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(71) Applicant: **ZG Lighting France S.A.**
75002 Paris (FR)

(72) Inventors:
- **Rocard, Florian**
92700 Colombes (FR)
- **Taron, Alexandre**
76750 Germain DES Essourts (FR)

(74) Representative: **Kiwit, Benedikt**
Mitscherlich PartmbB
Patent- und Rechtsanwälte
Sonnenstraße 33
80331 München (DE)

(54) **LIGHTING DEVICE AND SYSTEM FOR VARIABLE STREET LIGHTING**

(57) The present invention relates to a lighting device (100) for road and/or street lighting, comprising a light source (300-302) for emitting light with a first light distribution (LD1) in a main light emitting direction (310), and a reflector (200-203), which is positioned in front of the light source (300-302) along the main light emitting direction (310), with a reflector surface (220) for directing the light from the light source (300-302) towards an illumination area (IA) with a second light distribution (LD2), wherein the light source (300-302) is configured to vary the first light distribution (LD1) for illuminating different portions of the reflector surface (220), and wherein the reflector (200-203) is provided with respect to the light source (300-302) such that the second light distribution (LD2) of the light illuminating the illumination area (IA) is defined differently depending on the portions of the reflector surface (220) illuminated with the light of the first light distribution (LD1). The present invention also relates to a lighting system (700) with the lighting device (100) and a method for adapting the light distribution of the lighting device (100).

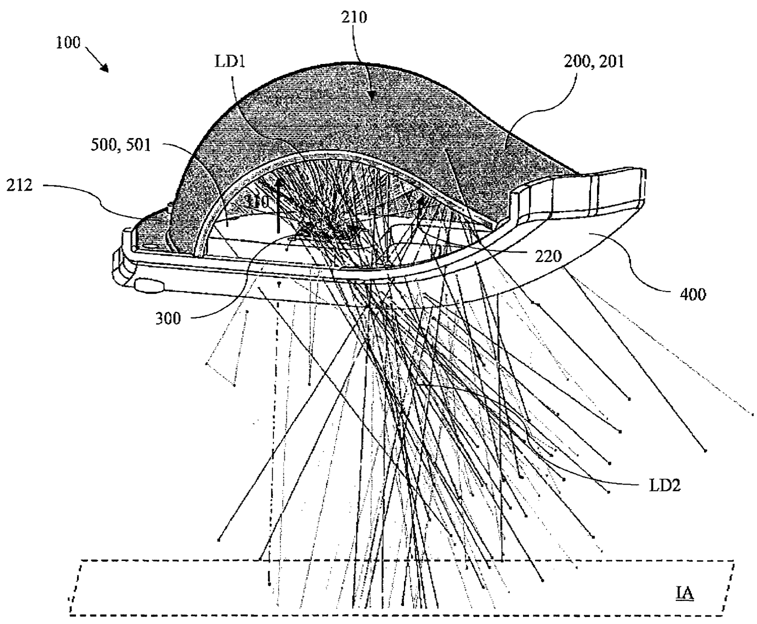

FIG 1

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Description

[0001] The present invention relates to a lighting device for road and/or street lighting comprising a light source for emitting light with a first light distribution in a main light emitting direction and a reflector, which is positioned in front of the light source along the main light emitting direction. The present invention relates further to a lighting system with the lighting device and a controller as well as a method for adapting the light distribution of the lighting device in this lighting system.

[0002] Illumination of roads, streets or urban areas is faced with a number of technical challenges. For example, it has been found that during the life span of a street lantern the conditions of the road or the surroundings may change so that the originally anticipated light situation does not correspond any longer with the momentary light situation. For example, the reflectivity characteristics of the road surface can change over time and therefore, the illuminance of the dedicated area distinguishes from its anticipated value. Moreover, the character of the surroundings of a road might change over time from a sparsely populated area to a highly populated area. Light pollution caused by street lighting might be a nuisance for inhabitants of the newly built homes.

[0003] However, the illumination situation may change instantaneously for street lighting. For example, the weather can transform a road from light absorbing under dry weather conditions to highly reflective under wet or icy weather conditions. The street lighting may thus cause danger for participants in road traffic. For example, by illuminating a wet road surface with a certain lighting configuration, the reflection of the light may cause momentary blindness for car drivers. In comparison, the same lighting configuration may be very suitable for a dry road surface.

[0004] The energy consumption caused by street lighting largely depends on daily operation times and the modes of the street lighting. Over the life span of the street lighting, the energy usage of the street lighting may accumulate to a high value.

[0005] Thus, there is a need for providing flexible street lighting solutions that can overcome these technical challenges.

[0006] In the prior art, attempts have been made to do so by adapting the light distribution of the street lighting. For example, it is known in the prior art to manually adapt the relative position of a light source to an optic, for example a reflector. However, this solution requires manually and mechanically setting the position of the light source in relation to the optic. However, this is not a viable solution if frequent changes of the light distribution are desired.

[0007] It is also known from the prior art to adapt the light distribution of the street lighting by changing a number of elements emitting light, each facing the road surface. However, such a solution has the disadvantage of primarily adapting the luminous intensity of the street lighting while the light distribution itself is not adjusted.

[0008] Moreover, the energy consumption of each of the known solutions is increased when adapting the light distribution. Also, the costs for producing, maintaining and adjusting the aforementioned solutions are increased due to a higher number of parts compared to non-variable street lighting solutions.

[0009] Thus, it is an object of the present invention to provide a lighting device, a lighting system and a method, by which the aforementioned drawbacks can be overcome. In particular, it is an object of the present invention to vary the light distribution of the street lighting such that the visual comfort and energy efficiency is improved while the number of components for the street lighting is kept low.

[0010] The object is to be accomplished by means of the independent claims. The dependent claims advantageously study further the central idea of the present invention.

[0011] According to a first aspect of the present invention, a lighting device for road and/or street lighting is provided. The lighting device comprises a light source for emitting light with a first light distribution in a main light emitting direction.

[0012] Therein, a "light distribution" is to be understood as a spatial distribution of luminous intensity. The luminous intensity represents the amount of light in a certain direction. The expression "main light emitting direction" is to be understood as a (mean) direction, which points into a half-space, into which the light of the light source is emitted.

[0013] The lighting device further comprises a reflector. The reflector is positioned in front of the light source along the main light emitting direction and has a reflector surface for directing the light from the light source towards an illumination area with a second light distribution.

[0014] Therein, the expression "illumination area" is to be understood as any area outside the physical structure (boundaries) of the lighting device. In particular, it is an area that is to be illuminated by the lighting device. For example, the illumination area can be a surface of a road or of a public square.

[0015] The light source of the lighting device is configured to vary the first light distribution in order to illuminate different portions of the reflector surface.

[0016] According to the present invention, the expression "portion" may be generally understood as an area or part of the reflector surface. A first portion may differ from a second portion, for example, if they are different in size or in their position. They may partially overlap or not overlap.

[0017] Moreover, the reflector is provided with respect to the light source such that the second light distribution of the light illuminating the illumination area is defined differently (i.e. differs) depending on the portions of the reflector surface that are illuminated with the light of the first light distribution coming from the light source.

[0018] In other words, the present invention is provided with a light source and a reflector that faces the light source such that the light from the light source is incident on the reflector. The light source is provided with the capability of illuminating different portions (or areas) of the reflector surface by varying the light source's first light distribution. Therefore, it is possible to distribute the luminous power of the light source over the reflector surface differently. The reflector of the lighting device is provided with respect to the light source such that the light distribution of the light being emitted towards the illumination area can be set differently depending on the light distribution of the light coming from the light source. This can mean, for example, that the reflector is positioned relative to the light source in a particular manner or that the reflector itself has a particular (structural) configuration that allows for variation of the second light distribution by illuminating it differently. It can also be a combination of the aforementioned configurations or be entirely different.

[0019] Effectively, by providing the lighting device in the aforementioned manner, the light emissive surface of the lighting device becomes adjustable. Thereby, it is not necessary to restrict or adapt the lighting device structurally as shown in the prior art or by increasing the number of light emitting elements, but merely to vary the light source's light distribution. Moreover, the light is emitted from the light source in an indirect manner towards the illumination area rather than being directly emitted thereto. Thereby, the illumination situation can accurately be defined and it can be avoided that light is emitted towards a space, which is not supposed to be illuminated. Thus, the light pollution can be reduced. Also, the efficiency of the lighting device can be increased as losses of light can be reduced and thus the costs for illumination can be reduced. Moreover, the lighting device of the present invention provides lighting with a defined light distribution. Further, the light distribution of the light illuminating the illumination area can be varied in a very simplistic and efficient manner. Furthermore, the interaction between light source and the structure and/or the position of the reflector surface with respect to the light source allows for setting a high number of different configurations of the resulting second light distribution.

[0020] According to a preferred embodiment of the present invention, the light source may be configured to vary the first light distribution by varying light distribution characteristics of the light source. The light distribution characteristics may be an effective light emitting area of the light source, an angle of the main light emitting direction with respect to the reflector or the reflector surface, and/or a relative position of the light source with respect to the reflector or the reflector surface.

[0021] In other words, the light emitted from the light source may be varied regarding its spacial distribution, for example by changing its emitting direction or the location, on which the light is emitted with respect to the reflector surface, or by changing the area, over which light is (effectively) emitted towards the reflector.

[0022] Thereby, photometric parameters of the light source such as the illuminance of the light source or the luminous intensity can be varied locally while maintaining the luminous power of the light source at the same level. In addition, the light source allows to illuminate different portions of the reflector surface in a defined manner so that the second light distribution can be accurately defined by illuminating the portions of the reflector surface that were designed for this purpose. Hence, the present invention allows to vary not only the spacial distribution of the luminous intensity of the light source, but also to vary its illuminance or luminous intensity locally. As a result, the lighting device according to the present invention allows for an indefinite number of different illumination settings and provides thereby a very flexible solution for street lighting. In addition, it is possible to save energy by cleverly redistributing luminous power to the portions of the reflector surface, which distribute the light to sections of the illumination area, where the light is needed or ought to be.

