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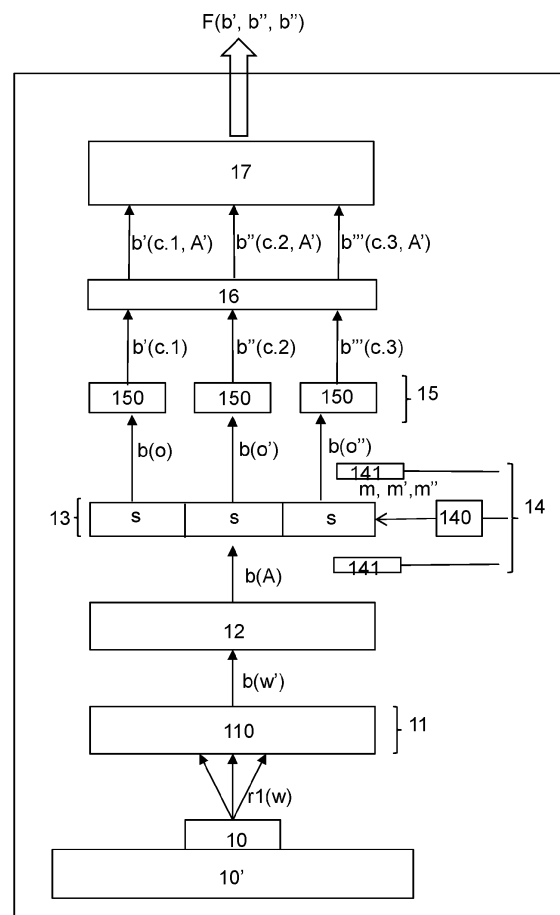
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(54) LIGHTING DEVICE FOR A VEHICLE

(57) The invention relates to a lighting device (1) for a vehicle, said lighting device (1) comprising at least one light source (10) that is configured to emit light rays (r1) according to a first range of wavelengths (w), wherein said lighting device (1) further comprises:

- a wavelength conversion layer (11) that is configured to receive said light rays (r1) and to transform them into a light beam (b) according to a second range of wavelengths (w'),
- a first polarizer (12) that is configured to receive said light beam (b) and to transmit it along a first plane (A),
- a liquid crystal layer (13) that is configured to receive said light beam (b) along said first plane (A) and to orientate the light beam (b) according to at least one orientation (o),
- an electric field generation module (14) that is configured to generate at least one electrical field (m) and to apply it to said liquid crystal layer (13) so as to create at least one area (s) that leads the liquid crystal layer (13) to orientate the light beam (b) according to said at least one orientation (o),
- a set of (15) color filters (150) that is configured to get respectively the light beam (b) with said at least one orientation (o) and to output at least one sub-light beam (b') with a color (c),
- a second polarizer (16) that is configured to receive said at least one sub-light beam (b') and transmit it along a second plane (A'),
- a first optical module (17) that is configured to receive said at least one sub-light beam (b') and to output a global light beam (F) which is composed of said at least one sub-light beam (b').

**Fig. 1****EP 4 502 456 A1**

Description

[0001] The present invention relates to a lighting device for a vehicle. Such a lighting device may be used, but not exclusively, in the automotive domain.

[0002] In the automotive domain, a lighting device for a vehicle comprises at least one light source that is configured to emit light rays according to a first range of wavelengths. The lighting device provides some light for the interior lighting or for lighting modules such as a headlamp or a rear lamp, or any other lighting products for the vehicle. The light source is usually a RGB Light Emitting Diode ("LED") or a laser light source. The RGB Light Emitting Diode is a multi-source with three R G and B emitters which have different sizes and with different geometric arrangements.

[0003] One problem of this prior art is that when one wants a high gamut of RGB colors, the range of gamut of this RGB LED or laser light source is too restrictive.

[0004] It is an object of the invention to provide a lighting device for a vehicle, which resolves the problem above-stated.

[0005] To this end, it is provided a lighting device for a vehicle, said lighting device comprising at least one light source that is configured to emit light rays according to a first range of wavelengths, wherein said lighting device further comprises:

- a wavelength conversion layer that is configured to receive said light rays and to transform them into a light beam according to a second range of wavelengths,
- a first polarizer that is configured to receive said light beam and to transmit it along a first plane,
- a liquid crystal layer that is configured to receive said light beam along said first plane and to orientate the light beam according to at least one orientation,
- an electric field generation module that is configured to generate at least one electrical field and to apply it to said liquid crystal layer so as to create at least one area that leads the liquid crystal layer to orientate the light beam according to said at least one orientation,
- a set of color filters that is configured to get respectively the light beam with said at least one orientation and to output at least one sub-light beam with a color,
- a second polarizer that is configured to receive said at least one sub-light beam and transmit it along a second plane,
- a first optical module that is configured to receive said at least one sub-light beam and to output a global light beam which is composed of said at least one sub-light beam.

[0006] According to non-limitative embodiments of the invention, the lighting device for a vehicle in accordance with the invention further comprises the following characteristics.

[0007] In a non-limitative embodiment, said wave-

length conversion layer is composed of a substrate of quantum dots.

[0008] In a non-limitative embodiment, said first range of wavelengths corresponds to one of the range of the blue light, of the red light, or of the green light.

[0009] In a non-limitative embodiment, said first range of wavelengths corresponds to the range of the blue light

[0010] In a non-limitative embodiment, the quantum dots are emitted in the red color emission wavelength and in the green color emission wavelength.

[0011] In a non-limitative embodiment, said second range of wavelengths corresponds to the range from the blue light to the red light in the visible spectrum, and until the infrared light.

[0012] In a non-limitative embodiment, the second plane is at 90° relative to the first plane.

[0013] In a non-limitative embodiment,

- said a liquid crystal layer is configured to orientate said light beam according to at least two different orientations,
- said electric field generation module is configured to generate at least two electrical fields and to apply them respectively to said liquid crystal layer so as to create at least two different areas that leads the liquid crystal layer to orientate the light beam according to said at least two different orientations,
- the set of color filters comprises at least two color filters that are configured to get respectively the light beam with one of the two orientations and to output at least two sub-light beams with respectively a first color and a second color, and
- the second polarizer is configured to receive said at least two sub-light beams and transmit them along a second plane,
- said first optical module is configured to receive said at least two sub-light beams and to output a global light beam which is composed of said at least two sub-light beams.

[0014] In a non-limitative embodiment, said liquid crystal layer is configured to orientate said light beam according to three different orientations.

[0015] In a non-limitative embodiment, said electric field generation module is configured to generate three electrical fields so as to create respectively three areas that leads the liquid crystal layer to orientate the light beam according to said three different orientations

[0016] In a non-limitative embodiment, said electrical field generation module comprises a thin film transistor layer and two electrodes that are disposed on each side of the liquid crystal layer.

[0017] In a non-limitative embodiment, said lighting device further comprises at least one second optical module that cooperates with the light rays of said light source and that convey them to at least one specific location of the wavelength conversion layer.

[0018] In a non-limitative embodiment, said light

source is a semiconductor source.

[0019] In a non-limitative embodiment, the semiconductor light source is part of a light emitting diode or a laser diode.

[0020] In a non-limitative embodiment, said first optical module comprises a guidelight or a reflector and/or an optical lens.

[0021] In a non-limitative embodiment, said substrate comprises separated substrate regions so as to form separated quantum dots regions.

[0022] In a non-limitative embodiment, said at least one light source is monocolour.

[0023] In a non-limitative embodiment, said set of color filters comprises one or a plurality of filters.

[0024] In a non-limitative embodiment, said set of color filters comprises two color filters.

[0025] There is also provided a lighting module comprising a housing configured to receive said lighting device according to any of the preceding characteristics.

