

DISPLAY STRUCTURE AND DISPLAY DEVICE**FIELD OF TECHNOLOGY**

[0001] This disclosure concerns display devices. In particular, some embodiments concern waveguide-based display devices with one or more diffraction gratings, and structures therefor.

BACKGROUND

5 [0002] Waveguide-based display device, such as augmented reality (AR) headsets, or smart glasses, may use diffraction grating(s) to couple light into a waveguide and/or out of the waveguide to project a virtual image onto a user's eye.

10 [0003] A challenge with such waveguide-based display device is to produce a color-balanced virtual image.

SUMMARY

[0004] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

15 [0005] It is an object to provide a display structure and a display device producing a color-balanced virtual image. 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.

[0006] According to a first aspect, a display structure comprises a waveguide, and a diffraction structure, the diffraction structure comprising: a diffraction grating arranged on a face of the waveguide, a first coating layer of transparent dielectric material, the first coating layer at least partially covering the diffraction grating and configured to shift a resonance band of the diffraction grating, and a second coating layer at least partially covering the first coating layer.

[0007] According to a second aspect, a display device comprises a display structure according to the first aspect.

[0008] 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.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The present disclosure will be better understood from the following detailed description read in light of the accompanying drawings, wherein:

[0010] FIG. 1 shows a planar view of a display structure according to an example embodiment,

[0011] FIG. 2 shows a cross-sectional view of a display structure according to an example embodiment,

[0012] FIG. 3 shows a cross-sectional view of a ridge of a display structure according to an example embodiment,

[0013] FIG. 4 shows a cross-sectional view of a ridge of a display structure according to another example embodiment,

5 [0014] FIG. 5A shows a spectral response of a baseline display structure,

[0015] FIG. 5B shows a spectral response of a display structure according to an example embodiment for a varying thickness of the coating layer,

10 [0016] FIG. 5C shows a spectral diffraction efficiency of a baseline display structure,

[0017] FIG. 5D shows a spectral diffraction efficiency of a display structure according to an example embodiment,

15 [0018] FIG. 5E shows a spectral diffraction efficiency of a display structure according to an example embodiment without an additional underlayer,

[0019] FIG. 5F shows a spectral diffraction efficiency of a display structure according to an example embodiment with an additional underlayer,

20 [0020] FIG. 6 illustrates a display device according to an example embodiment.

[0021] Unless specifically stated to the contrary, any drawing of the aforementioned drawings may be not drawn to scale such that any element in said drawing may be
25 drawn with inaccurate proportions with respect to other elements in said drawing in order to emphasize certain structural aspects of the embodiment of said drawing.

[0022] Moreover, corresponding elements in the embodiments of any two drawings of the aforementioned drawings may be disproportionate to each other in said two
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drawings in order to emphasize certain structural aspects of the embodiments of said two drawings.

DETAILED DESCRIPTION

[0023] FIG. 1 depict a planar view of a display structure 1000 according to an example embodiment. The display structure 1000 may be part of a display device.

[0024] In this specification, a "display device" may refer to an operable output device, e.g., electronic device, for visual presentation of images and/or data. A display device may generally comprise any part(s) or element(s) necessary or beneficial for visual presentation of images and/or data, for example, a power unit; an optical engine; a combiner optics unit, such as a waveguide-based combiner optics unit; an eye tracking unit; a head tracking unit; a gesture sensing unit; and/or a depth mapping unit. A display device may or may not be a portable display device, for example, a head-mounted display device, such as an augmented reality (AR) headset, and/or a see-through display device, such as smart glasses or head-up display.

[0025] Herein, a "head-mounted display device" may refer to a display device configured to be worn on the head, as part of a piece of headgear, and/or on or over the eyes.

[0026] Further, a "see-through display device" or "transparent display device" may refer to a display device allowing its user to see the images and/or data shown on the display device as well as to see through the display device.

[0027] Throughout this disclosure, a "display structure" may refer to at least part of an operable display

device. Additionally or alternatively, a display structure may refer to a structure suitable for use in a display device.

[0028] According to an embodiment, a display structure
5 1000 comprises a waveguide 101. The waveguide 101 may
comprise, for example, a substantially planar waveguide.
Alternatively, or additionally, the waveguide 101 may
also comprise curved sections. For example, the wave-
guide 101 may correspond to a lens of an augmented re-
10 ality (AR) headset, or smart glasses.