[0023] A particular advantage of this solution is that the adjustment does not rely on any structural movement or complicated mechanisms, but only on an adjustment of the light source. Thus, the design, production and maintenance of the lighting device can be improved and costs can be reduced

[0024] According to another preferred embodiment of the present invention, the reflector may be positioned with respect to the light source such that the light thereof is reflected from the reflector surface in a direction substantially opposite to the main light emitting direction.

[0025] Thereby, it can be achieved that substantially no light is emitted in a direction parallel to the main light emitting direction, thus providing for a lighting solution that, if at all, only marginally causes light pollution. In addition, substantially all of the luminous power emitted from the light source is received at the illumination area. Consequently, the efficiency of such a lighting device is increased.

[0026] According to a preferred embodiment of the present invention, the reflector surface and the light source may be relatively fix to each other. Alternatively or additionally, the reflector surface and the light source may be arranged such that the light emitted from the light source is directly received on the reflector surface. They may also be arranged such that all of the light emitted from the light source is directly received on the reflector surface or on the entire reflector surface.

[0027] Thus, the luminous power of the light source is maintained at a high level until the light exits the lighting device as reflection or absorption losses along the light path can be avoided. Moreover, by receiving substantially all of the light on the reflector surface, the control over the adjustment of the second light distribution is improved. Thus, the illumination situation can be defined more accurately.

[0028] According to a further preferred embodiment of the present invention, the reflector may have a curved, domed or at least partially spherical shape. Alternatively or additionally, the reflector or the reflector surface may be symmetrical. The reflector or the reflector surface may be mirror symmetrical with respect to a symmetry axis or a symmetry plane, which are defined in respect to the main light emitting direction. For instance, the symmetry axis may be orthogonal to the main light emitting direction and/or the symmetry plane may be parallel to the main light emitting direction.

[0029] By providing the lighting device with a reflector of a defined shape, the light emissive surface of the lighting device can be defined accurately. In particular, it can be avoided that light emitted towards the reflector is lost unintentionally. Therefore, the efficiency of the lighting device can be improved.

[0030] According to a preferred embodiment of the present invention, the light source may be positioned between the reflector's or the reflector surface's peripheral edges when viewed in a direction along the main light emitting direction. Alternatively or additionally, the light source is positioned in the middle of the peripheral edges of the reflector or the reflector surface.

[0031] Also, the light source may be positioned with respect to the reflector surface such that the second light distribution is a symmetrical light distribution. In particular, the second light distribution may be symmetrical to the symmetry axis or the symmetry plane of the reflector or the reflector surface. Alternatively or additionally, the second light distribution may be an asymmetrical light distribution.

[0032] Thereby, the second light distribution can be provided with a particular shape and light is distributed equally over the illumination area. For example, in urban areas this may be preferred due to aesthetic reasons as well as for reducing the number of lighting devices required to illuminate a large space.

[0033] According to a further preferred embodiment of the present invention, the reflector surface may comprise at least one light redirecting element to alter (locally) the light path of the light incident on the light redirecting element. Preferably, the light redirecting element may be formed such that the second light distribution is a uniform light distribution. Thereby, the visual comfort can be increased. Moreover, the light redirecting element may be formed such that the light being directed to the illumination area is equally distributed, in particular (locally) equally distributed over the illumination area. Alternatively or additionally, the light redirecting element may be provided within at least one, more, or all of the different portions of the reflector surface. The light redirecting elements may be formed by convex or concave shaped portions in or on the reflector surface. Additionally or alternatively, the light redirecting elements may be bowl shaped. The light redirecting elements may be calottes, e.g. with an inner radius of the calotte being in a range of 1 mm to 20 mm.

[0034] By providing the light redirecting element mentioned before, the light reflected by the reflector surface is mixed and distributed more uniformly. As a result, the second light distribution can be defined differently and in correlation to the illumination situation. For example, in urban areas it might be desirable to have an evenly spread light distribution rather than having an illuminated area with high and/or low contrast. Contrasts may be more desirable to accentuate features in public areas, such as historic sites or governmental buildings. With the present invention, either setting can be achieved.

[0035] The light redirecting elements may be provided integral with the reflector. Thereby, the number of parts in the lighting device can be reduced while improving the illumination properties of the lighting device. Moreover, as the lighting device is capable of illuminating different portions of the reflector, it is possible to switch between illumination of portions of the reflector surface that contain such redirecting elements or to purposely avoid such areas with light redirecting elements. Thus, the variability of setting a light distribution can be improved.

[0036] According to a preferred embodiment of the present invention, the reflector surface may be formed such that the light is directed in a direction different from the main light emitting direction. Preferably, the reflector surface is formed such that the light is directed away from the light source. Additionally or alternatively, the light may be directed towards at least one of the aforementioned peripheral edges of the reflector surface or the reflector. Alternatively or additionally, the reflector surface may be formed such that the light is directed in a direction towards the light source and substantially parallel to the main light emitting direction.

[0037] Thus, different illumination situations can be set flexibly and accurately depending on the surroundings of the lighting device and its purpose. Consequently, the lighting device has a high flexibility regarding its usage and a high cost saving potential.

[0038] According to a further preferential embodiment of the present invention, the light source may be a (electronically; e.g. preferably automatically) controllable light source. In particular, the light source may be configured to electronically and/or mechanically vary the first light distribution.

[0039] Thereby, it can be achieved that the illumination of the illumination area may be adjusted in accordance to a control. Thus, the lighting device can be used in a feedback system and it is possible to control the electric consumption of the lighting device by controlling the light source. In addition, the inrush current of the light source can be reduced and optimized such that the energy usage of the light source is improved and the heat emitting properties of the light source can be improved.

[0040] According to a preferred embodiment of the present invention, the light source may comprise a single lighting element or a group of such lighting elements. The lighting element may be an LED-element, an LED-string or an LED-array. The group of lighting elements may be arranged in a matrix or any other conceivable arrangement.

[0041] Thereby, the light source is provided with a flexible and economical lighting element so that costs for operating the lighting device can be reduced. Also, LED-elements can be controlled in a very simple and accurate manner. In addition, a number of different types of LED elements exist that can be selected depending on the illumination situation, such as LEDs with high luminous power or LEDs with low luminous power.

[0042] According to a further embodiment of the invention, the lighting device may comprise an optical element, such as a diffusor, for modifying the second light distribution. The optical element may be positioned with respect to the light source and to the reflector or the reflector surface such that the light, which is directed by the reflector surface towards the illumination area, passes directly through the optical element.

[0043] Thereby, an additional element is provided in the lighting device, by which the second light distribution can be adapted. The optical element may be used for changing the spectral composition of the light of the second light distribution. This improves the flexibility and variability of the lighting device even further.

[0044] According to a second aspect of the present invention, a lighting system for street lighting is provided, which comprises the aforementioned lighting device of the present invention, and a control unit for controlling the first light distribution.

[0045] The lighting system allows controlling and adapting the first light distribution of the light source. For example, it is possible to control the first light distribution in real time to improve reaction times of the adjustment of the illumination situation. Moreover, the lighting system has the same advantages and technical benefits as the aforementioned lighting device.

[0046] According to a preferred embodiment of the lighting system, the lighting system or the control unit may comprise a connection interface unit for receiving an external signal, whereby receipt of the external signal can be done via a cable or wirelessly.

[0047] Thus, information, control data or any type of signal can be transmitted to the lighting system and evaluated by the controller. Thus, additional information can be provided for the control. In addition, it is possible to provide a remotely controllable system.

[0048] Preferably, the lighting system may comprise a sensor unit. The sensor unit may be a presence sensor, a camera or a light sensor or a combination of any of the aforementioned sensors. The sensor unit is provided for detecting illumination information, which may include information about outside light, environmental information or presence of objects or humans. The illumination information may comprise information about detection of movement around the lighting system. The lighting system may be configured to automatically detect a change in surface conditions of the illumination area. The control unit may be configured to adapt the first light distribution in correspondence with control information. Such control information may be weather conditions, traffic conditions, changes in surface conditions of the illumination area and/or an external control signal.

[0049] By providing the lighting system with a sensor unit, the lighting system is capable of autonomous control as the control conditions can be established independently from externally provided information. Moreover, the information acquired by the lighting system represents more accurately the lighting situation in comparison to information collected by a sensor further afield. Thus, the effect of reducing energy consumption and adapting the illumination situation spontaneously and suitably can be improved.

[0050] According to a third aspect of the present invention, a method for adapting the light distribution of a lighting device for street lighting is provided. The method comprises the steps of providing the lighting system described before and a step of adapting the second light distribution by varying the first light distribution of the light emitted from the light source such that different portions of the reflector surface are illuminated in correlation to control information. The control information may be weather conditions, traffic conditions and/or changes in surface conditions of the illumination area.

[0051] With this method the same benefits and advantages over known solutions of the prior art can be achieved as described before for the lighting device and the lighting system.

[0052] Further features, advantages and objects of the present invention will become apparent for the skilled person when reading the following detailed description of embodiments of the present invention and when taking in conjunction with the figures of the enclosed drawings. In case numerals have been omitted from a figure, e.g. for reasons of clarity, the corresponding features may still be present in the figure.

Fig. 1	shows a first embodiment of a lighting device according to the present invention.
Fig. 2	shows a cross section of the lighting device of Fig. 1.
Fig. 3	shows a second embodiment of lighting device of the invention.
Fig. 4A, 4B	show two different configurations of an embodiment of a light source according to the present invention.
Fig. 5A, 5B	show light distributions of a lighting device of Fig. 3 when using different light distributions of the light source.
Fig. 6	shows light distributions of the lighting device of the invention resulting from different light distribu-

tions of the light source.

Fig. 7 shows an embodiment of a light redirecting element.

Figs. 8A, 8B show light distributions of a lighting device having a reflector with or without light redirecting elements of Fig. 7.

Figs. 9A, 9B show a third embodiment of a lighting device of the present invention with a reflector without redirecting elements of Fig. 7 and illustrate its resulting light distribution.

