



(51) International Patent Classification:
F21V 8/00 (2006.01)

(21) International Application Number:
PCT/GB2018/052356

(22) International Filing Date:
20 August 2018 (20.08.2018)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1714334.8 06 September 2017 (06.09.2017) GB

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP,

KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— with international search report (Art. 21(3))



WO 2019/048821 A1

(54) Title: OPTICAL DEVICE FOR USE IN AN AUGMENTED REALITY OR VIRTUAL REALITY DEVICE

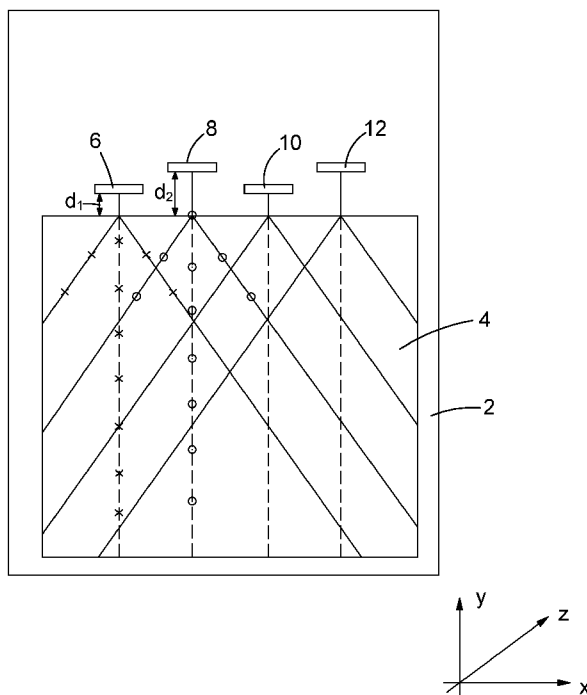


FIG. 1

(57) Abstract: An optical device or display is disclosed for use in an augmented reality or virtual reality device. The display includes a waveguide (2), an output element (4) and a plurality of input diffraction gratings (6, 8, 10, 12). Light from a plurality of projectors (16, 18, 20, 22) is diffracted by the input gratings (6, 8, 10, 12) so that it is coupled into the waveguide (2) by total internal reflection. The input gratings (6, 8, 10, 12) are provided in a staggered configuration in relation to the output element (4), with respect to a y-axis. Each input grating is adjacent another input grating that has a different separation distance from the output element (4). This can improve the evenness of illumination from the output element (4).

Optical Device for use in an Augmented Reality or Virtual Reality Device

The present invention relates to an optical device for use with an augmented reality or virtual reality device. In particular, the invention relates to a wide screen display
5 for an augmented reality device such as a head-up display.

In an augmented reality device a transparent waveguide is provided in front of a user's eye or eyes. A light projector transmits light towards the waveguide. Light can be coupled into the waveguide by an input diffraction grating. Light then
10 propagates within the waveguide by total internal reflection and an output diffraction grating couples light out of the waveguide and towards a viewer. In use, a viewer can see light from their external environment, transmitted through the transparent waveguide, as well as projected light from the projector. This can provide an augmented reality experience. These devices can be used in head-up displays in a
15 wide variety of applications, including industrial and automotive.

WO2016/020643 describes an optical device for expanding input light in two dimensions in an augmented reality display. In this arrangement an input diffractive optical element is configured to couple input light into a waveguide and two
20 diffractive optical elements are overlaid on one another in or on the waveguide. The lines in each of the overlaid diffractive optical elements are symmetrically angled with respect to rays from the input diffraction grating. Each of the overlaid diffractive optical elements can receive light from the input diffractive optical element and couple it towards the other diffractive optical element in the pair, which can then act
25 as an output diffractive optical element, coupling light out of the waveguide towards a viewer. In this way the optical device can achieve two-dimensional expansion of an input light source while simultaneously coupling light out of the waveguide so that it can be viewed by a user.