[0026] Some embodiments of methods and/or apparatus in accordance with embodiments of the present invention are now described, by way of example only, and with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram that illustrates a lighting device for a vehicle, according to a first non-limitative embodiment of the invention, said lighting device comprising at least one light source, a wavelength conversion layer, a first polarizer, a liquid crystal layer, an electric field generation module, a set of color filters, a second polarizer, and a first optical module,

Figure 2 is a schematic diagram that illustrates a lighting device for a vehicle, according to a second non-limitative embodiment of the invention,

Figure 3 illustrates some parts of a dashboard lighting module comprising the lighting device of figure 1 or figure 2, according to a non-limitative embodiment,

Figure 4 illustrates a sectional view of the dashboard lighting module of figure 3, according to a non-limitative embodiment,

Figure 5 illustrates a non-limitative example of an output spectrum after the wavelength conversion layer of the lighting device of figure 1 or 2,

Figure 6 illustrates a non-limitative example of an output spectrum after the liquid crystal module of the lighting device of figure 1 or 2, once an electrical field is applied to the liquid crystal module and light orientation is modified in respect to the first polarizer,

Figure 7 illustrates a non-limitative example of an output spectrum after the color filters of the lighting

device of figure 1 or 2,

Figure 8 illustrates a non-limitative example of an output spectrum after the second polarizer of the lighting device of figure 1 or 2.

[0027] In the following description, well-known functions or constructions by the man skilled in the art are not described in detail since they would obscure the invention in unnecessary detail.

[0028] The present invention relates to a lighting device 1 for a vehicle 2, said lighting device 1 being described in reference to figure 1 to 8, according to non-limitative embodiments.

[0029] In non-limitative embodiments, the vehicle 2 is a motor vehicle, an electrical vehicle or a hybrid vehicle.

[0030] The lighting device 1 provides light for lighting and/or signalling or for interior lighting or exterior lighting. In non-limitative embodiments, the lighting device 1 is part of a lighting module 20 of the vehicle 2. In non-limitative examples, the lighting module is a headlamp, or a rear lamp, or a dashboard lighting module, or any other kind of lamp, or an interior element of the vehicle 2. In non-limitative examples, the interior element is the roof, the control panel, a handle, part of a door, a dome light, a projection light, etc.

[0031] Figure 3 illustrates some elements of a lighting module 20 that is a dashboard lighting module. It comprises a housing 200 and a bezel 201. The housing 200 is configured to receive the lighting device 1. In figure 3, an electronic support 10' of the lighting device 1 with a plurality of light source 10 is illustrated and a light guide 170 of an optical module of the lighting device 1 is illustrated.

[0032] Figure 4 illustrates a sectional view G-G' of the lighting module 20 that incorporates the lighting device 1.

[0033] As illustrated in figures 1, 2 and 4, the lighting device 1 comprises :

- at least one light source 10,
- a wavelength conversion layer 11,
- a first polarizer 12,
- a liquid crystal layer 13,
- an electric field generation module 14,
- at least one color filter 15,
- a second polarizer 16, and
- a first optical module 17.

[0034] These different elements of the lighting device 1 are described in detail in the following.

Light source 10:

[0035] In a non-limitative embodiment, the lighting device 1 comprises only one light source 10. In a non-limitative example, it is the case when the lighting module 20 where the lighting device 1 is integrated, is a door handle lighting module.

[0036] In a non-limitative embodiment, the lighting device 1 comprises a plurality of light sources 10. In a non-limitative example, it is the case when the lighting module 20 where the lighting device 1 is integrated, is a dashboard lighting module. They are disposed along the electronic support 10' as illustrated in figure 3 in a non-limitative example.

[0037] The non-limitative embodiment of one light source 10 is taken as a non-limitative example in the following.

[0038] In a non-limitative embodiment, the light source 10 is a semiconductor source. In non-limitative variants of embodiment, the semiconductor light source is part of a light emitting diode or a laser diode. By light-emitting diode, one means any type of light-emitting diode, whether in non-limiting examples LED ("Light Emitting Diode"), OLED ("Organic LED"), AMOLED ("Active-Matrix-Organic LED" in English), or even FOLEDS ("Flexible OLED" in English).

[0039] The light source 10 is configured to emit light rays r1 according to a first range of wavelengths w.

[0040] In a non-limitative embodiment, the light source 10 is monocolor.

[0041] In a non-limitative embodiment, the first range of wavelengths w corresponds to one of the ranges of the blue light, of the red light, or of the green light. Hence, the light source 10 comprises only one monocolor emitter.

[0042] In a non-limitative embodiment, the first range of wavelengths w corresponds to the range of blue light. With the blue light, one can obtain all the gamut colors from blue to red in the visible spectrum (that is to say between 400 nanometers (nm) and 700 nanometers), contrary to a green light or red light only. So, depending on the application and colors that are needed, one can choose the green light or red light or blue light. It is to be noted that the first range of wavelengths w corresponding to deep blue or even ultraviolet can also be used. Generally speaking, with a first range of wavelengths w, one can obtain a lower energy second wavelength w' as explained in the following. In a non-limitative example, with 700nm, one can obtain a second wavelength w' from 700nm to 1000nm. In another non-limitative example, with 400nm, one can obtain from 400nm to 1000nm.

[0043] Light is emitted in a first wavelength w, instead of a mixture of different wavelengths such as a white light.

[0044] In a non-limitative embodiment, the light source 10 is disposed on an electronic support 10'. In a non-limitative embodiment, the electronic support 10' is a Printed Circuit Board Assembly (PCBA). The electronic support 10' comprises all the electronic components needed to control the light source 10, the liquid crystal layer 13 and the electric field generation module 14.

Wavelength conversion layer 11:

[0045] The wavelength conversion layer 11 is configured to receive the light rays r1 emitted by the light source 10 and to transform them into a light beam b according to

a second range of wavelengths w'. According to a second range of wavelengths w' means that the spectrum of the light beam b comprises one or a plurality of second wavelengths w'.

[0046] In non-limitative embodiment, the second range of wavelengths w' corresponds to the range from the blue light to the red light in the visible spectrum and until the infrared light. It is to be reminded that the range of infrared light is about 700 to 1000 nanometers.

[0047] The wavelength conversion layer 11 is composed of a substrate 110 of quantum dots.

[0048] In a non-limitative embodiment, the substrate 110 is a quantum dot film. The film is a thin flexible sheet where quantum dots are applied, allowing a great flexibility in the design. In this case, the wavelength conversion layer 11 is also called Quantum Dot Film and referred to as QDF in the following. This non-limitative embodiment is taken as a non-limitative example in the following. In non-limitative embodiment, thin film deposition techniques like drop casting, spin coating, spray coating, screen printing, lithography or ink-printing, can be used for the fabrication process of the QDF.

[0049] A quantum dot is an electronic structure obtained out of a semiconductor nanocrystal, with a size such that its electrons and holes are confined in all three spatial dimensions. When a quantum dot is excited with one wavelength, one obtains another wavelength depending on the size of the quantum dot. Depending on the particular sizes of the quantum dots, they emit light in a particular wavelength when they are excited, either electrically or luminescently. As a consequence, "Red" quantum dots would be quantum dots which emit light in the red color emission wavelength (also called red color wavelength or simply red wavelength) when excited, "Green" quantum dots would be quantum dots which emit light in the green color emission wavelength (also called green color wavelength or simply green wavelength) when excited, etc. It is the same for other color emission wavelengths such as yellow, orange, etc. One can sweep all monochromatic color wavelengths.

[0050] In a non-limitative embodiment, the substrate 110 comprises Red and Green quantum dots when the first wavelength w corresponds to the range of blue light. It permits to have a light beam b in the range from blue to red light in the visible spectrum. Indeed, some of the blue light is not absorbed by the quantum dots so that one obtains the blue wavelength, some of the blue light is absorbed by the quantum dots which leads to a conversion of the blue light into the red and green wavelengths. It is to be noted that blue quantum dots are not needed because the blue light is generated already by the light source 10.