[0029] The display structure 1000 may further comprise
an in-coupling (IC) structure 102 configured to couple
light into the waveguide 101.

[0030] The light may be generated by, for example, a
15 scanner-based optical engine. The light may represent
an image generated by, for example, such an optical
engine. Thus, the image may be referred to as, for ex-
ample, virtual image or AR image.

[0031] The in-coupling structure 102 may comprise a
20 diffraction grating on a face of the waveguide 101. The
in-coupling structure 102 may couple the light into the
waveguide 101 via diffraction. The in-coupling diffrac-
tion grating may be arranged on either face of the wave-
guide 101. The in-coupling diffraction grating may be
25 configured to function as a reflection-type diffraction
grating or as a transmission-type diffraction grating.
The side from which the in-coupling diffraction grating
is configured to in-couple the visible light does not
depend on which side of the waveguide 101 the in-cou-
30 pling diffraction grating is positioned.

[0032] The display structure 1000 may further comprise
an exit pupil expansion (EPE) structure 103 arranged on

a face of the waveguide 101 and configured to perform exit pupil expansion e.g., by pupil replication. The EPE structure 103 may comprise a diffraction grating on either one of the faces of the waveguide 101.

5 **[0033]** “Exit pupil expansion” may refer to a process of distributing light within a waveguide in a controlled manner so as to expand a portion of said waveguide where out-coupling of light occurs. Further, “pupil replication” may refer to an exit pupil expansion process,
10 wherein a plurality of exit sub-pupils are formed in an imaging system. The EPE structure 103 may be configured to perform exit pupil expansion along one or more other directions perpendicular to a thickness direction of the waveguide.

15 **[0034]** The display structure 1000 may further comprise an out-coupling (OC) structure 104 arranged on a face of the waveguide 101 and configured to out-couple light from the waveguide.

20 **[0035]** The out-coupling structure 104 may comprise a diffraction grating on a face of the waveguide 101. The out-coupling structure 104 may couple the light out of the waveguide 101 via diffraction. The out-coupling diffraction grating may be arranged on either face of the waveguide 101. The out-coupling diffraction grating may
25 be configured to function as a reflection-type diffraction grating or as a transmission-type diffraction grating. The side from which the out-coupling diffraction grating is configured to out-couple the light does not depend on which side of the waveguide 101 the out-coupling diffraction grating is positioned.
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30 **[0036]** The diffractive out-coupling structure 104 may be configured to perform exit pupil expansion. Both the

EPE structure 103 and the diffractive out-coupling structure 104 can be configured to expand the image. For example, the EPE structure 103 may expand the image in one direction and the diffractive out-coupling structure 104 can expand the image in a perpendicular direction. Alternatively, the EPE structure 103 may be configured to expand the image in two perpendicular directions and the diffractive out-coupling structure 104 may be configured to out-couple the light from the waveguide 101.

10 **[0037]** It should be understood that the geometry of the display structure 1000 illustrated in the embodiment of Fig. 1 is only exemplary and the display structure 1000 may be implemented in various other ways. For example, the waveguide 101, the in-coupling structure 102, 15 the EPE structure 103, and/or the out-coupling structure 104 can be of different sizes and/or shapes than what is illustrated in the embodiment of Fig. 1.

[0038] FIG. 2 shows a cross-sectional view of a display structure (e.g., display structure 1000 of FIG. 1) according to an example embodiment. The example embodiment of FIG. 2 may be in accordance with any of the example embodiments disclosed with reference to and/or in conjunction with FIG. 1. Additionally, or alternatively, although not explicitly shown in FIG. 2, the 25 example embodiment of FIG. 2 or any part thereof may generally comprise any features and/or elements of the example embodiments of FIG. 1 which are omitted from FIG. 2.

[0039] The display structure 1000 comprises a waveguide 101 and at least one diffraction structure 200. The diffraction structure 200 may be an in-coupling 30

structure 102, an EPE structure 103, an out-coupling structure 104, or any combination thereof.

[0040] In this disclosure, a "waveguide" may refer to an optical waveguide. Additionally, or alternatively, a
5 waveguide may refer to a two-dimensional waveguide, wherein light may be confined along a thickness direction of said waveguide. The waveguide may be made of transparent dielectric material.