30 It would be desirable to use the technology described in WO2016/020643 in wide screen augmented reality displays. One challenge in developing such a display is to ensure that outcoupled orders can be provided evenly. An object of the present invention is to provide an arrangement that addresses this challenge.

According to an aspect of the invention there is provided an optical device or display for use in an augmented reality or virtual reality device, comprising: a waveguide; a plurality of input diffractive optical elements configured to couple light into the waveguide; an output element configured to receive light from the plurality of input diffractive optical elements in the direction of a first axis, wherein the output element includes two diffractive optical elements overlaid on one another in or on the waveguide, wherein each of the two diffractive optical elements is configured to receive light from the input diffractive optical element and couple it towards the other diffractive optical element which can then act as an output diffractive optical element providing outcoupled orders towards a viewer; wherein the plurality of input diffractive optical elements are provided at at least two respective positions with respect to the first axis.

In this way, light from respective input diffractive optical elements can encounter the output element at different positions with respect to the first axis. This can advantageously improve the evenness with which outcoupled orders can be provided towards a viewer. Preferably, for light from a first input diffractive optical element, outcoupled orders do not coincide with outcoupled orders for light from a second input diffractive optical element.

Preferably first and second separation distances are provided on the first axis between the output element and respective input diffractive optical elements. In this way, a gap can be provided between an input diffractive optical element and the output element. In this way, light from the input diffractive optical element can totally internally reflect in the waveguide between the input diffractive optical element and the output element. It is conceivable that the first or second separation distance could be zero in some embodiments. In another arrangement, one of the first and second separation distances is approximately equal to the total internal reflection period in the waveguide.

The plurality of input diffractive optical elements may be provided in a staggered configuration so that adjacent input diffractive optical elements are provided in first and second positions with respect to the first axis. In some arrangements,

therefore, first and second separation distances may be provided sequentially for input diffractive optical elements along the width of the waveguide. Advantageously this can allow gaps between outcoupled orders created from a first input diffractive optical element to be filled by outcoupled orders created from an adjacent input diffractive optical element. In some embodiments there may be more than two separation distances for the input diffractive optical elements.

Light is preferably configured to travel from the plurality of input diffractive optical elements towards the output element by total internal reflection in the waveguide, and a total internal reflection period may be provided. The difference between the at least two respective positions with respect to the first axis is preferably different to the total internal reflection period. Thus, a difference in phase can be established between the outcoupled orders for light from the respective input diffractive optical elements. This can advantageously improve the evenness of the outcoupled orders in the output element.

The difference between the at least two respective positions with respect to the first axis may be approximately half of the total internal reflection period. In this way, the outcoupled orders can be provided substantially out of phase with one another in the output element.

The total internal reflection period may be related to the thickness of the waveguide as well as the angle with which light is diffracted by the input diffractive optical elements. This may also be related to the angle with which light is provided to the input diffractive optical element.

The two overlaid diffractive optical elements in the output element may be provided in or on the waveguide in different planes. The two overlaid diffractive optical elements may be provided on opposing surfaces of the waveguide. The two overlaid diffractive optical elements may be provided in substantially the same plane in the waveguide.

In a preferred arrangement the two overlaid diffractive optical elements can be provided in a photonic crystal.

Embodiments of the invention are now described, by way of example, with reference
5 to the drawings, in which:

Figure 1 is a schematic plan view of a display or optical device in an embodiment of the invention;

10 Figure 2 is a side view of the display shown in Figure 1; and

Figure 3 is an end view of the display shown in Figure 1.

Figures 1-3 show a display or optical device comprising a waveguide 2, an output
15 element 4 and a plurality of input diffraction gratings 6, 8, 10, 12. The waveguide 2 has a first surface 3 and a second surface 5. In this example the input diffraction gratings 6, 8, 10, 12 are provided on the first surface 3. A plurality of projectors 16, 18, 20, 22 provide light to the input gratings 6, 8, 10, 12 along a z-axis, referring to a Cartesian reference frame. Light from the projectors 16, 18, 20, 22 is diffracted by
20 the input gratings 6, 8, 10, 12 in the direction of the y-axis so that it is coupled into the waveguide 2 by total internal reflection. Light from the input gratings 6, 8, 10, 12 travels within the waveguide 2 by total internal reflection until it encounters the output element 4.

