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(71) Applicant *(for all designated States except US)*: **SIN-VENT AS** [NO/NO]; S.P. Andersens vei 5, NO-7465 Trondheim (NO).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **MATHIASSEN, John Reidar** [NO/NO]; Mellomlia 65, H0202, NO-7018 Trondheim (NO).

(74) Agent: **PROTECTOR IP CONSULTANTS AS**; Oscarsgate 20, NO-0352 Oslo (NO).

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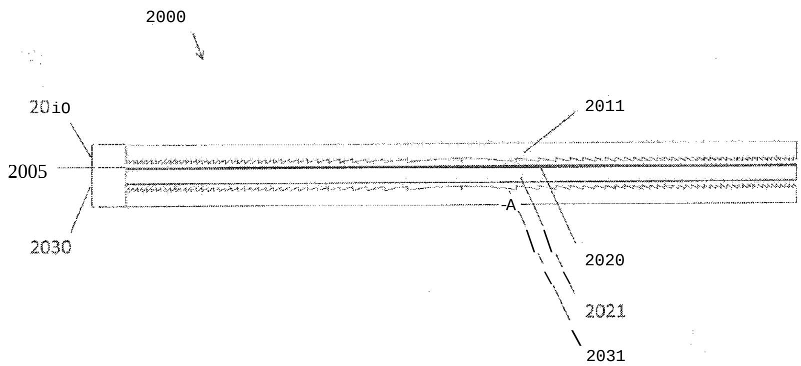
Fig. 14



(57) Abstract: This invention relates to a stereoscopic viewing aid for viewing images received from a stereoscopic imaging system, the imaging system comprising two channels providing images having two different sets of wavelength ranges, the viewing aid comprising two filtering means, the first transmitting light within the first set of wavelengths and the second transmitting light within the second set of wavelengths, each of said filtering means comprising a first optical device having a selected focal length at the corresponding wavelengths.

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VIEWING AID FOR STEREOSCOPIC 3D DISPLAY

FIELD OF THE INVENTION

The present invention relates generally to eyewear used as a viewing aid for stereoscopic 3D displays, and more particularly to eyewear used for viewing stereoscopic 3D displays based on wavelength-division multiplexing.

BACKGROUND OF THE INVENTION

Several different methods exist for providing stereoscopic 3D images when viewing displays, such as shutter glasses where the two images are shown in a sequence and a shutter is placed in the glasses determining which image is to be shown to which eye, and polarizing glasses and projectors or screens where the glasses only transmits the right or left image to the corresponding eye. The disadvantage with shutter glasses requires that the glasses are active (requiring batteries), are dark (visible light transmission of 20 %) and have a limited refresh rate. The disadvantages of polarizing glasses are the need for polarization retention in the screen, making it difficult to obtain a high stereo extinction ratio, and the relatively low visible light transmission (40-45 %) in the glasses. A more promising method, herein called the "Infitec" method or approach, is discussed in multiple references **(US 7,001,021 B2, EP 1 830 585 A2, WO 2004/038457 A2, WO 2008/061511 Al, WO 2009/026888 Al),** as well as in the referenced articles "LED-Based 3D Displays with Infitec Technology" and "Interference-Filter-Based Stereoscopic 3D LCD". The Infitec approach to stereoscopic 3D displays uses interference filters for wavelength-division multiplexing in the display and demultiplexing in the glasses. Infitec has several good properties, including passive glasses, the use of standard projection screens and an excellent stereo extinction ratio. Wavelength-division multiplexing stereoscopic 3D displays of both the projection type and transmissive types exist in the prior art (see references). However, the filters used in Infitec approach, and other similar solutions, are angle-sensitive. This angle dependency puts big constraints on the design of the eyewear, since the angle-of-incidence of incident light must be as close to perpendicular as possible for all viewing directions. In the prior art, this problem is circumvented by having curved lenses at a distance from the eye **(US 2007/0236809 Al, US 2008/0278807 Al)** or flat lenses with a narrow field of view. Some prior art include large guard bands between the left-eye transmission spectrum and right-eye transmission spectrum, in order to compensate for the angle-dependent shift of the transmission spectrum in the glasses. The angle dependency leads to design choices with loss of display brightness, color distortions when viewing off-screen objects and a reduced common color gamut between the left-eye image and right-eye image. The angle dependency of the Infitec interference filters further constrains the location of the filters in the optical path of the display or projector. A further disadvantage of the Infitec approach is the relatively high cost of the glasses, compared to glasses used with polarization-based stereoscopic 3D displays. The high cost of the prior art Infitec glasses is due to the high number of dielectric layers required - on the order of 50-100 layers - to obtain a high stereo extinction ratio. The cost of coating glasses with interference filters is roughly proportional to the number of dielectric layers and the combined thickness of all these layers, and thus the large number of layers results in a high cost for the glasses. Thus, there is a need for a viewing aid for stereoscopic 3D displays that enables greater freedom in the design of the display/projector and viewing aid, while retaining the good properties of the Infitec method and reducing or removing the disadvantages discussed above.

SUMMARY OF THE INVENTION

It is an objective of the present invention to provide improvements to the prior art in eyewear used as a viewing aid for stereoscopic 3D displays, in particular for such displays using wavelength-division multiplexing. It is a further objective of the present invention to provide improvements to the prior art in stereoscopic 3D displays in general. These objectives are obtained with eyewear as described above and characterized as defined in the independent claims.

The present invention provides eyewear for viewing a stereoscopic 3D display, where said display uses wavelength-division multiplexing. The present invention provides optical assemblies in the eyewear for wavelength-selective filtering. In exemplary embodiments of the present invention, both the display and optical assemblies in the eyewear include thin-film interference filters, rugate notch filters or holographic notch filters. These filter types have transmission spectra that are highly dependent on the angle-of-incidence to the filters. This angle dependency is a problem in the prior art, and puts severe constraints on both the eyewear design and the location of the filters in the optical path of the display or projector. Exemplary embodiments of the present invention provide eyewear that ensures that the angle-of-incidence to the filters in the eyewear is as close to perpendicular (0 degrees incidence) as possible, thus avoiding some of the problems of the prior art for stereoscopic 3D displays using such filters in the eyewear. A second problem in the prior art is the need for a high stereo extinction ratio in the eyewear filters, and thus the need for a large number of dielectric layers in the filters. This problem is due to both left-eye and right-eye images being equally focused when viewing said images through both lenses of the eyewear. Exemplary embodiments of the present invention provide eyewear with wavelength-selective defocusing of the left-eye image in the right-eye lens of the eyewear and of the right-eye image in the left-eye lens of the eyewear. By means of wavelength-selective defocusing of the complementary image, the perceived image quality of the left-eye and right-eye images - and the stereoscopically fused image pair - can be high, even with a lower stereo extinction ratio than used in the prior art.

In an exemplary embodiment of the present invention, the eyewear is suitable for viewing a stereoscopic 3D front-projection display. In another exemplary embodiment of the present invention, the eyewear is suitable for viewing a stereoscopic 3D transmissive flat-panel display with an edge-lit backlighting unit (BLU) using narrow-band LED or laser illumination.

The present invention thus is an improvement over the Infitec approach, by reducing the angle-dependency of the transmission spectra of the eyewear, and by reducing the need for very many layers in the filters. The present invention further improves the prior art by enabling greater design freedom with respect to choosing display and eyewear filter sets with increased brightness, larger color gamut, higher visible light transmission and less color distortions.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described with reference to the accompanying figures, illustrating the invention by way of examples, in which:

FIG. 1 shows a block diagram of a stereoscopic 3D display; and

FIG. 2 shows a block diagram of a display unit of the projection display; and

FIG. 3 shows a block diagram of a display unit of the backlit transmissive display type; and

FIG. 4 shows a block diagram of a stereo illumination unit used in the stereoscopic 3D projection display system of **FIG. 2** and in the stereoscopic 3D backlit transmissive display system of **FIG. 3**; and

FIG. 5 shows a diagram of the control signals for the stereo illumination unit of **FIG. 4;** and

FIG. 6 shows the relationship between the display unit imaging surface and the viewing aid, according to an exemplary embodiment of the present invention; and

FIG. 7 shows transmission spectra of the illumination combiner and viewing aid, according to an exemplary embodiment of the present invention; and

FIG. 8 shows transmission spectra of the illumination combiner and viewing aid, according to an exemplary embodiment of the present invention; and

FIG. 9 shows a photograph of prior art wavelength-demultiplexing glasses of the Infitec type; and

FIG. 10 shows a schematic illustration of the lenses of the prior art; and

FIG. 11 shows the lens assembly, being of a flat type, of the lenses of the eyewear illustrated in **FIG. 6,** according to an exemplary embodiment of the present invention; and

FIG. 12 shows the lens assembly, being of a curved type, of the lenses of the eyewear illustrated in **FIG. 6,** according to an exemplary embodiment of the present invention; and

FIG. 13 shows the operation of a region of the lens assembly of the lenses of the eyewear illustrated in **FIG. 6,** according to an exemplary embodiment of the present invention; and

FIG. 14 shows the use of two Fresnel lenses in the lens assembly of **FIG. 11,** according to an exemplary embodiment of the present invention; and

FIG. 15 shows the use of two Fresnel lenses in the lens assembly of **FIG. 11,** according to an exemplary embodiment of the present invention; and

FIG. 16 shows the use of two Fresnel lenses in the lens assembly of **FIG. 11,** according to an exemplary embodiment of the present invention; and

FIG. 17 shows the use of two Fresnel lenses in the lens assembly of **FIG. 11,** according to an exemplary embodiment of the present invention; and

FIG. 18 shows the use of two diffractive lenses in the lens assembly of **FIG. 11,** according to an exemplary embodiment of the present invention; and

FIG. 19 shows the use of two diffractive lenses in the lens assembly of **FIG. 11,** according to an exemplary embodiment of the present invention; and

FIG. 20 shows the use of two diffractive lenses in the lens assembly of **FIG. 11,** according to an exemplary embodiment of the present invention; and

FIG. 21 shows the transmission spectrum of display filters included in an example filter set, according to an exemplary embodiment of the present invention; and

FIG. 22 shows the diffraction efficiency of a first multi-order diffractive lens included in an example lens set, according to an exemplary embodiment of the present invention; and

FIG. 23 shows the diffraction efficiency of a second multi-order diffractive lens included in an example lens set, according to an exemplary embodiment of the present invention; and

FIG. 24 shows the transmission spectrum of the left-eye display filter and right-eye eyewear filter, included in an example filter set, according to an exemplary embodiment of the present invention; and

FIG. 25 shows the transmission spectrum of the right-eye display filter and left-eye eyewear filter, included in an example filter set, according to an exemplary embodiment of the present invention; and

The following reference numerals are used in the specification and drawings:

Number	Name	Context
10	Stereoscopic 3D display system	
11	Left-eye image data	In stereoscopic 3D display system **10**
12	Right-eye image data	In stereoscopic 3D display system **10**
13	Display unit	In stereoscopic 3D display system **10**
14	Eyewear	In stereoscopic 3D display system **10**
15	Left eye	In stereoscopic 3D display system **10**
16	Right eye	In stereoscopic 3D display system **10**
101	Stereo illumination unit	In display unit **13**
102	Illumination optics	In projection-display embodiments of display unit **13**
103	Spatial light modulator(s)	In projection-display embodiments of display unit **13**
104	Projection optics	In projection-display embodiments of display unit **13**
105	Screen surface	In projection-display embodiments of display unit **13**
112	Backlight illumination optics	In transmissive-display embodiments of display unit **13**
113	Transmissive display panel	In transmissive-display embodiments of display unit **13**
201	Left-eye illumination source	In stereo illumination unit **101**
202	Right-eye illumination source	In stereo illumination unit **101**
203	Illumination combiner	In stereo illumination unit **101**
221	Left-eye illumination source control signal	Control signal for left-eye illumination source **201**
222	Right-eye illumination source control signal	Control signal for right-eye illumination source **202**
130	Display unit imaging surface	Imaging surface of display unit **13**
2100	Spatial imaging element	Small spatial region of display unit imaging surface **130**
2101	Left-eye targeted light ray bundle	Light ray bundle from spatial imaging element **2100** to left eye **15**

2102	Right-eye targeted light ray bundle	Light ray bundle from spatial imaging element 2100 to right eye 16
2001	Left-eye lens	Lens over left-eye portion of eyewear 14
2002	Right-eye lens	Lens over right-eye portion of eyewear 14
1501	Left-eye illumination combiner transmission spectrum	Transmission spectrum of left-eye illumination through illumination combiner 203
1502	Right-eye illumination combiner transmission spectrum	Transmission spectrum of right-eye illumination through illumination combiner 203
2401	Left-eye lens transmission spectrum	Transmission spectrum of left-eye lens 2001
2402	Right-eye lens transmission spectrum	Transmission spectrum of right-eye lens 2002
2201	Flat lens	Prior art flat lens of the Infitec type
2210	Filter	Filter of flat lens 2201
2220	Filter substrate	Filter substrate of flat lens 2201
2202	Curved lens	Prior art curved lens of the Infitec type
2230	Filter	Filter of curved lens 2202
2240	Filter substrate	Filter substrate of curved lens 2202
2000	Lens assembly	In left-eye lens 2001 and right-eye lens 2002
2010	Outer optical assembly	In lens assembly 2000
2005	Geometrical surface	In lens assembly 2000
2020	Filter	In embodiment of lens assembly 2000
2030	Inner optical assembly	In lens assembly 2000
2040	Eye pupil	In illustration of operation of lens assembly 2000
2050	Entry light ray	In illustration of operation of lens assembly 2000
2055	Corrected light ray	In illustration of operation of lens assembly 2000
2070	Exit light ray	In illustration of operation of lens assembly 2000
2080	Exit light ray angle	In illustration of operation of lens assembly 2000
2095	Distortion offset	In illustration of operation of lens assembly

		2000
2011	Outer Fresnel lens	In embodiment of lens assembly **2000**
2021	Filter substrate	In embodiment of lens assembly **2000**
2031	Inner Fresnel lens	In embodiment of lens assembly **2000**
2140	Low-index layer	In embodiment of lens assembly **2000**
2150	Lens substrate	In embodiment of lens assembly **2000**
2311	Outer lens substrate	In embodiment of lens assembly **2000**
2312	Outer diffractive surface	In embodiment of lens assembly **2000**
2322	Inner diffractive surface	In embodiment of lens assembly **2000**
2321	Inner lens substrate	In embodiment of lens assembly **2000**

DETAILED DESCRIPTION OF THE INVENTION

A general illustration of a stereoscopic 3D display system **10** shown in **FIG. 1.** Left image data **11** and right image data **12** are input to display unit **13.** Display unit **13** displays the left image data **11** and right image data **12** onto the same or substantially the same spatial imaging grid by means of wavelength- and time-division multiplexing. Eyewear **14** performs wavelength-selective filtering, ensuring that the left eye **15** observes the left image data **11** and the right eye **16** observes the right image data **12.**

In one embodiment of the present invention, the display unit **13** is a projection display. A display unit **13** of the projection display type is illustrated in **FIG. 2.** A stereo illumination unit **101** performs wavelength- and time-division multiplexing of the illumination. Illumination optics **102** images the illumination onto one or more spatial light modulators **103.** Projection optics **104** images the surface of one or more spatial light modulators **103** onto the projection screen **105.**

The display unit **13** may alternatively be a backlit transmissive display. A display unit **13** of the backlit transmissive type is illustrated in **FIG. 3.** One or more stereo illumination units **101** perform wavelength- and time-division multiplexing of the illumination. Backlight illumination optics **112** ensures that the illumination from stereo illumination units **101** is delivered to the rear of the transmissive display panel **113.** An exemplary embodiment of a stereo illumination unit **101** is illustrated in **FIG. 4.** Stereo illumination unit **101** performs wavelength- and time-division multiplexing of the illumination. A left-eye illumination source **201** delivers left-eye illumination **211** to illumination combiner **203.** A right-eye illumination source **202** delivers right-eye illumination **212** to the illumination combiner **203.** The illumination combiner **203** delivers left-eye illumination **211** and right-eye illumination **212** to the output illumination **213** ensuring that output illumination **213** has the same or substantially the same etendue as the left-eye illumination **211** and right-eye illumination **212.** Illumination optics **102** images the output illumination **213** onto one or more spatial light modulators **103** as indicated in **FIG. 2.**

Control signals to left-eye illumination source **201** and right-eye illumination source **202,** are illustrated in **FIG. 5,** showing a time multiplexed solution. Left-eye illumination control signal **221** controls the emission of left-eye illumination **211** from left-eye illumination source **201.** Right-eye illumination control signal **222** controls the emission of right-eye illumination

212 from right-eye illumination source **202.** The left-eye illumination source **201** and right-eye illumination source **202** may preferably be individually controllable. The time-division multiplexing of said two illumination sources is done by setting the control signals **221** and **222** such that in any one time period substantially only one of the illumination sources **201** or **202** emits illumination. In **FIG. 5** this time-division multiplexing is illustrated, for 4 time intervals **Tl, T2, T3** and **T4,** by left-eye illumination control signal **221** being in the ‘on' state in time intervals **Tl** and **T3** and right-eye illumination control signal being ‘off in these two time intervals, and by right-eye illumination control signal **222** being in the ‘on' state in time intervals **T2** and **T4** and left-eye illumination control signal being ‘off in these two time intervals. Time-division multiplexing of the display of left image data **11** and right image data **12** is preferably achieved by display unit **13** displaying the left image data **11** in time intervals in which left-eye illumination control signal **221** is in the ‘on' state and by display unit **13** displaying right image data **12** in time intervals in which right-eye illumination control signal **222** is in the ‘on' state. Display unit **13** may display substantially only left image data **11** during time intervals in which left-eye illumination control signal **221** is in the ‘on' state, and display substantially only right image data **12** during time intervals in which right-eye illumination control signal **222** is in the ‘on' state. By way of example, there may be commonalities between left image data **11** and right image data **12,** and in said example there may be time intervals in which both left-eye illumination control signal **221** and right-eye illumination control signal **222** are in the ‘on' state, and in said time intervals the common image data between left image data **11** and right image data **12** may be displayed, with the advantage of said example being an increased duty cycle of both illumination sources and thus increased displayed brightness.

Referring to **FIG. 7** and **FIG. 8,** a wavelength-division multiplexing in stereo illumination unit **101** can be characterized by the left-eye illumination combiner transmission spectrum **1501** seen by the left-eye illumination **211** as it passes through illumination combiner **203** and is wavelength-multiplexed into the output illumination **213,** and similarly characterized by the right-eye illumination combiner transmission spectrum **1502** seen by the right-eye illumination **212** as it passes through illumination combiner **203** and is wavelength-multiplexed into the output illumination **213.** Thus, when left-eye illumination control signal **221** is in the ‘on' state and right-eye illumination control signal **222** is in the 'off state, the spectrum of output illumination **213** of stereo illumination unit **101** is exactly or approximately equal to the spectrum of left-eye illumination **211** multiplied by the left-eye illumination combiner transmission spectrum **1501.** Thus similarly, when right-eye illumination control signal **222** is in the 'on' state and left-eye illumination control signal **221** is in the 'off state, the spectrum of output illumination **213** of stereo illumination unit **101** is exactly or approximately equal to the emission spectrum of left-eye illumination **212** multiplied by the right-eye illumination combiner transmission spectrum **1502.**

The corresponding wavelength-selective filtering in eyewear **14** can be characterized by the left-eye lens transmission spectrum **2401** of left-eye lens **2001** of eyewear **14,** and similarly characterized by the right-eye lens transmission spectrum **2402** of right-eye lens **2002** of eyewear **14.** Example embodiments of left-eye eyewear transmission spectrum **2401** and the right-eye lens transmission spectrum **2402** are also illustrated in **FIG.** 7 and **FIG. 8.** These two figures will be explained in a following paragraph.

