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(54) **LIGHTING DEVICE**

(57) The present invention relates to a lighting device that comprises a first and a second light source (104, 105) arranged at a distance from each other, a reflector (102) for reflecting light emitted by the first and the second light source (104, 105), and switching means (302, 303) for switching the first and the second light source (104, 105) on and off independently from each other.

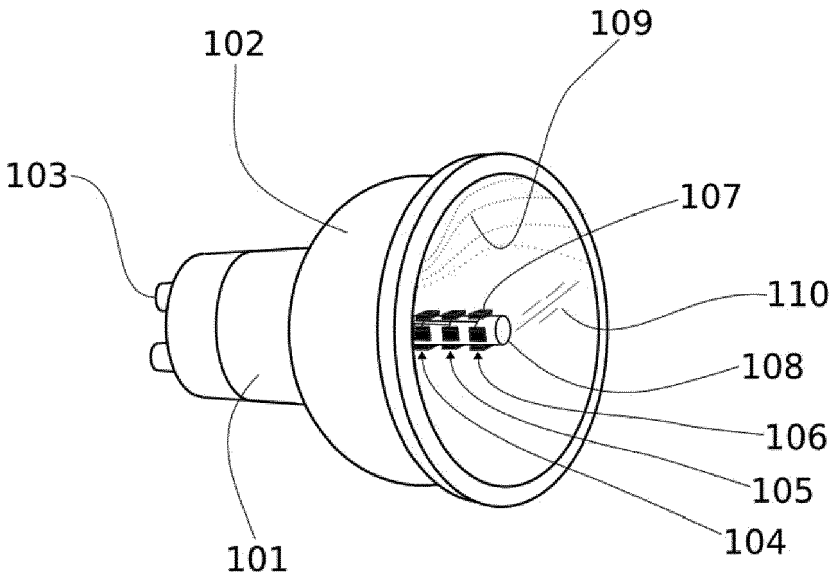

Fig. 1

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Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates to a lighting device according to the preamble of the appended independent claim.

BACKGROUND OF THE INVENTION

[0002] Lighting devices having an adjustable beam angle are known in the prior art. In some known lighting devices the beam angle is adjusted by changing the distance between a light source and a reflector, whereas in other known lighting devices the beam angle is adjusted by changing the distance between a light source and a lens. A common feature of these known lighting devices is that the adjusting of the beam angle is done by changing the position of an optical element.

[0003] A problem associated with the known lighting devices is that their beam angle is mechanically adjustable. In the known lighting devices, a mechanism is required for moving an optical element, such as a light source, a reflector or a lens at different positions in order to adjust the beam angle. Such moving mechanisms are complicated, expensive to manufacture, and they can easily be damaged. Another problem is that in some of the known lighting devices the adjusting of the beam angle must be performed manually, making them difficult to use.

OBJECTIVES OF THE INVENTION

[0004] It is the main objective of the present invention to reduce or even eliminate the prior art problems presented above.

[0005] It is an objective of the present invention to provide a lighting device having an adjustable beam angle. In more detail, it is an objective of the invention to provide a lighting device enabling to adjust the beam angle without moving any optical elements. It is a further objective of the invention to provide a lighting device that is robust and easy to manufacture.

[0006] In order to realise the above-mentioned objectives, the lighting device according to the invention is characterised by what is presented in the characterising part of the appended independent claim. Advantageous embodiments of the invention are described in the dependent claims.

DESCRIPTION OF THE INVENTION

[0007] A typical lighting device according to the invention comprises a first and a second light source arranged at a distance from each other, and a reflector for reflecting light emitted by the first and the second light source. A typical lighting device according to the invention also comprises switching means for switching the first and the second light source on and off independently from each other.

[0008] In the lighting device according to the invention, the light sources can be switched on and off independently from each other using the switching means. This means that the light sources can be switched individually, so that the light sources can be on or off at the same time, or one of the light sources can be on when the other light source is off. Because the light sources are arranged at a distance from each other, i.e. at different positions relative to the reflector, the lighting device can produce different beam angles depending on whether the first light source or the second light source is turned on. The beam angle of the lighting device can thus be changed by simply switching the light sources on and off. The distance between the light sources is typically in the range of 0.1 cm to 10 cm, but in some lighting applications the distance between the light sources can be greater, such as in the range of 10 cm to 25 cm, or in the range of 25 cm to 100 cm.