[0051] Figure 5 illustrates the output spectrum of the light beam b that contains three wavelengths Blue, Red and Green referred to as respectively B, R, G. In the x axis is the wavelength w in nanometers (nm) and in the y axis is the intensity I in Arbitrary Units (A.U).

[0052] It is to be noted that the more the density of the

quantum dots is in the substrate 110, the more the green and the red are excited, the less there is blue light.

[0053] Of course, depending on the first wavelength w of the light source 10 and the desired final color one wants to obtain at the output of the lighting device 1, different quantum dots will be used.

[0054] In the substrate 110, one can create different color regions by doping the substrate with different quantum dots deposition. Thus, one can tune the colors in the substrate 110. Hence, in a non-limitative embodiment, the substrate 110 comprises a combination of different sizes of quantum dots and of different material for the quantum dots to obtain different colors. Hence, one can synthesise quantum dots for specific wavelengths. It is not possible with proprietary single color materials such as monocolour classical LEDs as they have a fixed band-gap in the bulk alloy material and therefore only one color is possible for them.

[0055] Hence, with the quantum dots, one can tune one or a plurality of colors, that is to say one can have one or a plurality of second wavelengths w' in the light beam b . In a non-limitative example, considering Red and Green quantum dots in the substrate 110 of the wavelength conversion layer 10, we will have Red plus Green plus Blue second wavelengths w' .

[0056] It is to be noted that when the substrate 110 comprises quantum dots that are tuned to only one color, for example "Red" quantum dots, with a first wavelength w in the range of blue light, one obtains:

- a mix color of red and blue if there is some residual blue coming from the light source 10, or
- a red color if the color filter 15 used afterwards removes the residual blue coming from the light source 10 or if the QDF absorbs all the blue light to convert to red color with no residual blue left coming from the light source 10.

[0057] In a non-limitative embodiment, each quantum dot comprises a core and a shell. The quantum dot acts as the core and is covered with a shell that acts as a passivation element for the core, to increase the quantum confinement and therefore reduce the number of dangling bonds which causes a low value in the QY (quantum yield) parameter.

[0058] In a non-limitative embodiment, the core is spherical or pyramidal.

[0059] In non-limitative embodiments, the core comprises a combination of at least two elements from the list : In, P, Zn, Se, Cu, S, Mn and the shell comprises a combination of at least two elements from the list : Zn, Se and S. These materials have been proven to be suitable for the automotive application.

[0060] In non-limitative embodiments, the core/shell quantum dots are formed by CuInS₂/ZnS or InP/ZnS. These particular materials and their alloys have been proved to be suitable for automotive purposes since they are compliant with international norms applied to auto-

motive components like Global Automotive Declarable Substance List (GADSL) or Restriction of Hazardous Substances (RoHS). Moreover, these particular alloys are able to cover the visible spectrums, and also the invisible spectrum such as near infrared (NIR) or infrared (IR), which is interesting for automotive lighting applications. In addition, these alloys offer high values of photoluminescence quantum yield (PL QY) at low full width half maximum (FWHM) values, which implies a high efficiency and high purity of color achieved. To be more precise, CuInS₂ has a spectrum range from green (around 500nm) to infrared (above 700 nm), a photoluminescence quantum yield (PL QY) more than 90% and full width half maximum (FWHM) less than 100 nm. As for InP, we have a spectrum range usually from green (around 500 nm) to red (above 600 nm), a photoluminescence quantum yield (PL QY) more than 85% and full width half maximum (FWHM) less than 50 nm.

[0061] In a non-limitative embodiment, the wavelength conversion layer 11 further comprises two barrier films, arranged in such a way that the substrate 110 is embedded between the two barrier films. In this case, when the substrate 110 is a QDF, the QDF is embedded between two films, which are usually made of PET, and which confers stability and protection to the film.

[0062] In order to tune the colors, one can also divide the substrate 110 physically in different regions 1100 as illustrated in figure 2 and locate the different colors independently in different regions 1100. Hence, in a non-limitative embodiment, the substrate 110 comprises separated substrate regions 1100 so as to form separated quantum dots regions. With the different regions 1100, one can also tune different colors, one per each region 1100. In order to separate the substrate 110 in different regions, in non-limitative embodiment, thin film deposition techniques, micro/nano fabrications process, lithography process, or laser process can be used.

First polarizer 12:

[0063] The first polarizer 12 is configured to receive said light beam b and to transmit it along a first plane A.

[0064] The input is the spectrum given by the combination of color from the light source 10 and the different colors due to the different quantum dots incorporated in the substrate 110, which are excited by the light source 10.

[0065] In the non-limitative example taken, considering Red and Green quantum dots in the substrate 110 of the wavelength conversion layer 10 and the blue light source 10, we will have Red plus Green plus Blue second wavelengths w' . Thus, the input is the spectrum given by the combination of the blue color from the blue light source and from the red color and green color from the Red and Green quantum dots.

[0066] In a first non-limitative embodiment, the first polarizer 12 is a vertical polarizer also referred to as V-polariser. The first plane A is then the vertical vibration

plane. In a second non-limitative embodiment, the first polarizer 12 is a horizontal polarizer also referred to as H-polariser. The first plane A is then the horizontal vibration plane.

[0067] The light is vibrating in different planes: one horizontal vibration plane and one vertical vibration plane. When the first polarizer 12 is a vertical polarizer, it means that it will keep the light that vibrates in the vertical vibration plane and discard the light that vibrates in the horizontal vibration plane. Hence, in this case, it outputs the light beam b in the vertical vibration plane. Conversely, when the first polarizer 12 is a horizontal polarizer, it means that it will keep the light that vibrates in the horizontal vibration plane and discard the light that vibrates in the vertical vibration plane. Hence, in this case, it outputs the light beam b in the horizontal vibration plane.

Liquid crystal layer 13:

[0068] The liquid crystal layer 13 is configured to receive said light beam b along said first plane A and to orientate the light beam b according to at least one orientation o. According to one orientation means that the light beam b vibrates in a new vibration angle different from the first plane A. It is due to the molecules' alignment inside the liquid crystal layer 13 because of the electrical field generated. An orientation o is a vibration angle. Hence, the liquid crystal layer 13 permits to modify the vibration angle of the light coming from the first polarizer 12.

[0069] The liquid crystal is able to modify the vibration plane of the light (a new vibration angle is given by the electric field generation module 14 described herein-after). This new vibration angle is in between the vertical and horizontal vibration planes i.e., between 90° (degrees) and 0° range. The liquid crystal layer 13 is composed of liquid crystal molecules as well-known by the person skilled in the art.

[0070] The liquid crystal layer 13 comprises at least one area s (created by the electrical field generation module 14 described later on) that leads the liquid crystal layer 13 to orientate the light beam b according to said at least one orientation o. An area s is also called a segment s.

[0071] In a first non-limitative embodiment, the liquid crystal layer 13 is configured to orient said light beam b according to one orientation o.

[0072] In a second non-limitative embodiment, the liquid crystal layer 13 is configured to orient said light beam b according to two different orientations o, o'.

[0073] In a third non-limitative embodiment, the liquid crystal layer 13 is configured to orient said light beam b according to three different orientations o, o', o".

[0074] Figure 6 illustrates the output of the liquid crystal layer 13 when there are three independent vibration angles. One has three independent areas s1, s2, s3 with a light beam b vibrating in three independent vibration

angles that are in a non-limitative example 0° (degrees), 45° and 90° for respectively areas s1, s2 and s3.

Electric field generation module 14:

[0075] The electric field generation module 14 is configured to generate at least one electrical field m and to apply it to said liquid crystal layer 13 so as to create at least one area s within the liquid crystal layer 13 that leads the liquid crystal layer 13 to orientate the light beam b according to said at least one orientation o.