25 The output element 4 comprises two diffractive optical elements that are overlaid on one another in or on the waveguide 2. The lines of each of the overlaid diffractive optical elements are symmetrically angled with respect to the y-axis and the rays from respective input gratings 6, 8, 10, 12. Each of the overlaid diffractive optical elements can receive light from an input grating and couples it towards the other
30 diffractive optical element in the pair, which can then act as an output diffractive optical element, coupling light out of the waveguide towards a viewer. In this way, and as explained in WO2016/020643, the output element 4 can achieve two-dimensional expansion of an input light source while simultaneously coupling light out of the waveguide 2 so that it can be viewed by a user.

Light can either be diffracted or transmitted on first interaction with the output element 4. Thus, a proportion of the light received from each input grating 6, 8, 10, 12 continues to be totally internally reflected within the waveguide 2 until its next interaction with the diffractive structures of the output element 4. This is apparent from Figure 2, which shows propagation of the transmitted component by total internal reflection in the waveguide 2.

In Figure 2 the rays are shown as if the diffractive structures for the output element 4 are located on the first surface 3 of the waveguide 2. This is possible, but they could also be located on the second surface 5. In another arrangement, in particular in the case of a photonic crystal, the diffractive structures could be provided in the interior of the waveguide 2.

The input gratings 6, 8, 10, 12 are provided in a staggered configuration in relation to the output element 4, with respect to the y-axis. The first input grating 6 is separated from the output element 4 by a first distance, d_1 , in the direction of the y-axis. The second input grating 8 is separated from the output element 4 by a second distance, d_2 , in the direction of the y-axis. The first and second distances are used in turn for input gratings across the width of the waveguide 2. Thus, each input grating is adjacent another input grating that has a different separation distance from the output element 4.

Diffracted rays from one of the input gratings on the first surface 3 of the waveguide are reflected by the second surface 5 of the waveguide 2, and then travel back towards the first surface 3. A total internal reflection period, p , may be defined as the distance along the y-axis between successive points at which the rays interact with the first surface 3 or the second surface 5. The period, p , is related to the thickness, t , of the waveguide 2. The period, p , is also related to the angle at which rays are diffracted from the input gratings 6, 8, 10, 12.

The difference between the first and second differences, $d_2 - d_1$, is chosen as half of the total internal reflection period, $p/2$. In this way, outcoupled orders from rays emanating from adjacent input gratings can be provided out of phase with one another. This is achieved because rays from a first input grating 6 are at a first

surface 3 of the waveguide at the same point on the y-axis as rays from a second input grating 8 are at the second surface 5 (and *vice-versa*).

Light is expanded in the x-y plane when it encounters the output element 4, and rays
5 are coupled out of the output element 4 in the z-axis, towards a viewer. Light is directed from the input gratings 6, 8, 10, 12 in the y-axis towards the output element 4. Rays fan out from an initial point of contact with the output element 4 in a v-shaped cone. As explained in WO2016/020643, at each point of interaction, rays can be diffracted or coupled out of the waveguide 2 towards a viewer. Figure 1 is a
10 schematic diagram showing the points at which rays in v-shaped cones originating in first and second input gratings 6, 8 are coupled out of the waveguide 2. Outcoupled orders are provided in positions that are out of phase from one another, when considering rays emanating from first and second respective input gratings 6, 8. Thus, where the v-shaped cones intersect, gaps in the outcoupled orders
15 originating from the first input grating 6 can be filled by outcoupled orders originating from the second input grating 8. Advantageously, this can improve the evenness of illumination from the output element 4. The output element 4 can be used in a wide screen augmented reality display, such as a head-up display.