[0009] The switching means may comprise switches that are configured to control the electrical current supplied to the light sources. Preferably, the switches are analog switches, such as MOSFETs. The switching means may comprise, for example, a first switch that is electrically connected to the first light source, and a second switch that is electrically connected to the second light source. The first and the second switch are configured to turn on and off the first and the second light source, respectively. The switching means may comprise a control unit, such as a microcontroller, for controlling the switches. The control unit is controlled by a control signal. The control signal can be communicated to the lighting device using wireless or power-line communication (PLC) techniques. In PLC, the control signal is transmitted over power lines to the lighting device. The electronic components of the switching means may be mounted on a circuit board that is arranged inside the lighting device.

[0010] The lighting device may comprise more than two light sources, which can be switched on and off independently from each other using the switching means. The number of the light sources in the lighting device can be, for example, two, three, four, five, or more than five. Each of the light sources of the lighting device may consist of one or more lighting elements. The number of the lighting elements can vary, for example, based on the optical characteristics of the lighting elements, such as their brightness, beam angle and/or colour. The lighting element(s) can have different beam angles, such as 30-60 degrees, 60-90 degrees, 90-120 degrees or 120-150 degrees. The lighting elements are preferably light emitting diode (LED) elements. The light sources can be arranged inside the reflector.

[0011] The reflector can have different shapes and sizes for different applications. The reflector is preferably concave, such as parabolic or elliptical. The reflector can be essentially dome-shaped or hyperbolic. The reflector

may be integrated into a light bulb, for example by being attached to a base of the light bulb.

[0012] The lighting device according to the invention is a reflector-type lighting device, wherein the reflector is used to produce a desired beam spread of the light emitted by the light sources. The reflector may be integrated to the lighting device. The lighting device according to the invention can be a light bulb or spotlight with an integrated reflector, or it can be a lighting fixture wherein the reflector is integrated to the lighting fixture and the light sources are interchangeable.

[0013] The lighting device according to the invention may comprise a base to which the reflector is attached or integrated. The base is provided with electrical contact means through which electrical current can be supplied to the lighting device. The electrical contact means may comprise a threaded screw cap that can be screwed into a correspondingly threaded socket of a lighting fixture. The screw cap can be, for example, an Edison screw cap, such as an E27 or E14 type screw cap having a diameter of 27 mm or 14 mm, respectively. The screw cap comprises a threaded sleeve contact and a middle contact that are separated from each other by an electrically non-conductive part. The electrical contact means may alternatively comprise a bi-pin connector, such as GU10, that can be twist-locked into position in a bi-pin socket.

[0014] The lighting device can be intended to be connected to the mains supply, whereby the lighting device comprises a power supply circuit that is configured to convert an AC mains voltage to a DC voltage in order to drive the light sources. The lighting device may comprise a circuit board on which electronic components of the power supply circuit are mounted. The circuit board is arranged inside the base and it is electrically connected to the electrical contact means and the light sources.

[0015] The lighting device may comprise a transparent cover that is attached to the opening of the reflector. The transparent cover protects the light sources and the reflector against damages. The lighting device may also comprise a heat sink to dissipate heat produced by the light sources. The heat sink can be attached to the reflector.

[0016] An advantage of a lighting device according to the invention is that the beam angle of the lighting device can be changed easily, without moving any optical elements such as a light source, a reflector or a lens. Another advantage of a lighting device according to the invention is that the beam angle of the lighting device can be controlled remotely. Still another advantage of a lighting device according to the invention is that the lighting device is robust and easy to manufacture.

[0017] According to an embodiment of the invention the first and the second light source are fixed relative to the reflector. This means that the light sources are immovable with respect to the reflector. The light sources may, for example, be mounted on a support element, which is attached to the same base than the reflector or which is attached directly to the reflector.

[0018] According to an embodiment of the invention the reflector is symmetrical about an axis, and the first and the second light source are located essentially on said axis. The axis about which the reflector is symmetrical is called an axis of symmetry. The light sources are preferably arranged on the axis of symmetry in such a manner that the central beam of each light source is essentially perpendicular to the axis of symmetry. The reflector can be rotationally symmetrical about the axis of symmetry. Rotationally symmetrical means symmetrical in the sense of a rotational symmetry of order n (i.e. *n*-fold rotational symmetry), where n is an integer value greater than 1. A reflector has a rotational symmetry of order n if its transforms are identical when it is rotated about the axis of symmetry by an angle of 360°/*n*. As an extreme case of a rotational symmetry is the rotational symmetry of an infinite order. A reflector having a rotational symmetry of an infinite order means that the reflector is symmetrical about the axis of symmetry with respect to any angle.