The operation of the stereoscopic 3D display system **10** can be illustrated as in **FIG. 6.** The display unit imaging surface **130** is the imaging surface of display unit **13.** In a projection display embodiment of display unit **13,** the display unit imaging surface **130** may be a front- or rear-projection projection screen. In a backlit transmissive display embodiment of display unit **13,** the display unit imaging surface **130** may be the visible surface of a transmissive display panel **113.** A spatial imaging element **2100,** or pixel, is a small region of the display unit imaging surface **130.** In one embodiment of the present invention, a spatial imaging element **2100** displays wavelength- and time-division multiplexed imaging elements from both the left image data **11** and the right image data **12.** A left-eye targeted light ray bundle **2101** is a light ray bundle, emitted from spatial imaging element **2100,** which reaches left eye **15** after being transmitted through left-eye lens **2001.** A right-eye targeted light ray bundle **2102** is a light ray bundle, emitted from spatial imaging element **2100,** which reaches right eye **16** after being transmitted through right-eye lens **2002.** The spectra, measured over the temporal integration time of the eye, of light ray bundles **2101** and **2102,** before being transmitted through lenses **2001** and **2002,** are exactly or substantially a superposition of two spectra, where the first spectrum is the spectrum of left-eye illumination **211** multiplied by left-eye illumination combiner transmission spectrum **1501** and the second spectrum is the spectrum of right-eye illumination **212** multiplied by right-eye illumination combiner transmission spectrum **1502.** According to one possible solution, the left-eye lens **2001** has transmission spectrum **2401** ensuring that the regions, of the spectrum of left-eye targeted light ray bundle **2101,** outside of the transmission bands of left-eye illumination combiner transmission spectrum **1501,** are blocked or substantially blocked in left-eye lens **2001,** thus blocking right image data **12** displayed at spatial imaging element **2100** from view of left eye **15,** and thus transmitting through left-eye lens **2001** left image data **11** displayed at spatial imaging element **2100.** Similarly, according to one possible solution, the right-eye lens **2002** has transmission spectrum **2402** ensuring that the regions, of the spectrum of right-eye targeted light ray bundle **2102,** outside of the transmission bands of right-eye illumination combiner transmission spectrum **1502,** are blocked or substantially blocked in right-eye lens **2002,** thus blocking left image data **11** displayed at spatial imaging element **2100** from view of right eye **16,** and thus transmitting through right-eye lens **2002** right image data **12** displayed at spatial imaging element **2100.**

According to displays used with some embodiments of the present invention, the illumination combiner **203** has transmission spectra **1501** and **1502** that are spectrally complementary or substantially spectrally complementary and where the output illumination **213** of illumination combiner **203** has the same or substantially the same etendue as left-eye illumination **211** or right-eye illumination **212.** In displays used with some embodiments of the present invention, this etendue is preserved or substantially preserved, even with no need for or substantially no need for guard bands between the cut-on/cut-off of pass bands in transmission spectrum **1501** and the cut-off/cut-on of neighboring pass bands in transmission spectrum **1502.** Illumination combiner **203** may be of the type presented in prior art references (WO **2010/059453 A2, US 3,497,283).**

Embodiments of the present invention may also be used with displays that do not have an illumination combiner **203** in stereo illumination unit **101.** Examples of such displays are filter-wheel based projection system displays **(EP 1 830 585 A2)** and transmissive displays of the backlit type **(US 2007/0188711 Al).** When used with displays not including an illumination combiner **203,** transmission spectrum **1501** may be defined as filtering the display illumination used for displaying left image data **11** and transmission spectrum **1502** may be defined as filtering the display illumination used for displaying right image data **12.**

According to some embodiments of the present invention, the left-eye lens transmission spectrum **2401** is independent or substantially independent of the angle-of-incidence of the left-eye target light ray bundle **2101** to the left-eye lens **2001.** In an embodiment of the present invention, the right-eye lens transmission spectrum **2402** is independent or substantially independent of the angle-of-incidence of the right-eye target light ray bundle **2102** to the right-eye lens **2002.** This angle-independence is achieved by the left-eye lens **2001** and right-eye lens **2002** each including a lens assembly **2000.** Lens assembly **2000** and its operation is illustrated in several figures and described in following paragraphs. The substantial angle-independence of the transmission spectrum of lens assembly **2000** results in no need for or substantially no need for guard bands between the cut-on/cut-off of pass bands in transmission spectrum **1501** and the cut-off/cut-on of neighboring pass bands in transmission spectrum **1502,** and similarly the substantial angle-independence of the transmission spectrum of lens assembly **2000** results in no need for or substantially no need for guard bands between the cut-on/cut-off of pass bands in transmission spectrum **2401** and the cut-off/cut-on of neighboring pass bands in transmission spectrum **2402.** Lens assembly **2000** has a transmission spectrum angle-independence that is superior to some prior art lenses used in glasses eyewear of the Infitec type illustrated in **FIG. 9** described in **WO2009/026888, EP1830585** and other references.

Returning to **FIG. 7** the spectra have substantially evenly distributed pass bands with four pass bands in each transmission spectrum. Left-eye illumination combiner spectrum **1501** has pass bands in wavelength regions **Wl, W3, W5** and **W7.** Right-eye illumination combiner spectrum **1502** has pass bands in wavelength regions **W2, W4, W6** and **W8.** In the exemplary embodiment in **FIG. 7,** transmission spectra **2401** and **2402** are similar to transmission spectra **1501** and **1502,** with slight differences to take into account the small (compared to the prior art) angle-dependency, in lens assembly **2000,** of the filter implementations of transmission spectra **2401** and **2402.** Exemplary embodiments similar to the illustration in **FIG. 7** are suitable for broad-spectrum LED illumination, narrow-spectrum LED illumination and broad-spectrum lamp illumination.

As discussed in the prior art **(US 2008/0284982 Al),** the use of more than three pass bands in transmission spectra **1501, 1502, 2401** or **2402** can enable a larger common color gamut for displaying of both left image data **11** and right image data **12.**

An exemplary embodiment illustrated in **FIG. 8** has three narrow pass bands in each of the left-eye illumination combiner transmission spectrum **1501** and right-eye illumination combiner transmission spectrum **1502.** Transmission spectrum **1501** has pass bands in wavelength regions **Wl, W3** and **W5.** Transmission spectrum **1502** has pass bands in wavelength regions **W2, W4** and **W6.** In the exemplary embodiment in **FIG. 8,** the left-eye lens transmission spectrum **2401** is a multi-notch filter with notches located in wavelength regions **W2, W4** and **W6,** and the right-eye lens transmission spectrum **2402** is a multi-notch filter with notches located in wavelength regions **Wl, W3** and **W5.** Exemplary embodiments similar to the illustration in **FIG. 8** are suitable for narrow-filtered broad-spectrum LED illumination, narrow-spectrum LED illumination, narrow-filtered broad-spectrum lamp illumination and laser illumination. Exemplary embodiments similar to that illustrated in **FIG. 8** enable substantially clear viewing of off-screen objects, due to the high visible light transmission of the transmission spectra **2401** and **2402.** By way of example, a visible light transmission of 75% is possible with narrowband RGB LED illumination, and visible light transmission of greater than 90% is possible with RGB laser illumination.

Narrow guard bands between the pass bands of left-eye illumination combiner transmission spectrum **1501** and the pass bands of right-eye illumination combiner transmission spectrum **1502** ensure that there is little or no stereo crosstalk, within the manufacturing tolerances of the filter implementations of spectra **1501, 1502, 2401** and **2402** and within the small angle-dependency, in lens assembly **2000,** of the filter implementations of transmission spectra **2401** and **2402.** By way of example, an angle-shift of less than 5 degrees is possible, for filter implementations in lens assembly **2000,** for all viewing directions within ±30 degrees and for variations in interocular distance of ±10 mm and variations in focal point location of ±5 mm.

As an example, some of the above mentioned embodiments of filters **1501, 1502, 2401** and **2402** may be characterized as performing metameric wavelength-division multiplexing or metameric wavelength-division demultiplexing. Metamerism implies that two different spectra may have the same perceived color. In the case of metameric wavelength-division multiplexing, two substantially complementary spectra, each having the same or substantially the same color primaries, are combined. This principle, also in part discussed in the prior art **(US 2008/0284982 Al, US 2007/0188711 Al),** implies that stereoscopic wavelength-division multiplexing can be achieved with the same or substantially the same perceived on-screen and off-screen colors. The embodiments of the present invention are however not limited to including filters enabling metameric wavelength-division multiplexing.

A photograph of prior art wavelength-division demultiplexing glasses for stereoscopic 3D display systems, using interference filters of the Infitec type, is shown in **FIG. 9.** These prior art glasses are of two main types: flat lens and curved lens. Flat lens glasses of the prior art are illustrated in the two leftmost glasses in **FIG. 9,** denoted by A and B. A pair of curved lens glasses of the prior art is illustrated in the rightmost glasses in **FIG. 9,** denoted by C. Due to the angle-sensitivity of the thin-film interference filters used in the prior art wavelength-demultiplexing glasses, flat lens glasses are most suited for glasses with a narrow field of view as shown in A and B in **FIG. 9.** Curved lens glasses, such as shown in C in **FIG. 9,** have an increased field of view. A schematic illustration of a radial cross-section of the lenses of the prior art glasses of both above-mentioned types is shown in **FIG. 10.** Glasses of the flat-lens type include a flat lens **2201** comprising a filter **2210** deposited on a flat filter substrate **2220.** Said filter of the Infitec type is a thin-film interference filter, but may also be a rugate notch filter or holographic notch filter **(US 2007/0247709 Al).** The aforementioned filters are angle-sensitive with the transmission spectrum being shifted towards shorter wavelengths with increasing angle of incidence (AOI) to the filter, and the relative wavelength shift in percent is found by

$$\Delta\lambda_{rel} = 100\left(1 - \sqrt{1 - \frac{\sin^2\theta}{n^{*2}}}\right),$$

where Θ is the AOI and n^* is the effective refractive index. The effective refractive index of the filter is approximately the lowest refractive index or the refractive index of the lowest-index layer in the filter. For a typical multi-layer thin-film interference filter with $Si0_2$ as the lowest-index layer (refractive index 1.48 at 555 nm) the wavelength shift is approximately 1.5% for an AOI of 15 degrees, corresponding to a shift in the transmission spectrum of approximately 8.5 nm at 555 nm. Thus, for a field-of-view of 15 degrees, the filter **2210** in flat lens **2201** must have guard bands of at least 1.5% between each pass band of the left-eye transmission spectra and neighboring pass bands of the right-eye transmission spectra. For narrow-band illumination sources such as narrow-band LEDs, such a large guard band results in significant loss of brightness, with the loss of brightness increasing proportionally to the number of pass bands. Note that the relationship between AOI and relative wavelength shift is nonlinear, and for example reducing the AOI by a factor of 3 from 15 to 5 degrees results in a reduction in the relative wavelength shift by a factor of approximately 9 from approximately 1.5% to approximately 0.17%. It is thus obvious that it is desirable to reduce the AOI to the filters.

One way of reducing the AOI to the filters is to deposit said filters on a curved substrate. The curved lens 2202 of the prior art (US 2008/0278807 Al, US 2007/0236809 Al), illustrated in FIG. 32B, uses this approach. Glasses of the curved-lens type include a curved lens 2202 comprising a filter 2230 deposited on a curved filter substrate 2240. If curved lens 2202 has a radius of curvature equal to the distance from the eye center of rotation to said curved lens, the AOI of all viewable light rays is approximately 0 degrees. Thus, ideally this appears to be a good solution, although such ideal lenses may be ergonomically disadvantageous due to their large curvature and/or large size. The prior art (US 2007/0236809 Al) has solutions that enable cost-effective manufacturing of uniaxially curved lenses by roll-coated deposition of dielectric multilayer filters onto a flexible substrate. For more general biaxially-curved lenses, thin-film interference filters are deposited layer by layer, in deposition systems designed for flat substrates, in a manner that is subject to an effect called runoff. Runoff implies that the thickness of these layers is reduced with increasing curvature, and thus also reduces the optical path length through the filter with increasing curvature. Such a reduction in optical path length results in a relative wavelength shift towards shorter wavelengths. An exemplary runoff at the edge of curved lenses with 50 mm diameter, and radius of curvature of 120 mm, is 1.0%. An exemplary runoff at the edge of curved lenses with 50 mm diameter, and radius of curvature of 90 mm, is 1.5%. Thus, even with a perfect curved lens with 90 mm radius of curvature at a distance of 90 mm from the pupil of the eye, there is a substantial amount of wavelength shift in the transmission spectrum. In the prior art, the stereo cross-talk is required to be on the order of 0.5 % or less to provide high-quality stereo image viewing, thus requiring many layers and costly filters. The need for a low amount of stereo cross-talk in the prior art is due to both left-eye and right-eye images being in focus when viewed through the eyewear lenses for both eyes. The above mentioned weaknesses of the prior art motivates for a new approach to designing lenses for wavelength-selective filtering in eyewear for stereoscopic 3D display systems.

The viewing aid, according to some embodiments of the present invention, thus relates to a solution where the incident angle on the filter is adjusted so as to improve the filtering efficiency. According to one embodiment of the eyewear **14,** the left-eye lens **2001** and right-eye lens **2002** both include a lens assembly **2000,** said lens assembly being substantially flat, and said lens assembly comprising an outer optical assembly **2010** and an inner optical assembly **2030** as illustrated in **FIG. 10.** In the same figure, outer optical assembly **2010** and inner optical assembly **2030** are interfaced at geometrical surface **2005,** with geometrical surface **2005** being planar in this embodiment. In an alternative embodiment of the eyewear **14,** the left-eye lens **2001** and right-eye lens **2002** both include a lens assembly **2000,** said lens assembly having a substantial curvature, and said lens assembly comprising an outer optical assembly **2010** and an inner optical assembly **2030** as illustrated in **FIG. 12.** In the same figure, outer optical assembly **2010** and inner optical assembly **2030** are interfaced at geometrical surface **2005,** with geometrical surface **2005** having substantial curvature in this embodiment. In some embodiments of the present invention, the filter **2020** in embodiments of lens assembly **2000** included in left-eye lens **2001** has a transmission spectrum equal to or substantially similar to transmission spectrum **2401** of the left-eye lens **2001.** In some embodiments of the present invention, the filter **2020** in embodiments of lens assembly **2000** included in right-eye lens **2002** has a transmission spectrum equal to or substantially similar to transmission spectrum **2402** of the right-eye lens **2002.** In plain English, this means that the filter **2020** contributes the most to the shape of the transmission spectrum of lens assembly **2000,** and that the remaining components in optical assemblies **2010** and **2030** are substantially clear in the visible spectrum.

The operation of lens assembly **2000,** is illustrated in **FIG. 13** and in an illustration of the operation of an embodiment of lens assembly **2000** said figure is understood to be an illustration of an exploded view of a portion of a radial cross-section of substantially flat lens assembly **2000** illustrated in **FIG. 11.** In another embodiment, the operation of lens assembly **2000,** is illustrated in **FIG. 13** and in an illustration of the operation of an embodiment of lens assembly **2000** said figure is understood to be an illustration of an exploded view of a portion of a radial cross-section of substantially flat lens assembly **2000** illustrated in **FIG. 12.** The main purpose of said embodiments of lens assembly **2000** is to ensure that all or substantially all light rays that are transmitted from an imaging element **2100** on display unit imaging surface **130** through eye pupil **2040** of the viewer of the stereoscopic 3D display system **10** are transmitted through lens assembly **2000** free or substantially free from visible optical distortion and that all or substantially all such said light rays are transmitted through geometrical surface **2005** with an AOI equal to or substantially close to 0 degrees. An entry light ray **2050** originates from left-eye targeted light ray bundle **2101** or right-eye targeted light ray bundle **2102** illustrated in **FIG. 6**. By way of example, an entry light ray **2050** may have an angle-of-incidence to the outer optical assembly **2010** that differs from 0 degrees. In an illustration of the operation of an embodiment of the present invention, entry light ray **2050** has an entry light ray angle **2080** relative to a fixed normal vector, said ray enters outer optical assembly **2010,** is transmitted through outer optical assembly **2010,** exits optical assembly **2010** as corrected light ray **2055** with an AOI substantially normal to geometrical surface **2005,** enters inner optical assembly **2030,** is transmitted through inner optical assembly **2030,** exits inner optical assembly as exit light ray **2070** with an exit light ray angle substantially the same as entry light ray angle **2080** and passes through or substantially near the eye pupil **2040.** Exit light ray **2070** can be projected back in the direction from which entry light ray **2050** entered the lens assembly **2000,** and the distortion offset **2095** can be found as the offset between the back-projected exit light ray **2070** and the entry light ray **2050.** By way of example, the distortion offset **2095** can be minimized by minimizing the optical thickness of portions of the outer optical assembly **2010** and inner optical assembly **2030.**

Lens assembly **2000** may be an afocal system in the case where the viewer of stereoscopic 3D display system **10** does not require vision correction or where said viewer is wearing vision-corrective eyewear or contact lenses. In a preferred embodiment of lens assembly **2000,** inner optical assembly **2030** has a focal length of between 25 and 50 mm, outer optical assembly **2010** has a focal length of between -25 and -50 mm, and the focal lengths are chosen, depending on the distance between the two optical assemblies, such that the lens assembly **2000** is an afocal system with a magnification as close to 1 as possible.

Lens assembly **2000** may be a focal system in the case where the viewer of stereoscopic 3D display system **10** requires vision correction and said viewer is not wearing additional vision-corrective eyewear or contact lenses. In a preferred embodiment of lens assembly **2000,** inner optical assembly **2030** has a focal length of between 25 and 50 mm, outer optical assembly **2010** has a focal length of between -25 and -50 mm, and the focal lengths are chosen, depending on the distance between the two optical assemblies, such that the lens assembly **2000** is an focal system providing vision correction, and with a magnification as close to 1 as possible.

In an exemplary embodiment, of a substantially flat lens assembly **2000,** illustrated in **FIG. 14** and for illustrative purposes shown with exaggerated lens assembly thickness and Fresnel facet height, outer optical assembly **2010** includes a plano-concave outer Fresnel lens **2011** with the concave side nearer geometrical surface **2005,** and inner optical assembly **2030** includes a filter **2020** placed on geometrical surface **2005,** a filter substrate **2021** and a plano-convex inner Fresnel lens **2031** with the convex side nearer geometrical surface **2005,** and the lens profile of the two said Fresnel lenses are substantially the same. By way of example, the two said Fresnel lenses can be designed such that, for a nominal inter-ocular distance and lens-to-eye distance, and over an entire field-of-view of 30 degrees for all entry light rays **2050** with a projected trajectory passing through the eye pupil **2040,** the angle-of-incidence, of all corrected light rays **2055,** to the filter **2020** is 0 degrees. By way of further example, the two said Fresnel lenses can be designed such that the AOI, of all corrected light rays **2055** to the filter **2020,** is within ±5 degrees, for all viewing directions within ±30 degrees and for deviations from a nominal interocular distance of ±10 mm and deviations from a nominal lens-to-eye distance of ±5 mm. By way of example, this results in a maximum relative wavelength shift in the transmission spectra **2401** and **2402** of only 0.2% relative to the said transmission spectra at 0 degrees AOI.

In an exemplary embodiment, of a substantially flat lens assembly **2000** of the present invention, illustrated in **FIG. 15** and for illustrative purposes shown with exaggerated lens assembly thickness and Fresnel facet height, outer optical assembly **2010** includes a plano-concave outer Fresnel lens **2011** with the flat side nearer geometrical surface **2005,** a substrate **2150** for outer Fresnel lens **2011,** a low-index layer **2140,** a filter **2020** placed on geometrical surface **2005,** and filter substrate **2021.** In said embodiment, inner optical assembly **2030** includes a plano-convex inner Fresnel lens **2031** with the flat side nearer filter **2020,** and the lens profile of the two said Fresnel lenses are substantially the same.

In an exemplary embodiment, of a substantially flat lens assembly **2000** of the present invention, illustrated in **FIG. 16** and for illustrative purposes shown with exaggerated lens assembly thickness and Fresnel facet height, outer optical assembly **2010** includes a plano-concave outer Fresnel lens **2011** with the flat side nearer geometrical surface **2005,** a low-index layer **2140,** a filter **2020** placed on geometrical surface **2005,** and filter substrate **2021.** In said embodiment, inner optical assembly **2030** includes a plano-convex inner Fresnel lens **2031** with the flat side nearer filter **2020,** and the lens profile of the two said Fresnel lenses are substantially the same.

In an embodiment of the lens assembly **2000** of the present invention, the function of low-index layer **2140** is to redirect light rays or light wave fronts by total or frustrated total internal reflection, where said light is incident on the shadow sides of the Fresnel facets, so as not to reach the pupil **2040.** This function may, by way of example, reduce scatter or blur in the image perceived through lens assembly **2000** by ensuring that the operation of the Fresnel lens is as close as possible to the desired operation of an ideal lens.