[0041] The waveguide 101 may comprise a first face 201
10 and a second face 202 for confining light in the waveguide by total internal reflection. In this disclosure, "total internal reflection" may refer to total or substantially total internal reflection. The second face is arranged opposite the first face 101 and towards a
15 thickness direction therefrom.

[0042] In this disclosure, a "face" of a waveguide may refer to a part of a surface of said waveguide viewable from or facing a certain viewing direction. Additionally, or alternatively, faces of a waveguide may refer
20 to surfaces suitable for or configured to confine light in said waveguide by total internal reflection.

[0043] The diffraction structure 200 comprises a diffraction grating 210. The "diffraction grating" may refer to an optical grating the operation of which is
25 based on diffraction of light. Generally, a diffraction grating may comprise one or more structural features with at least one dimension of the order of the wavelengths of visible light, for example, at least one dimension less than one micrometer. Generally, a diffraction grating may be implemented as a single-region
30 diffraction grating or as a multi-region diffraction

grating. Diffraction gratings may generally be implemented, at least, as surface relief diffraction gratings or volume holographic diffraction gratings, and they may be configured to function as transmission- and/or reflection-type diffraction gratings.

[0044] The waveguide 101 and diffraction structure 200 form a resonant waveguide grating structure also called grating coupler. For specific light frequencies (within a resonance band), the diffraction structure 200 couples light in/out of a guided mode of the waveguide. If the diffraction structure 200 is used as an in-coupling structure, the resonant light is coupled into a guided mode of the waveguide. If the diffraction structure 200 is used as an out-coupling structure, the resonant light is coupled out of a guided mode of the waveguide. Off-resonance light incident on the diffraction structure 200 remains in the guided mode of the waveguide.

[0045] For a specific light frequency, the larger the diffraction efficiency of the diffraction structure 200, the larger percent of light is coupled in/out. As illustrated by FIG. 5A, the diffraction efficiency of the diffraction structure 200 may vary along the visible spectrum. In the example of FIG. 5A, there is a heavy loss of red color wavelengths while green wavelengths are dominant. As a result, the virtual image may not be color balanced. The color balance of the virtual image may be affected by the in-coupling structure 102, the EPE structure 103, and/or the out-coupling structure 104.

[0046] The diffraction grating 210 may be a surface relief grating. In particular, the diffraction grating

210 may comprise an alternance of depressions and elevations. The elevations may be ridges 211. In FIG. 2, the ridges 211 extend longitudinally perpendicular to the plane of the drawing. The ridges 211 may have a
5 rectangular cross-sectional shape as illustrated on FIG. 2, or any other suitable cross-sectional shape.

[0047] In example embodiments, the diffraction grating 210 may have a fill factor F in a range of 0 to 1, in a range of 0.01 to 0.99, in a range of 0.05 to 0.95,
10 in a range of 0.1 to 0.9, or in a range of 0.2 to 0.8. The fill factor F is the fraction of the grating period that is filled with the grating material.

[0048] The diffraction grating 210 may be formed at least partly using nanoimprint lithography. In other
15 embodiments, any suitable fabrication method(s), for example, nanoimprint lithography and/or grayscale electron-beam lithography, may be used.

[0049] FIG. 3 depicts a zoomed view of zone Z1 (as indicated on FIG. 2) around a ridge 211 of a diffraction
20 structure 200 according to an example embodiment. The example embodiment of FIG. 3 may be in accordance with any of the example embodiments disclosed with reference to and/or in conjunction with FIG. 1 or 2. Additionally or alternatively, although not explicitly shown in
25 FIG. 3, the example embodiment of FIG. 3 or any part thereof may generally comprise any features and/or elements of the example embodiments of FIG. 1 or 2 which are omitted from FIG. 3.

[0050] The diffractive structure 200 may comprise a
30 first coating layer 301 and a second coating layer 302. The first coating layer 301 covers partially, substantially completely, or completely the diffraction grating

210. The second coating layer 302 covers partially, substantially completely, or completely the first coating layer 301.

[0051] The first coating layer 301 may be formed directly on the diffraction grating 210. The second coating layer 302 may be formed directly on the first coating layer 301. Alternatively, the diffractive structure 200 may comprise one or more additional layers between the first coating layer 301 and the second coating layer 302, and/or between the diffraction grating 210 and the first coating layer 301. The diffractive structure 200 may also comprise one or more additional layers on top of the second coating layer 302.