Figs. 10A, 10B show the lighting device from Fig. 9 with a reflector having light redirecting elements and show its resulting light distribution.

Fig. 11 shows an embodiment of a sensor unit of the present invention.

Fig. 12 shows an embodiment of a lighting system of the invention.

Figs. 13A to 13D shows an example for adapting the light distribution of a lighting device of the invention based on road conditions.

Figs. 14A, 14B shows an example for adapting the light distribution of a lighting device of the invention based on weather conditions.

[0053] Figures 1 to 14 show different aspects and embodiments of the present invention.

[0054] According to a first aspect of the present invention, a lighting device 100 for road and/or street lighting is provided. Figures 1, 2, 3, 5, 9A and 10A show different embodiments of the lighting device 100.

[0055] The lighting device 100 comprises a light source 300 for emitting light with a first light distribution LD1 in a main light emitting direction 310. The light source 300 and its corresponding main light emitting direction 310 are exemplarily illustrated in Figures 1 to 3, 5A, 5B, 9A and 10A.

[0056] The light source 300 may comprise a single lighting element 331 or a group of lighting elements 331. This is exemplarily displayed in Figures 4A and 4B. The lighting elements 331 may be an LED-element, an LED-string or an LED-array. The lighting elements 331 may be grouped together. For example, in Figures 4 the lighting elements 331 are arranged in a matrix. The lighting elements 331 may be placed on a board 330, which may be mounted in the lighting device 100. Moreover, the lighting elements 331 may be connected to a supply unit (not displayed), by which the lighting elements 331 may be supplied with electric energy. Such a supply unit may be a (controllable) LED-driver. However, the light source 300 is not restricted to an LED as light emitting element 331. Instead, light bulbs may be used, for example.

[0057] The light source 300 may be provided as a single light source 300 or may be provided with several separate light sources 300. This is exemplarily illustrated in Figure 3, which shows two separate light sources 301, 302. The light sources 301, 302 may be the same or different from each other, for example, regarding their light emitting properties, their orientation or main light emitting direction 310, their type of light emitting element 311 or emission spectrum.

[0058] The lighting device 100 further comprises a reflector 200, by which the light from the light source 300 is directed towards an illumination area IA,

[0059] Figures 1 to 3 and 8 to 10 show different embodiments of the reflector 200. The reflector 200 may have a curved, domed or at least partially spherical shape. However, the reflector 200 is not restricted to these shapes, but can have any other form, for example, a cubic or conic form. In particular, the reflector 200 may be designed as a freeform. The reflector 200 may also have a symmetrical or an asymmetrical shape. For example, the reflector 200 may be mirror symmetrical with respect to a symmetry axis SA or a symmetry plane SP. The symmetry axis SA may be orthogonal to the main light emitting direction 310. This is exemplarily illustrated in Figures 2, 3 and 6. The symmetry plane SP may be at least parallel and also preferably, be orthogonal to the main light emitting direction 310. A projection of the symmetry plane SP is illustrated in Figures 3 and 6.

[0060] The reflector 200 may have a cover side 210, which faces away from the light source 300 and may be provided for covering the lighting device 100 to the outside. For example, it is conceivable that the reflector 200 forms at least a part of a housing of the lighting device 100. The reflector 200 may be of any material, like metal or plastic. The reflector 200 may be provided as one part or as multiple parts connected to each other. The reflector 200 in Figures 1, 3, 8, 9 and 10 is illustrated as a single part.

[0061] The reflector 200 comprises a reflector surface 220, by which the light from the light source 300 is directed towards an illumination area IA with a second light distribution LD2. This is exemplarily illustrated in Figures 1, 2, 9 and 10.

[0062] The reflector surface 220 may be provided on a side surface of the reflector 200 that faces towards the light source 300. The reflector surface 220 may be defined by peripheral edges 221 of the reflector 200 that may surround the reflector surface 220 and/or be circumferential with the reflector 200. This is exemplarily illustrated in Figures 2 and 8. The reflector surface 220 may have a symmetrical or an asymmetrical shape. Therein, the shape of the reflector surface 220 may be independent from or coupled with the shape of the reflector 200. In particular, the reflector surface 220 may be provided as a freeform. The reflector surface 220 may comprise a coating or other means to improve light reflectivity. The reflector 200 and the reflector surface 220 may be integrally provided or they may be different parts connected to each other.

[0063] The reflector 200 is positioned in front of the light source 300 along the main light emitting direction 310. This is exemplarily illustrated in Figures 1 to 3, 9A and 10A.

[0064] Preferably, the reflector surface 220 and the light source 300 are each fixed in their relative position to each other. Thus, the reflector 200/the reflector surface 220 may be statically provided with respect to each other. Additionally or alternatively, the reflector 200 and the light source 300 may be arranged such that all of the light emitted from the light source 300 is directly received on the reflector surface 220. This is exemplarily illustrated in Figures 1 to 3, 5, 9A and 10A. In particular, there is no additional element provided between the light source 300 and the reflector 200/the reflector surface 220. The reflector 200 may be positioned with respect to the light source 300 such that the light thereof is reflected from the reflector surface 220 in a direction substantially opposite to the main light emitting direction 310. This is exemplarily illustrated in Figures 1, 2 and 5. The light source 300 may be positioned below the reflector surface 220 and between the peripheral edges 221 when viewed in a direction along the main light emitting direction 310. This is exemplarily displayed in Figures 1 and 5. Preferably, the light source 300 may be positioned in the middle of the peripheral edges 221 of the reflector surface 220 along an axis, for example the symmetry axis SA, orthogonal to the main light emitting direction 310. This is exemplarily illustrated in Figures 1, 2, 9A and 10A.

[0065] If more than one light source 300 is provided, the light sources 300 may be provided with respect to the reflector 200 such that the light sources 300 are arranged symmetrical to each other or evenly distributed. A symmetrical arrangement of the two light sources 301, 302 with respect to the reflector 200 is exemplarily illustrated in Figures 3 and 5. Alternatively or additionally, the light sources 300 may be arranged in a regular, circular or line pattern, for example when viewed in a direction opposite to the main light emitting direction 310. However, the light sources 300 may be distributed arbitrarily or unevenly with respect to the reflector surface 220 also.

[0066] Moreover, the light source 300 is configured to vary the first light distribution LD1 for illuminating different portions of the reflector surface 220. This is exemplarily illustrated in Figures 5 and 9.

[0067] Therein, the light source 300 may be configured to vary the first light distribution LD1 by varying light distribution characteristics. The light distribution characteristics may be parameters, by which the light emitted from the light source 300 may be defined. Preferably, the light source 300 may be a controllable light source 300 to vary at least the light distribution characteristics.

[0068] For example, the light distribution characteristics may be the light source's 300 effective light emitting area, an angle of the main light emitting direction 310 with respect to the reflector 200 or to the reflector surface 220, and/or a relative position of the light source 300 with respect to the reflector 200 or to the reflector surface 220. However, this enumeration of the light distribution characteristics is not complete and the light distribution characteristics may comprise also additional parameters, such as spectral composition of the light. Figure 4 illustrates exemplarily, how the first light distribution LD1 of the light source 300 may be varied.

[0069] In Figure 4, the light source 300 is provided as an electronically controllable light source 300. For example, the control of the light source 300 may be effected by activating and deactivating different lighting elements 331 by changing their energy supply. In Figure 4A, indicated by dashed lines, the light source 300 is divided in four sections (groups) of lighting elements 331, each section forming a channel 341-344 of the light source 300. Each channel 341-344 may be separately controllable. By changing activation of one or more of the channels 341-344, the relative position of the light source 300 with respect to the reflector surface 220 may be varied. Also, the effective light emitting area of the light source 300 may be varied, for example, if activation of channels 341 and 344 is changed to activating only channel 342.

[0070] Figure 4B shows an alternative configuration of the light source 300, in which the lighting elements 331 are grouped only in two channels 341, 342. This is also indicated by dashed lines. In particular, the channels 341, 342 are arranged symmetrical with respect to a channel axis 350.

[0071] Thus, it is clear that the light source 300 of Figure 4A can vary the first light distribution LD1 more accurately than the light source 300 of Figure 4B. However, the complexity and the costs of designing and controlling the respective light source 300 can be reduced with the light source 300 of Figure 4B compared to the one of Figure 4A. Generally, it is also conceivable that the light source 300 may be configured to mechanically vary the first light distribution LD1.

[0072] Thus, the light source 300 may be provided such that varying the light distribution characteristics is accomplished without additional components interfering with the light being emitted from the light source. In particular, the light source 300 may be provided such that the first light distribution LD1 is varied independently from additional mechanical and/or optical components, such as light shades, meshes, lenses, reflectors and/or mirrors.

[0073] Moreover, the reflector 200 is provided with respect to the light source 300 such that the second light distribution LD2 of the light illuminating the illumination area IA is defined differently depending on the portions of the reflector surface 220 illuminated with the light of the first light distribution LD1. This is exemplarily illustrated in Figures 5, 6, 13 and 14.

[0074] Figure 6 illustrates the technical effects of this feature. The second light distribution LD2 is defined differently by setting the first light distribution LD1 differently. For example, the second light distribution LD2 may be set to illuminate different areas of the illumination area IA. The second light distribution LD21 illuminates primarily a strip of a road while keeping the light away from the road's pavement and its surroundings. The second light distributions LD22 and LD23, however, illuminate a substantially V-shaped area including the pavement on both sides of the road. Thus, it is apparent that the lighting device 100 allows optimizing illumination of a surface with high positional accuracy. Moreover, it is also possible to define the light distribution characteristics of the second light distribution LD2 with this feature. For example, the direction of the light with the second light distribution LD2 may be varied depending on the application. For example, the angle of light may be varied. The high flexibility of the lighting device 100 is a result of its capability to define the second light distribution LD2 differently to the first light distribution LD1 by accordingly defining the portions of the reflector surface 220 in this regard.