[0019] According to an embodiment of the invention the reflector is a parabolic reflector. A parabolic reflector is rotationally symmetrical about its central axis, i.e. the axis of symmetry. A parabolic reflector has a shape that is part of a circular paraboloid, i.e. the surface generated by a parabola revolving around its axis of symmetry. In a parabolic reflector, a spherical wave generated by a light source placed in the focal point is reflected into a plane wave propagating as a collimated beam along the axis of symmetry through the opening of the parabolic reflector. The light sources of the lighting device are preferably located essentially on the axis of symmetry of the parabolic reflector. The light sources can be arranged inside the parabolic reflector.

[0020] According to an embodiment of the invention the reflector comprises a piecewise linear surface. This means that the reflector comprises a plurality of concentric truncated cone sections arranged in series from a first such section nearest a central axis of the reflector to a last such section defining an outer perimeter of the reflector, each section having an outer perimeter and an inner perimeter relative to the central axis, the outer perimeter of each section except the last section being connected with the inner perimeter of the succeeding section, and the sections being located with respect to each other along the central axis. Each of the truncated cone sections may consist of a plurality of planar segments. An advantage of providing the reflector with the piecewise linear surface is that the evenness of the light scattered from the reflector is improved. For example, the changes in the colour temperature of the light are reduced due to the piecewise linear surface of the reflector.

[0021] According to an embodiment of the invention the first light source is located on a focal point of the reflector. The focal point is situated on a central axis of the reflector, which central axis passes from the vertex of the reflector through the center of the opening of the

reflector. When the first light source is located on the focal point of the reflector, the second light source is preferably located on the central axis of the reflector and farther from the vertex of the reflector than the first light source.

[0022] According to an embodiment of the invention the lighting device comprises a support element arranged to extend along the axis of symmetry of the reflector, on which support element the first and the second light source are mounted. The support element is preferably a rod having a first end and a second end. The first end of the rod is arranged at the vertex of the reflector, and the second end extends towards or through the center of the opening of the reflector. The light sources are mounted on the side of the rod and preferably in such a manner that the central beam of each light source is essentially perpendicular to the central axis of the reflector. The rod can have, for example, a circular cross section or an N-sided regular polygonal cross section. A lighting element of a light source can be mounted on each side of the rod having an N-sided regular polygonal cross section. The surface of the rod can be made of a PCB material. The rod can comprise a PCB formed in a roll. The inside of the rolled PCB can be filled with a heat conductive material so that heat produced by the light sources can be efficiently dissipated.

[0023] According to an embodiment of the invention the lighting device comprises a first and a second reflector element mounted on the support element to change the beam angles of the first and the second light source, the first reflector element being arranged in connection with the first light source and the second reflector element being arranged in connection with the second light source. Each of the reflector elements is preferably mounted on the support element in such a manner that the reflecting surface of the reflector element can reflect the light from the light source towards the reflector. The reflector elements may comprise one or a plurality of reflecting parts. If the light sources comprise a plurality of lighting elements, each of the lighting elements can be provided with a reflecting part.

[0024] According to an embodiment of the invention the support element is a rod, the diameter of which increases from one end to the other. In other words, the diameter of the rod that is arranged to extend along the axis of symmetry of the reflector increases either towards the vertex or towards the opening of the reflector. An advantage of providing the reflector with a rod having a diameter that increases from one end to the other is that it enables to optimize the beam spread of the lighting device. Thus, it is possible to use the diameter of the rod as one design variable in optimizing the beam spread of the lighting device.

[0025] According to an embodiment of the invention the first and the second light source are light emitting diodes.

[0026] According to an embodiment of the invention the first and the second light source comprise a plurality of light emitting diodes. The number of the light emitting diodes in each light source can be, for example, two, three, four five, or more than five.

[0027] According to an embodiment of the invention the light emitting diodes of each light source are arranged in a circle at regular intervals from each other. The light emitting diodes are preferably arranged in such a manner that the central axis of the reflector is essentially perpendicular to the plane of the circle, which the light emitting diodes constitute.

[0028] According to an embodiment of the invention the lighting device comprises communication means for receiving a control signal to control the switching means. The communication means may be configured to receive the control signal that is transmitted wirelessly and/or using power-line communication (PLC) techniques. The communication means may comprise an antenna for receiving the control signal. The antenna may be electrically connected to a control unit, such as a microcontroller, that is configured to control the operation of switches electrically connected to the light sources. The antenna can be constituted, for example, by a wiring which electrically connects the light sources to the switching means. This wiring is preferably arranged on a surface of a support element, on which support element the light sources are mounted. The communication means may be configured to receive and transmit data from and to a lighting control device. The lighting control device is used to control one or more lighting devices in a lighting system.