By way of example, low-index layer **2140** may be an air gap, a low-index nanoporous coating, an ultrathin metal film operating around the percolation threshold, a low-index nanoneedle coating or a low-index optical metamaterial. By way of example, the refractive index of low-index layer **2140** may be chosen, depending on the refractive index of outer Fresnel lens **2011** or outer Fresnel lens substrate **2150,** so as that all light incident on the draft side of the Fresnel lens facets is reflected by total internal reflection. By way of example, said Fresnel lens and substrate may have a refractive index of 1.6 and low-index layer **2140** may have a refractive index less than 1.25.

Lens assembly **2000** may also be manufactured without a low-index layer **2140,** as illustrated in **FIG. 17.**

Embodiments of lens assembly **2000** of the curved type may be created similarly to the embodiments of lens assembly **2000** of the flat types illustrated in **FIG. 14, FIG. 15, FIG. 16** or **FIG. 17,** by outer optical assembly **2010** and inner optical assembly **2030** both including a lens being smooth and curved on one side and similarly curved but faceted on the other side.

In an exemplary embodiment, of a substantially flat lens assembly **2000,** illustrated in **FIG. 18** and for illustrative purposes shown with exaggerated lens assembly thickness, outer optical assembly **2010** includes an outer lens solid **2311** and an outer diffractive surface **2312,** and inner optical assembly **2030** includes an inner lens solid **2321,** an inner diffractive surface **2322,** a filter **2020** placed on geometrical surface **2005** and a filter substrate **2021.** Said outer diffractive surface **2312** and inner diffractive surface **2322** are, in a preferred embodiment of the present invention, multi-order diffractive lenses (US **5,589,982).** In a preferred embodiment of lens assembly **2000** in left-eye lens **2001,** the outer diffractive surface **2312** and inner diffractive surface **2322** are both multi-order diffractive lenses with their respective design wavelengths and diffraction orders chosen so as to provide a combined diffraction efficiency, for lens assembly **2000,** that is high for wavelength regions corresponding to passbands in display filter **1501** and low for wavelength regions corresponding to passbands in display filter **1502.** Similarly, for lens assembly **2000** in right-eye lens **2002,** the outer diffractive surface **2312** and inner diffractive surface **2322** are both multi-order diffractive lenses with their respective design wavelengths and diffraction orders chosen so as to provide a combined diffraction efficiency, for lens assembly **2000,** that is high for wavelength regions corresponding to passbands in display filter **1502** and low for wavelength regions corresponding to passbands in display filter **1501.** In plain English, this means that the design wavelength and diffraction orders, of the left-eye and right-eye multi-order diffractive lens pairs, can be chosen so as to provide a focused left-eye image and a defocused right-eye image when viewing the display through the left-eye lens, and vice-versa for the other eye. The advantage of this is a lowered requirement on the stereo extinction ratio in the filters **2020,** due to a reduction in the perceived stereo crosstalk when the opposite-eye image is viewed as a blurred out-of-focus image. A lower requirement on the stereo extinction ratio implies that fewer dielectric layers are required in filters **2020,** thus reducing the cost of manufacturing these filters.

In an exemplary embodiment, of a substantially flat lens assembly **2000,** illustrated in **FIG. 19** and for illustrative purposes shown with exaggerated lens assembly thickness, outer optical assembly **2010** includes a filter **2020,** an outer lens solid **2311** and an outer diffractive surface **2312,** and inner optical assembly **2030** includes an inner lens solid **2321,** and an inner diffractive surface **2322,** with geometrical surface **2005** positioned between outer diffractive surface **2312** and inner diffractive surface **2322.** Said outer diffractive surface **2312** and inner diffractive surface **2322** are, in a preferred embodiment of the present invention, multi-order diffractive lenses (US **5,589,982).** The exemplary embodiment in **FIG. 20** makes use of the reduced stereo extinction requirements described in a previous paragraph. Reduced stereo extinction requirements, and the defocusing of the opposite-eye image, enables placement of filter **2020** on the outer surface of lens solid **2311,** in applications where locally-reduced image contrast is acceptable, despite the angle-dependency of the transmission spectrum that results from this placement. The embodiment in **FIG. 19** has fewer parts and is potentially thinner than the embodiment in **FIG. 18,** which might be an advantage in some applications.

In an exemplary embodiment, of a substantially flat lens assembly **2000,** illustrated in **FIG. 20** and for illustrative purposes shown with exaggerated lens assembly thickness, outer optical assembly **2010** includes an outer lens solid **2311** and an outer diffractive surface **2312,** and inner optical assembly **2030** includes an inner lens solid **2321,** and an inner diffractive surface **2322,** with geometrical surface **2005** positioned between outer diffractive surface **2312** and inner diffractive surface **2322.** Said outer diffractive surface **2312** and inner diffractive surface **2322** are, in a preferred embodiment of the present invention, multi-order diffractive lenses **(US 5,589,982).** The exemplary embodiment in **FIG. 20** makes use of the reduced stereo extinction requirements described in a previous paragraph. Reduced stereo extinction requirements, and the defocusing of the opposite-eye image, enables elimination of filter **2020** from lens assembly **2000,** in applications where locally-reduced image contrast is acceptable. Compensation in left-eye image data **11** and right-eye image data **12,** using known information about the optical transfer function of the compound lenses, in lens assemblies **2000** of left-eye lens **2001** and right-eye lens **2002,** can be applied to improve the local image contrast. The embodiment in **FIG. 20** has fewer parts and is potentially thinner than the embodiment in **FIG. 18.** A further advantage of the embodiment in **FIG. 20** is the absence of a filter **2020,** thus removing the cost of depositing multi-layer dielectric filters.

Embodiments of lens assembly **2000** of the curved type may be created similarly to the embodiments of lens assembly **2000** of the flat types illustrated in **FIG. 18, FIG. 19,** or **FIG. 20,** by outer optical assembly **2010** and inner optical assembly **2030** both including a lens solid being smooth and curved on one side and similarly curved but having a diffractive surface.

Someone knowledgeable in the field will understand that embodiments of the present invention are not limited to configurations illustrated in **FIGS. 14-20,** and there are additional possible embodiments of lens assembly **2000** comprising two lenses of opposite focal length, where said lenses may be diffractive or refractive. The choice of embodiments of the present invention may depend on factors such as the trade-off chosen between manufacturing complexity and image quality.

In an embodiment of lens assembly **2000** of the present invention, including refractive or diffractive lenses, said lenses can, by way of example, be manufactured using a process where a master mold created by diamond-turning, e-beam lithography or ion-beam lithography. By way of example, such a process may be injection molding, compression molding, hot embossing, or UV-embossing using UV-curable polymers. By way of example, said diffractive lenses may each be replicated in one monolithic piece in a material such as glass or acrylic, or replicated as a micro-structure onto a premade substrate such as glass or acrylic. By way of example, said lenses have a facet height of between 0.5 μιη and 30 μιη.

Someone knowledgeable in the field will understand that an embodiment of the present invention may include a lens assembly **2000** manufactured in other means than by diamond-turning or n-step lithography etching of a mold, and molding of flat diffractive or refractive lenses or curved diffractive or refractive lenses. By way of example, said lens assembly may include lenses with spatially varying index of refraction, spatially varying diffraction and said lenses may be created using gradient-index materials, optical metamaterials, and replication of nano-structured patterns or volumetric holographic elements

In a preferred embodiment of the stereoscopic 3D display system **10,** the display unit **13** is a projection display and the stereo illumination unit **101** includes light-emitting diodes (LEDs) in left-eye illumination source **201** and right-eye illumination source **202** In a further variation of said embodiment, LEDs are narrow-band monochromatic LEDs. By way of example, said monochromatic LEDs are of the PT-120 type produced by Luminus Devices Ltd. An advantage of using narrow-band monochromatic LEDs is that it enables a large color gamut. A further advantage of using narrow-band monochromatic LEDs is that it enables the use of wavelength-selective filtering eyewear **14** with substantially clear glasses having a color-neutral photopically-weighted transmission of approximately 75%. Said clear glasses are enabled by left-eye illumination combiner transmission spectrum **1501,** right-eye illumination combiner transmission spectrum **1502,** left-eye lens transmission spectrum **2401** and right-eye lens transmission spectrum **2402** similar to said transmission spectra illustrated in **FIG. 8.**

In an embodiment of the stereoscopic 3D display system **10,** the display unit **13** is a projection display and the stereo illumination unit **101** includes solid-state lasers in left-eye illumination source **201** and right-eye illumination source **202.** By way of example, said solid-state lasers are solid-state semiconductor lasers. By way of example, said solid-state lasers are arrays of vertical extended cavity lasers (VECSELs) (US **7,359,420 B2).** The use of lasers enables a large color gamut further enables the use of wavelength-selective filtering eyewear **14** with substantially clear glasses having a color-neutral photopically-weighted transmission of greater than 90%. Said clear glasses are enabled by left-eye illumination combiner transmission spectrum **1501,** right-eye illumination combiner transmission spectrum **1502,** left-eye lens transmission spectrum **2401** and right-eye lens transmission spectrum **2402** similar to said transmission spectra illustrated in **FIG. 8.** By way of example, said transmission spectra are obtained using multi-band pass thin-film interference filters **1002, 1003** in spectral combiner **1000** and multi-notch thin-film interference filters in filter **2020** of lens assembly **2000** in left-eye lens **2001** and right-eye lens **2002.** By way of another example, said transmission spectra **2401** and **2402** are obtained using rugate notch filters in filter **2020** of lens assembly **2000** in left-eye lens **2001** and right-eye lens **2002.** By way of another example, said transmission spectra **2401** and **2402** are obtained using holographic notch filters in filter **2020** of lens assembly **2000** in left-eye lens **2001** and right-eye lens **2002.** By way of example, an AOI of less than 5 degrees to the filters **2020,** made possible by said lens assembly **2000,** enables the use of advanced notch filters, with narrow notches, such as rugate notch filters and holographic notch filters.

In an embodiment of the stereoscopic 3D display system **10,** the display unit **13** is a projection display and spatial light modulator(s) **103** is a single spatial light modulator capable of spatial modulation of illumination and said spatial modulation is insensitive or substantially insensitive to the polarization state of said illumination. By way of example, said single spatial light modulator is a digital micro-mirror device (DMD) of the type produced by Texas Instruments Ltd., left image data **11** and right image data **12** each include three color channels, and said single spatial light modulator modulates all three said color channels of both left image data **11** and right image data **12.** Virtually flicker-free stereoscopic 3D display is possible by using LEDs in stereo illumination unit **101** and a DMD as a spatial light modulator **103** in display unit **13.** By way of example, LEDs and solid-state semiconductor lasers have switching times of 1 microsecond. By way of example, DMDs modulate on the order of 30 000 binary frames per second.

In an embodiment of the stereoscopic 3D display system **10,** the display unit **13** is a projection display and spatial light modulator(s) **103** is two or more spatial light modulators. By way of example, said spatial light modulators are a digital micro-mirror device (DMD) of the type produced by Texas Instruments Ltd.

In an embodiment of the stereoscopic 3D display system **10,** the display unit **13** is a backlit transmissive display and the stereo illumination unit **101** includes light-emitting diodes (LEDs) in left-eye illumination source **201** and right-eye illumination source **202** and where said LEDs are a substantial source of the illumination in left-eye illumination **211** and right-eye illumination **212.** In a variation of said embodiment, left-eye illumination source **201** emits left-eye illumination **211** including illumination perceived as red, illumination perceived as green and illumination perceived as blue. In a variation of said embodiment, right-eye illumination source **202** emits right-eye illumination **212** including illumination perceived as red, illumination perceived as green and illumination perceived as blue. In a further variation of said embodiment, LEDs are narrow-band monochromatic LEDs. By way of example, said monochromatic LEDs are of the PT-120 type produced by Luminus Devices Ltd. By way of example, the use of narrow-band monochromatic LEDs enables a large color gamut. By way of example, the use of narrow-band monochromatic LEDs enables the use of wavelength-demultiplexing eyewear **14** with substantially clear glasses having a color-neutral photopically-weighted transmission of greater than 75%. By way of example, said clear glasses are enabled by left-eye illumination combiner transmission spectrum **1501,** right-eye illumination combiner transmission spectrum **1502,** left-eye lens transmission spectrum **2401** and right-eye lens transmission spectrum **2402** similar to said transmission spectra illustrated in **FIG. 8.** By way of example, said transmission spectra are obtained using multi-bandpass thin-film interference filters **1002, 1003** in spectral combiner **1000** and multi-notch thin-film interference filters in filter **2020** of lens assembly **2000** in left-eye lens **2001** and right-eye lens **2002.**

In an embodiment of the stereoscopic 3D display system **10,** the display unit **13** is a backlit transmissive display and the stereo illumination unit **101** includes solid-state lasers in left-eye illumination source **201** and right-eye illumination source **202** and where said solid-state lasers are a substantial source of the illumination in left-eye illumination **211** and right-eye illumination **212.** In a variation of said embodiment, left-eye illumination source **201** emits left-eye illumination **211** including illumination perceived as red, illumination perceived as green and illumination perceived as blue. In a variation of said embodiment, right-eye illumination source **202** emits right-eye illumination **212** including illumination perceived as red, illumination perceived as green and illumination perceived as blue. By way of example, said solid-state lasers are solid-state semiconductor lasers. By way of example, said solid-state lasers are arrays of vertical extended cavity lasers (VECSELs) (US **7,359,420 B2).** The use of lasers enables a large color gamut and further enables the use of wavelength-demultiplexing eyewear **14** with substantially clear glasses having a color-neutral photopically-weighted transmission of greater than 90%. By way of example, said clear glasses are enabled by left-eye illumination combiner transmission spectrum **1501,** right-eye illumination combiner transmission spectrum **1502,** left-eye lens transmission spectrum **2401** and right-eye lens transmission spectrum **2402** similar to said transmission spectra illustrated in **FIG. 8.** By way of example, said transmission spectra are obtained using multi-band pass thin-film interference filters **1002, 1003** in spectral combiner **1000** and multi-notch thin-film interference filters in filter **2020** of lens assembly **2000** in left-eye lens **2001** and right-eye lens **2002.** By way of another example, said transmission spectra **2401** and **2402** are obtained using rugate notch filters in filter **2020** of lens assembly **2000** in left-eye lens **2001** and right-eye lens **2002.** By way of another example, said transmission spectra **2401** and **2402** are obtained using holographic notch filters in filter **2020** of lens assembly **2000** in left-eye lens **2001** and right-eye lens **2002.** By way of example, an AOI of less than 5 degrees to the filters **2020,** made possible by said lens assembly **2000,** enables the use of advanced notch filters, with narrow notches, such as rugate notch filters and holographic notch filters.

In an embodiment of the stereoscopic 3D display system **10,** the display unit **13** is a transmissive display and transmissive display panel **113** is a transmissive display panel capable of spatial modulation of illumination and said spatial modulation is insensitive or substantially insensitive to the polarization state of said illumination. By way of example, said transmissive display panel is a MEMS-panel of the digital micro shutter (DMS) type produced by Pixtronix Inc., left image data **11** and right image data **12** each include three color channels, and said transmissive display panel modulates, in a field-sequential fashion, all three said color channels of both left image data **11** and right image data **12.** Virtually flicker-free stereoscopic 3D display is possible by using LEDs or solid-state semiconductor lasers in stereo illumination unit **101** and a DMS-panel as transmissive display panel **113** in display unit **13.** By way of example, LEDs and solid-state semiconductor lasers have switching times of 1 microsecond. By way of example, the micro shutters in DMS-panels have response times in the order of 100 microseconds. By way of example, display unit **13** includes one or more stereo illumination units **101** and backlight illumination optics **112** configured as an edge-lit backlighting unit (BLU), and by further way of example this BLU is a variation of the type described in **(US 2008/0019147 Al)** with modifications made to accommodate one or more stereo illumination units **101.**

In an embodiment of the stereoscopic 3D display system **10,** the display unit **13** is a transmissive display and transmissive display panel **113** is a transmissive display panel capable of spatial modulation of illumination and said spatial modulation is substantially only effective for illumination of one of two orthogonal polarization states. By way of example, said transmissive display panel is a thin-film transistor liquid crystal display (TFT-LCD) panel, left image data **11** and right image data **12** each include three color channels, and said transmissive display panel modulates, in a field-sequential fashion, all three said color channels of both left image data **11** and right image data **12.** By way of example, said TFT-LCD panel has a field rate of at least 360 Hz, high enough to display at least 60 color stereo images per second. By way of example, display unit **13** includes one or more stereo illumination units **101** and backlight illumination optics **112** configured as an edge-lit backlighting unit (BLU), and by further way of example this BLU is a variation of the type described in **(US 2008/0019147 Al)** with modifications made to accommodate one or more stereo illumination units **101.**

In an embodiment of the stereoscopic 3D display system **10,** the display unit **13** is a transmissive display and transmissive display panel **113** is a transmissive display panel capable of spatial modulation of illumination and said spatial modulation is substantially only effective for illumination of one of two orthogonal polarization states. By way of example, said transmissive display panel is a thin-film transistor liquid crystal display (TFT-LCD) panel, left image data **11** and right image data **12** each include three color channels, said transmissive display simultaneously displays all three color channels, and said transmissive display panel modulates, in a field-sequential fashion, left image data **11** and right image data **12.** By way of example, said TFT-LCD panel has a field rate of at least 120 Hz, high enough to display at least 60 color stereo images per second. By way of example, display unit **13** includes one or more stereo illumination units **101** and backlight illumination optics **112** configured as an edge-lit backlighting unit (BLU), and by further way of example this BLU is a variation of the type described in **(US 2008/0019147 Al)** with modifications made to accommodate one or more stereo illumination units **101.** The possibility of pulsing LEDs at a substantially high brightness, during shorter duty cycles, enables a LED- or laser-illuminated stereoscopic 3D backlit transmissive 3-color TFT-LCD display of the present invention, using stereo illumination unit **101,** to have a substantially higher brightness than a similar LED- or laser-illuminated stereoscopic 3D displays using liquid crystal shutter glasses or switchable polarization rotators.

In a preferred embodiment of the present invention, where the display unit **13** is a transmissive display including one or more stereo illumination units **101,** the backlight illumination optics **112** is of the edge-lit type similar to that described in reference **US 2010/0014027 Al.** Referring to this reference let **AXXX** denote the numbered items in said reference. In said preferred embodiment, the edge illuminator numbered **A101** has input illumination **A401** originating from one stereo illumination unit **101** and input illumination **A402** originating from another stereo illumination unit **101.** The advantage of said preferred embodiment, as compared to edge-lit embodiments in WO **2009/026888 Al,** is that stereo illumination unit **101** couples the left-eye illumination **211** and right-eye illumination **212** into substantially the same optical path, thus preserving etendue and doubling the amount of illumination within a given acceptance angle as compared to WO **2009/026888 Al.**

In a preferred embodiment of the present invention, where the display unit **13** is a transmissive display including one or more stereo illumination units **101,** the backlight illumination optics **112** is of the edge-lit type similar to that described in reference **US 2008/0019147 Al.** Referring to this reference let **BXXX** denote the numbered items in said reference. In said preferred embodiment, locations in the LCD system **B3,** containing LEDs **B6** include LED-illuminated stereo illumination combiners **101.**

An advantage of edge-lit backlighting units is the relative simplicity and low cost. If cost issues can be resolved, an embodiment of the present invention may include a display unit **13** of the transmissive display type, where backlight illumination optics **112** is of the direct-lit type including a large number of stereo illumination units **101.** The advantage of this approach, compared to the prior art described in referenced article "Interference-Filter-Based Stereoscopic 3D LCD" is the increased brightness and illumination uniformity due to the coupling of left-eye illumination **211** and right-eye illumination **212** into substantially the same optical path, thereby preserving etendue. The advantage of direct-lit backlighting, well known in the prior art, is the possibility of very high static constrast ratios obtained by local dimming. Displays with edge-lit backlighting units typically have a static contrast ratio limited by the contrast ratio of the transmissive display panel.

Example Filter and Diffractive Lens Set - **FIGS. 21-25**

This example filter set is intended for use with narrow-band RGB LEDs, and is optimized to provide a high visible light transmission in color-neutral glasses while still having a large stereo color gamut. This filter set has three pass bands in the left-eye display filter, three pass bands in the right-eye display filter, four pass bands in the left-eye eyewear filter and four pass bands in the right-eye eyewear filter. This filter set is illustrated by actual interference filter designs.