[0076] In a non-limitative embodiment illustrated in figure 1 and 2, the electric field generation module 14 comprises:

- a Thin Film Transistors "TFT" referred to as 140 in the figures, and
- two electrodes 141 that are disposed on each side of the liquid crystal layer 13.

[0077] The TFT functions as a switch. When the switch is open (activated), it generates the electrical field(s), and when it is closed (deactivated), there is no electrical field generated. Hence, the electric field generation module 14 permits to dynamically control the liquid crystal layer 13. In a non-limitative embodiment, the electrical field is created by the application of a voltage difference between the two electrodes 141. In a non-limitative example, the voltage is up to 5 Volts (V). A voltage variation in a range (between 0V and 5V in a non-limitative example) creates different intensities of the electrical field. Different intensities means different orientations o are able to achieve for the liquid crystal layer 13.

[0078] When an electrical field is applied to the liquid crystal layer 13, the liquid crystal molecules within the liquid crystal layer 13 can be oriented. Their orientation o can be aligned with the first plane A. When one has the same orientation as the first plane A, it means that the light passes through the liquid crystal molecules without any obstacle. Depending on the orientation o relative to the first plane A, the light passes more or less.

[0079] The different areas s that are created in the liquid crystal layer 13 create different orientations o of the light beam b in the first plane A. One obtains different vibration angles of the light beam b. It enables modifying the vibration angle of the light beam b coming from the first polarizer 12.

[0080] In a first non-limitative embodiment, the electric field generation module 14 is configured to generate one electrical field m and to apply it to said liquid crystal layer 13 so as to create one area s that leads the liquid crystal layer 13 to orientate the light beam b according to one orientation o. One orientates the vibration of the light beam b in the first plane A according to only one vibration angle. In a non-limitative example, one can obtain one area s where the light beam b vibrates on a first vibration angle of 30°.

[0081] In a second non-limitative embodiment, the

electric field generation module 14 is configured to generate two electrical fields m , m' and to apply them respectively to said liquid crystal layer 13 so as to create two different areas s that leads the liquid crystal layer 13 to orientate the light beam b according to said at least two different orientations o , o' . One orientates the vibration of the light beam b in the first plane A according to two independent vibration angles. In a non-limitative example, one can obtain two independent area s where the light beam b vibrates on a first vibration angle of 30° and on a second vibration angle of 60° .

[0082] In a third non-limitative embodiment illustrated in figure 1 and 2, the electric field generation module 14 is configured to generate three electrical fields m , m' , m'' so as to create respectively three areas s that leads the liquid crystal layer 13 to orientate the light beam b according to said three different orientations o , o' , o'' . One orientates the vibration of the light beam b in the first plane A according to three independent vibration angles.

Color filter 15:

[0083] As illustrated in figure 1 and 2, the lighting device 1 comprises a set 15 of color filters.

[0084] The set 15 of color filters comprises one or a plurality of color filters 150. In the non-limitative example illustrated in figures 1 and 2, it comprises three color filters 150.

[0085] The input of the set of color filters 15 is the light beam b that vibrates according to the new vibration orientation(s) o . Hence, the set 15 of color filters is configured to get the light beam b with said at least one orientation o and to output at least one sub-light beam b' with a color c .

[0086] In non-limitative embodiments, a color filter 15 is a Red color filter, or a Green color filter, or a Blue color filter. A Red color filter for example means that it only lets the red color pass through (with any orientation o). It means that it only lets the color with a second wavelength w' in the range of red light pass through. The colors filters 150 do not change the orientation o given from the output of the liquid crystal layer 13. They only filter the color from the spectrum, to keep just with wavelength of interest.

[0087] In a first non-limitative embodiment, the lighting device 1 comprises one color filter 15 that is configured to get the light beam b with one orientation o and to output one sub-light beam b' , with a first color $c.1$ with one orientation o . Hence, the input is the light beam b in the first plane A with the orientation o , that is to say a light beam b that vibrates in one new vibration angle.

[0088] In a second non-limitative embodiment, the lighting device 1 comprises two color filters 15 that are configured to get respectively the light beam b with two orientations o , o' and to output two sub-light beam b' , b'' with respectively a first color $c.1$ and a second color $c.2$. Hence, the input is a light beam b in the first plane A with two orientations o , o' , that is to say the light beam b that vibrates according to two new vibration angles. The out-

put is two colors with two different orientations o , o' , respectively.

[0089] In a third non-limitative embodiment illustrated in figure 1 and 2, the lighting device 1 comprises three color filters 15 that are configured to get respectively the light beam b with one of the three orientations o , o' , o'' and to output three sub-light beam b' , b'' , b''' with respectively a first color $c.1$, a second color $c.2$, and a third color $c.3$. Hence, the input is a light beam b in the first plane A with three orientations o , o' , o'' . The output is three colors with three different orientations o , o' , o'' respectively.

[0090] Figure 7 illustrates a non-limitative example of the output of a set 15 of color filters with three color filters 150. 150(R) referred to as a Red color filter, 150(G) referred to as a Green color filter, and 150(B) referred to as a Blue color filter. At the output of the Red color filter 150, one has a first sub-light beam b' that vibrates at an angle of 0° with the same intensity I as the one at the output of the liquid crystal layer 13. At the output of the Green color filter 150, one has a second sub-light beam b'' that vibrates at an angle of 45° with the same intensity I as the one at the output of the liquid crystal layer 13. At the output of the Blue color filter 150, one has a third sub-light beam b''' that vibrates at an angle of 90° with about the same intensity I as the one at the output of the liquid crystal layer 13.

Second polarizer 16:

[0091] The second polarizer 16 is configured to receive the output of the set 15 of color filters. It receives said at least one sub-light beam b' and transmits it along a second plane A' . The second polarizer 16 permits to adjust the final intensity of the first color $c.1$, second color $c.2$ when applied and third color $c.3$ when applied.

[0092] The intensity of the light (proportion of the light), from the independent area s , will change. It changes because of the different vibrations of light from the independent area s , when the light hits the second polarizer 16. If the vibration angle of the incident light that arrives on the second polarizer 16 is equal to the second plane A' , the light passes in a 100%. On the other hand, if light is vibrating at a 90° angle, we have 0% light output.

[0093] Hence, depending on the vibration angle, i.e., on the orientation o of a sub-light beam b' , the intensity of light will vary.

[0094] In a first non-limitative embodiment, the second polarizer 16 is a vertical polarizer. The second plane A' it then the vertical vibration plane. In a second non-limitative embodiment, the second polarizer 16 is a horizontal polarizer. The second plane A' it then the horizontal vibration plane.

[0095] It is to be noted that the second plane A' is at 90° relative to the first plane A . Hence, when the first polarizer 12 is a vertical polarizer, the second polarizer is a horizontal polarizer. Conversely, when the first polarizer 12 is a horizontal polarizer, the second polarizer is a vertical polarizer.

[0096] Hence, if after the liquid crystal layer 13, the orientation of a color is horizontal, with the H-polarizer 16, one gets 100% of the color. If after the liquid crystal layer 13, the orientation of a color is 45°, with the H-polarizer 16, one gets 50% of the color. If after the liquid crystal layer 13, the orientation of a color is 90°, with the H-polarizer 16, one gets 0% of the color. In other words, the more the orientation increases in degrees (up to 90°), the lesser the proportion of color is.

[0097] Hence, if after the liquid crystal layer 13, the orientation of a color is vertical, with the V-polarizer 16, one gets 100% of the color. If after the liquid crystal layer 13, the orientation of a color is 45°, with the V-polarizer 16, one gets 50% of the color. If after the liquid crystal layer 13, the orientation of a color is 0°, with the V-polarizer 16, one gets 0% of the color. In other words, the more the orientation decreases in degrees (until 0°), the lesser the proportion of color is.