[0075] The light source 300 may be positioned with respect to the reflector surface 220 such that the second light distribution LD2 is a symmetrical and/or an asymmetrical light distribution. In particular, the second light distribution LD2 may be symmetrical with respect to the symmetry axis SA or the symmetry plane SP of the reflector 200 or the reflector surface 220. This is exemplarily displayed in Figure 6. For example, the distance between the light source 300 and the reflector surface 220 may be set correspondingly to the shape of the reflector surface 220. Moreover, the position of the light source 300 relative to the reflector surface 200 in a plane substantially perpendicular to the main light emitting direction 310 may be adapted also in correspondence to the shape of the reflector surface 220 or, for example, depending on the design requirements on the second light distribution LD2.

[0076] In particular, the reflector surface 220 may have a form, by which the light from the light source 300 is directed in a direction towards the light source 300 and substantially parallel to the main light emitting direction 310. This is exemplarily illustrated in Figures 1, 2 and 5.

[0077] Moreover, the reflector surface 220 may be formed such that the light is directed in a direction different from the main light emitting direction 310, preferably away from the light source 300. Also, the light may be directed towards at least one of the peripheral edges 221 of the reflector 200 or the reflector surface 220. This is illustrated, for example, in Figures 9A and 10A. However, it is also conceivable that the reflector surface 220 comprises a design that combines the aforementioned two shapes of the reflector surface 220.

[0078] Figures 1, 2 and 8 exemplarily show a first embodiment of the reflector 200, 201. The reflector 201 may be bowl shaped and comprise at least three distinguishable portions. A first portion may raise substantially linearly from an edge of the reflector 201, preferably the peripheral edge 221, towards a second portion that is spherical and forming a middle portion of the reflector 201. A third portion being connected to the second portion may have a curved shape extending towards a further edge of the reflector 200, preferably the peripheral edge 221. The second light distribution LD2 may be varied depending on the portion being illuminated by the light of the light source 300. For example, as illustrated in Figures 1 and 2, the light with the first light distribution LD1 may illuminate the second portion, having a spherical shape, such that the light is primarily reflected towards an area in front of the reflector 200 along a direction substantially reverse to the main light emitting direction 310. However, by illuminating the first or the third portion of the reflector 200, the second light distribution LD2 is defined differently (not illustrated). However, this embodiment of the reflector 200 is only an example and not to be understood as delimiting the present invention.

[0079] Figure 3 exemplarily shows a second embodiment of the reflector 200, 202. The reflector 202 may have a shape of the character "eight" (in a top view) and preferably comprises three portions. A first and third portion may have substantially an identical or similar shape to each other. The first and third portion may be connected via the second portion, which may be smaller in height and width compared to the other two portions (first and third portion). By varying the light from the light sources 301, 302 the portions of the reflector 200 allow to vary the second light distribution of the lighting device 100. Naturally, this embodiment is only an example and not to be understood as delimiting for the present invention.

[0080] Figures 9A and 10A exemplarily show a third embodiment of the reflector 200, 203. The reflector 203 may comprise three portions, of which two outer portions may be substantially identical and a third, preferably middle, portion may form a cone, under which preferably, when viewed along the main light emitting direction, the light source 300 is positioned. Thus, when primarily illuminating the first portion of the reflector 200 the light may be distributed equally around the lighting device 100 while mainly omitting illumination of the area directly underneath the lighting device 100. However, when the second light distribution LD2 may be changed illuminating any or all of the other two portions. Naturally, this embodiment is only an example and not to be understood as delimiting for the present invention.

[0081] Thus, the shape of the reflector 200 may be configured to correspond with the type and/or the light emitting properties of the light source 300. In addition, the relative position of the light source 300 with respect to the reflector 300 may be aligned with the shape of the reflector 200 or vice versa.

[0082] Furthermore, the reflector surface 220 may comprise at least one light redirecting element 251 for altering the light paths of light that is incident thereon. The light redirecting element 251 may be provided within at least one, more or all of the different portions of the reflector surface 220. Figure 7 shows an example of the light redirecting element 251.

[0083] In Figure 7, the light redirecting element 251 is a tapered or cone shaped protrusion from the reflector surface 220 towards the light source 300. Thus, the light redirecting element 251 may have a substantially triangular cross section. However, the light redirecting element 251 may also have any other shape or cross section. In particular, the light redirecting element 251 may be formed by convex or concave shaped portions in or on the reflector surface 220. The light redirecting elements may be bowl shaped, for example as a protrusion from the reflector surface 220 towards the light source 300 or as a concave opening in the reflector surface 220. The light redirecting element 251 may have the shape of a calotte, preferably with an inner radius of the calotte in a range of 1 mm to 20 mm. Moreover, the light redirecting element 251 may be provided integrally with the reflector surface 220 or as a separate element that may be connected to the reflector 200 by holding forces, e.g. applied via glue or magnets.

[0084] Figures 8, 9B and 10B illustrate the effects of providing a multitude 250 of light redirecting elements 251 on the reflector surface 220.

[0085] For example, it can be found that the second light distribution LD2 of the reflector 200 with a smooth surface, as displayed in Figure 8A, may be more compact and elongated in comparison to the second light distribution LD2 that is obtained with a reflector 200 having the multitude 250 of light redirecting elements 251.

[0086] Similarly, in Figure 9B, the second light distribution LD2 relates to the reflector 200 without light redirecting elements 251 while the second light distribution LD2 of Figure 10B relates to the reflector 200 with the light redirecting elements 251. By comparing the two second light distributions LD2, it can be found that the light of the lighting device 100 is more evenly and more widely spread if the light redirecting elements 251 are used.

[0087] Thus, the light redirecting elements 251 may be formed and/or arranged such that the second light distribution LD2 is a uniform distribution, preferably such that the light being directed to the illumination area IA is locally equally distributed.

[0088] The lighting device 100 may further comprise an optical element 400, such as a diffusor, for modifying the second light distribution LD2. Figures 1, 3, 5, 9 and 10 show different examples for the optical element 400. The optical element 400 may be preferably positioned with respect to the light source 300 and the reflector 200/reflector surface 220 such that the light being directed by the reflector surface 220 passes directly through the optical element 400.

[0089] The light source 300 may be mounted on a mounting bracket 500. Figures 1, 3, 5, 9 and 10 show different examples 501-503 for the mounting bracket 500. The mounting bracket 500 may also be formed by the optical element 400. The mounting bracket 500 may be formed of a transparent or reflective material. The mounting bracket 500 may have a symmetrical, a rotationally symmetrical with respect to main light emitting direction 310 or an asymmetrical shape.

[0090] Preferably, the light source 300 is arranged on the mounting bracket 500 and/or the optical element 400 such that heat inside the lighting device 100 can be guided away efficiently. The reflector 200 may be provided with a mounting portion 212 for mounting the reflector 200 with the optical element 400 and/or the mounting bracket 500. The reflector 200 and the optical element 400 may form a housing of the lighting device 100. Preferably, the optical element 400 may be placed inside an opening of the reflector 200 that may form a light emissive surface/area of the lighting device 100.

[0091] According to a second aspect of the present invention, a lighting system 700 for street lighting is provided. In particular, the lighting system 700 comprises the aforementioned lighting device 100 and a control unit 710 for controlling the first light distribution LD1. This is exemplarily illustrated in Figure 12.

[0092] Figure 6, for example, may illustrate different illumination situations that are obtained by varying the first light distribution LD1.

[0093] The lighting system 700 or the control unit 710 may comprise a connection interface unit 720 for receiving an external signal, preferably via a cable 722 or wirelessly 721. For example, the connection interface unit 720 illustrated in Figure 12 may be a Bluetooth port, a wireless internet router or an optical data interface.

[0094] The lighting system 700 may further comprise a sensor unit 730 for detecting illumination information. The illumination information may include information about sun or outside light, environmental information, presence of objects 800, such as vehicles like cars, or humans, and/or if movement within the illumination area IA has been registered. The sensor unit 730 may therefore comprise a presence sensor or a camera 731. Alternatively or additionally, the sensor unit 730 may comprise a light sensor. Figure 11 illustrates schematically how the sensor unit 730 may be formed by combing different types of sensors to obtain a single multifunction luminance sensor 731.

[0095] By providing the lighting system 700 with the sensor unit 730, automatic detection of a change in road surface conditions 753 of the illumination area IA may be accomplished. As shown in Figure 12 exemplarily, the camera 731 may be used thereto. For example, a characterization of the road surface conditions 753 may be made based on a correlation between a measured luminance level and a height h of mounting the lighting device 100 above the illumination area IA.

[0096] Moreover, the control unit 710 may be configured to adapt the first light distribution LD1 in correspondence with the illumination information and/or control information. For example, the control information may be based on the illumination information. The control information may be derived from weather conditions 751, traffic conditions 752 or changes in road surface conditions 753 of the illumination area IA. Alternatively, the control information may be an external control signal.

[0097] For example, the road surface conditions 753 may change over time. This is exemplarily displayed in Figure 13. Therein, it is illustrated how the road surface condition 753 changes from a road being of a standardized type R4 with high surface reflectivity, which is typically the case immediately after building the road, to a road being of type R1 with low surface reflectivity. Thereby, it is exemplarily illustrated that having information about the road surface conditions 753 (by measurement and/or by provision as external information) and having the control unit 710 allow to adapt the second light distribution LD2 the light emitted from the lighting device 100 to changes of the road. Thereby, it is possible to save energy as an initially needed high light output can be reduced over time to a lower light output. Thus, reducing the overall energy consumption is possible.

[0098] In addition, the road safety provided by the lighting system 700 can be improved. For example, as illustrated in Figure 14, the second light distribution LD2 can be adapted to the weather conditions 751. Thus, for example, the overall luminance can be kept uniformly despite the change in the illumination situation. Thus, the approach of the present invention may correspond at least partially with the Lumiroute approach of optimizing the luminance in correspondence with the road surface.

[0099] Moreover, the light system 700 may comprise multiple lighting devices 100 that are connected to each other. The different lighting devices 100 may be controllable by a single control unit 710 or each lighting device 100 may be controlled by a separate control unit 710. The control unit 710 may be configured to learn over time to adjust the lighting depending on acquired information, such as time stamp or sensor data.