The transmission spectra of the left-eye display filter **1501** and right-eye display filter **1502** are shown in **FIG. 21,** together with the emission spectra of red, green and blue PT-120 LEDs (Luminus Devices Inc., MA, USA). Filters **1501** and **1502** both have three pass bands.

The transmission spectra of the left-eye display filter **1501** and right-eye eyewear filter **2402** are illustrated in **FIG. 24.** Eyewear filter **2402** is a triple-notch filter with four pass bands. The transmission spectra, of right-eye display filter **1502** and left-eye eyewear filter **2401,** are illustrated in **FIG. 25.** Eyewear filter **2401** is a quadruple-notch filter with four pass bands, where three of the notches block the pass bands of display filter **1502** and one notch attenuates an emission peak in fluorescent illuminants.

The left-eye color gamut is substantially similar to the right-eye color gamut. A small amount of color correction is needed, and the relative luminances of the color primaries are between 20-25 %, resulting in a stereo lumens efficiency after color correction of approximately 10 %. The filter set is designed to have an absence of substantial color distortions. Regardless of illuminant, the visible light transmission is approximately 70±10% for all three tristimulus values. These eyewear filters enable clear viewing of off-screen objects with no substantial color distortions.

FIG. 22 shows the diffraction efficiency of an exemplary embodiment of a multi-order diffractive lens for use in lens assembly **2000** in left-eye lens **2001.** The diffraction efficiency is near unity for all passbands in left-eye display filter transmission spectrum **1501,** and substantially reduced for all passbands in right-eye display filter transmission spectrum **1502.** **FIG. 23** shows the diffraction efficiency of an exemplary embodiment of a multi-order diffractive lens for use in lens assembly **2000** in right-eye lens **2002.** The diffraction efficiency is near unity for all passbands in right-eye display filter transmission spectrum **1502,** and substantially reduced for all passbands in left-eye display filter transmission spectrum **1501.** In plain English, this means that the design wavelength and diffraction orders, of the left-eye and right-eye multi-order diffractive lens pairs, can be chosen so as to provide a focused left-eye image and a defocused right-eye image when viewing the display through the left-eye lens, and vice-versa for the other eye.

A disadvantage of the glasses filters **2401** and **2402,** of the example filter set illustrated in **FIG. 24** and **FIG. 25,** is the complexity of designing notch filters with high extinction ratio. By utilizing the a lowered requirement on the stereo extinction ratio in the filters **2020,** due to a reduction in the perceived stereo crosstalk when the opposite-eye image is viewed as a blurred out-of-focus image, fewer dielectric layers are required in filters **2020** to obtain a satisfactory image quality, thus reducing the cost of manufacturing these filters. It is also understood, that in some embodiments of the present invention, the combination of the filtering means in the display, illustrated by display filter left-eye transmission spectrum **1501** and right-eye transmission spectrum **1502,** and diffractive filtering means in the viewing aid, illustrated by multi-order diffractive lens diffraction efficiencies in **FIG. 22** and **FIG. 23,** is sufficient to provide an acceptable stereoscopic image without the use of relatively costly dielectric multi-layer filters in the viewing aid. Thus, there is the possibility for both high-end and regular glasses for use with the same display filters.

Other Displays

Someone knowledgeable in the field will understand that the present invention may include display units **13** of types other than imaging projection display of **FIG. 2** or transmissive flat-panel displays of **FIG. 3.** By way of example, display unit **13** may be a of the holographic image projection type, including spatial light modulators that spatially modulate the phase of laser illumination, or both the phase and the magnitude of the laser illumination, and in said example there may be holographic projection optics that perform a Fourier transform of the phase and/or magnitude of the laser illumination spatially modulated by said spatial light modulators, so as to project said Fourier-transformed spatially-modulated laser illumination onto a viewable display surface. By way of example, said spatial light modulator(s) may be a ID array of phase-modulating elements and a scanning device, similar to a grating light valve (GLV) but operating in a uniaxial holographic image projection mode, whereby the GLV MEMS modulates the position or state of its array elements in such a way that the Fourier transform, of laser illumination having its phase modulated by the ID array, is equal to or substantially equal to a vertical or horizontal scan line of left image **11** or right image **12.** By way of example, said scanning device may be a mechanically rotating mirror, an oscillating resonant-mode MEMS mirror or a solid-state holographic scanning device with associated optics. By way of example, said solid-state holographic scanning device may include a second ID array for phase modulation of laser illumination. By way of example, said spatial light modulator(s) may be 2D ferroelectric liquid crystal on silicon (FLCOS) microdisplay(s) modulating the phase of laser illumination, similar to the system developed by Light Blue Optics Ltd. By way of example, said spatial light modulator(s) may be 2D phase-modulating MEMS microdisplay, similar to the microdisplay(s) currently applied e.g. to adaptive optics systems in telescopes.

Thus to summarize, the invention relates to a stereoscopic viewing aid for viewing images received from a stereoscopic imaging system, the imaging system comprising two channels providing images having two different sets of wavelength ranges. The viewing aid comprising two filtering means, one for each eye, the first transmitting light within the first set of wavelengths and the second transmitting light within the second set of wavelengths representing the images of the two stereoscopic channels. Each of the filtering means comprises a first optical device or assembly 2010, 201 1, 2013, 2312 having a predetermined focal length at the corresponding wavelengths so as to change the incident angle of the light from the imaging system relative to a surface of the viewing aid 2005. This surface may be curved or constitute a plane surface.

Preferably the focal length is negative so as to reduce the incident angle and thus also reduce the difference in direction of light from the different parts of the imaging system. This is especially advantageous if the filtering means comprises a dielectric filter 2020 transmitting light within one of said sets of wavelengths positioned after said first optical device so that said optical device reduces the angle of incident on said filter, thus also reducing the variation in the wavelength of the filtered light..

Preferably the first optical device is a first lens on the first surface for decreasing the angle between the light from the imaging system onto a filter, and the second optical device or assembly 2030 surface being provided with a second lens 203 1,2322 for essentially re-establishing the direction of the incoming light from the imaging system. In this embodiment, the first and first and second lenses are preferably constituted by Fresnel lenses 201 1, 2031, but diffractive and refractive lenses are also possible, as well as combinations of such. The first and second lenses combined may constitute an afocal system.

According to one embodiment the first and second lenses combined are a focal system providing vision correction, so that a user may have specially designed 3D-glasses compatible to their eyes, thus eliminating the need for simultaneous use of two sets of viewing aids when watching the 3D images.

The first optical device/assembly 2010 may alternatively be provided with a first diffractive filter 2312 having a focal length within one of said sets of wavelengths while scattering light outside said set of wavelengths or diffusing the light outside the selected wavelengths. This way a filtering of said light is obtained without a dielectric filter between the lenses. Preferably this system also comprises a second optical device constituted by a second diffractive surface 2322 for essentially re-establishing the direction of the incoming light within said range of wavelengths from the imaging system. This system may also include a course dielectric filter removing most, although not all, of the light, thus reducing the requirements of the diffractive filter or dielectric filter.

As stated above, if two optical devices are used they may have opposite focal lengths or the combined focal length may be selected so as to match the eye of the individual user.

List of references

US 2008/0019147 Al	LED Color Management and Display Systems
US 2010/0014027 Al	LED Backlight having Edge Illuminator for Flat Panel LCD Displays
US 7,359,420 B2	Manufacturable Vertical Extended Cavity Surface Emitting Laser Arrays
EP 1 830 585 A2	Method and Device for Performing Stereoscopic Image Display Based on Color Selective Filters
US 6,698,890 Bl	Device for Projecting a Color Image
US 7,001,021 B2	Device for Projecting a Stereo Color Image
WO 1998/049837 Al	Method and Facility for Light-Beam Projection of Images on a Screen
WO 2000/074392 Al	Device for Projecting a Colour Image
WO 2004/038457 A2	Stereo Projection System and Projection Device Therefor
WO 2008/061511 Al	Stereo Projection with Interference Filters
WO 2009/026888 Al	System for Reproducing Stereographic Images
WO 2010/059453 A2	High Durability Color Combiner
US 3,497,283	Color Selection Polarizing Beam Splitter
US 2007/0188711 Al	Multi-Functional Active Matrix Liquid Crystal Displays
US 2008/0284982 Al	Spectral Separation Filters for 3D Stereoscopic D-Cinema Presentation
US 2008/0278807 Al	Method and System for Shaped Glasses and Viewing 3D Images
US 2007/0236809 Al	Forming Spectral Filters
DE 199 24 167 A 1	VerfahrenzurAufzeichnung und Wiedergabe von FarbbildenmitgestigerterWiedergabetreue
US 2007/0247709 Al	3-D Projection Full Color Multimedia Display
LED-Based 3D Displays with Infitec Technology	2008 LED Projection Systems Report, Section 4.8.4. LED-Based 3D Displays with Infitec Technology, Insight Media LLC, October 2008.
Interference-Filter-Based Stereoscopic 3D LCD	Interference-Filter-Based Stereoscopic 3D LCD, A. Simon, M.G. Prager, S. Schwarz, M. Fritz, and H. Jorke, Journal of Information Display, Vol. 11, No. 1, March 2010.
US 5,589,982	Polychromatic Diffractive Lens
Polychromatic Multiorder Diffractive Lens	Spectral Properties of Multiorder Diffractive Lenses, Dean Faklis and G. Michael Morris, APPLIED OPTICS, Vol. 34, No. 14, 10 May 1995, Optical Society of America.

Claims

1. Stereoscopic viewing aid for viewing images received from a stereoscopic imaging system, the imaging system comprising two channels providing images having two different sets of wavelength ranges, the viewing aid comprising two filtering means, the first transmitting light within the first set of wavelengths and the second transmitting light within the second set of wavelengths, each of said filtering means comprising a first optical device having a selected focal length at the corresponding wavelengths.

2. Viewing aid according to claim 1, wherein the filtering means comprises a dielectric filter transmitting light within one of said sets of wavelengths positioned after said first optical device, the first optical device having a negative focal length so that it reduces the angle of incidence on said filter.

3. Stereoscopic viewing aid according to claim 2, wherein the first optical device is a first lens on the first surface for collimating light from the imaging system so as to decrease the angle between the light from the imaging system onto a filter, and the second filter surface being provided with a second lens for essentially re-establishing the direction of the incoming light from the imaging system.

4. Viewing aid according to claim 2, wherein said first and second lenses are constituted by Fresnel lenses.

5. Viewing aid according to claim 2, wherein said first and second lenses are diffractive lenses.

6. Viewing aid according to claim 2, wherein said first and second lenses combined are an afocal system.

7. Viewing aid according to claim 2, wherein said first and second lenses combined are a focal system providing vision correction.

8. Viewing aid according to claim 1, wherein said first optical device is a diffractive filter having said selected focal length within one of said sets of wavelengths while scattering light outside said set of wavelengths, thus providing a filtering of said light.

9. Viewing aid according to claim 8, comprising a second optical device for essentially re-establishing the direction of the incoming light within said range of wavelengths from the imaging system.

10. Viewing aid according to claim 8, comprising an additional filter.

11. Viewing according to claim 1, comprising two optical devices having opposite focal lengths at said sets of wavelengths.