[0098] If only one first color c.1 is output by the set of color filters 15 with an orientation o, the second polarizer 16 outputs one first color c.1 with a first intensity i1.

[0099] If a first color c.1 and a second color c.2 are output by the set of color filters 15 with respectively an orientation o and o', the second polarizer 16 outputs the first color c.1 with a first intensity and the second color c.2 with a second intensity i2. The second intensity i2 can be different or equal to the first intensity i1.

[0100] If a first color c.1, a second color c.2, and a third color c.3 are output by the set of color filters 15 with respectively an orientation o, o', and o'', the second polarizer 16 outputs the first color c.1 with a first intensity i1, the second color c.2 with a second intensity i2, and the third color c.3 with a third intensity i3. The second intensity i2 can be different or equal to the first intensity i1 and to the third intensity i3. In the same manner, the third intensity i3 can be different or equal to the first intensity i1 and to the second intensity i2.

[0101] Hence, at the output of the second polarizer 16, one has different intensities of R, and/or G and/or B colors.

[0102] Figure 8 illustrates a non-limitative example where the second polarizer 16 is an H-polarizer and where there are three colors c.1, c.2 and c.3 with three different intensity i1, i2 and i3.

[0103] With the output of the three colors filters 150 of figure 7, one can see that:

- the output of the first color (Red color) that is horizontally oriented is 100%,
- the output of the first color (Green color) that is 45° oriented is 50%,
- the output of the first color (Blue color) that is vertically oriented is 0%.

[0104] It means that:

- for the Red color, one has a first intensity i1 that is 100% of the intensity I of the initial light beam b,

- for the Green color, one has a second intensity i2 that is 50% of the intensity I of the initial light beam b,
- for the Blue color, one has a third intensity i3 that is 0% of the intensity I of the initial light beam b.

[0105] In this non-limitative example, there is no blue light at the output of the second polarizer 16.

Optical module 17

[0106] The optical module 17 is configured to receive said at least one sub-light beam b' and to output a global light beam F which is composed of said at least one sub-light beam b'.

[0107] In a non-limitative embodiment, the optical module 17 comprises a guidelight, or a reflector and/or an optical lens. In the non-limitative example illustrated in figures 3 and 4, it comprises a guidelight 170. In a non-limitative embodiment illustrated in figure 4, it further comprises a light diffuser 171.

[0108] In a first non-limitative embodiment, the optical module 17 is configured to receive one sub-light beam b' with a first color c.1 with a first intensity and to output a global light beam F which is composed of said one sub-light beam b'.

[0109] In a second non-limitative embodiment, said optical module 17 is configured to receive two sub-light beam b', b'' with respectively a first color c.1 with a first intensity and a second color c.2 with a second intensity and to output a global light beam F which is composed of said two sub-light beam b', b''.

[0110] In a third non-limitative embodiment, said optical module 17 is configured to receive three sub-light beam b', b'', b''' with respectively a first color c.1 with a first intensity, a second color c.2 with a second intensity and a third color c.3 with a third intensity and to output a global light beam F which is composed of said three sub-light beam b', b'', b'''.

[0111] In a second non-limitative embodiment illustrated in figure 2, the lighting device 1 further comprises at least one second optical module 19 that cooperates with the light rays r1 of the light source 10 and that conveys them to at least one specific location of the wavelength conversion layer 11. This specific location is not in regard with the output of the light rays r1 from the light source 10. In a non-limitative embodiment, the second optical module 19 is a lightguide. It permits placing the light source 10 away from the wavelength conversion layer 11. Due to the vehicle's volume and geometry, sometimes it is needed to locate the light source 10 far away from the final output, i.e., from the first optical module 17. The same goes for the wavelength conversion layer 11. The second optical module 19 permits more flexibility in the design.

[0112] In a non-limitative variant of embodiments, the lighting device 1 further comprises a plurality of different second optical modules 19 that cooperate with the light rays r1 of the light source 10 and convey them to respec-

tively different specific locations of the wavelength conversion layer 11. In another non-limitative variant of embodiment, such an additional second optical module 19 is configured to bring the light rays r1 of the light source 10 to another decorative element.

[0113] It is to be understood that the present invention is not limited to the aforementioned embodiments and variations and modifications may be made without departing from the scope of the invention. In this respect, the following remarks are made. All statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof. Hence, in a non-limitative embodiment, the liquid crystal layer 13 is configured to orient the light beam b according to more than three orientations. In other non-limitative embodiments, the light source 10 is a RGB light source or a white light source.

[0114] Hence, some embodiments of the invention may comprise one or a plurality of the following advantages:

- it permits to have different variation of colors R, G B or colors composed of any combination of R, G, B colors; it permits to adjust the proportion of the R, G and B wavelengths to obtain a desired color,
- it permits to have a higher gamut of RGB colors than the prior art that uses RGB LEDs or than a lighting device that only comprises a wavelength conversion layer of quantum dots with nor polarizer, no crystal liquid layer and no color filters,
- it reduces the cost when using blue LEDs as no phosphor layer is added, contrary to white LEDs,
- it reduces the cost when using blue LEDs, as a blue LED is less complex than a RGB LED,
- it reduces the complexity of the lighting device as one needs to drive only one light source instead of a plurality of light sources such as RGB LEDs,
- it is more efficient in terms of lumens for the global light beam F,
- it gives more thermal stability as one obtains similar lumens for the global light beam F at high temperatures than at room temperature,
- in term of temperature, as the filtering of color(s) is performed away from the light source 10, it doesn't affect the temperature of the light source 10 and thus of the whole lighting device 1,
- it is more stable than the prior art as one can control the color that is output by the lighting device 1,
- it is more efficient than the prior art as one can spectrally determine the second wavelengths w',
- it permits color tuning as it is possible to synthesise quantum dots of the wavelength conversion layer for specific wavelengths.

Claims

1. Lighting device (1) for a vehicle, said lighting device (1) comprising at least one light source (10) that is configured to emit light rays (r1) according to a first range of wavelengths (w), wherein said lighting device (1) further comprises:
 - a wavelength conversion layer (11) that is configured to receive said light rays (r1) and to transform them into a light beam (b) according to a second range of wavelengths (w'),
 - a first polarizer (12) that is configured to receive said light beam (b) and to transmit it along a first plane (A),
 - a liquid crystal layer (13) that is configured to receive said light beam (b) along said first plane (A) and to orientate the light beam (b) according to at least one orientation (o),
 - an electric field generation module (14) that is configured to generate at least one electrical field (m) and to apply it to said liquid crystal layer (13) so as to create at least one area (s) that leads the liquid crystal layer (13) to orientate the light beam (b) according to said at least one orientation (o),
 - a set of (15) color filters (150) that is configured to get respectively the light beam (b) with said at least one orientation (o) and to output at least one sub-light beam (b') with a color (c),
 - a second polarizer (16) that is configured to receive said at least one sub-light beam (b') and transmit it along a second plane (A'),
 - a first optical module (17) that is configured to receive said at least one sub-light beam (b') and to output a global light beam (F) which is composed of said at least one sub-light beam (b').
2. Lighting device (1) according to claim 1, wherein said wavelength conversion layer (11) is composed of a substrate (110) of quantum dots.
3. Lighting device (1) according to any of the preceding claims, wherein said first range of wavelengths (w) corresponds to one of the range of the blue light, of the red light, or of the green light.
4. Lighting device (1) according to the preceding claim, wherein said first range of wavelengths (w) corresponds to the range of the blue light.
5. Lighting device (1) according to claim 2 and claim 4, wherein the quantum dots are emitted in the red color emission wavelength and in the green color emission wavelength.
6. Lighting device (1) according to the preceding claim, wherein said second range of wavelengths (w') cor-

responds to the range from the blue light to the red light in the visible spectrum, and until the infrared light.