[0100] According to a third aspect of the present invention, a method for adapting the light distribution of the lighting device 100 for street lighting is provided. The method comprises the steps of providing the aforementioned lighting system 700 and adapting the second light distribution LD2 by varying the first light distribution LD1 such that different portions of the reflector surface 220 are illuminated in correlation to the control information. Naturally, the method may also comprise any of the steps that may be derived from the description of the features of the lighting system 700 and the lighting devices 100. The present invention is not limited by the embodiments as described hereinabove, as long as being covered by the appended claims. All the features of the embodiments described herein above can be combined in any possible way and can be interchangeably provided.

Claims

1. Lighting device (100) for road and/or street lighting, comprising:

   - a light source (300-302) for emitting light with a first light distribution (LD1) in a main light emitting direction (310), and
   - a reflector (200-203), which is positioned in front of the light source (300-302) along the main light emitting direction (310), with a reflector surface (220) for directing the light from the light source (300-302) towards an illumination area (IA) with a second light distribution (LD2),

   wherein the light source (300-302) is configured to vary the first light distribution (LD1) for illuminating different portions of the reflector surface (220), and wherein the reflector (200-203) is provided with respect to the light source (300-302) such that the second light distribution (LD2) of the light illuminating the illumination area (IA) is defined differently depending on the portions of the reflector surface (220) illuminated with the light of the first light distribution (LD1).

2. Lighting device (100) according to claim 1, wherein the light source (300-302) is configured to vary the first light distribution (LD1) by varying light distribution characteristics, the light distribution characteristics preferably comprising at least one of the following: (effective) light emitting area of the light source (300-302), angle of the main light emitting direction (310) with respect to the reflector (200-203)/reflector surface (220), and/or relative position of the light source (300-302) with respect to the reflector (200-203)/reflector surface (220).

3. Lighting device (100) according to claim 1 or claim 2, wherein the reflector (200-203) is positioned with respect to the light source (300-302) such that the light thereof is reflected from the reflector surface (220) in a direction substantially opposite to the main light emitting direction (310), and/or
   wherein the reflector surface (220) and the light source (300-302) are relatively fixed to each other and/or arranged such that (all of) the light emitted from the light source (300-302) is directly received on the reflector surface (220).

4. Lighting device (100) according to any one of the preceding claims, wherein the reflector (200-203) has a curved, preferably domed or at least partially spherical shape, and/or
   wherein the reflector (200-20a)/reflector surface (220) is symmetrical, preferably mirror symmetrical with respect to a symmetry axis (SA) or a symmetry plane (SP), the symmetry axis (SA) being preferably orthogonal to the main light emitting direction (310), the symmetry plane (SP) being preferably at least parallel to the main light emitting direction (310).

5. Lighting device (100) according to any one of the

preceding claims, wherein the light source (300-302) is positioned between, preferably in the middle of, the reflector's (200-203)/reflector surface's (220) peripheral edges (221) when viewed in a direction along the main light emitting direction (310), and/or wherein the light source (300-302) is positioned with respect to the reflector surface (220) such that the second light distribution (LD2) is a symmetrical, preferably with regards to the symmetry axis (SA) or the symmetry plane (SP) of the reflector (200-203)/reflector surface (220), and/or an asymmetrical light distribution.

6. Lighting device (100) according to any one of the preceding claims, wherein the reflector surface (220) comprises at least one light redirecting element (250, 251) for preferably locally altering the light paths of light incident thereon,
wherein the light redirecting elements (250, 251) are formed such that the second light distribution (LD2) is a uniform distribution, preferably such that the light being directed to the illumination area (IA) is preferably locally equally distributed, and/or
wherein the light redirecting element (250, 251) is provided within at least one, more or all of the different portions of the reflector surface (220).

7. Lighting device (100) according to claim 6, wherein the light redirecting elements (250, 251) are formed by convex or concave shaped portions in or on the reflector surface (220), and/or
wherein the light redirecting elements (250, 251) are bowl shaped, and/or wherein the light redirecting elements (250, 251) are calottes, preferably with an inner radius of the calotte in a range of 1 mm to 20 mm.

8. Lighting device (100) according to any one of the preceding claims, wherein the reflector surface (220) is formed such that the light is directed in a direction different from the main light emitting direction (310), preferably away from the light source (300-302), and/or more preferred towards at least one of the peripheral edges (221) of the reflector (200)/reflector surface (220), and/or
wherein the reflector surface (220) is formed such that the light is directed in a direction oriented towards the light source (300-302) and/or (substantially) parallel to the main light emitting direction (310).

9. Lighting device (100) according to any one of the preceding claims, wherein the light source (300-302) is a controllable light source (300-302), and/or
wherein the light source (300-302) is configured to electronically and/or mechanically vary the first light distribution (LD1),
wherein the light source (300-302) preferably comprises a single lighting element (331) or a group of lighting elements (331), which are preferably arranged in a matrix, wherein the lighting element (331) is preferably an LED-element, an LED-string or an LED-array.

10. Lighting device (100) according to any one of the preceding claims, wherein the lighting device (100) further comprises an optical element (400), such as a diffusor, for modifying the second light distribution (LD2), wherein the optical element (400) is preferably positioned with respect to the light source (300-302) and the reflector (200-203)/reflector surface (220) such that the light being directed by the reflector surface (220) passes (directly) through the optical element (400).

11. Lighting system (700) for street lighting comprising:

- the lighting device (100) according to any one of the preceding claims, and
- a control unit (710) for controlling the first light distribution (LD1).

12. Lighting system (700) according to claim 11, wherein the lighting system (700) or the control unit (710) comprises a connection interface unit (720) for receiving an external signal, preferably via a cable (722) or wirelessly (721).

13. Lighting system (700) according to any one of claims 11 or 12, wherein the lighting system (700) comprises a sensor unit (730), such as a presence sensor, a camera (731) and/or a light sensor, for detecting illumination information, which preferably includes information about natural light, environmental information, presence of objects (800) or humans, and/or registration of movement, and/or
wherein the lighting system (700) is configured to automatically detect a change in (road) surface conditions (753) of the illumination area (IA).

14. Lighting system (700) according to any one of claims 11 to 13, wherein the control unit (710) is configured to adapt the first light distribution (LD1) in correspondence with control information, such as weather conditions (751), traffic conditions (752), changes in surface conditions (753) of the illumination area (IA) and/or an external control signal.

15. Method for adapting the light distribution of a lighting device (100) for street lighting, comprising the steps of:

- providing the lighting system (700) according to any one of claims 11 to 14, and
- adapting the second light distribution (LD2) of the light being directed to the illumination area (IA) by varying the first light distribution (LD1) of

the light emitted from the light source (300-302) such that different portions of the reflector surface (220) are illuminated in correlation to control information, such as weather conditions (751), traffic conditions (752), and/or changes in surface conditions (753) of the illumination area (IA).