[0052] The first coating layer 301 may cover the elevations of the diffraction grating 210 and optionally the depressions. In particular, the first coating layer 301 may cover at least some of the ridges 211, and more specifically an upper surface 212 of the ridge 211 and optionally side surfaces 213, 214 of the ridge 211.

[0053] In the case of a reflection-type diffraction grating, the second coating layer 302 may be a reflective coating. In particular, the second coating layer 302 may comprise or consist of a metal such as Silver or Aluminum. Such a reflective coating can improve the brightness efficiency of the display structure.

[0054] In any embodiment, the second coating layer 302 may be a transparent coating. In particular, the second coating layer 302 may comprise or consist of a transparent material such as silicon dioxide (SiO_2), aluminum oxide (AlO_3), and/or magnesium fluoride (MgF_2). Such a transparent coating can improve the brightness efficiency of the display structure.

[0055] The first coating layer 301 may be a transparent dielectric coating.

[0056] The first coating layer 301 can shift the resonance band of the diffractive grating 210 (e.g., along the visible spectrum). The first coating layer 301 can be configured (e.g., the material and/or thickness of the first coating layer 301 can be selected) to adjust the diffraction efficiency for at least one visible wavelength (e.g., a first visible wavelength) in relation to at least another visible wavelength (e.g., a second visible wavelength), e.g., to improve the uniformity of the diffraction efficiency across the visible spectrum. This can be used to adjust the intensities of the various colors (e.g., red, green, and blue) in the virtual image, e.g., to produce an evenly distributed white color in the virtual image.

[0057] The first coating layer 301 has a first thickness (t_1). The second coating layer 302 has a second thickness (t_2). Herein, a "thickness" of a coating layer may refer to a measure of the extent of said coating layer along a thickness direction of a waveguide. In particular, the "thickness" of a coating layer may be measured over the elevations of the diffraction grating 210. In example embodiments, t_1 may be greater than or equal to 5 nm and/or less than or equal to 40 nm. In example embodiments, t_2 may be greater than or equal to 100 nm and/or less than or equal to 250 nm.

[0058] The first coating layer 301 may comprise, consist essentially of, or consist of a first material having a first refractive index (n_1) at a visible wavelength (λ_{vis}). The diffraction grating 210 (e.g., the

ridges 211 forming the diffraction grating 210) may comprise, consist essentially of, or consist of a second material having a second refractive index (n_2).

[0059] In example embodiments, n_2 is greater than n_1 .

5 In example embodiments, n_1 is greater than or equal to 1.3, and/or less than or equal to 2.7. In example embodiments, n_2 is greater than or equal to 2.4 and/or less than or equal to 2.9. It should be appreciated that n_2 can depend on the wavelength of the light. For example,
10 ple, for short visible wavelengths (blue) n_2 may be large, such as close to 2.8, and for long visible wavelengths (red) n_2 may be small, such as close to 2.4.

[0060] In example embodiments, the first material may be comprise one or a combination of the following materials:
15 rials: Titanium nitride (TiN) (e.g., with a refractive index RI of approximately 2.7), Niobium pentoxide (Nb₂O₅) (e.g., RI ~2.24), Zirconium dioxide (ZrO₂) (RI ~2.11), Tantalum pentoxide (Ta₂O₅) (RI ~2.05), Silicon nitride (Si₃N₄) (RI ~1.98), Hafnium(IV) oxide (HfO₂) (RI ~1.87), Aluminum oxide (Al₂O₃) (RI ~1.77), Silicon di-
20 oxide (SiO₂) (RI~1.45), or Magnesium fluoride (MgF₂) (RI ~1.38).

[0061] The first coating layer 301 may comprise a plurality of sublayers of transparent dielectric material.
25 For example, the first coating layer 301 may comprise (or consist of) a first sublayer of Magnesium fluoride (MgF₂) and a second sublayer of Silicon dioxide (SiO₂). MgF₂ and SiO₂ can provide an advantageous wavelength-dependent resonance as a function of the fill factor.