7. Lighting device (1) according to any of the preceding claims, wherein the second plane (A') is at 90° relative to the first plane (A). 5
8. Lighting device (1) according to any of the preceding claims, wherein : 10
 - said a liquid crystal layer (13) is configured to orientate said light beam (b) according to at least two different orientations (o, o'),
 - said electric field generation module (14) is configured to generate at least two electrical fields and to apply them respectively to said liquid crystal layer (13) so as to create at least two different areas (s) that leads the liquid crystal layer (13) to orientate the light beam (b) according to said at least two different orientations (o, o'), 15
 - the set (15) of color filters comprises at least two color filters (150) that are configured to get respectively the light beam (b) with one of the two orientations (o, o') and to output at least two sub-light beams (b', b'') with respectively a first color (c.1) and a second color (c.2), and 25
 - the second polarizer (16) is configured to receive said at least two sub-light beams (b', b'') and transmit them along a second plane (A'), 30
 - said first optical module (17) is configured to receive said at least two sub-light beams (b', b'') and to output a global light beam (F) which is composed of said at least two sub-light beams (b', b''). 35
9. Lighting device (1) according to the preceding claim, wherein : 40
 - said liquid crystal layer (13) is configured to orientate said light beam (b) according to three different orientations (o, o', o''). 45
10. Lighting device (1) according to the preceding claim, wherein said electric field generation module (14) is configured to generate three electrical fields so as to create respectively three areas (s) that leads the liquid crystal layer (13) to orientate the light beam (b) according to said three different orientations (o, o', o''). 50
11. Lighting device (1) according to any of the preceding claims, wherein said electrical field generation module (14) comprises a thin film transistor layer (140) and two electrodes (141) that are disposed on each side of the liquid crystal layer (13). 55

12. Lighting device (1) according to any of the preceding claims, wherein said lighting device (1) further comprises at least one second optical module (19) that cooperates with the light rays (r1) of said light source (10) and that convey them to at least one specific location of the wavelength conversion layer (11).
13. Lighting device (1) according to any of the preceding claims, wherein said light source (10) is a semiconductor source.
14. Lighting device (1) according to the preceding claim, wherein the semiconductor light source (10) is part of a light emitting diode or a laser diode.
15. Lighting device (1) according to any of the preceding claims, wherein said first optical module (17) comprises a guidelight or a reflector and/or an optical lens.