[0029] According to an embodiment of the invention the lighting device comprises power supplying means for supplying electric power to the first and the second light source. The power supplying means may comprise a switched-mode power supply (SMPS) that is configured to convert an AC mains voltage to a DC voltage in order to drive the light sources. The electronic components of the power supplying means may be mounted on a circuit board that is arranged inside the lighting device.

[0030] According to an embodiment of the invention the lighting device is a light bulb or a lighting fixture. Preferably, the reflector is integrated to the lighting fixture.

[0031] The exemplary embodiments of the invention presented in this text are not interpreted to pose limitations to the applicability of the appended claims. The verb "to comprise" is used in this text as an open limitation that does not exclude the existence of also unrecited features. The features recited in the dependent claims are mutually freely combinable unless otherwise explicitly stated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032]

Fig. 1 illustrates a lighting device according to a first embodiment of the invention,

figs. 2A-2C illustrate the operation of the lighting de-

vice according to fig. 1,

fig. 3 illustrates a partial cross-sectional view of the lighting device according to fig. 1,

fig. 4 illustrates a cross-sectional view of a lighting device according to a second embodiment of the invention,

fig. 5 illustrates a cross-sectional view of a lighting device according to a third embodiment of the invention, and

fig. 6 illustrates a lighting device according to a fourth embodiment of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

[0033] The same reference signs are used of the same or like components in different embodiments.

[0034] Fig. 1 illustrates a lighting device according to a first embodiment of the invention. The lighting device is a light bulb that comprises a base 101 and a reflector 102 attached to the base 101. The base 101 is provided with a bi-pin connector 103 through which electrical current can be supplied to the lighting device.

[0035] The lighting device of fig. 1 comprises three light sources 104, 105 and 106 arranged at a distance from each other. Each of the light sources 104, 105 and 106 consists of four light emitting diode (LED) elements 107, which are mounted on a side of a rod 108 that extends along the axis of symmetry of the reflector 102. The LED elements 107 of each light source 104, 105 and 106 are mounted on the rod 108 in such a manner that the four LED elements 107 are at the same distance from the vertex of the reflector 102 and arranged around the rod 108 at regular intervals from each other. The central beam of each LED element 107 is essentially perpendicular to the axis of symmetry of the reflector 102. The LED elements 107 of the first light source 104 are located essentially on a focal point of the reflector 102. The LED elements 107 of the second light source 105 and the third light source 106 are located further from the vertex of the reflector 102 than the LED elements 107 of the first light source 104.

[0036] The reflector 102 is used for reflecting light emitted by the LED elements 107. The reflector 102 has a curved inner surface 109 that is designed to produce a desired beam spread for each of the light sources 104, 105 and 106. The light sources 104, 105 and 106 are arranged inside the reflector 102. A transparent cover 110 made of glass is attached to the opening of the reflector 102. The transparent cover 110 protects the LED elements 107 and the reflector 102 against damages. The light sources 104, 105 and 106, i.e. the sets of the four LED elements 107, can be switched on and off independently from each other using switching means (not shown in fig. 1) of the lighting device. The LED elements 107 of the light source 104, 105 or 106 are always on or off at the same time. The light sources 104, 105 and 106 can be switched individually on or off, so that one of the sets of the four LED elements 107 can be on when the other sets are off. Because the light sources 104, 105 and 106 are at different positions relative to the reflector 102, the lighting device can produce different beam angles depending on which light source 104, 105 or 106 is turned on. The beam angle of the lighting device can thus be changed by simply switching the light sources 104, 105 and 106 on and off.

[0037] The lighting device of fig. 1 comprises power supplying means (not shown in fig. 1) for supplying electric power to the light sources 104, 105 and 106. The lighting device also comprises communication means (not shown in fig. 1) for receiving a control signal to control the switching means.

[0038] Figs. 2A-2C illustrate the operation of the lighting device according to fig. 1. Fig. 2A shows a situation where the first light source 104 located essentially on the focal point of the reflector 102 is on, and the second 105 and the third 106 light source are off. The lighting device produces a narrow beam angle, which makes the light focused and intense, like a spotlight. This kind of lighting is used when the main purpose of the light is to be directed, for example, on a specific object or person, not an area. Fig. 2B shows a situation where the second light source 105 is on and the first 104 and the third 106 light source are off. In this case the light beam of the lighting device is wider and less intense, giving more general light. A wider beam angle distributes the light better. Fig. 2C shows a situation where the third light source 106, which is located furthest from the vertex of the reflector 102, is on, and the first 104 and the second 105 light source are off. Now, the beam angle of the lighting device is wide and thus the light covers a wide area. An example of using this kind of light is when a large room needs to be lighted.