30 **[0062]** In example embodiments, the second material may be titanium dioxide (TiO₂) (e.g., with a RI of approximately 2.45 at a wavelength of 520 nm).

[0063] The first coating layer 301 and/or the second coating layer 302 may be formed at least partly using evaporation or sputtering. In other embodiments, any suitable fabrication method(s) may be used.

5 [0064] **FIG. 4** depicts a zoomed view of zone Z1 (as indicated on FIG. 2) around a ridge 211 of a diffraction structure 200 according to an example embodiment. The example embodiment of FIG. 4 may be in accordance with any of the example embodiments disclosed with reference
10 to and/or in conjunction with FIG. 1 to 3. Additionally, or alternatively, although not explicitly shown in FIG. 4, the example embodiment of FIG. 4 or any part thereof may generally comprise any features and/or elements of the example embodiments of FIG. 1 to 3 which
15 are omitted from FIG. 3.

[0065] The diffractive structure 200 may further comprise a first underlayer 401 and a second underlayer 402 between the waveguide 101 and the diffraction grating 210.

20 [0066] The first underlayer 401 covers partially, substantially completely, or completely the waveguide 101. The second underlayer 402 covers partially, substantially completely, or completely the first underlayer 401. The diffraction grating 210 is arranged on the
25 second underlayer 402. The diffraction grating 210 covers partially, substantially completely, or completely the second underlayer 402.

[0067] The first underlayer 401 may be formed directly on the waveguide 101. The second underlayer 402 may be
30 formed directly on the first underlayer 401. The diffraction grating 210 may be arranged directly on the second underlayer 402. Alternatively, the diffractive

structure 200 may comprise one or more additional layers between the waveguide 101 and first underlayer 401, and/or between the first underlayer 401 and the second underlayer 402, and/or between the second underlayer 402 and the diffraction grating 210.

[0068] The first underlayer 401 and second underlayer 402 can be implemented in combination or independently of the first coating layer 301 and the second coating layer 302.

10 **[0069]** The first underlayer 401 may be a transparent dielectric layer. The second underlayer 402 may be a transparent dielectric layer.

[0070] The first 401 and second 402 underlayers can shift the resonance band of the diffractive grating 210 (e.g., along the visible spectrum). The second underlayer 402 can be configured (e.g., the material and/or thickness of the second underlayer 402 can be selected) to adjust the diffraction efficiency for at least one visible wavelength (e.g., a third visible wavelength) in relation to at least another visible wavelength (e.g., a fourth visible wavelength), e.g., to improve the uniformity of the diffraction efficiency across the visible spectrum. This can be used to adjust the intensities of the various colors (e.g., red, green, and blue) in the virtual image, e.g., to produce an evenly distributed white color in the virtual image.

20 **[0071]** The first 401 and second 402 underlayers maybe used in combination with the first coating layer 301 to adjust the diffraction efficiency for the same or for different visible wavelengths.

[0072] The first underlayer 401 has a third thickness (t_3). The second underlayer 402 has a fourth thickness

(t_4). Herein, a "thickness" of a layer may refer to a measure of the extent of said layer along a thickness direction of a waveguide. In example embodiments, t_3 may be greater than or equal to 20 nm and/or less than or equal to 60 nm. In example embodiments, t_4 may be greater than or equal to 5 nm and/or less than or equal to 20 nm.

[0073] The first underlayer 401 may comprise, consist essentially of, or consist of a third material having a third refractive index (n_3) at a visible wavelength (λ_{vis}). The second underlayer 402 may comprise, consist essentially of, or consist of a fourth material having a fourth refractive index (n_4).

[0074] In example embodiments, n_3 is greater than n_4 . In example embodiments, n_4 is greater than or equal to 1.3, and/or less than or equal to 2.7. In example embodiments, n_3 is greater than or equal to 2.4 and/or less than or equal to 2.8. It should be appreciated that n_3 can depend on the wavelength of the light. For example, for short visible wavelengths (blue) n_3 may be large, such as close to 2.8, and for long visible wavelengths (red) n_3 may be small, such as close to 2.4.