CLAIMS

1. An optical device for use in an augmented reality or virtual reality device,
5 comprising:
a waveguide;
a plurality of input diffractive optical elements configured to couple light
into the waveguide;
an output element configured to receive light from the plurality of input
10 diffractive optical elements in the direction of a first axis, wherein the output
element includes two diffractive optical elements overlaid on one another in or
on the waveguide, wherein each of the two diffractive optical elements is
configured to receive light from the input diffractive optical element and couple it
towards the other diffractive optical element which can then act as an output
15 diffractive optical element providing outcoupled orders towards a viewer;
wherein the plurality of input diffractive optical elements are provided at at
least two respective positions with respect to the first axis.
2. The optical device of claim 1, wherein first and second separation
20 distances are provided on the first axis between the output element and
respective input diffractive optical elements.
3. The optical device of claim 1 or claim 2, wherein the plurality of input
diffractive optical elements are provided in a staggered configuration so that
25 adjacent input diffractive optical elements are provided in first and second
positions with respect to the first axis.
4. The optical device of any of the preceding claims, wherein light is
configured to travel from the plurality of input diffractive optical elements towards
30 the output element by total internal reflection in the waveguide, and a total
internal reflection period is provided, and wherein the difference between the at
least two respective positions with respect to the first axis is different to the total
internal reflection period.

5. The optical device of claim 4, wherein the difference between the at least two respective positions with respect to the first axis is approximately half of the total internal reflection period.

5

6. The optical device of any of the preceding claims wherein the two overlaid diffractive optical elements in the output element are provided in or on the waveguide in different planes.

10 7. The optical device of claim 6 wherein the two overlaid diffractive optical elements are provided on opposing surfaces of the waveguide.

8. The optical device of claim 6, wherein the two overlaid diffractive optical elements are provided in substantially the same plane in the waveguide.

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9. The optical device of any of claims 1 to 5, wherein the two overlaid diffractive optical elements are provided in a photonic crystal.