[0039] Fig. 3 illustrates a partial cross-sectional view of the lighting device according to fig. 1. In fig. 3 the components of the power supplying means, the switching means and the communication means are illustrated. The power supplying means comprise a switched-mode power supply 301 for converting an AC mains voltage to a DC voltage. The input of the switched-mode power supply 301 is electrically coupled to the bi-pin connector 103 and the output of the switched-mode power supply 301 is electrically coupled to the light sources 104, 105 and 106. The switching means comprise switches 302 that are electrically coupled to the light sources 104, 105 and 106. The purpose of the switches 302 is to control the electrical current supplied from the switched-mode power supply 301 to the light sources 104, 105 and 106. The switches 302 are controlled by a control unit 303, the operation of which is controlled by a control signal. The control signal is received with an antenna 304 of the communication means. The antenna 304 is electrically connected to a control unit 305 of the communication means.

The control unit 305 conveys the control signal to the control unit 303 in order to control the operation of the switches 302.

[0040] Fig. 4 illustrates a cross-sectional view of a lighting device according to a second embodiment of the invention. The lighting device of fig. 4 is similar to the lighting device of fig. 1, except that it further comprises reflector elements 401 mounted on the rod 108. One reflector element 401 is arranged in connection with each of the light sources 104, 105 and 106. The purpose of the reflector elements 401 is to change the beam angles of the light sources 104, 105 and 106.

[0041] Fig. 5 illustrates a cross-sectional view of a lighting device according to a third embodiment of the invention. The lighting device of fig. 5 is similar to the lighting device of fig. 1, except that the reflector 102 comprises a piecewise linear surface. The reflector 102 of fig. 5 comprises a plurality of concentric truncated cone sections 501 arranged in series from a first such section nearest a central axis of the reflector 102 to a last such section defining an outer perimeter of the reflector 102, each section having an outer perimeter and an inner perimeter relative to the central axis. The outer perimeter of each section except the last section is connected with the inner perimeter of the succeeding section, and the sections are located with respect to each other along the central axis of the reflector 102.

[0042] Fig. 6 illustrates a lighting device according to a fourth embodiment of the invention. The lighting device is a fixed luminaire with an integrated reflector 102. The lighting device comprises three light sources 104, 105 and 106 which each consist of four LED elements 107 mounted on a rod 108. The light sources 104, 105 and 106 are arranged at a distance from each other. The LED elements 107 of the first light source 104 are located essentially on a focal point of the reflector 102. The LED elements 107 of the second 105 and the third 106 light source are located further from the vertex than the LED elements 107 of the first light source 104. The reflector 102 is attached to a base 101 of the lighting device. The base 101 is attached to an adjustable shaft 601 that is attached to a coupling part 602. The coupling part 602 allows the lighting device to be coupled to a track of a lighting system. The beam angle of the lighting device can be changed by switching the light sources 104, 105 and 106 on and off using switching means (not shown in fig. 6).

[0043] Only advantageous exemplary embodiments of the invention are described in the figures. It is clear to a person skilled in the art that the invention is not restricted only to the examples presented above, but the invention may vary within the limits of the claims presented hereafter. Some possible embodiments of the invention are described in the dependent claims, and they are not to be considered to restrict the scope of protection of the invention as such.

Claims

1. A lighting device, comprising:

- a first and a second light source arranged at a distance from each other, and
- a reflector for reflecting light emitted by the first and the second light source,

characterised in that the lighting device comprises:

- switching means for switching the first and the second light source on and off independently from each other.

2. The lighting device according to claim 1, **characterised in that** the first and the second light source are fixed relative to the reflector.

3. The lighting device according to claim 1 or 2, **characterised in that** the reflector is symmetrical about an axis, and the first and the second light source are located essentially on said axis.

4. The lighting device according to claim 3, **characterised in that** the reflector is a parabolic reflector.

5. The lighting device according to any of the preceding claims, **characterised in that** the reflector comprises a piecewise linear surface.

6. The lighting device according to any of the preceding claims, **characterised in that** the first light source is located on a focal point of the reflector.

7. The lighting device according to any of the preceding claims, **characterised in that** the lighting device comprises a support element arranged to extend along the axis of symmetry of the reflector, on which support element the first and the second light source are mounted.