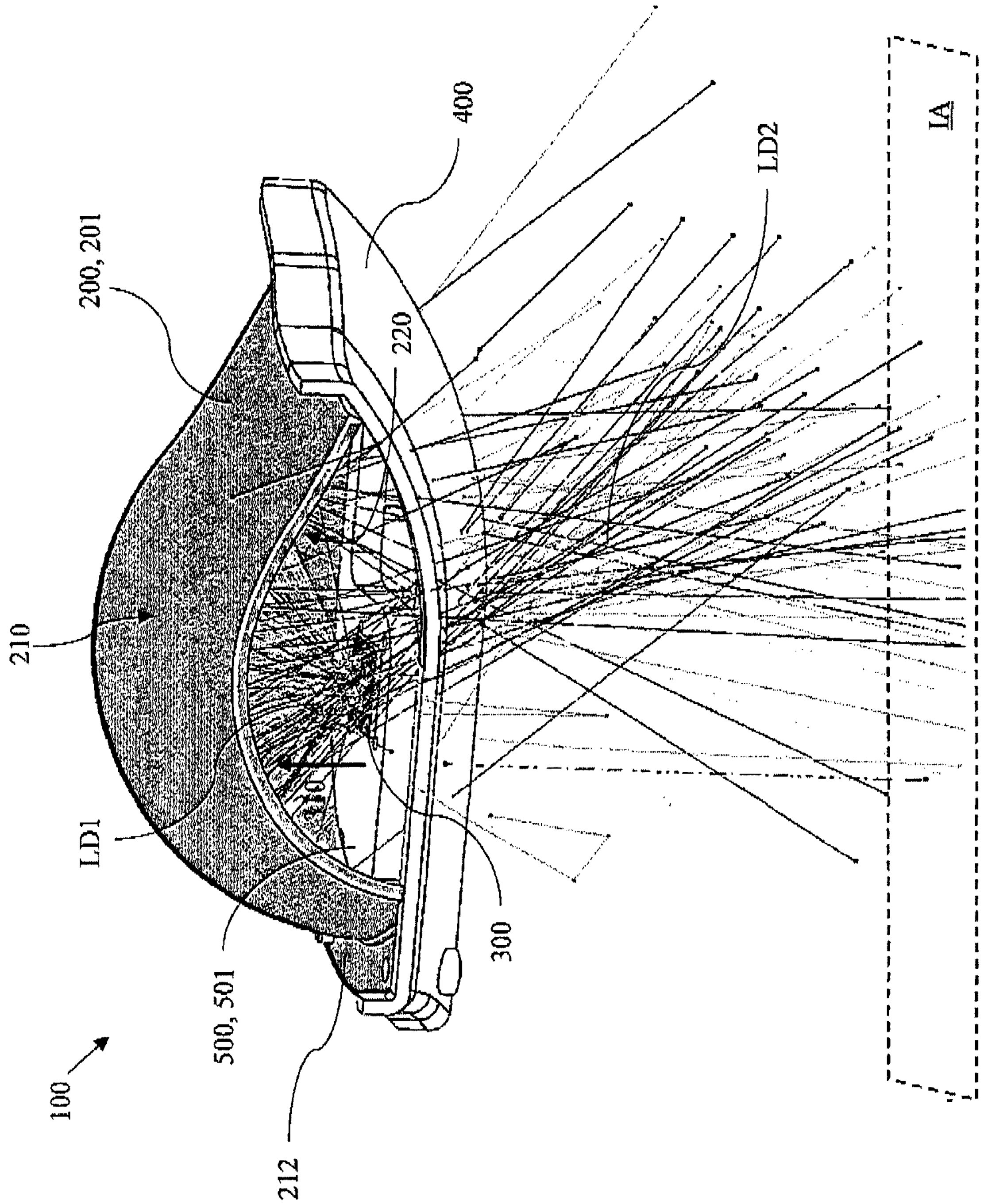

FIG 1

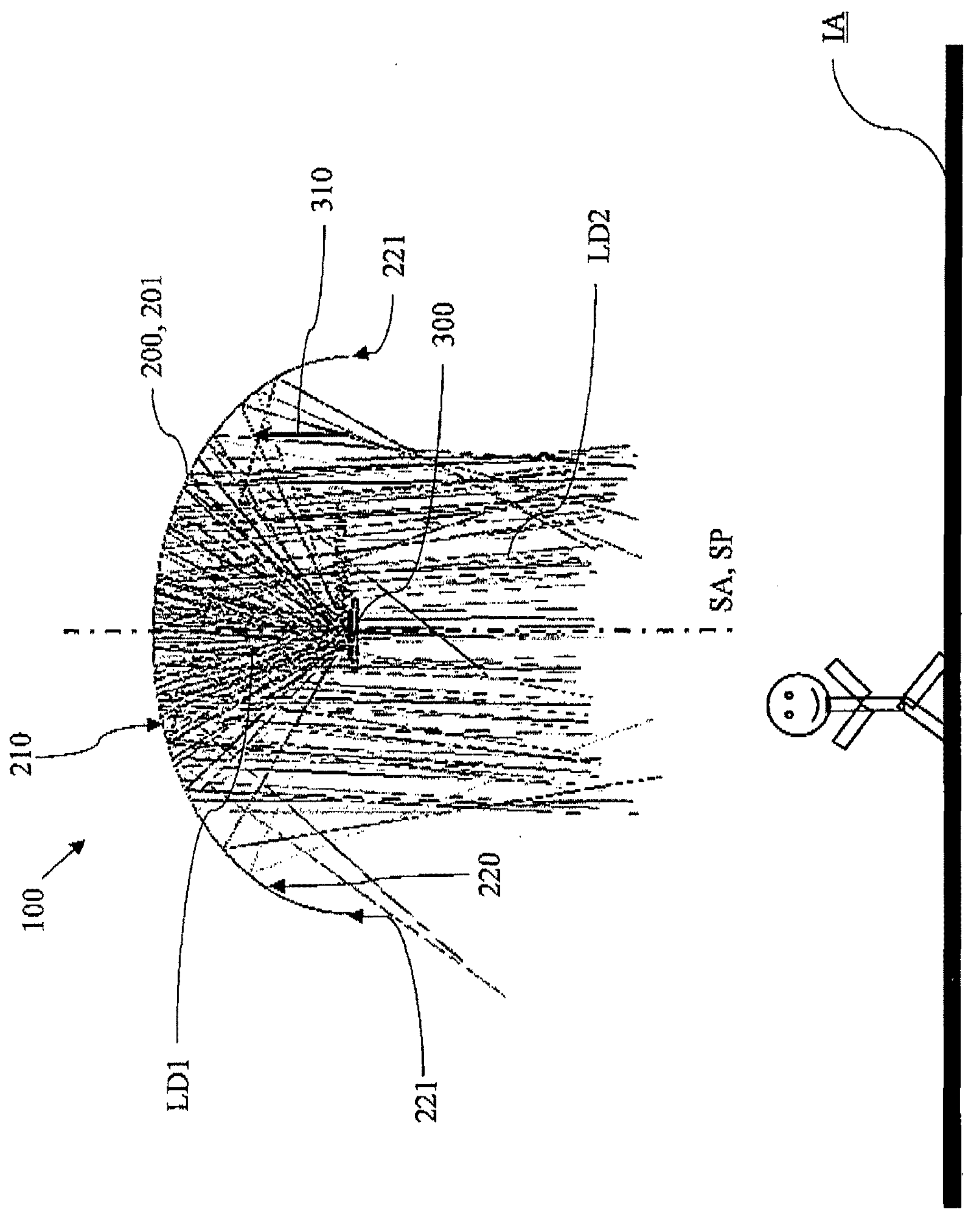

FIG 2

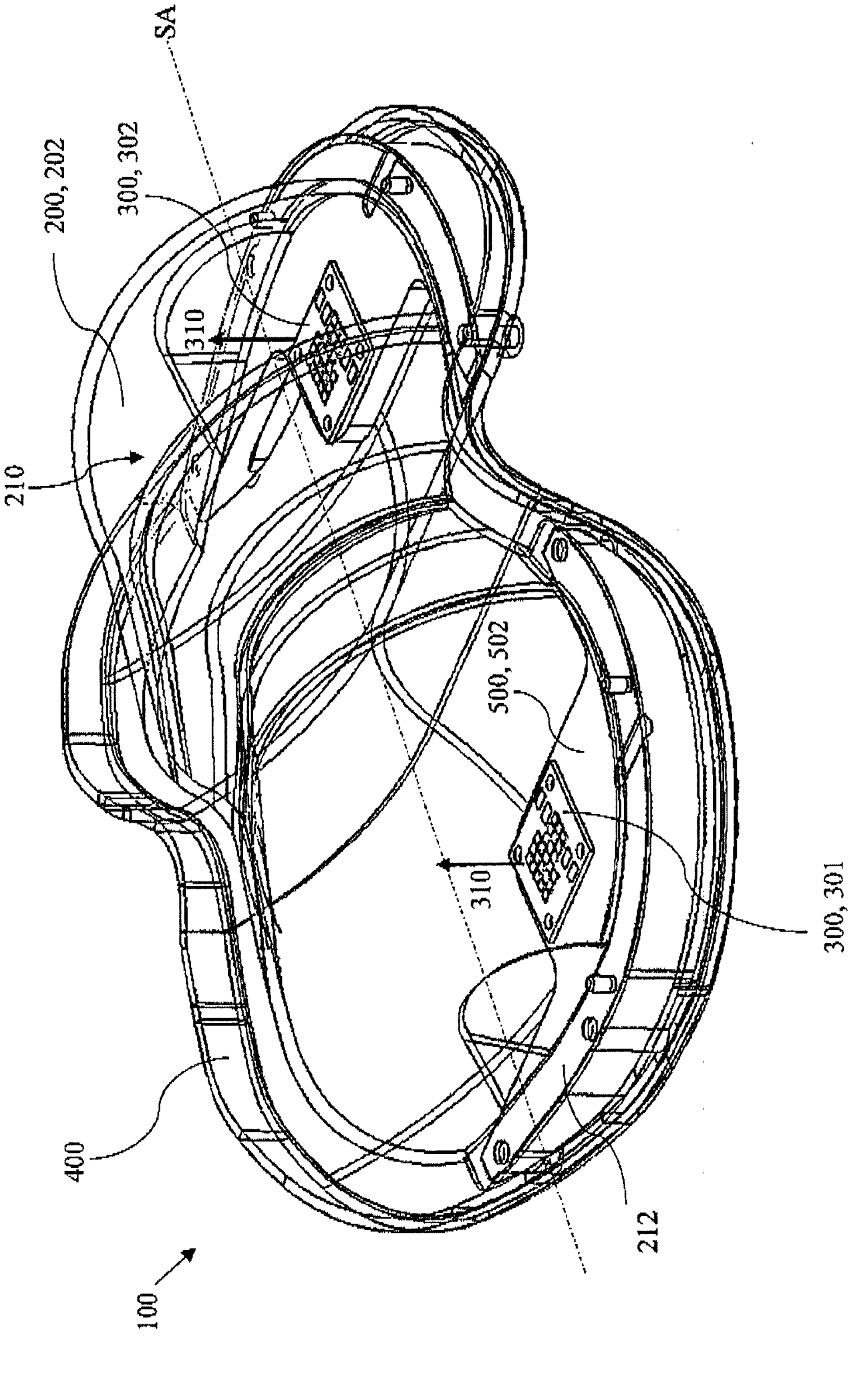

FIG 3

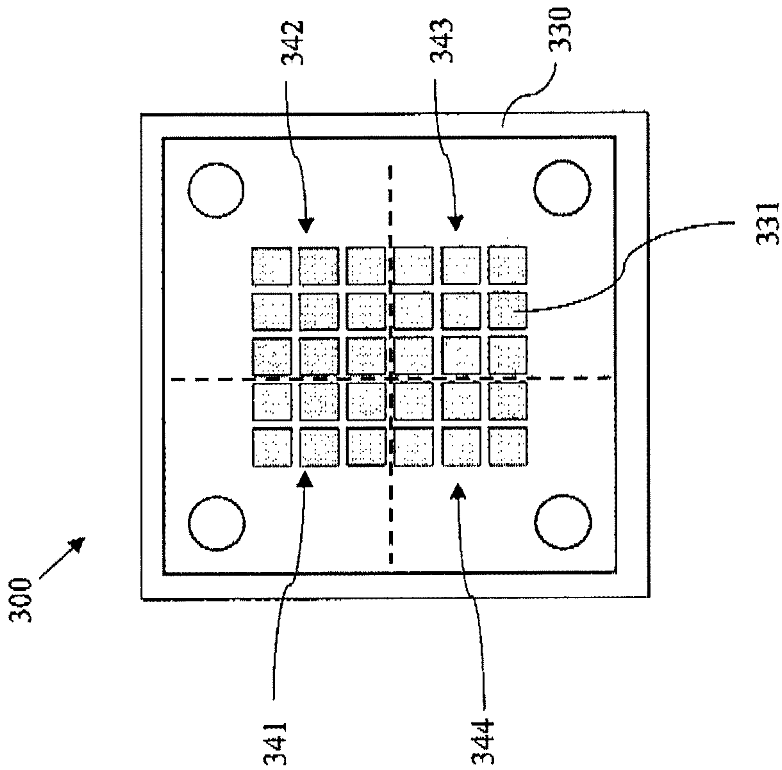

FIG 4A

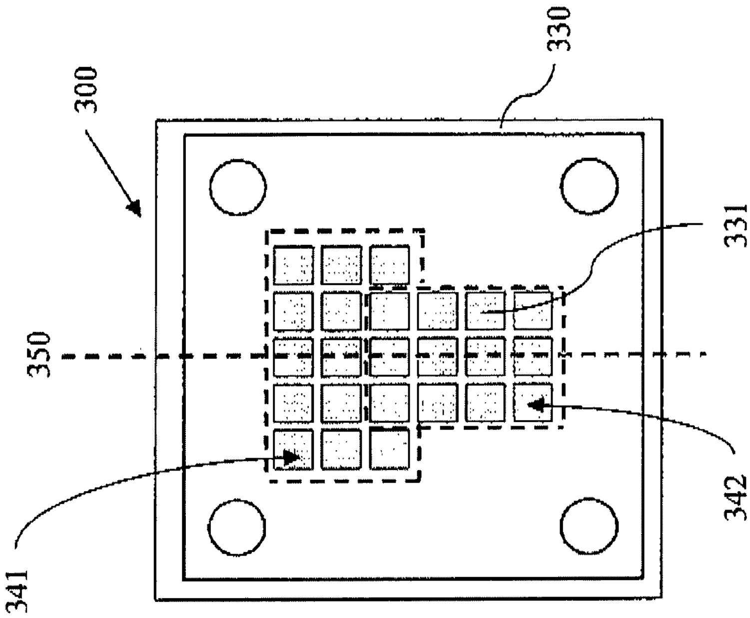