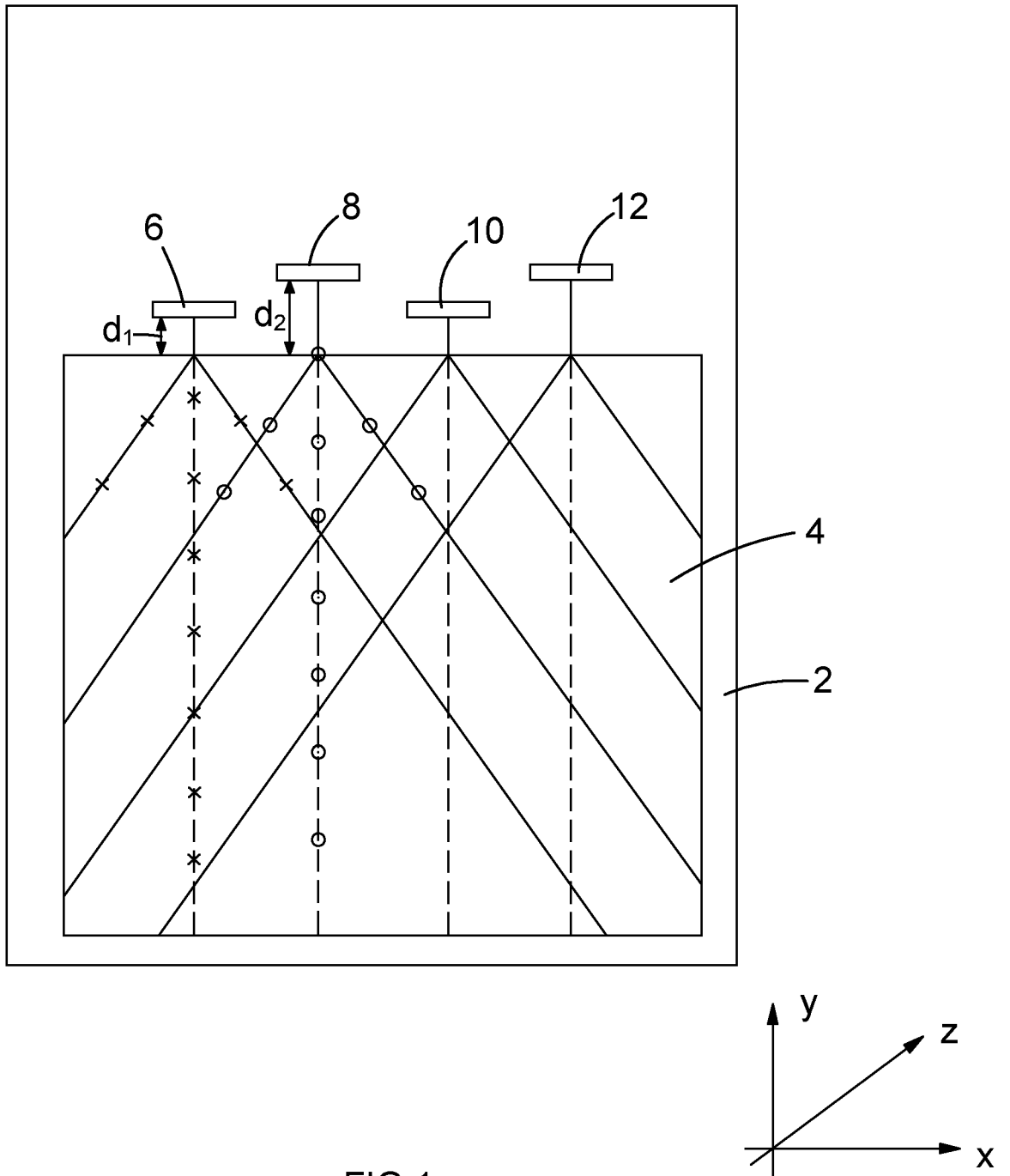
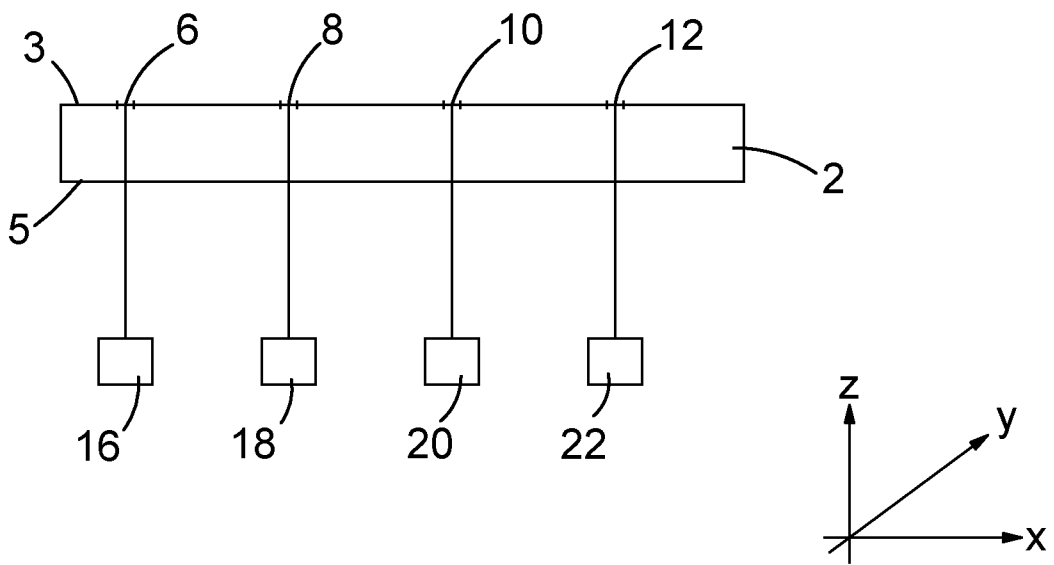
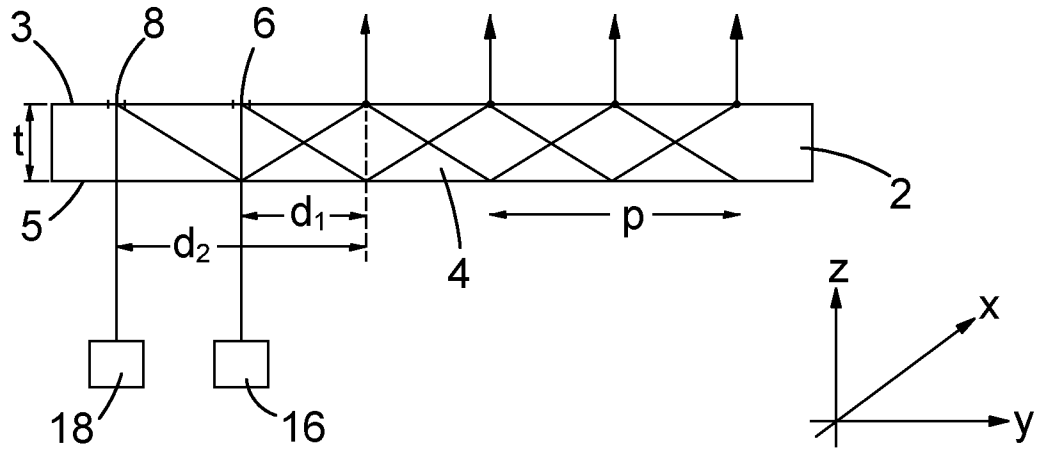


