the claims and other equivalent features and acts are intended to be within the
15 scope of the claims.

[0158] It will be understood that the benefits and advantages described above may relate to one embodiment or may relate to several embodiments. The embodiments are not limited to those that solve any or all of the
20 stated problems or those that have any or all of the stated benefits and advantages. It will further be understood that reference to 'an' item may refer to one or more of those items.

[0159] Aspects of any of the embodiments described
25 above may be combined with aspects of any of the other embodiments described to form further embodiments without losing the effect sought.

[0160] The term 'comprising' is used herein to mean including the method, blocks or elements identified, but

that such blocks or elements do not comprise an exclusive list and a method or apparatus may contain additional blocks or elements.

[0161] It will be understood that the above description is given by way of example only and that various modifications may be made by those skilled in the art. The above specification, examples and data provide a complete description of the structure and use of exemplary embodiments. Although various embodiments have been described above with a certain degree of particularity, or with reference to one or more individual embodiments, those skilled in the art could make numerous alterations to the disclosed embodiments without departing from the spirit or scope of this specification.

CLAIMS:

1. An arrangement (100) for optical measurements, the arrangement (100) comprising:

- an image source (101);
- 5 - at least one camera (103); and
- a mounting arrangement (104) for a waveguide (105), wherein the waveguide (105) comprises an in-coupling structure (111) for coupling light into the waveguide (105) and an out-coupling structure (112) for coupling light out of the waveguide (105);

10 wherein the image source (101) is configured to produce light (131) comprising a test image and the image source (101) is arrangeable to direct the light to the in-coupling structure (111) of the waveguide (105);

15 the at least one camera (103) is arrangeable to receive light (132) out-coupled by the out-coupling structure (112) to a first side (121) of the waveguide (105) and to receive light (133) out-coupled by the out-coupling structure (112) to a second side (122) of the waveguide (105); and

20 the at least one camera (103) is configured to produce a first image based on the light (132) out-coupled by the out-coupling structure (112) to the first side (121) of the waveguide (105) and produce a second image based on the light (133) out-coupled by the out-coupling structure (112) to the second side (122) of the waveguide (105).

2. The arrangement (100) according to claim 1, further comprising a reflector (102) arrangeable to the second side (122) of the waveguide (105) for receiving the light (133) out-coupled by the out-coupling structure (112) to the second side (122) of the waveguide (105), wherein the reflector (102) is configured to reflect at least a part of the light (133) received from the out-coupling structure (112) to the at least one camera (103) and the at least one camera (103) is further configured to produce the second image based on the light (134) received from the reflector (102).

3. The arrangement (100) according to claim 2, wherein the reflector (102) comprises a retroreflector.

4. The arrangement (100) according to claim 3, wherein retroreflector is further configured to rotate the test image by substantially 180 degrees.

5. The arrangement (100) according to claim 1, wherein the at least one camera (103) comprises a first camera arrangeable to receive the light (132) out-coupled by the out-coupling structure (112) to the first side (121) of the waveguide (105) and a second camera arrangeable to receive the light (133) out-coupled by the out-coupling structure (112) to the second side (122) of the waveguide (105), wherein the first camera is configured to produce the first image based on the light (132) out-coupled by the out-coupling structure (112) to the first side (121) of the waveguide (105) and

the second camera is configured to produce the second image based on the light (133) out-coupled by the out-coupling structure (112) to the second side (122) of the waveguide (105).

5

6. The arrangement (100) according to any preceding claim, further comprising a computing device (301) configured to:

10 obtain the first image and the second image from the at least one camera (103); and

compare a relative position of the first image and the second image.

7. The arrangement (100) according to claim 6,
15 wherein the computing device (301) is further configured to determine an alignment of the image source (101) in relation to the waveguide (105) based on the comparison of the relative position of the first image and the second image.

20

8. The arrangement (100) according to claim 7,
wherein the computing device (301) is further configured to adjust the alignment between the image source (101) and the waveguide (105) by controlling the image source
25 (101).

9. The arrangement (100) according to claim 7, further comprising an actuator (401) coupled to the computing device (301), wherein the computing device (301)
30 is further configured to adjust the alignment between

the image source (101) and the waveguide (105) based on the determined alignment between the image source (101) and the waveguide (105) using the actuator (401).

5 10. The arrangement (100) according to any preceding claim, wherein the test image comprises at least one alignment marker (502).

10 11. A method (700) for an optical measurement, the method comprising:

 arranging (701) at least one camera on at least a first side of a waveguide;

 producing (703) light comprising a test image using an image source;

15 directing (704) the light to an in-coupling structure of the waveguide, wherein the in-coupling structure is configured to couple the light into the waveguide and the waveguide comprises an out-coupling structure for coupling light out of the waveguide;

20 receiving (705) light out-coupled by the out-coupling structure to a first side of the waveguide using the at least one camera thus producing a first image;

 receiving (707) light out-coupled by the out-coupling structure to a second side of the waveguide using
25 the at least one camera thus producing a second image;
 and

 comparing (708) a relative position of the first image and the second image.

12. The method according to claim 11, the method further comprising arranging a reflector on the second side of the waveguide and receiving, using the reflector, the light out-coupled by the out-coupling structure to the second side of the waveguide; and

the receiving (707) the light out-coupled by the out-coupling structure to the second side of the waveguide using the at least one camera thus producing the second image comprises: reflecting, using the reflector, at least a part of the light received by the reflector from the out-coupling structure to the at least one camera and producing, using the at least one camera, the second image based on the light received from the reflector.

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13. The method according to claim 12, wherein the reflector comprises a retroreflector.

14. The method according to claim 11, wherein the at least one camera (103) comprises a first camera and a second camera and the arranging (701) the at least one camera on at least the first side of the waveguide comprises:

arranging the first camera on the first side of the waveguide;

arranging the second camera on the second side of the waveguide;

the receiving (705) light out-coupled by the out-coupling structure of the waveguide to the first side of the waveguide using the at least one camera thus

producing the first image comprises receiving the light out-coupled by the out-coupling structure to the first side of the waveguide using the first camera thus producing the first image; and

5 the receiving (707) light out-coupled by the out-coupling structure to the second side of the waveguide using the at least one camera thus producing the second image comprises receiving light out-coupled by the out-coupling structure to the second side of the waveguide
10 using the second camera thus producing the second image.

15 15. The method (700) according to any of claims 11 - 14, the method (700) further comprising determining (709) an alignment between the image source and the waveguide based on the comparison of the relative position of the first image and the second image.

20 16. The method (700) according to claim 15, the method (700) further comprising adjusting (710) the alignment between the image source and the waveguide based on the determined alignment between the image source and the waveguide.

25 17. The method (700) according to any of claims 11 - 16, wherein the test image comprises at least one alignment marker.

18. The method (700) according to any of claims 11 - 17, wherein the in-coupling structure comprises an in-

coupling diffraction grating and the out-coupling structure comprises an out-coupling diffraction grating.

19. The method (700) according to any of claims 11
5 - 18, wherein the image source comprises a projector of
a see-through display device and a lens of the see-
through display device comprises the waveguide.