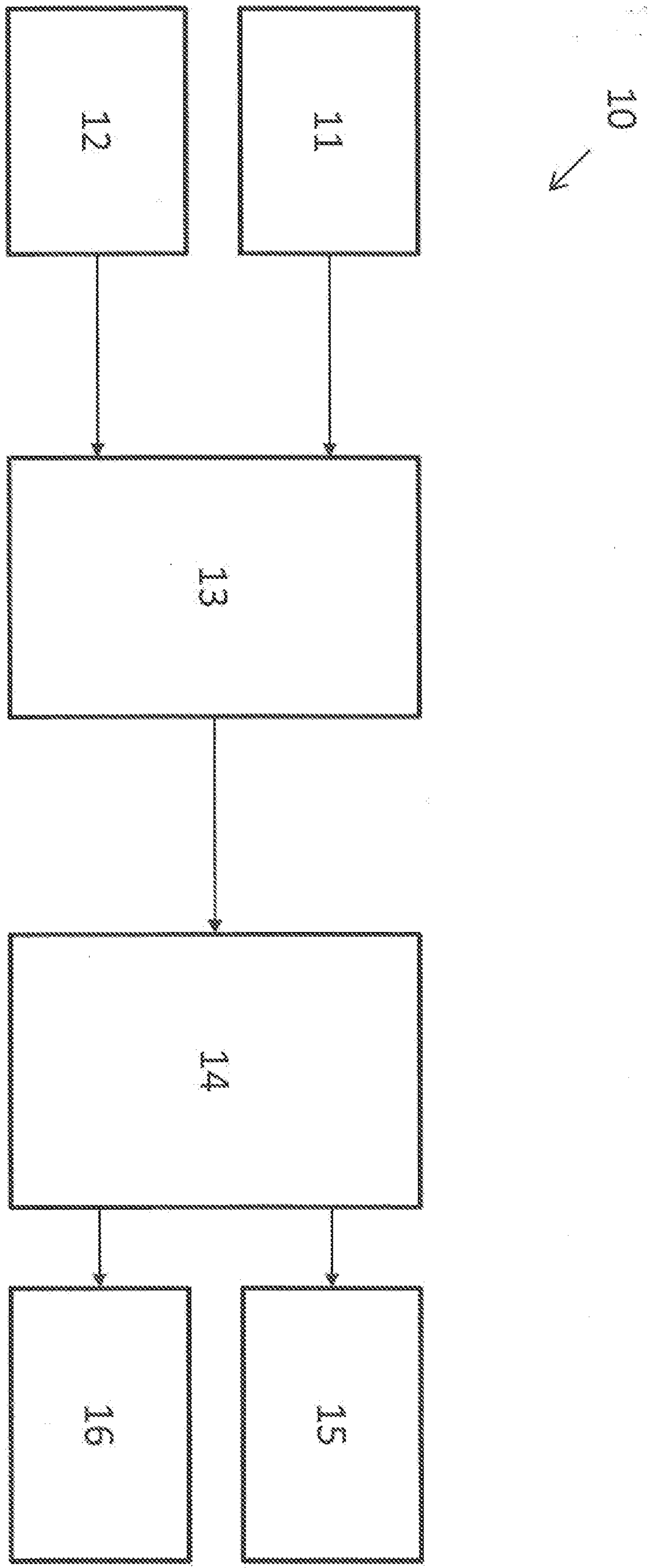


Fig. 1

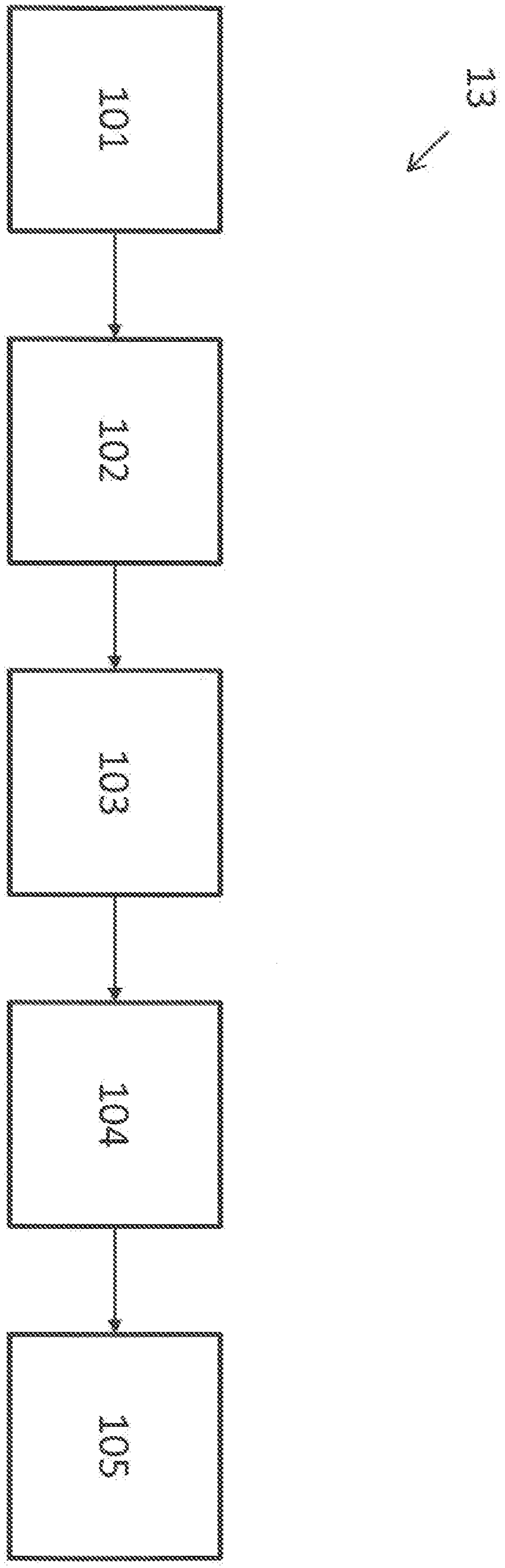


Fig. 2

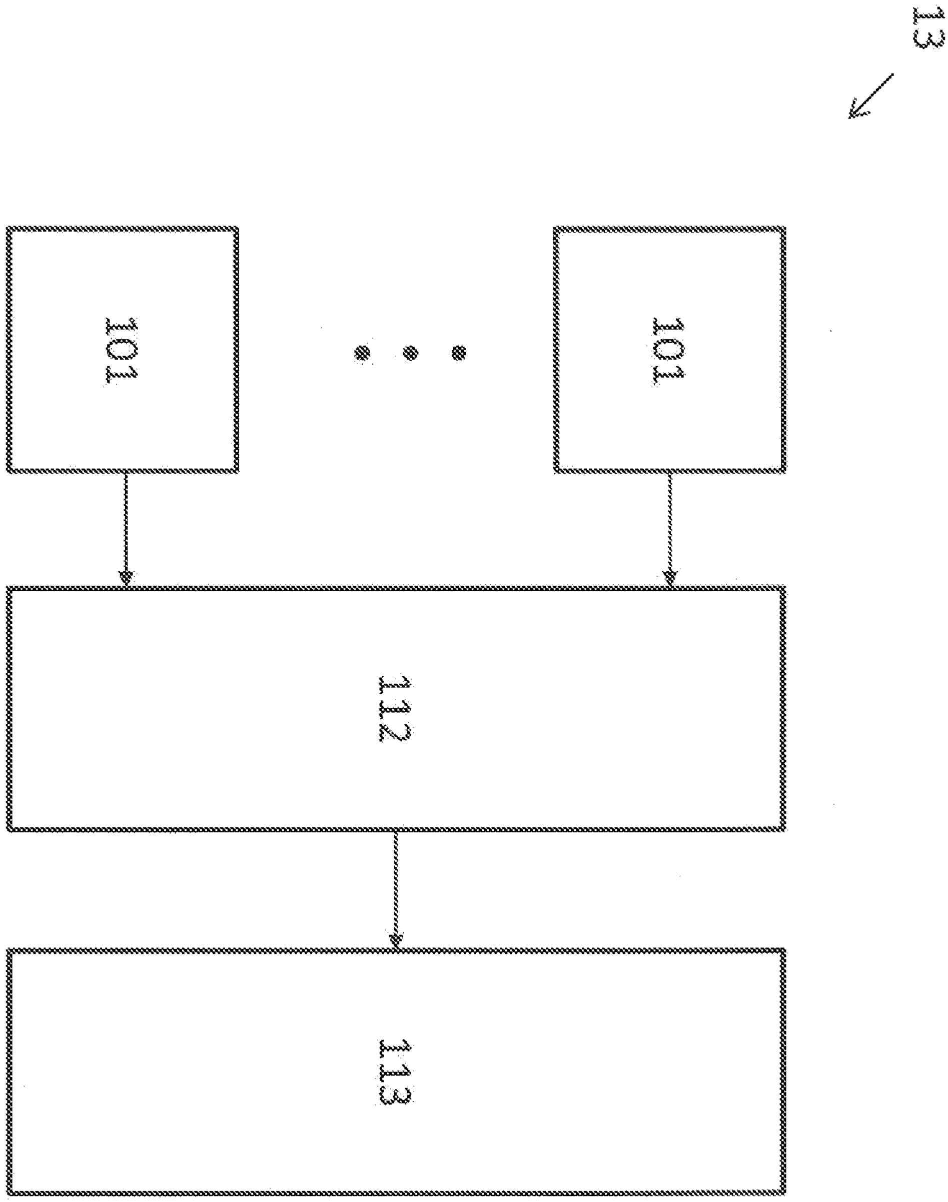


Fig. 3

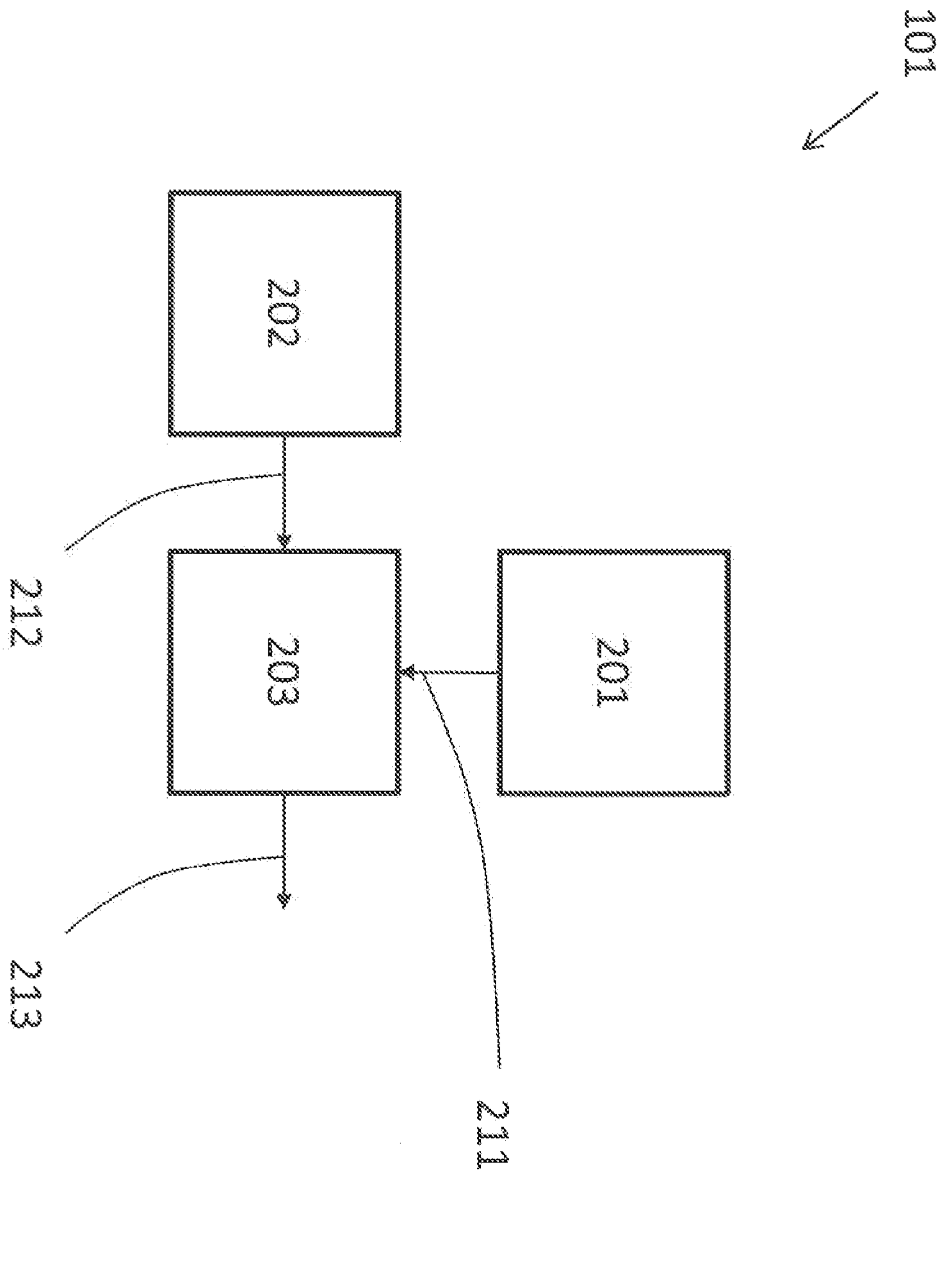


Fig. 4

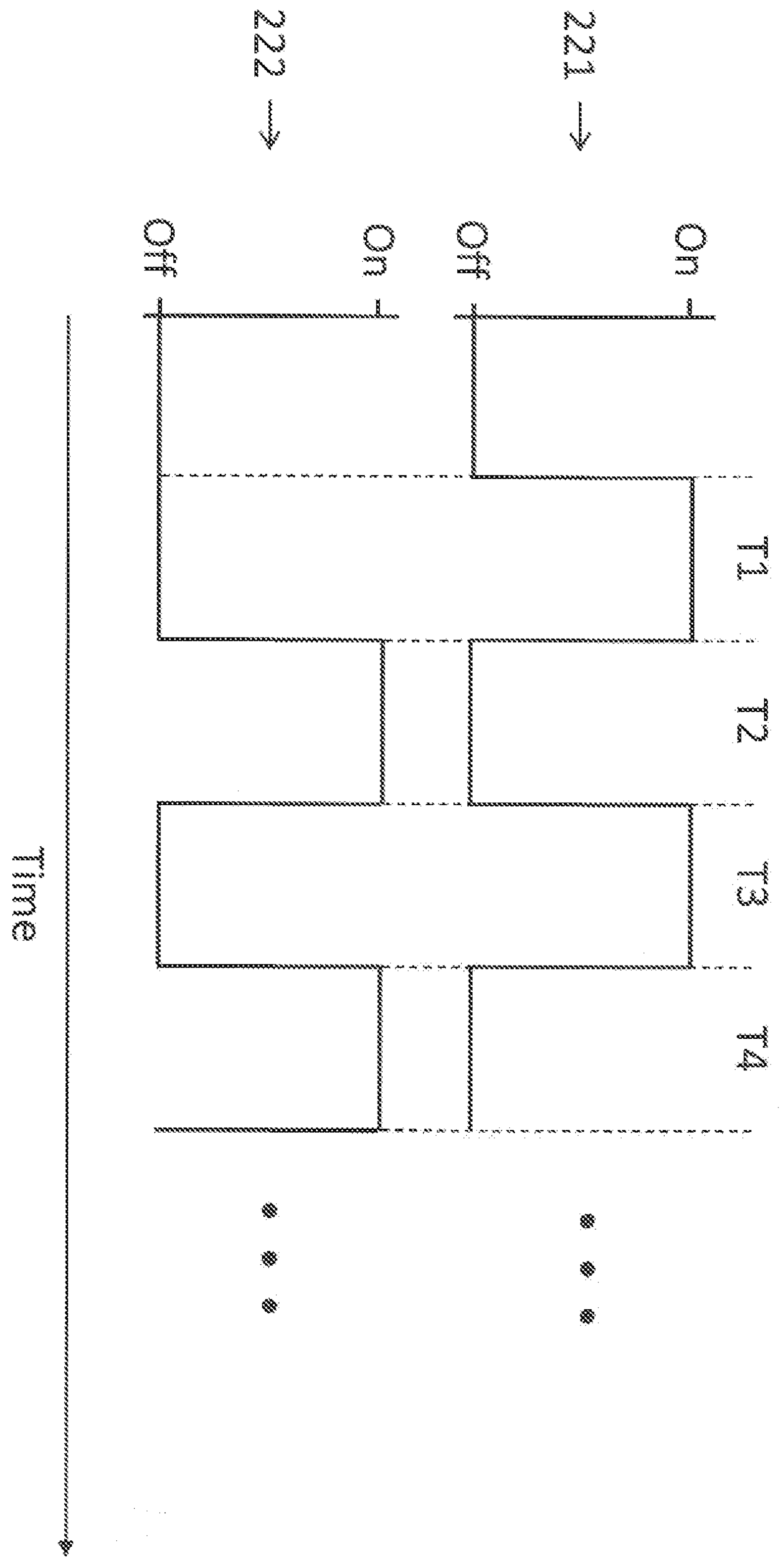


Fig. 5

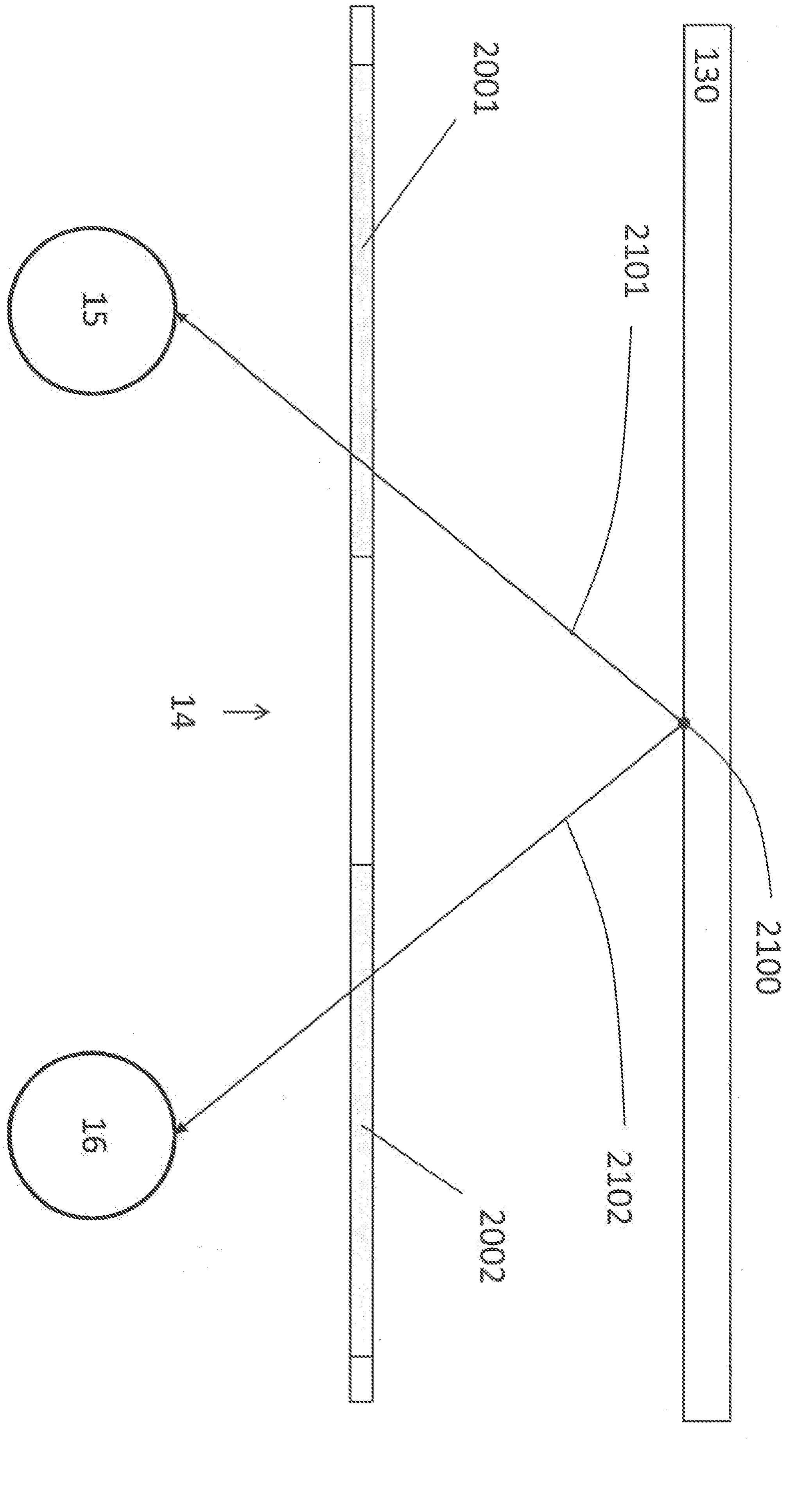


Fig. 6

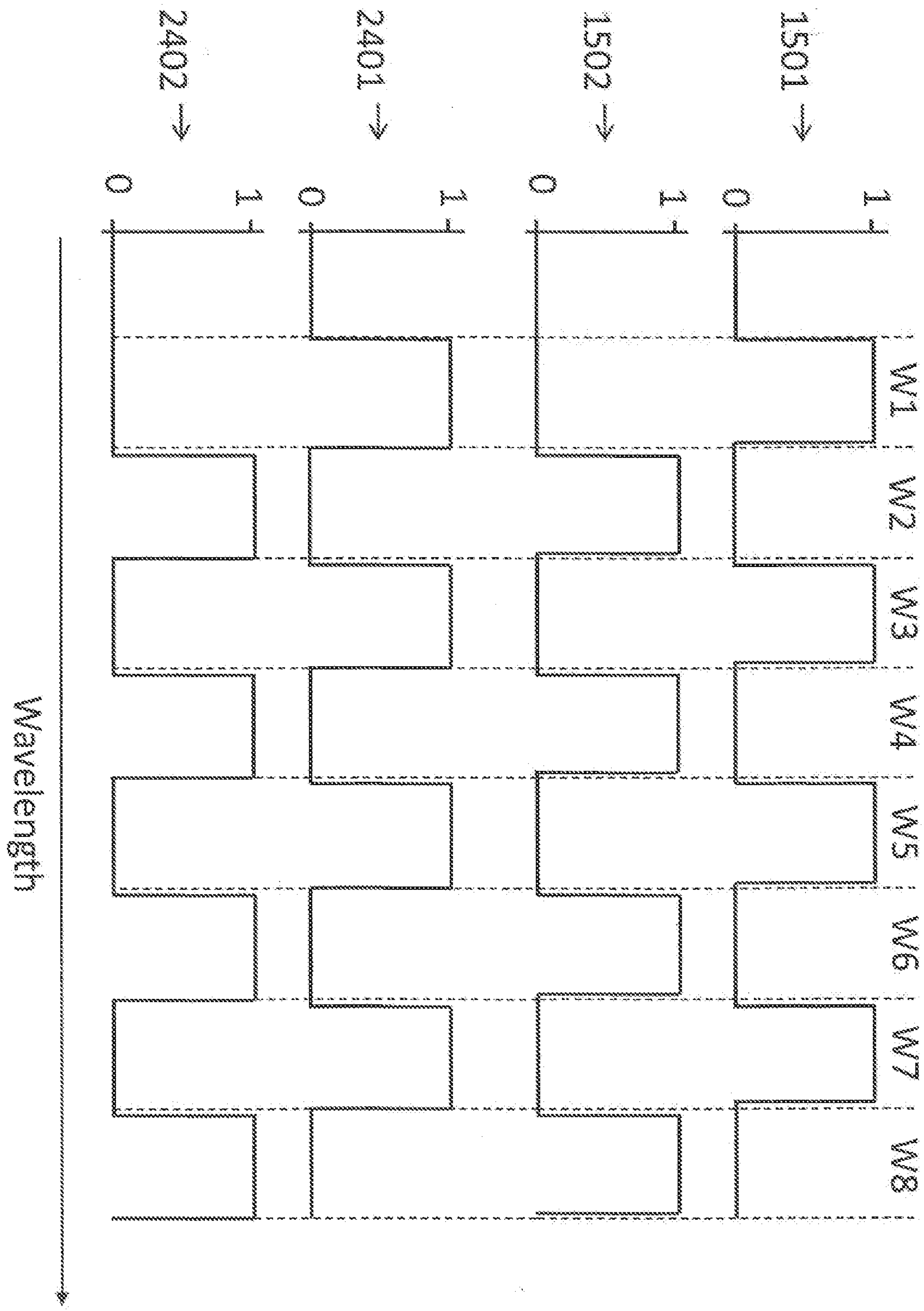


Fig. 7

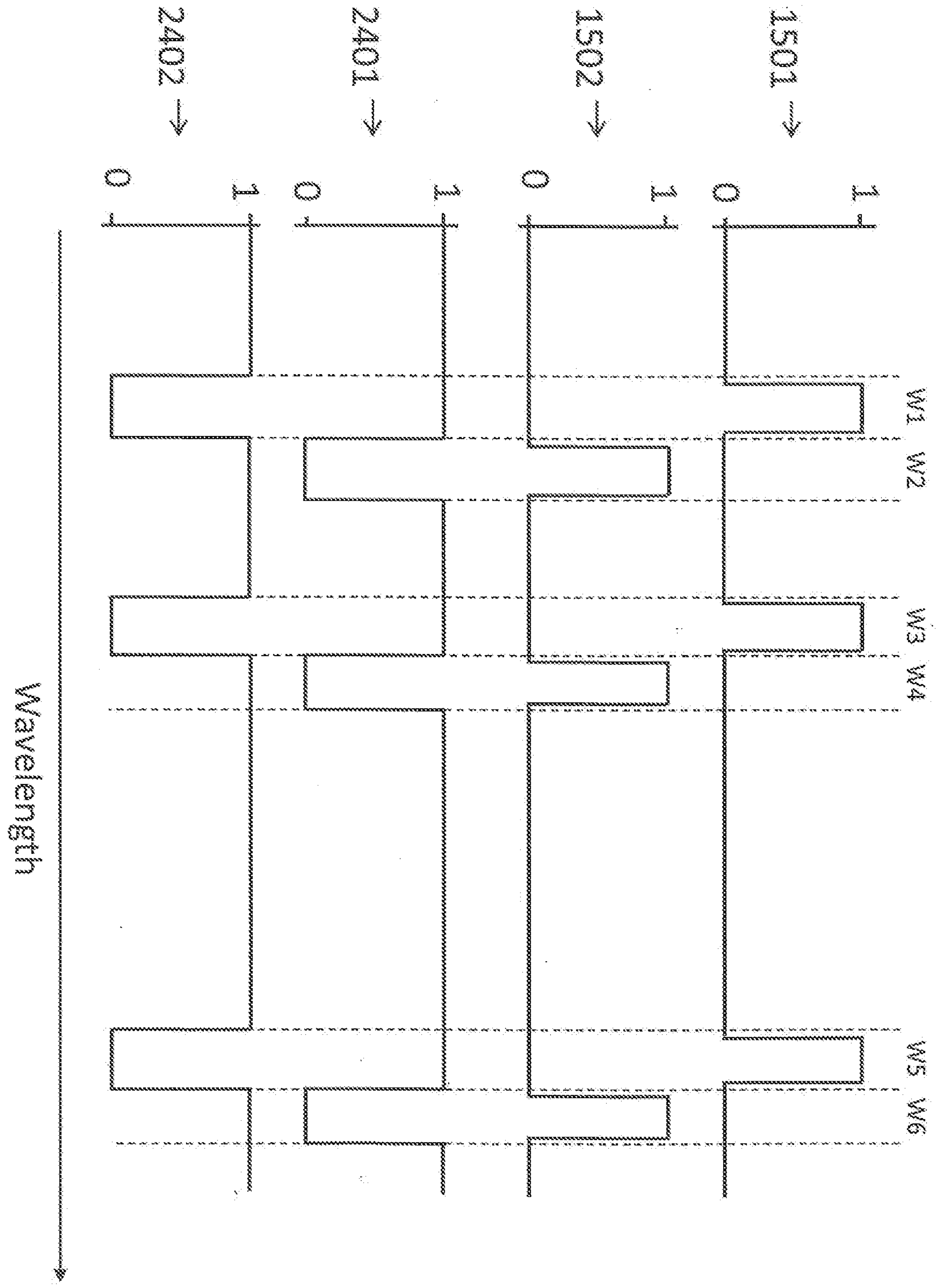
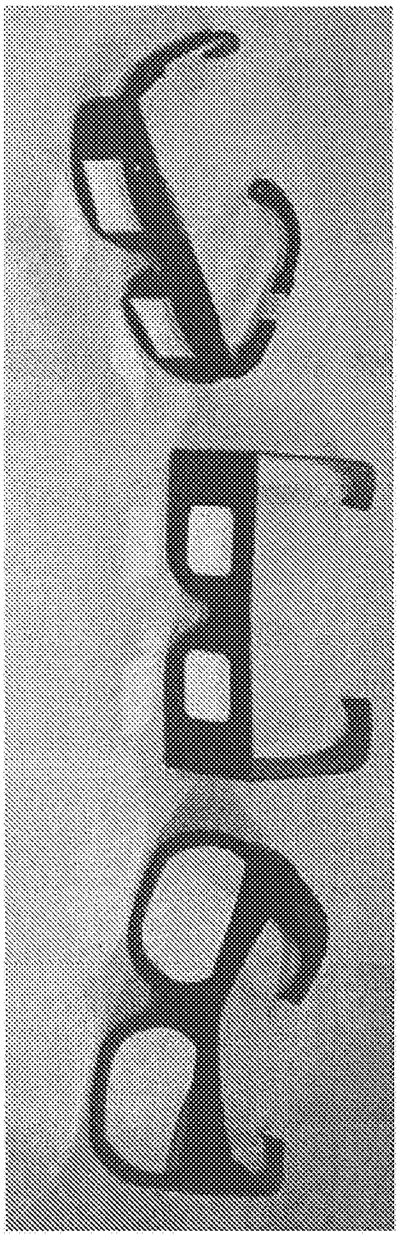