FIG 4B

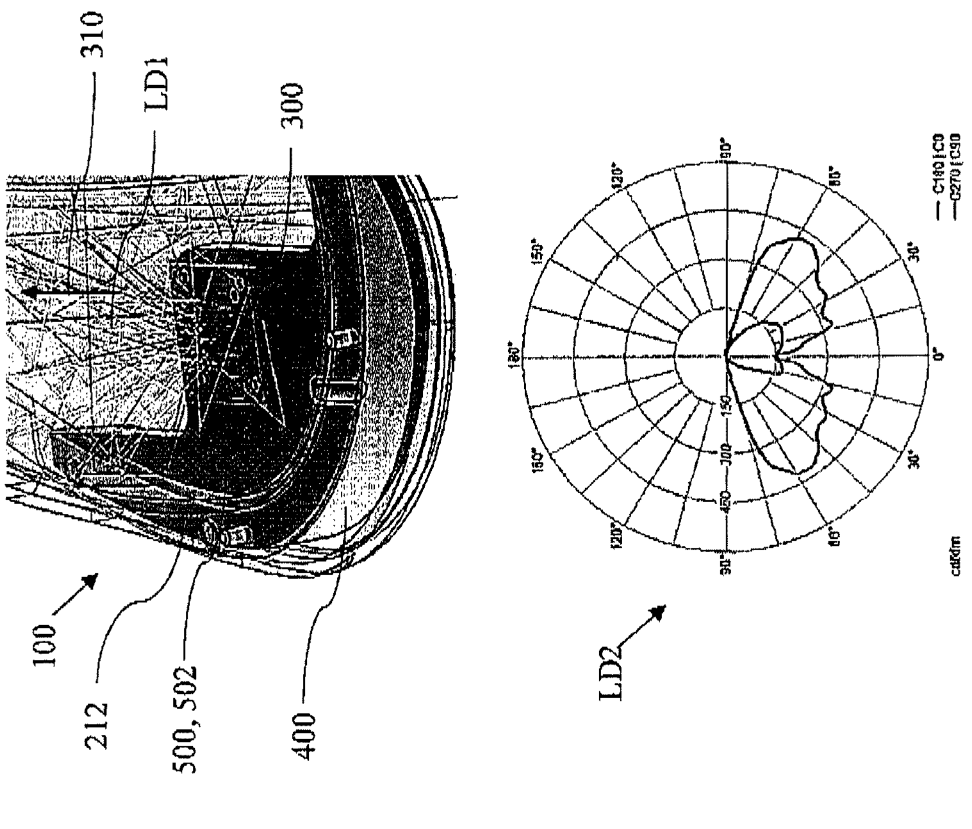
100
310
LD1
300
212
500, 502
400
LD2
cd/klm
— C180 | C0
— C270 | C90

FIG 5A

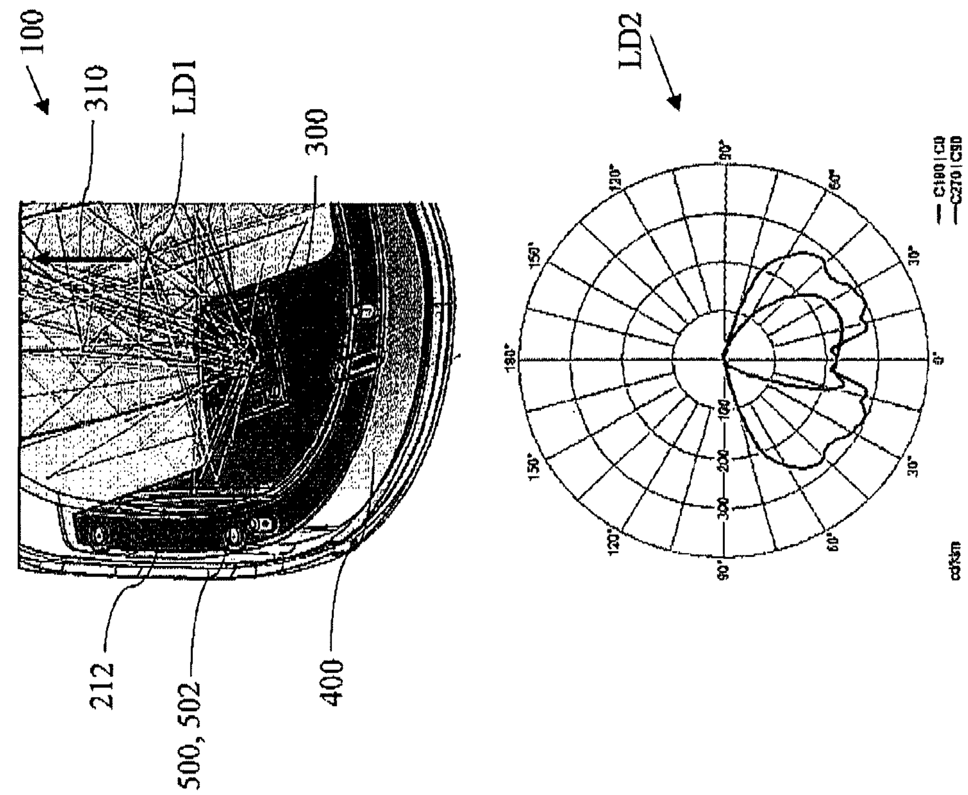
100
310
LD1
300
212
500, 502
400
LD2
cd/klm
— C180 | C0
— C270 | C90