8. The lighting device according to claim 7, **characterised in that** the lighting device comprises a first and a second reflector element mounted on the support element to change the beam angles of the first and the second light source, the first reflector element being arranged in connection with the first light source and the second reflector element being arranged in connection with the second light source.

9. The lighting device according to claim 7 or 8, **characterised in that** the support element is a rod, the diameter of which increases from one end to the other.

10. The lighting device according to any of the preceding claims, **characterised in that** the first and the sec-

ond light source are light emitting diodes.

11. The lighting device according to any of claims 1 to 9, **characterised in that** the first and the second light source comprise a plurality of light emitting diodes.

12. The lighting device according to claim 11, **characterised in that** the light emitting diodes of each light source are arranged in a circle at regular intervals from each other.

13. The lighting device according to any of the preceding claims, **characterised in that** the lighting device comprises communication means for receiving a control signal to control the switching means.

14. The lighting device according to any of the preceding claims, **characterised in that** the lighting device comprises power supplying means for supplying electric power to the first and the second light source.

15. The lighting device according to any of the preceding claims, **characterised in that** the lighting device is a light bulb or a lighting fixture.

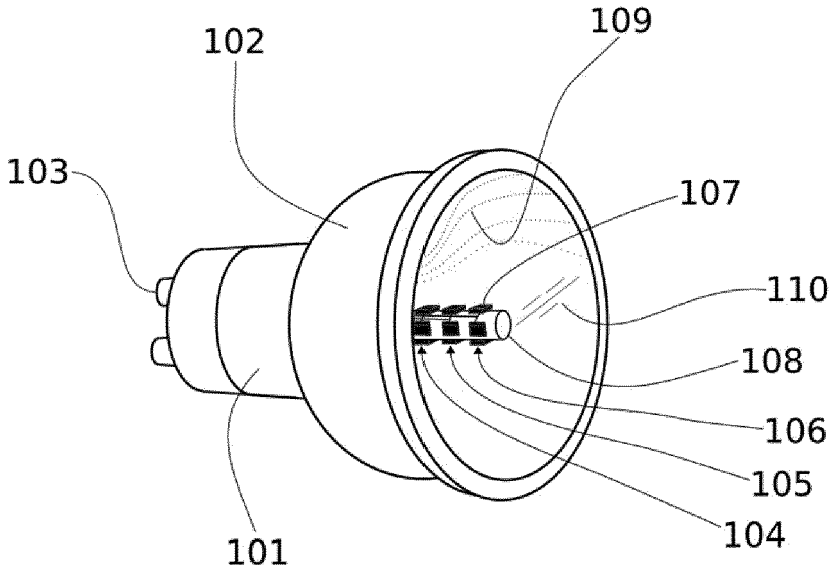

Fig. 1

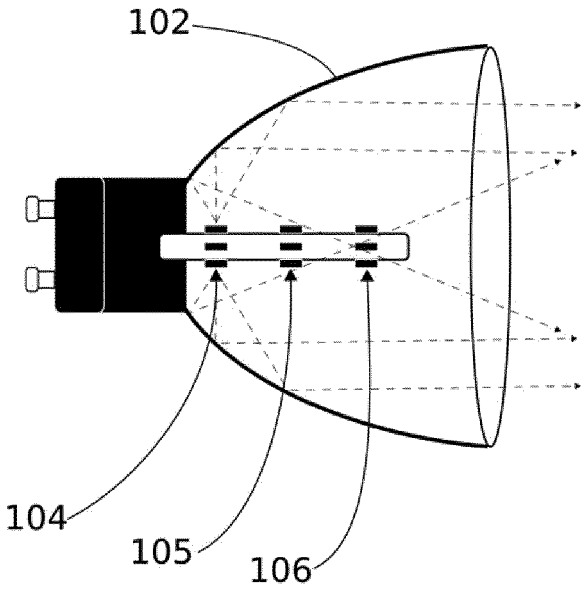

Fig. 2A

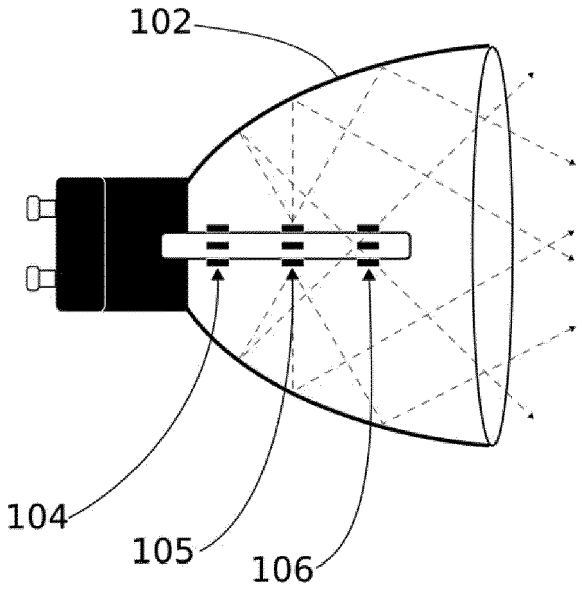

Fig. 2B

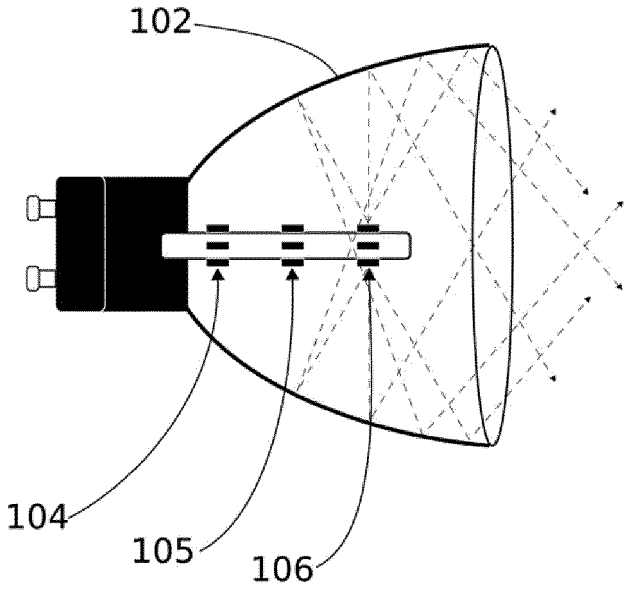

Fig. 2C