Fig. 8



A B C

Fig. 9 (Prior Art Glasses)

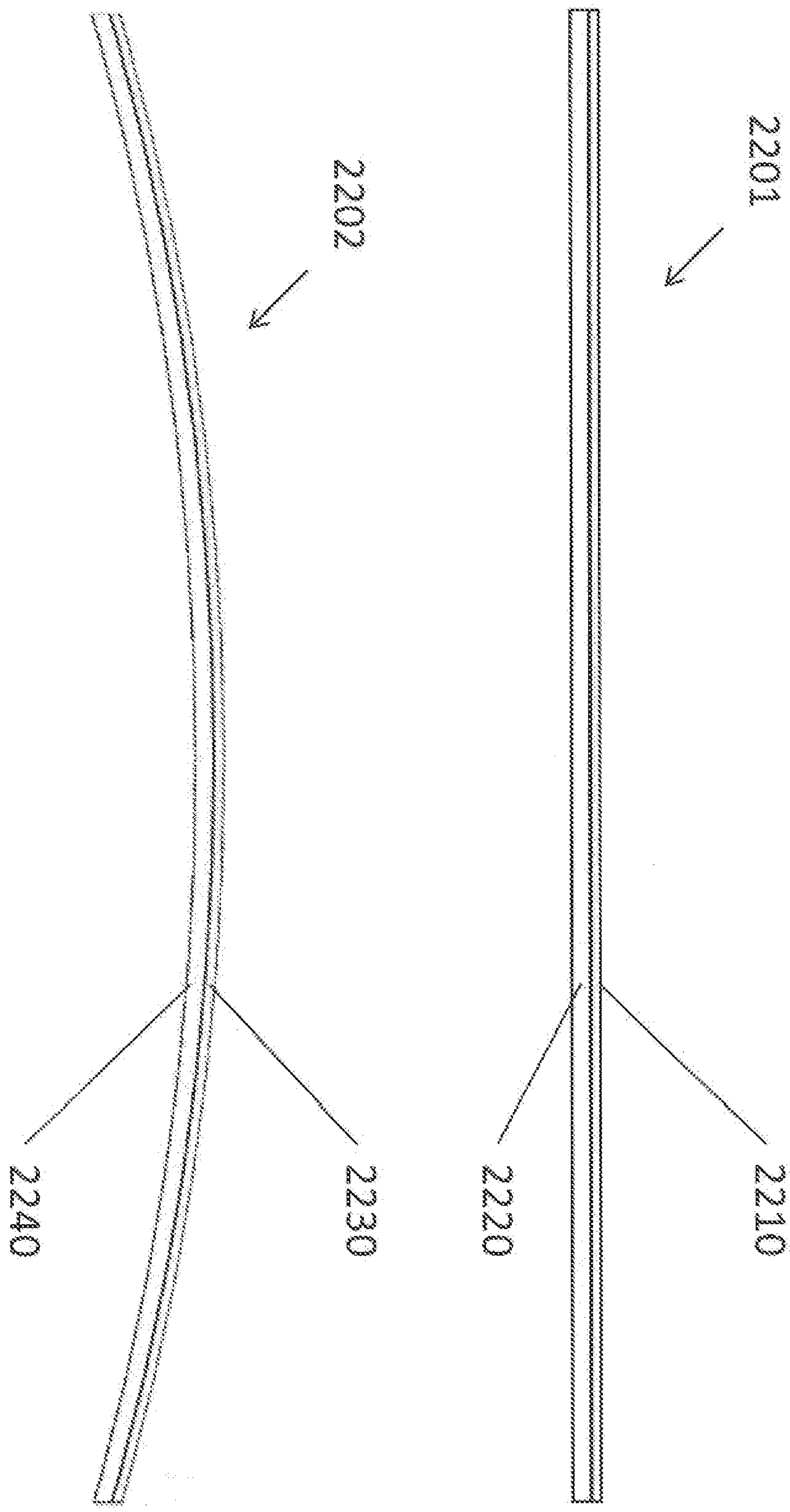


Fig. 10 (Prior Art Glasses)