FIG.1



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2018/052356

A. CLASSIFICATION OF SUBJECT MATTER
INV. F21V8/00
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2017/015302 A1 (MAGIC LEAP INC [US]) 26 January 2017 (2017-01-26) abstract; figures 1,2 paragraph [0003] - paragraph [0014] -----	1-9
A	US 2006/126142 A1 (CHOI JIN-SEUNG [KR]) 15 June 2006 (2006-06-15) abstract; figures 5-8 paragraph [0001] - paragraph [0021] paragraph [0035] - paragraph [0037] -----	1-9
A	WO 2016/020643 A1 (WAVE OPTICS LTD [GB]) 11 February 2016 (2016-02-11) abstract; figure 1 -----	1-9

Further documents are listed in the continuation of Box C.

See patent family annex.

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- "O" document referring to an oral disclosure, use, exhibition or other means
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Date of the actual completion of the international search 20 November 2018	Date of mailing of the international search report 27/11/2018
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2018/052356

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2017015302 A1	26-01-2017	AU 2016296723 A1	08-02-2018
		CA 2991642 A1	26-01-2017
		CN 107850784 A	27-03-2018
		EP 3326023 A1	30-05-2018
		JP 2018528457 A	27-09-2018
		KR 20180030681 A	23-03-2018
		US 2017038579 A1	09-02-2017
		WO 2017015302 A1	26-01-2017

US 2006126142 A1	15-06-2006	KR 20060066974 A	19-06-2006
		US 2006126142 A1	15-06-2006

WO 2016020643 A1	11-02-2016	AU 2015298504 A1	09-02-2017
		BR 112017002290 A2	16-01-2018
		CA 2956872 A1	11-02-2016
		CN 106575034 A	19-04-2017
		DK 3175280 T3	28-05-2018
		EP 3175280 A1	07-06-2017
		ES 2670022 T3	29-05-2018
		GB 2529003 A	10-02-2016
		HK 1217044 A1	16-12-2016
		HR P20180778 T1	10-08-2018
		HU E037328 T2	28-08-2018
		JP 2017528739 A	28-09-2017
		KR 20170039655 A	11-04-2017
		LT 3175280 T	25-07-2018
		PL 3175280 T3	28-09-2018
		PT 3175280 T	18-05-2018
		SI 3175280 T1	28-09-2018
		TR 201806707 T4	21-06-2018
		US 2018210205 A1	26-07-2018
		WO 2016020643 A1	11-02-2016