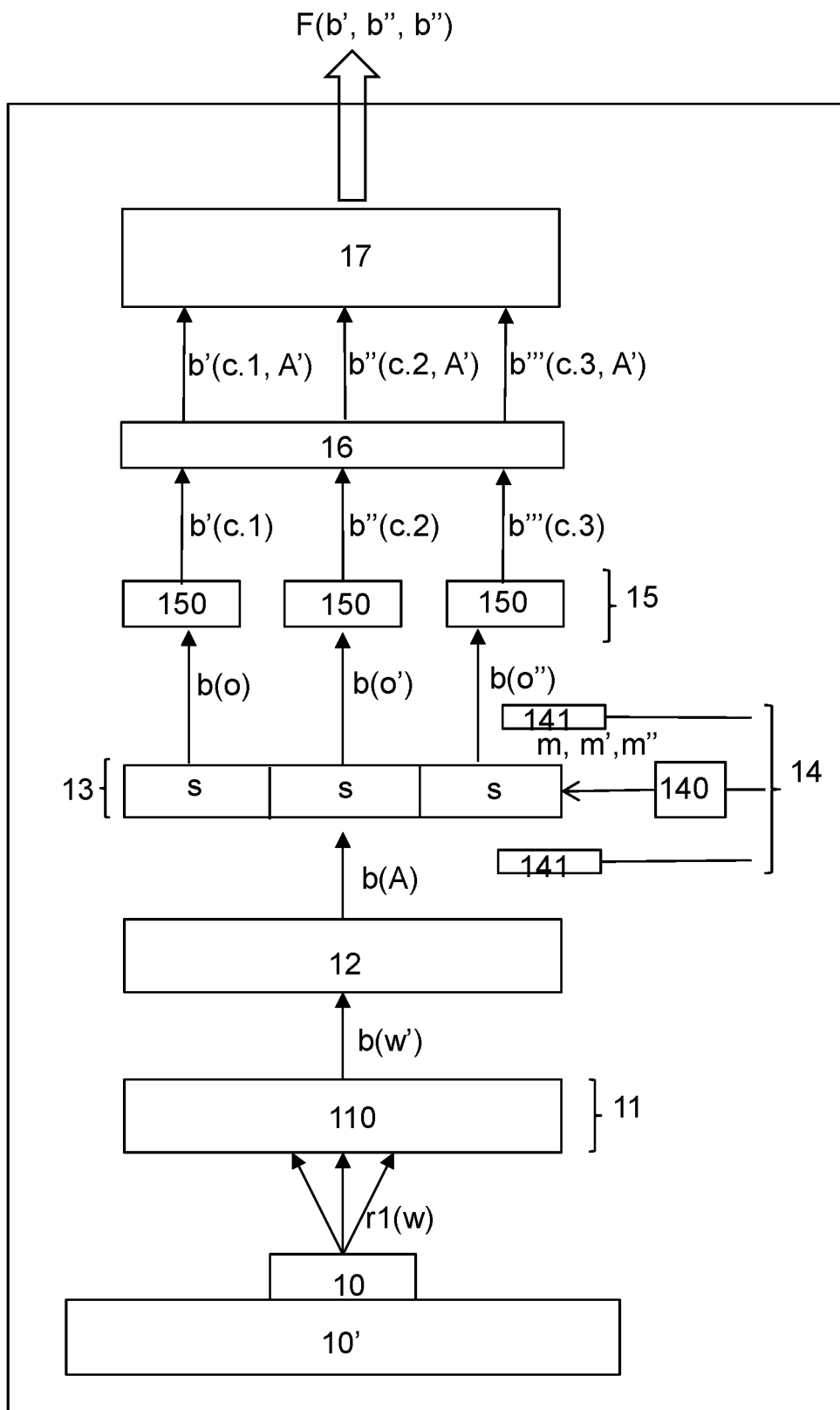


Fig. 1

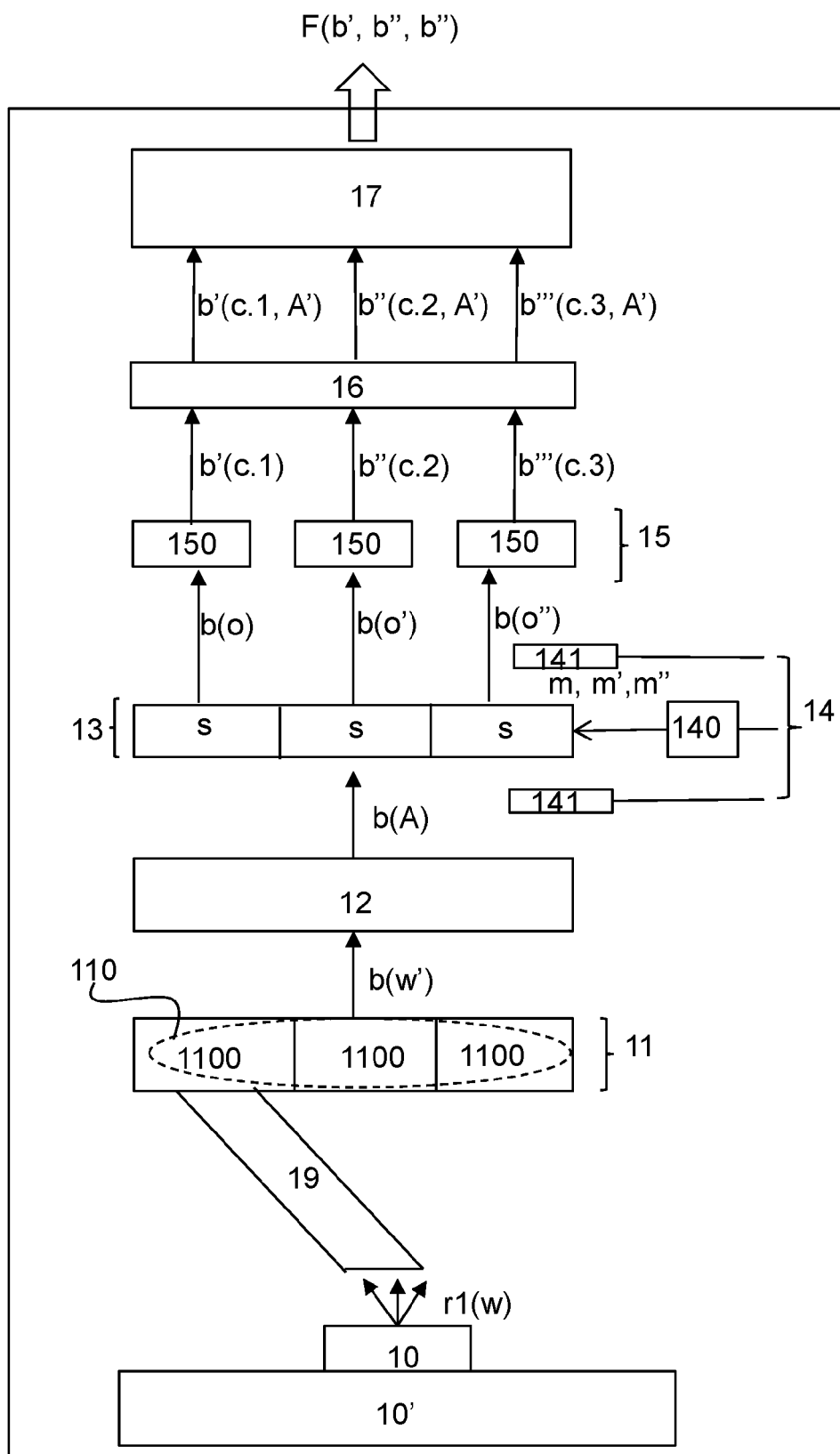


Fig. 2

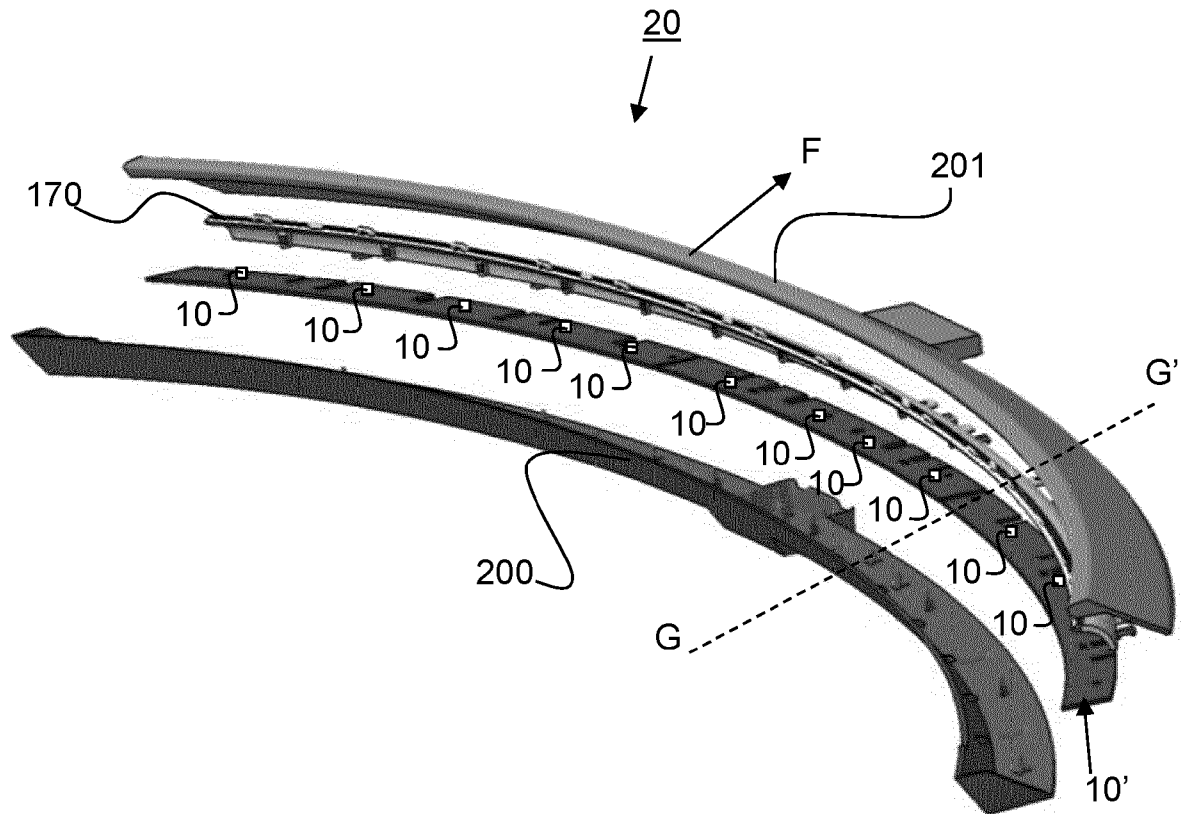


Fig. 3

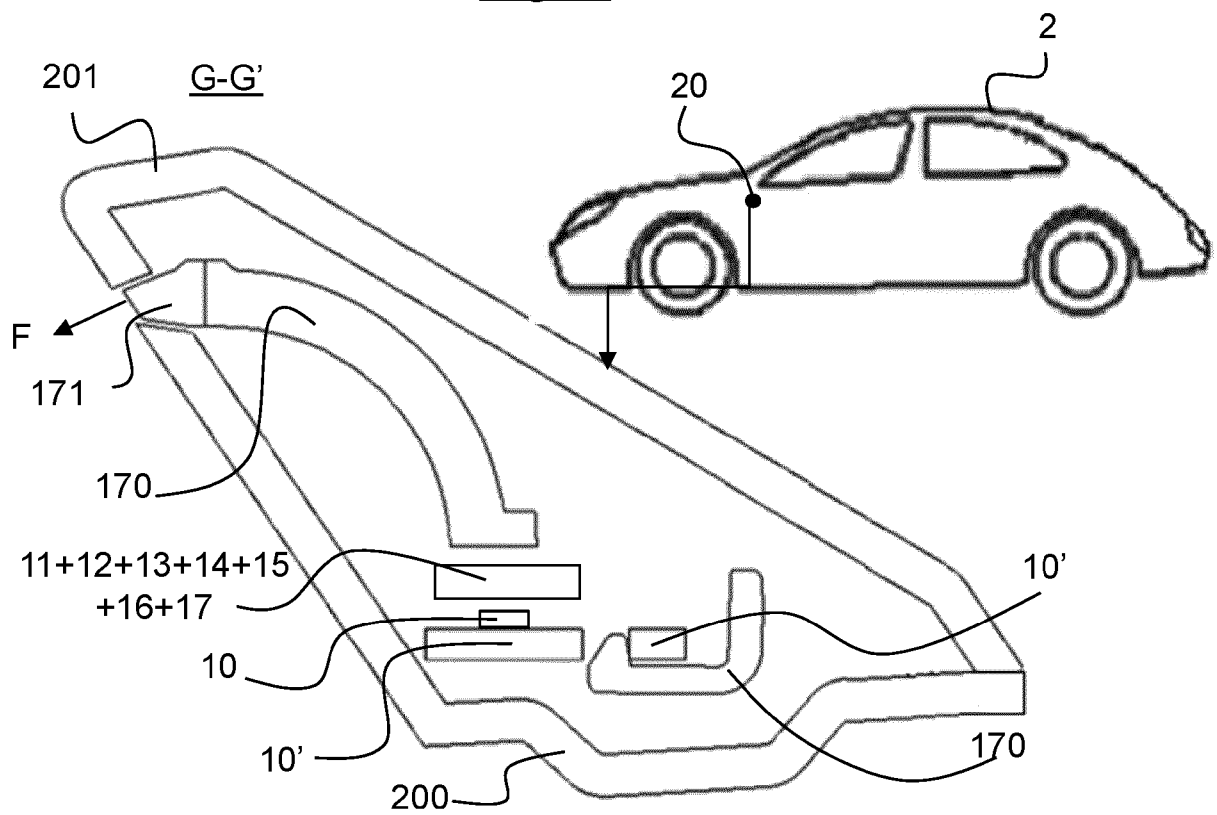


Fig. 4

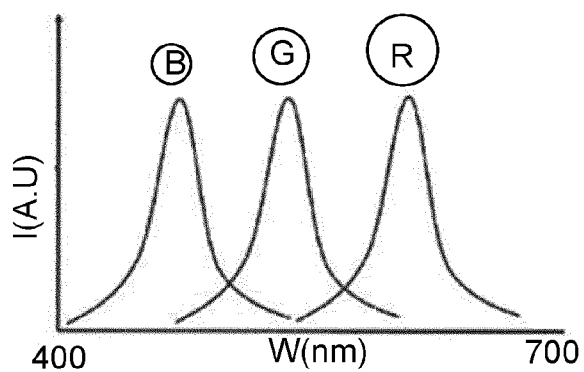


Fig. 5

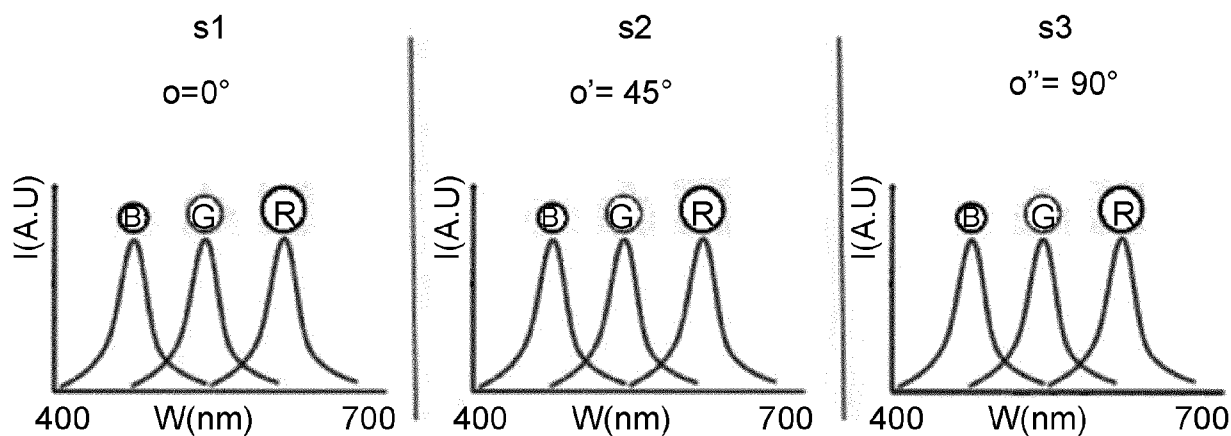


Fig. 6

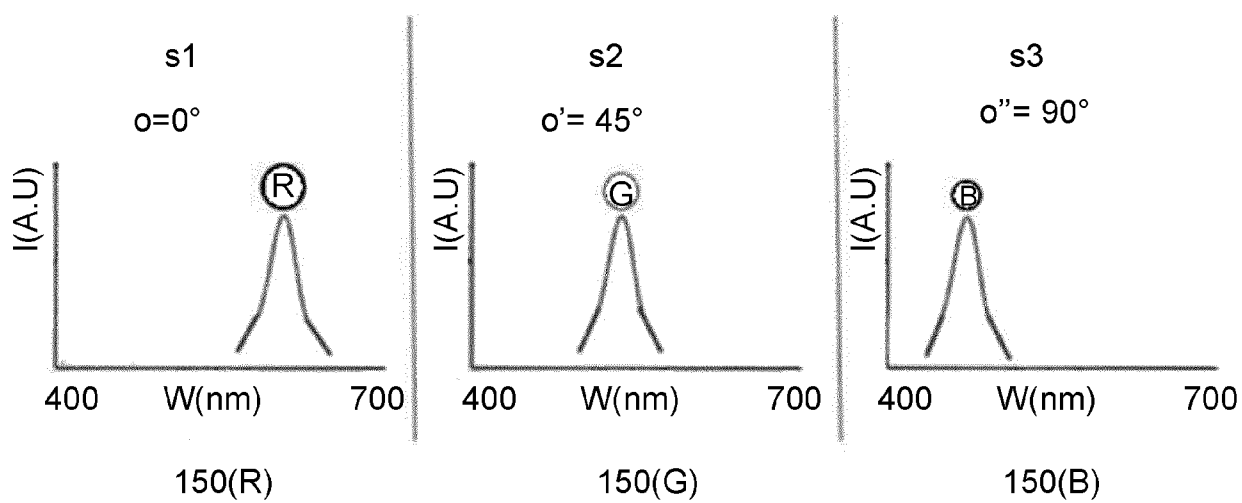