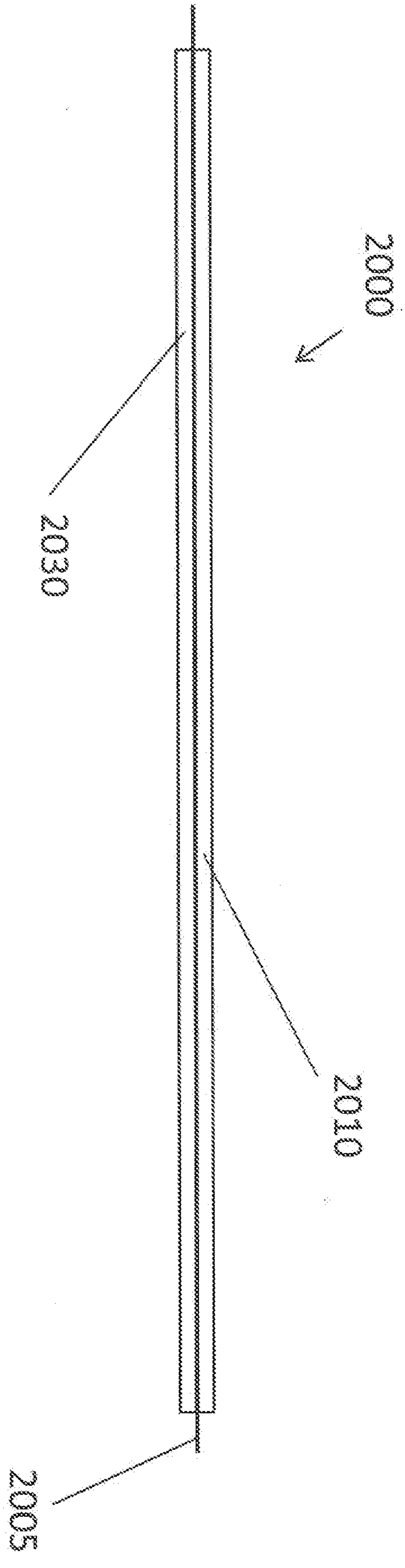


Fig 11

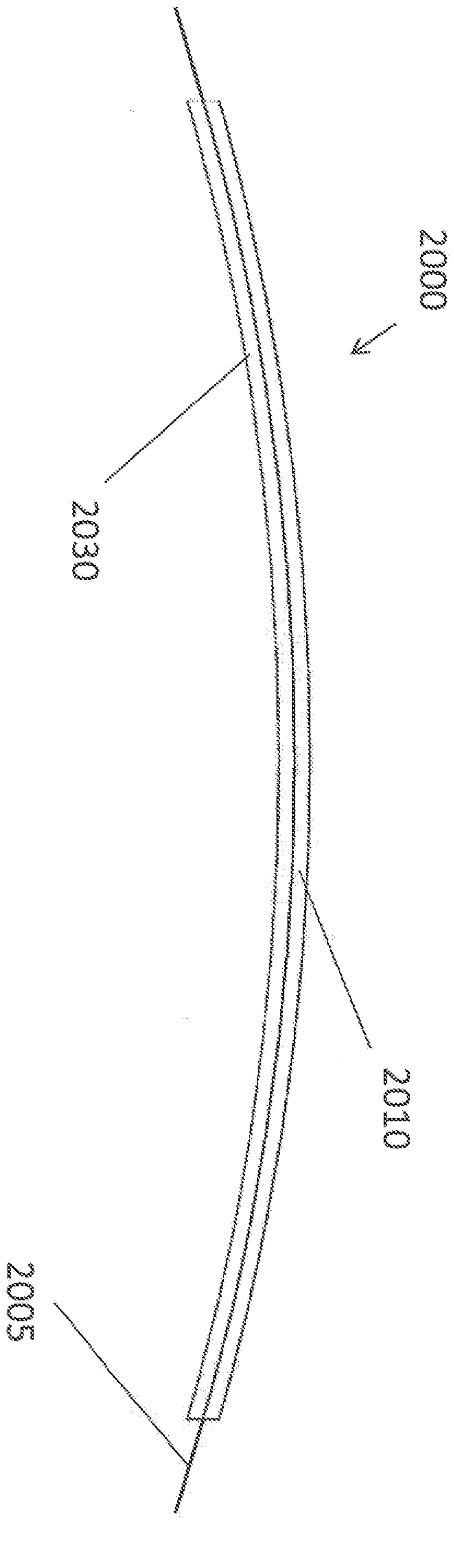


Fig 12

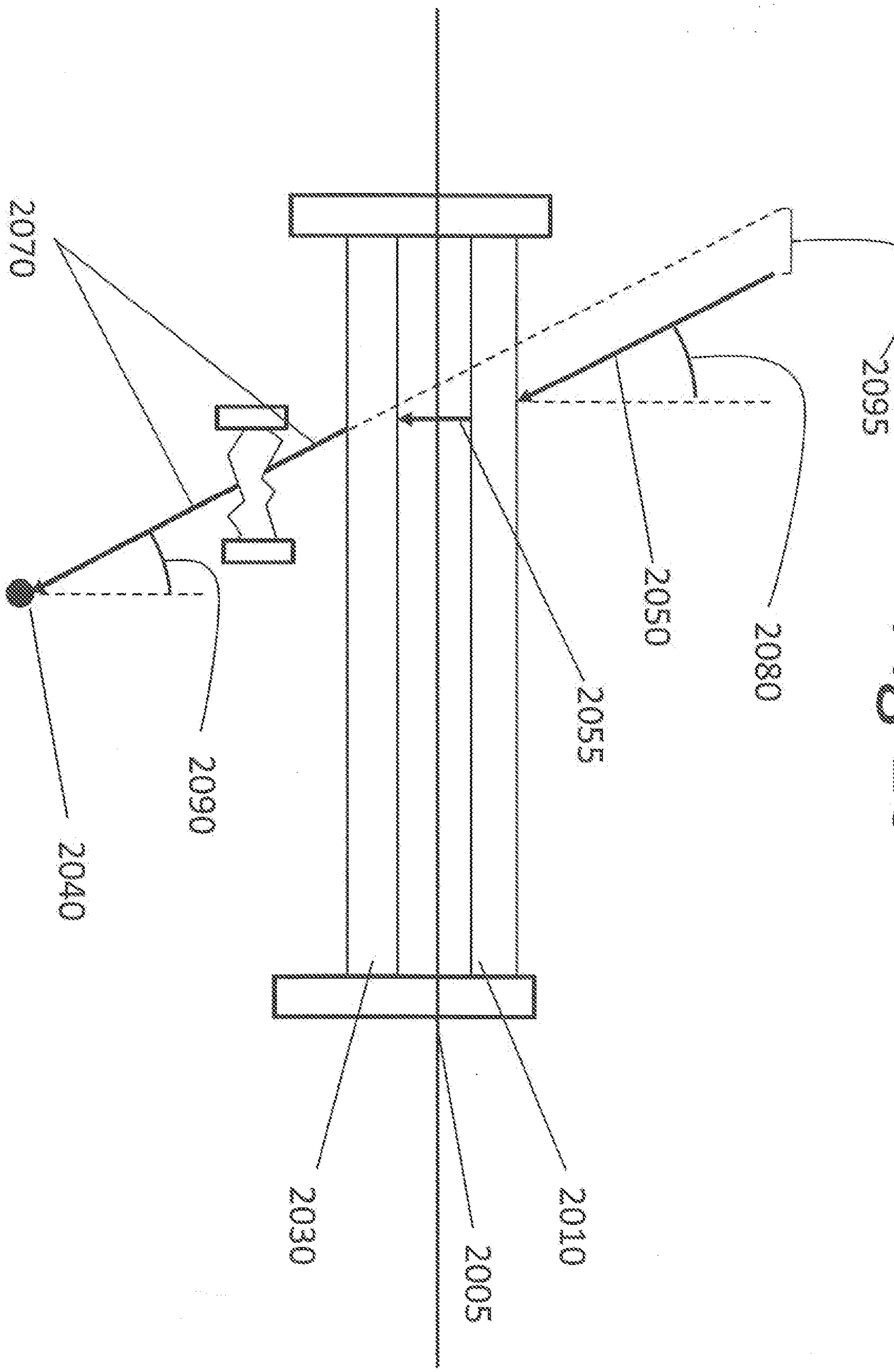


Fig 13

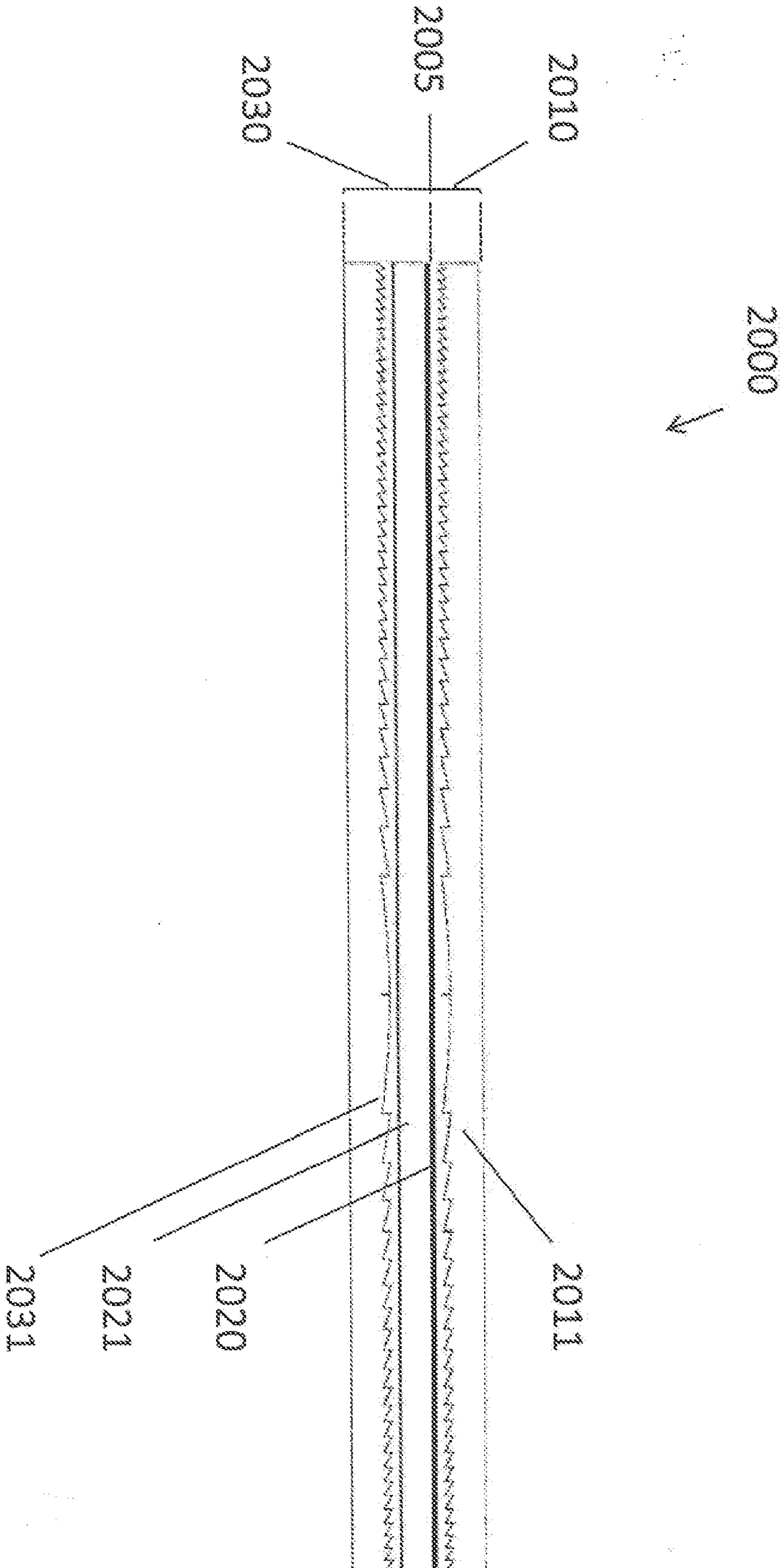


Fig. 14

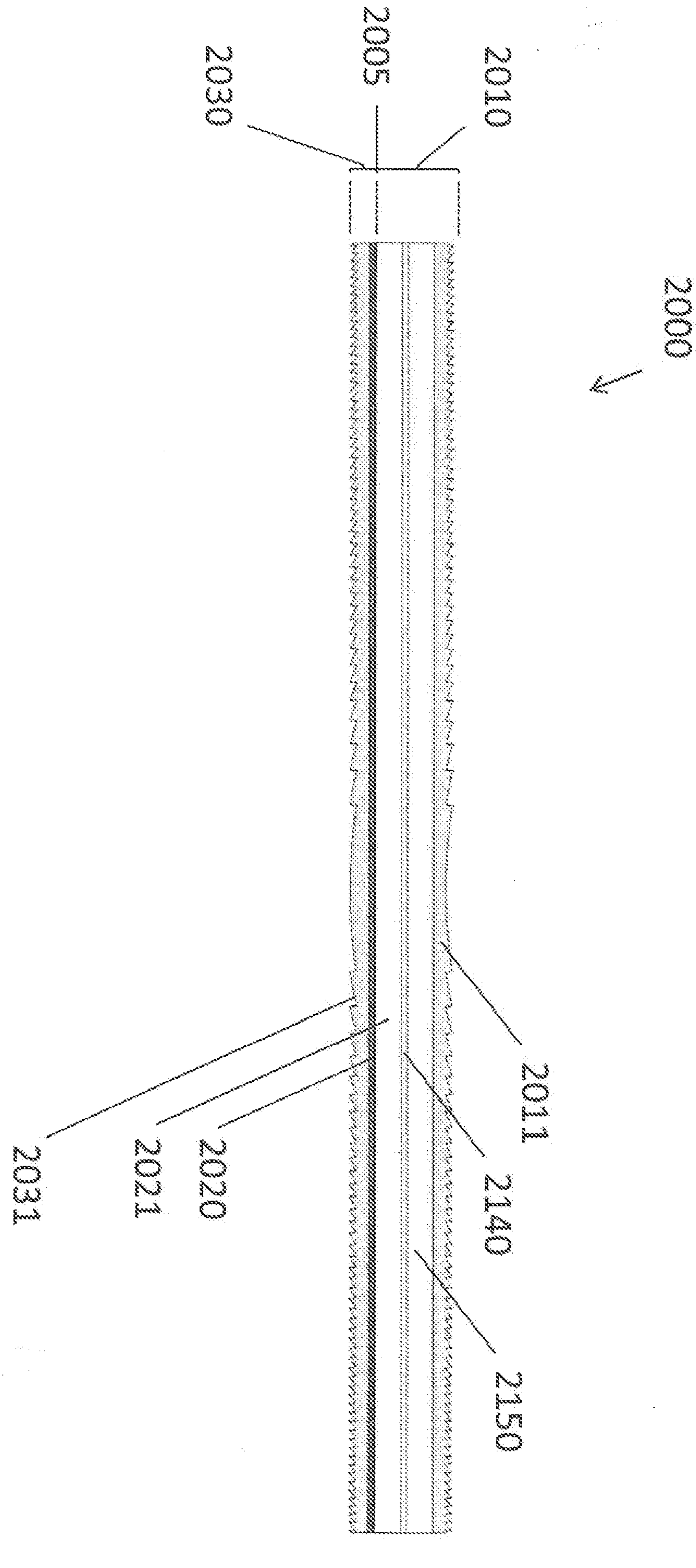


Fig. 15

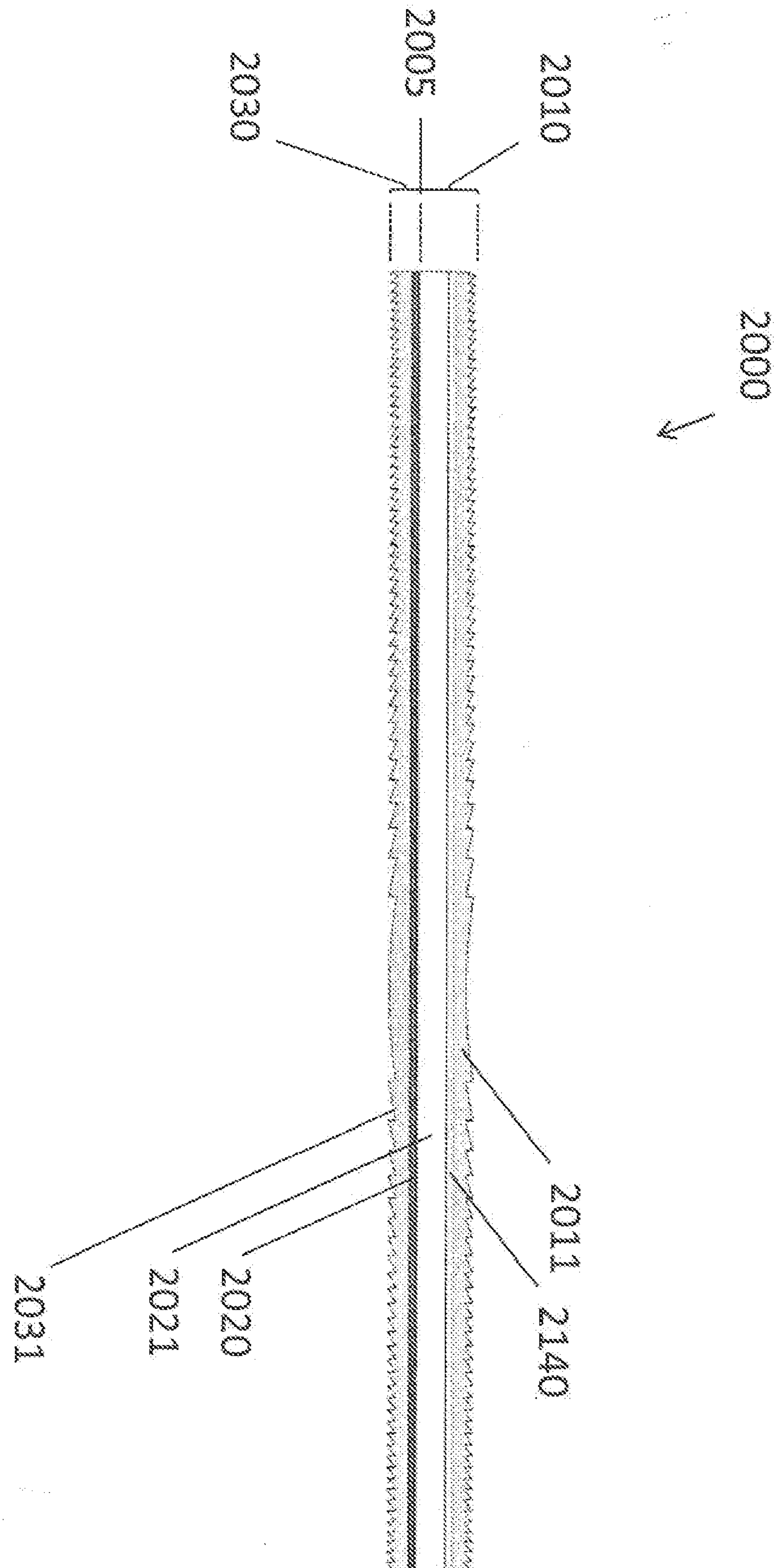


Fig. 16

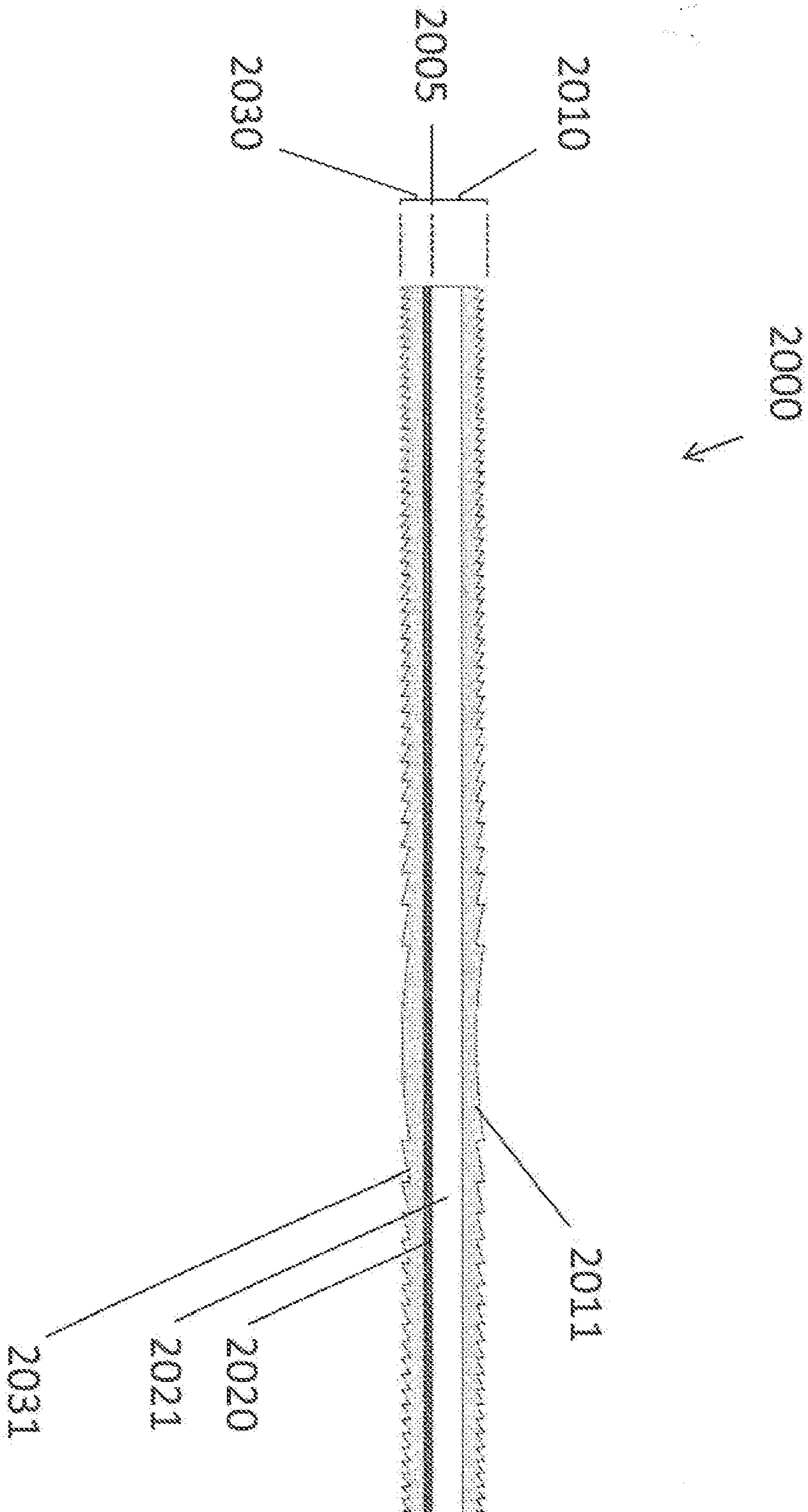


Fig. 17

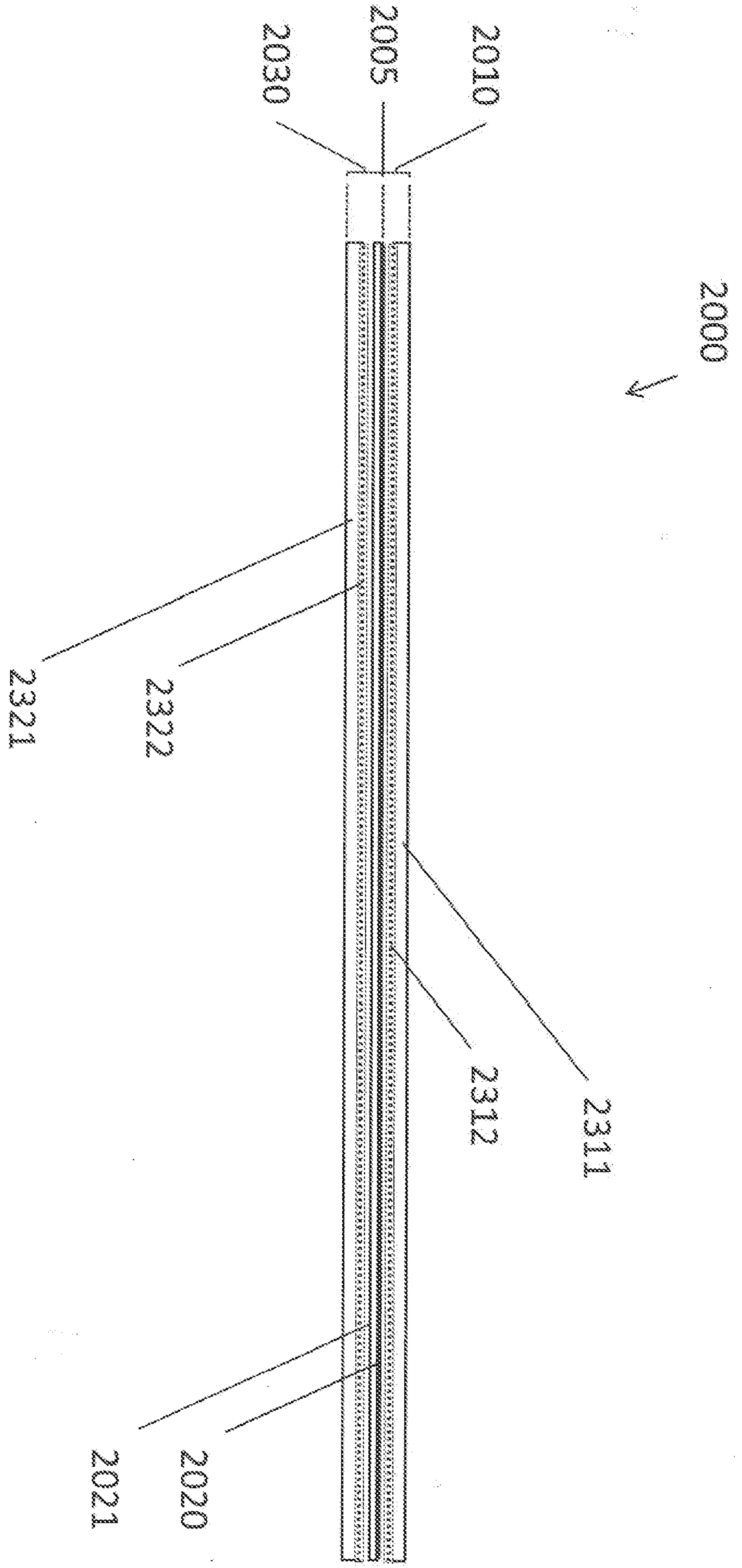


Fig. 18

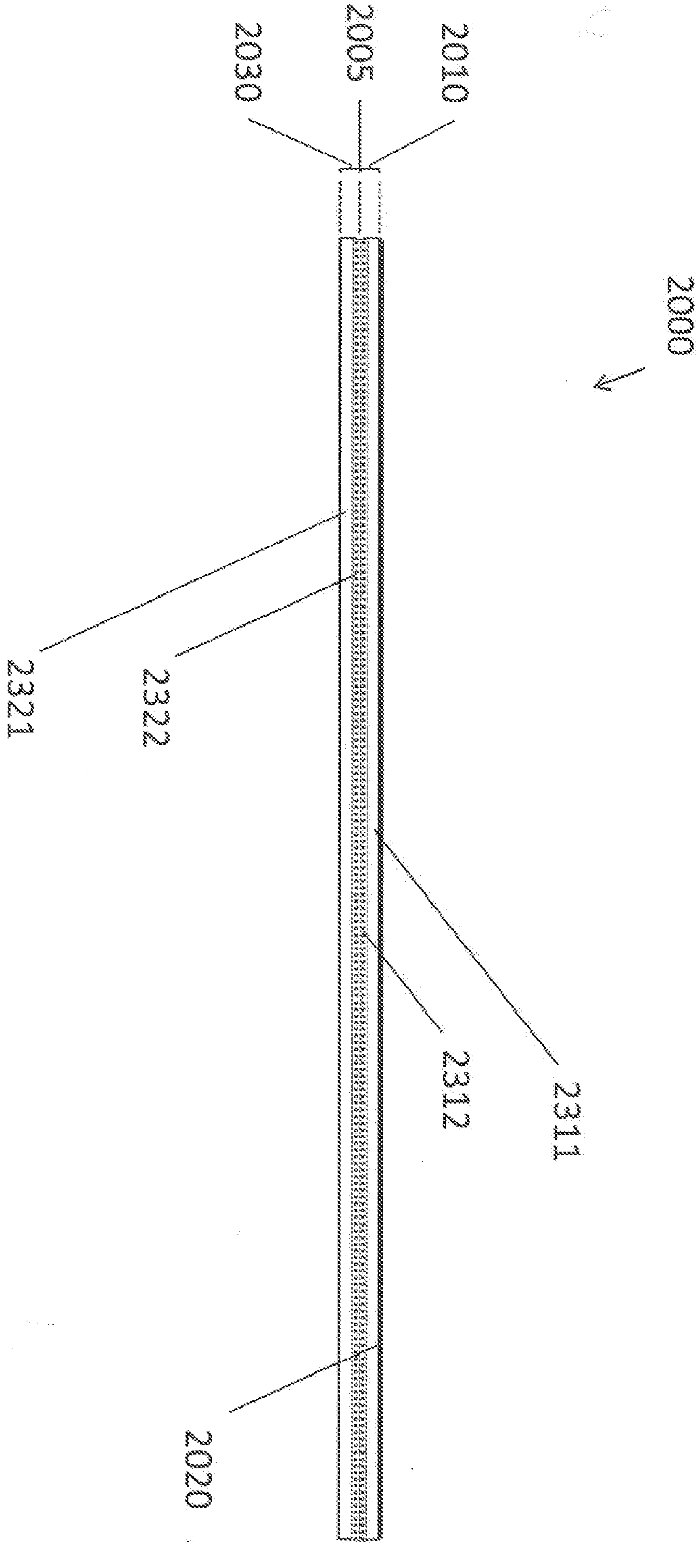


Fig. 19

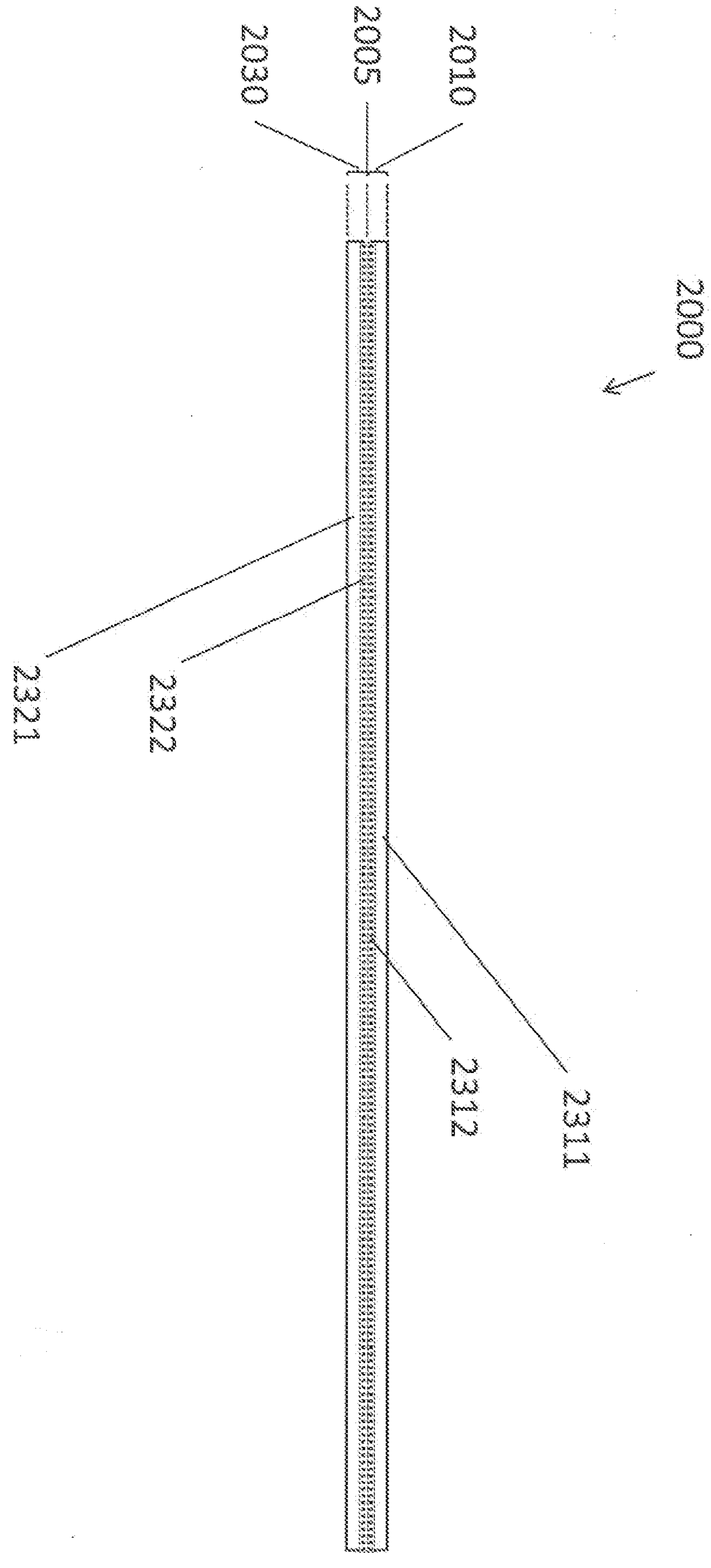


Fig. 20

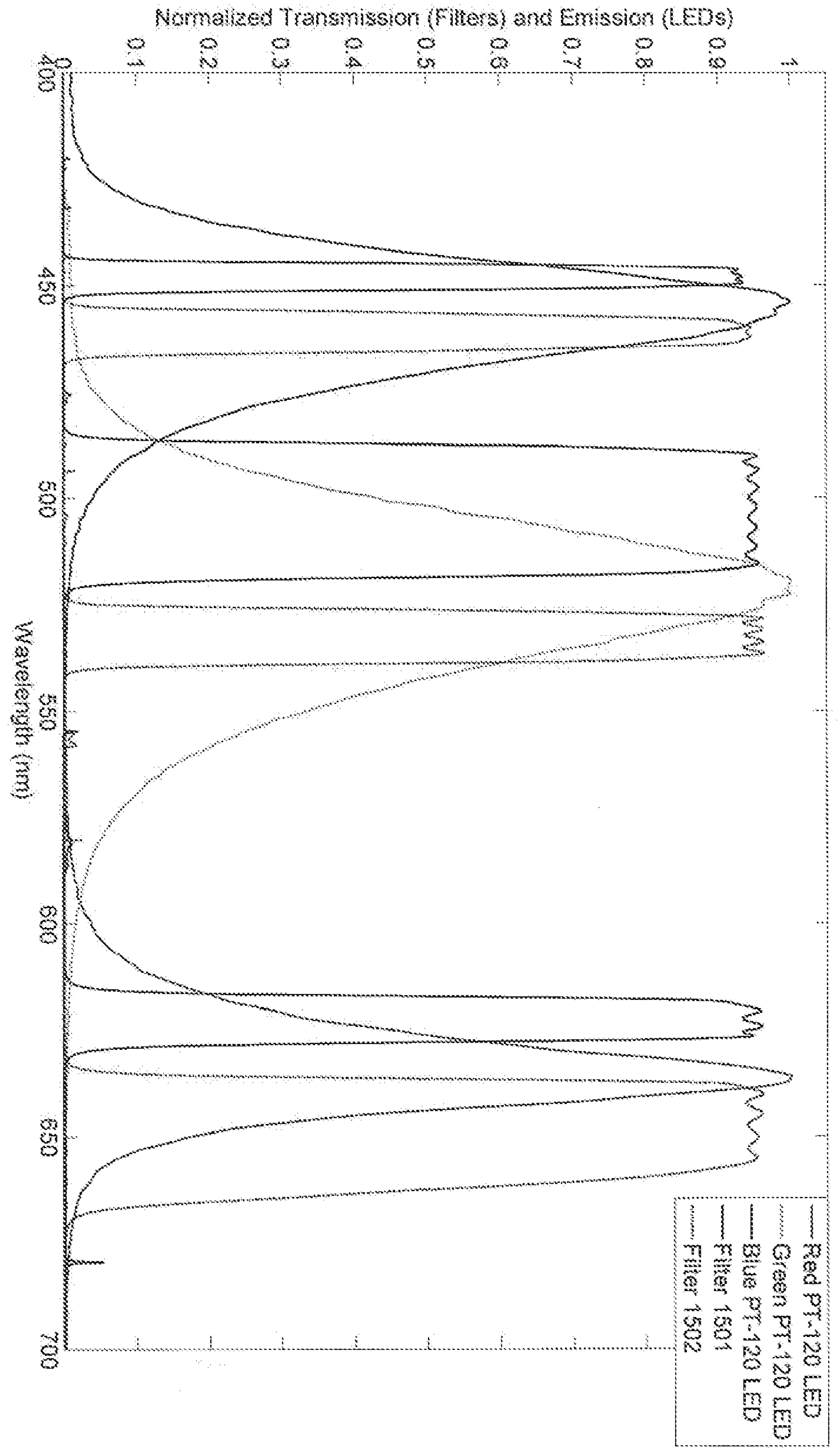

Transmission Spectrum of Display Filters 1501 and 1502
Normalized Transmission (Filters) and Emission (LEDs)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
450
500
550
600
650
700
Wavelength (nm)
Red PT-120 LED
Green PT-120 LED
Blue PT-120 LED
Filter 1501
Filter 1502