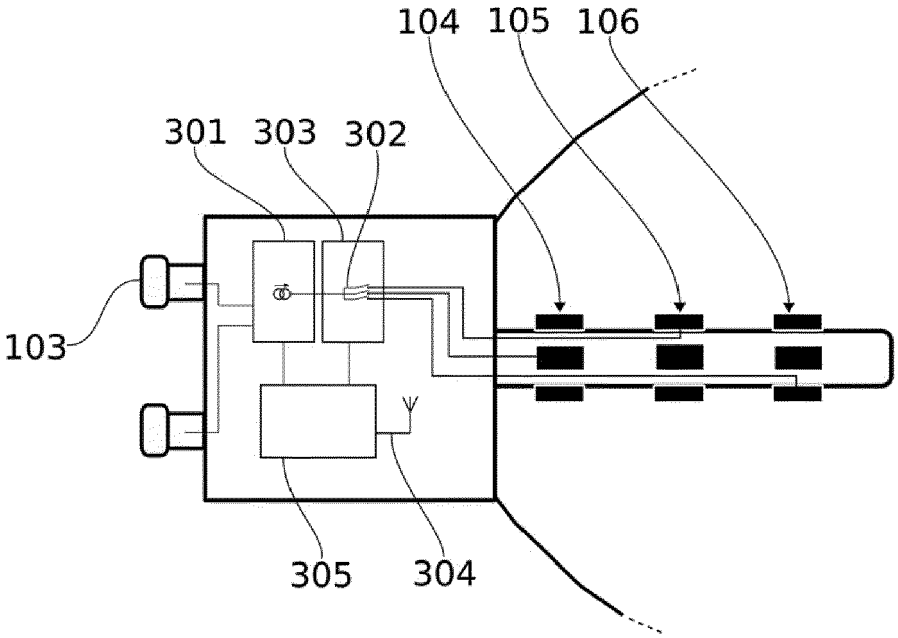

Fig. 3

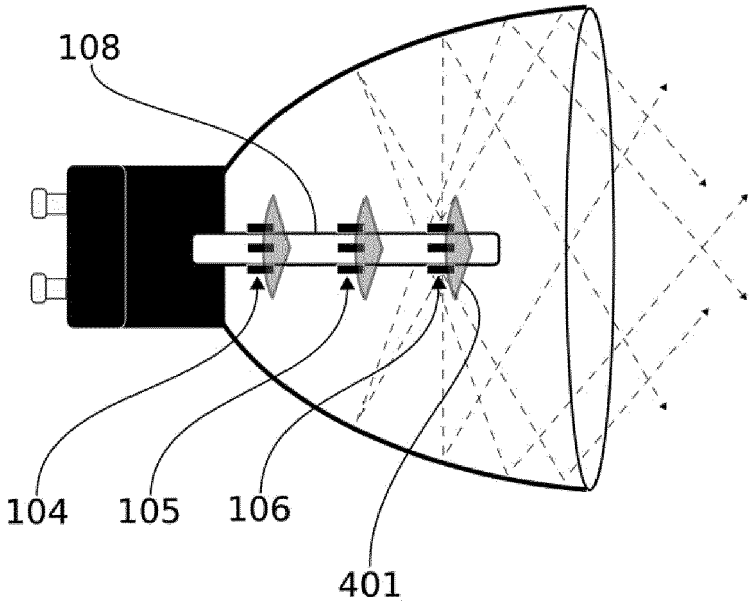

Fig. 4

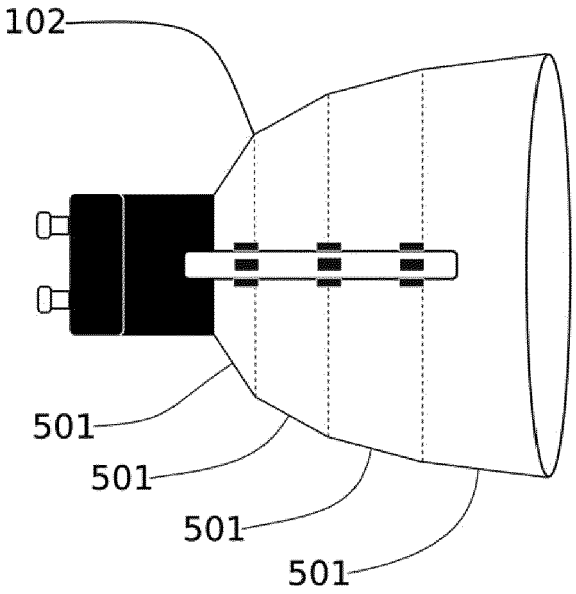

Fig. 5

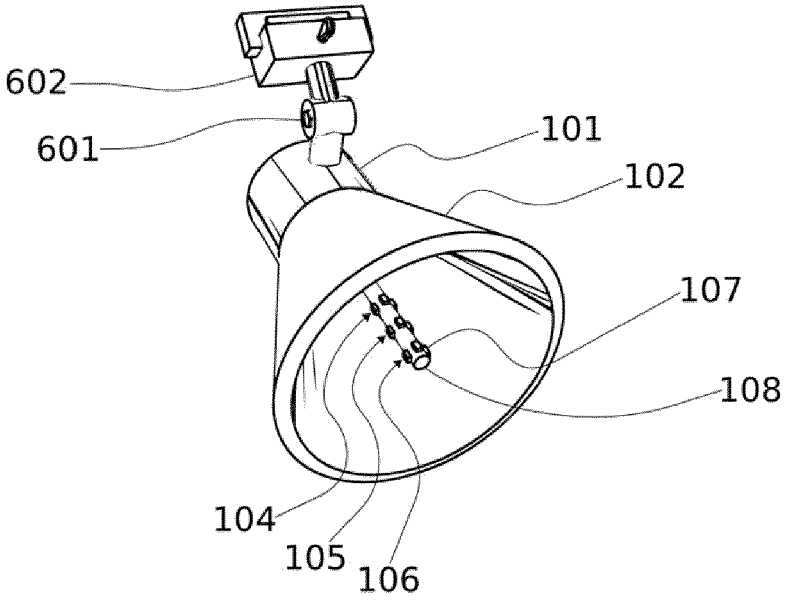

Fig. 6

Europäisches Patentamt
European Patent Office
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EUROPEAN SEARCH REPORT

Application Number
EP 16 15 6534

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2003/227774 A1 (MARTIN PAUL S [US] ET AL) 11 December 2003 (2003-12-11) * paragraph [0042] - paragraph [0079]; figures 2A,10A,19D,20 *	1-15	INV. F21K99/00 F21V7/06 F21V7/04 F21V23/04
X	US 2013/235601 A1 (TAKAHASHI KOJI [JP]) 12 September 2013 (2013-09-12) * paragraph [0145] - paragraph [0171] * * figure 14 *	1-7,9, 10,13,14	ADD. F21Y111/00 F21Y115/10
X	WO 2015/145855 A1 (MITSUBISHI CHEM CORP [JP]) 1 October 2015 (2015-10-01) * paragraph [0094] - paragraph [0128] * * figures 11-14 *	1-7, 10-15	
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