Fig. 7

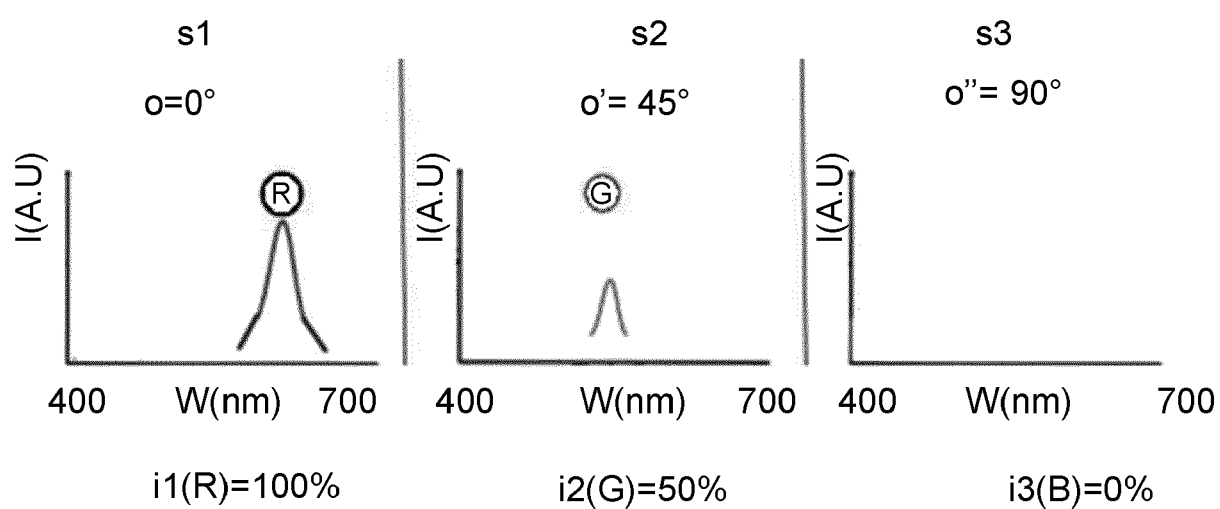


Fig. 8



EUROPEAN SEARCH REPORT

Application Number

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Place of search		Date of completion of the search	Examiner
Munich		12 December 2023	Carneiro, Joaquim
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