Fig. 21

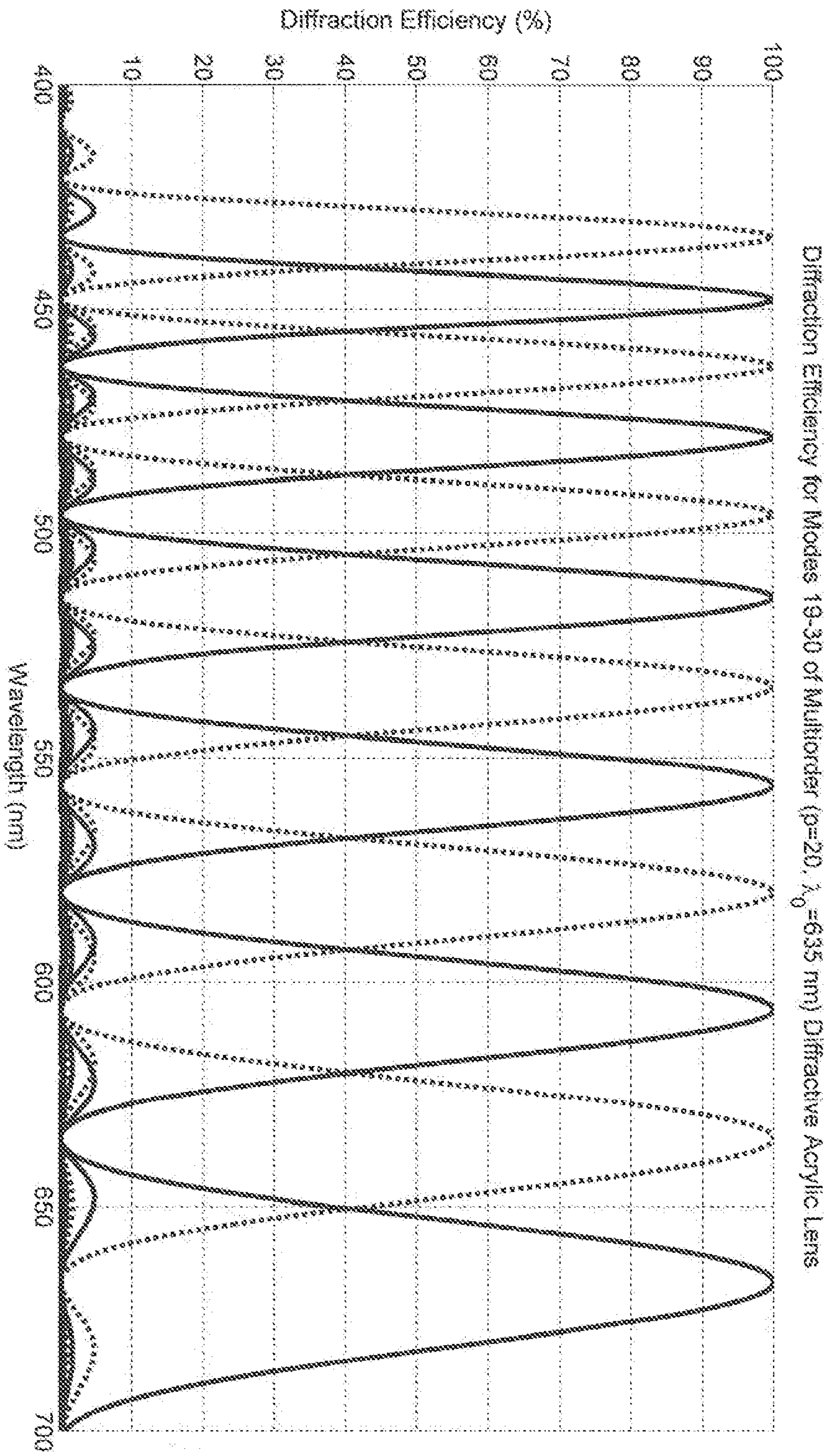

Diffraction Efficiency for Modes 19-30 of Multiorder (p=20, λ0=635 nm) Diffractive Acrylic Lens
Diffraction Efficiency (%)
Wavelength (nm)
0
10
20
30
40
50
60
70
80
90
100
400
450
500
550
600
650
700

Fig. 22

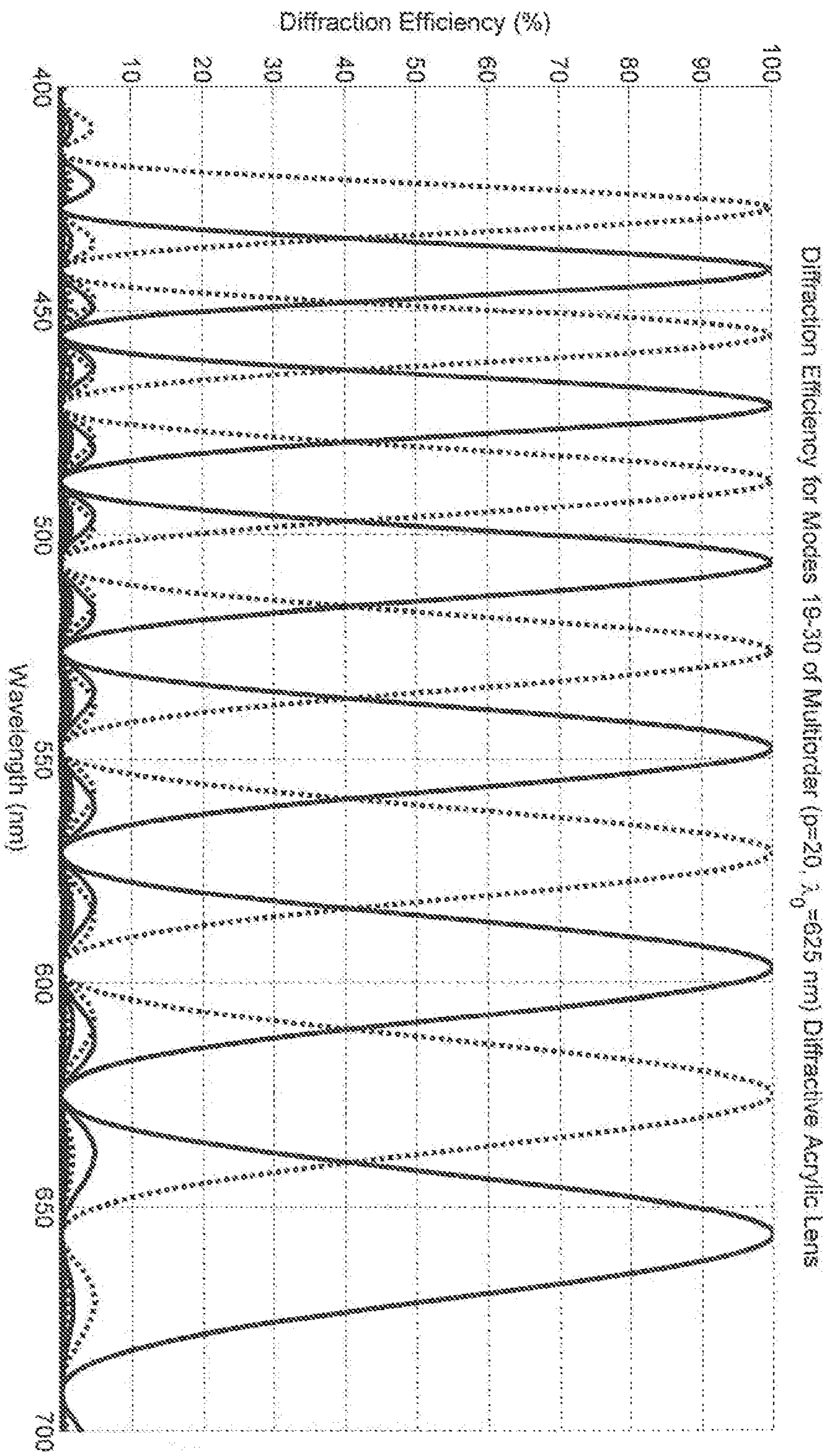

Diffraction Efficiency for Modes 19-30 of Multiorder (p=20, λ0=625 nm) Diffractive Acrylic Lens
Diffraction Efficiency (%)
10
20
30
40
50
60
70
80
90
100
Wavelength (nm)
400
450
500
550
600
650
700

Fig. 23

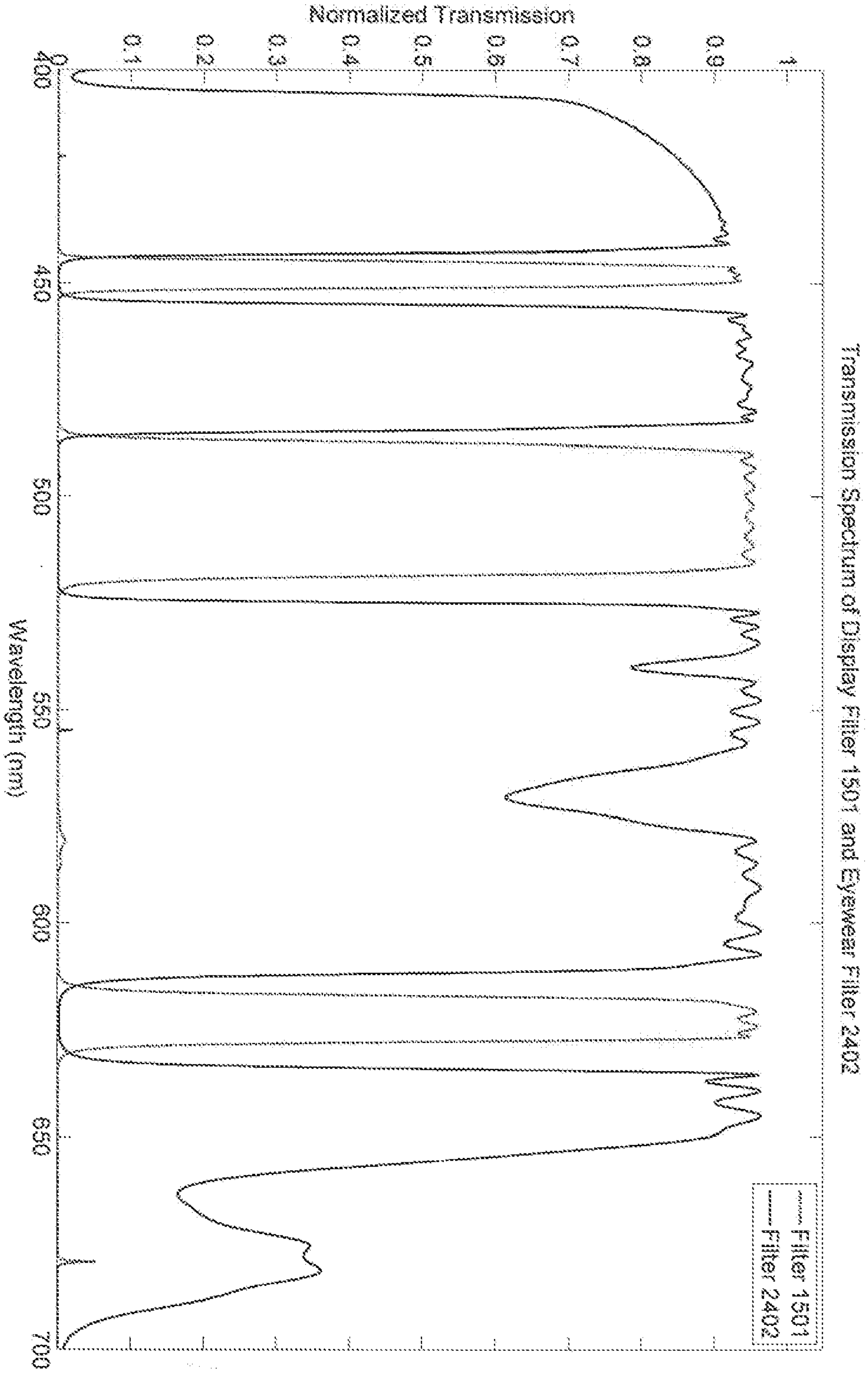
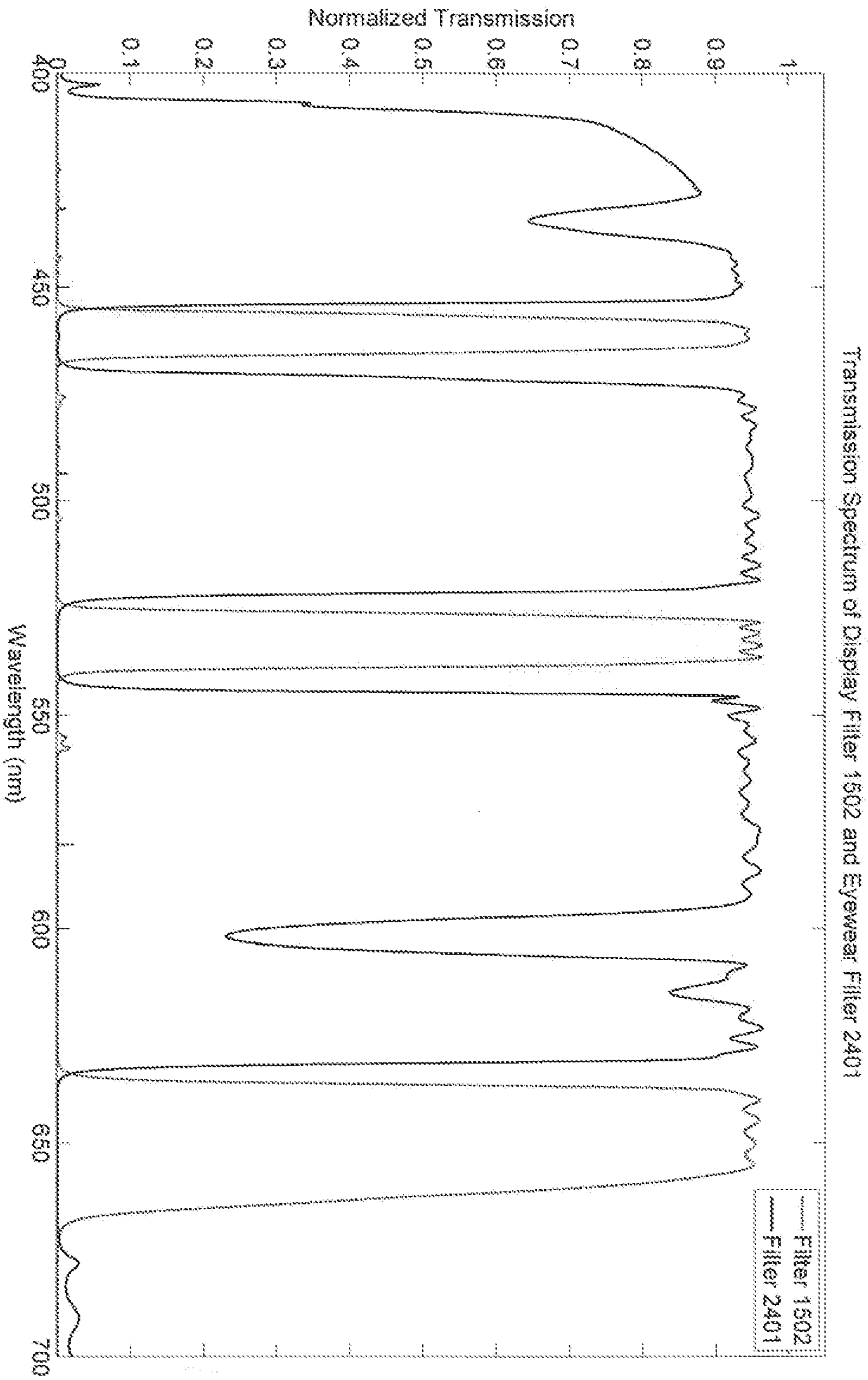

Transmission Spectrum of Display Filter 1501 and Eyewear Filter 2402
Normalized Transmission
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
450
500
550
600
650
700
Wavelength (nm)
Filter 1501
Filter 2402

Fig. 24

Fig. 25


Transmission Spectrum of Display Filter 1502 and Eyewear Filter 2401
Normalized Transmission
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
450
500
550
600
650
700
Wavelength (nm)
Filter 1502
Filter 2401

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/06Q792

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B27/22 H04N13/0Q
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 H04N

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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/278807 Al (RICHARDS MARTIN JOHN [US] ET AL) 13 November 2008 (2008-11-13) cited in the application	1
Y	abstract figures 4A, 4B	2-7, 11
X	US 2007/236809 Al (LIPPEY BARRET [US] ET AL) 11 October 2007 (2007-10-11)	1
A	figures paragraph [0006] - paragraph [0017]	2-11
Y	EP 1 564 566 Al (SEIKO EPSON CORP [JP]) 17 August 2005 (2005-08-17) abstract; figures 1-3 paragraph [0008] paragraph [0013] - paragraph [0028]	2-7, 11

-/- -

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 September 2011	04/10/2011

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

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2001/048505 AI (SI LLI PHANT ALLAN [US]) 6 December 2001 (2001-12-06) abstract	1
X	US 4 717 239 A (STEENBLI K RICHARD A [US]) 5 January 1988 (1988-01-05) abstract figures 10A-10D	1,8-10
A	US 5 589 982 A (FAKLIS DEAN [US] ET AL) 31 December 1996 (1996-12-31) cited in the application abstract; figure 2	8-10
A	EP 1 429 173 AI (ESCHENBACH OPTI K GMBH & CO [DE]) 16 June 2004 (2004-06-16) abstract; figures paragraph [0007]	8-10

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2011/060792

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos. :

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-7, 11

A stereoscopic working aid comprising two filtering means operating in a first and a second wavelength range and each filtering means comprises a first optical device having a selected focal length wherein the filtering means comprises a dielectric filter and the optical device has a negative focal length.

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2. claims: 8-10

A stereoscopic working aid comprising two filtering means operating in a first and a second wavelength range and each filtering means comprises a first optical device having a selected focal length wherein the optical device is a diffractive element which focuses only the light of the desired wavelength band.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2011/06Q792

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