[0075] In example embodiments, the fourth material may be one or a combination of two or more of the following materials: Titanium nitride (TiN) (e.g., with a refractive index RI of approximately 2.7), Niobium pentoxide (Nb₂O₅) (e.g., RI ~2.24), Zirconium dioxide (ZrO₂) (RI ~2.11), Tantalum pentoxide (Ta₂O₅) (RI ~2.05), Silicon nitride (Si₃N₄) (RI ~1.98), Hafnium(IV) oxide (HfO₂) (RI

~1.87), Aluminum oxide (AL₂O₃) (RI ~1.67), Silicon dioxide (SiO₂) (RI~1.45), or Magnesium fluoride (MgF₂) (RI ~1.38).

[0076] In example embodiments, the third material may
5 be titanium dioxide (TiO₂) (e.g., with a RI of approximately 2.45 at a wavelength of 520 nm).

[0077] The fourth material may be the same as the first material. The third material may be the same as the second material.

10 [0078] The first underlayer 401 and/or the second underlayer 402 may be formed at least partly using evaporation or sputtering. In other embodiments, any suitable fabrication method(s) may be used.

[0079] In some example embodiments, the values of the
15 refraction indexes (e.g., n_1 , n_2 , n_3 , n_4) may be considered at a λ_{vis} of 500 nm. In other example embodiments, the values of the refraction indexes may be considered at any suitable visible wavelength, i.e., any wavelength within a spectral range extending from 380 nm to 760 nm.
20 For example, in some example embodiments, the relevant visible wavelength may be selected from the group consisting of 450 nm, 460 nm, 470 nm, 480 nm, 490 nm, 500 nm, 510 nm, 520 nm, 530 nm, 540 nm, 550 nm, 560 nm, 570 nm, 580 nm, 590 nm, 600 nm, 610 nm, 620 nm, 630 nm,
25 640 nm, and 650 nm.

[0080] FIG. 5B shows a spectral response of a display structure according to an example embodiment for a thickness of the first coating layer varying from 5 nm to 40 nm. FIG. 5B shows that the diffraction efficiency
30 varies with the thickness of the first coating layer.

[0081] FIG. 5C shows a spectral diffraction efficiency of a baseline display structure without the first

coating layer. FIG. 5D shows a spectral diffraction efficiency of a display structure according to an example embodiment with the first coating layer. FIGs 5C and 5D show that the first coating layer shifts the resonance band of the diffractive grating along the visible spectrum, thereby adjusting the diffraction efficiency of the various visible wavelengths.

[0082] FIG. 5E shows a spectral diffraction efficiency of a display structure according to an example embodiment with no underlayer. FIG. 5F shows a spectral diffraction efficiency of a display structure according to an example embodiment with a first and a second underlayer. FIGs 5E and 5F show that the first and second underlayer shift the resonance band of the diffractive grating along the visible spectrum, thereby adjusting the diffraction efficiency of the various visible wavelengths.

[0083] FIG. 6 depicts a display device 6000 according to an example embodiment. The example embodiment of FIG. 6 may be in accordance with any of the example embodiments disclosed with reference to and/or in conjunction with any of FIGs 1 to 4. Additionally, or alternatively, although not explicitly shown in FIG. 6, the example embodiment of FIG. 6 or any part thereof may generally comprise any features and/or elements of any of the example embodiments of FIGs 1 to 4 which are omitted from FIG. 6.

[0084] In the example embodiment of FIG. 6, the display device 6000 is implemented as a see-through head-mounted display device, more specifically, as spectacles comprising a see-through display. In other embodiments, a display device may be implemented in any suitable

manner, for example, as a see-through and/or as a head-mounted display device.

[0085] In the example embodiment of FIG. 6, the display device 6000 comprises a frame 601 and a display structure 1000 supported by the frame 601. In other embodiments, a display device may or may not comprise such frame.

[0086] In the example embodiment of FIG. 6, the display structure 6200 comprises a waveguide 101, an in-coupling structure 102 for coupling light into the waveguide 101, an EPE structure 103 configured to receive light from the in-coupling structure 102, and a reflection-type out-coupling structure 104 configured to receive light from the EPE structure 103. In other embodiments, a display structure may or may not comprise such EPE structure. In other embodiments, the out-coupling structure 104 may be transmission-type.

[0087] As shown in FIG. 6, the display device 6000 further comprises an optical engine 140 configured to direct light into the waveguide 101 for propagation in the waveguide 101 by total internal reflection. In other embodiments, a display device may or may not comprise such optical engine.

[0088] It is obvious to a person skilled in the art that with the advancement of technology, the basic idea of the invention may be implemented in various ways. The invention and its embodiments are thus not limited to the examples described above, instead they may vary within the scope of the claims.

[0089] It will be understood that any 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 stated problems or those that have any or all of the stated benefits and advantages.

[0090] The term "comprising" is used in this specification to mean including the feature(s) or act(s) followed thereafter, without excluding the presence of one or more additional features or acts. It will further be understood that reference to 'an' item refers to one or more of those items.

CLAIMS

1. A display structure (1000) comprising a waveguide (101), and a diffraction structure (200), the diffraction structure (200) comprising:

5 a diffraction grating (210) arranged on a face (201) of the waveguide (101),

a first coating layer (301) of transparent dielectric material, the first coating layer (301) at least partially covering the diffraction grating (210) and configured to shift a resonance band of the diffraction grating (210), and

10 a second coating layer (302) at least partially covering the first coating layer (301).

2. A display structure (1000) according to claim 1, wherein the second coating layer (302) is a reflective coating.

3. A display structure (1000) according to claim 2, wherein the second coating layer (302) is a metallic coating.

4. A display structure (1000) according to claim 1, wherein the second coating layer (302) is a transparent coating.

25 5. A display structure (1000) according to any preceding claim, wherein one or more of a material and a thickness of the first coating layer (301) are selected to adjust a diffraction efficiency of the diffraction grating (210) for at least a first visible wavelength in relation to at least a second visible wavelength.

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6. A display structure (1000) according to the preceding claim, wherein a material of the first coating layer (301) has a first refractive index (n_1) at a visible wavelength (λ_{vis}), wherein a material of the diffraction grating (210) has a second refractive index (n_2) at a visible wavelength (λ_{vis}), wherein the second refractive index (n_2) is greater than the first refractive index (n_1).

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7. A display structure (1000) according to claim 6, wherein the first refractive index (n_1) is greater than or equal to 1.3 and/or less than or equal to 2.7.

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8. A display structure (1000) according to claim 6 or 7, wherein the second refractive index (n_2) is greater than or equal to 2.4 and/or less than or equal to 2.9.

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9. A display structure (1000) according to any of claims 5 to 8, wherein the thickness of the first coating layer (301) is greater than or equal to 5 nm, and/or less than or equal to 40 nm.

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10. A display structure (1000) according to any preceding claim, wherein the display structure (210) further comprises:

a first underlayer (401) of transparent dielectric material; and

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a second underlayer (402) of transparent dielectric material, the second underlayer (402) at least partially covering the first underlayer (401),

and wherein the diffraction grating (210) is arranged on the second underlayer (402).

11. A display structure (1000) according to the preceding claim, wherein the first underlayer (401) and the second underlayer (402) are configured to shift the resonance band of the diffraction grating (210).

12. A display structure (1000) according to the preceding claim, wherein one or more of a material and a thickness of the second underlayer (402) are selected to adjust a diffraction efficiency of the diffraction grating (210) for at least a third visible wavelength in relation to at least a fourth visible wavelength.

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13. A display structure (1000) according to the preceding claim, wherein a material of the first underlayer (401) has a third refractive index (n_3) at a visible wavelength (λ_{vis}), wherein a material of the second underlayer (402) has a fourth refractive index (n_4) at a visible wavelength (λ_{vis}), wherein the third refractive index (n_3) is greater than the fourth refractive index (n_4).

14. A display structure (1000) according to claim 13, wherein the fourth refractive index (n_4) is greater than or equal to 1.3 and/or less than or equal to 1.7.

15. A display structure (1000) according to any of claims 13 or 14, wherein the third refractive index (n_3) is greater than or equal to 2.4 and/or less than or equal to 2.9.

16. A display structure (1000) according to any of claims 12 to 15, wherein the thickness of the second underlayer (402) is greater than or equal to 5 nm, and/or
5 less than or equal to 40 nm.

17. A display structure (1000) according to any of the preceding claims, wherein the diffraction structure (200) is an in-coupling structure, an exit pupil expansion structure, or an out-coupling structure.
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18. A display device (6000), comprising a display structure (6200) according to any of the preceding claims.