FIG 5B

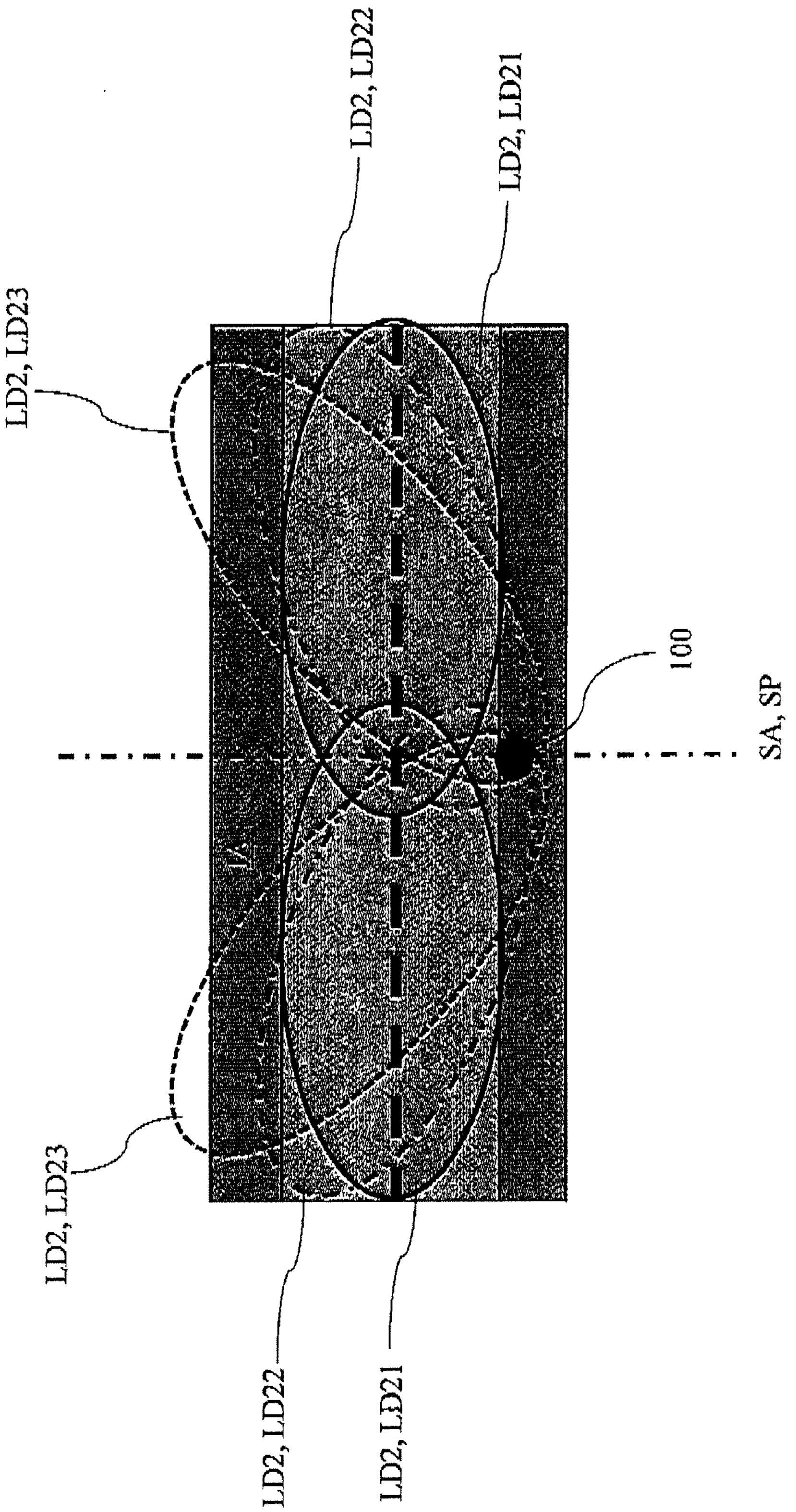

FIG 6

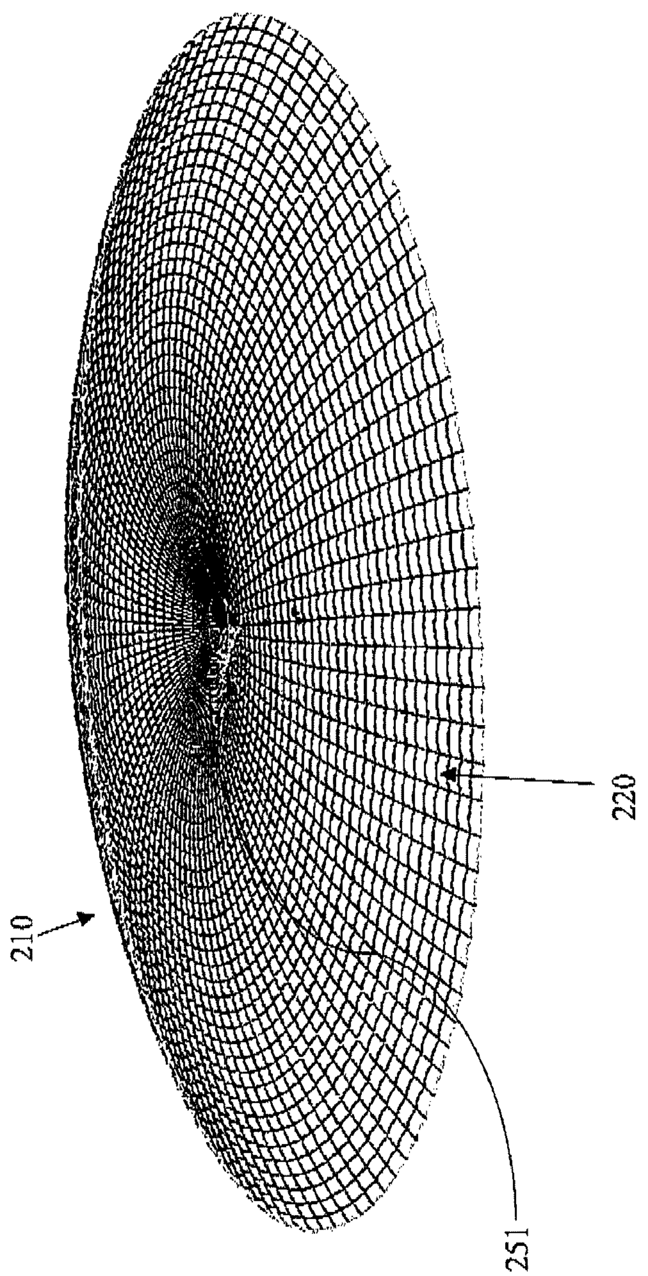

FIG 7

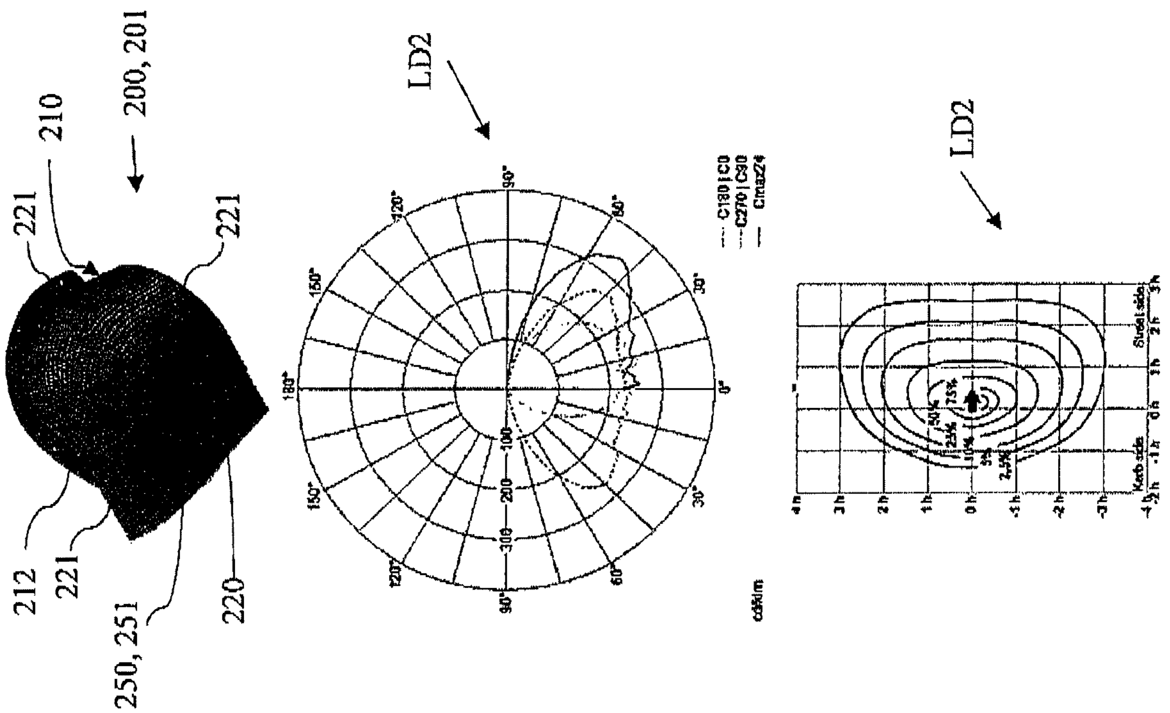
221
210
200, 201
221
212
221
250, 251
220
LD2
90°
120°
150°
180°
150°
120°
90°
60°
30°
0°
30°
60°
100
200
300
cd/klm
C180 | C0
C270 | C90
Cmax24
LD2
Kerb side
Street side
75%
50%
25%
10%
5%
2,5%

FIG 8B

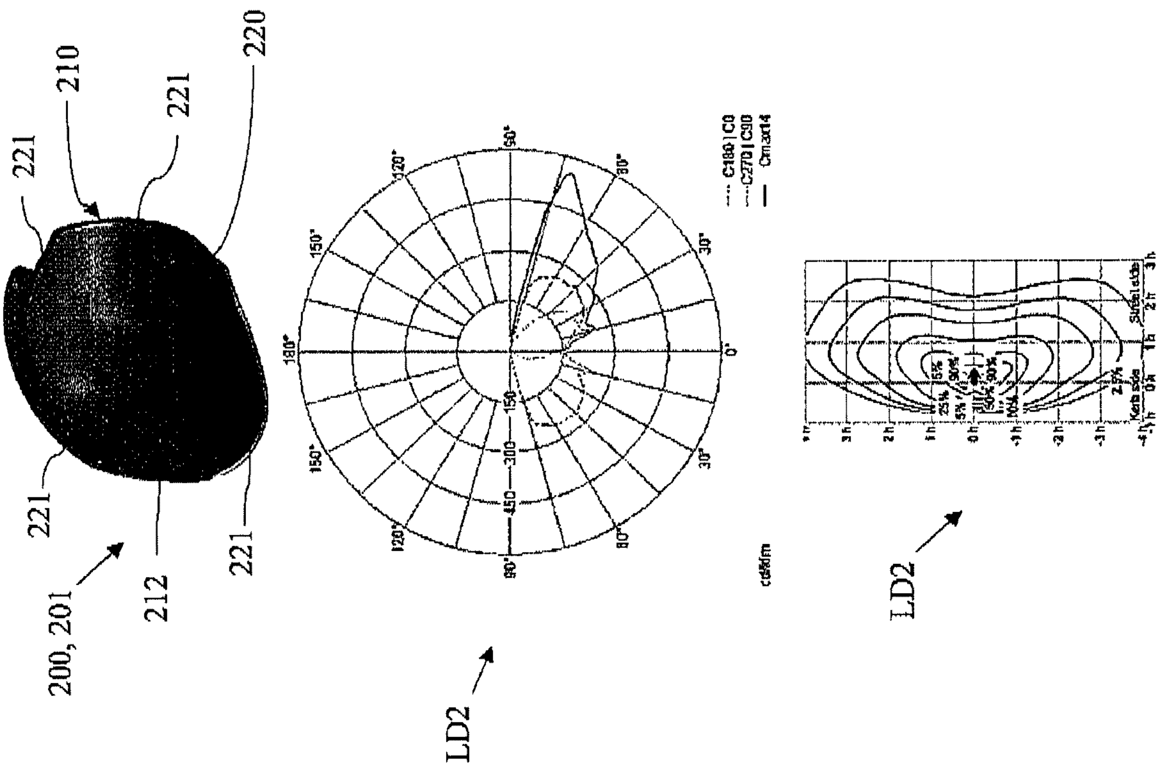
221
210
221
220
221
200, 201
212
221
LD2
90°
120°
150°
180°
150°
120°
90°
60°
30°
0°
30°
60°
150
300
450
cd/klm
C180 | C0
C270 | C90
Cmax14
LD2
Kerb side
Street side
2,5%
5%
25%
50%
90%

FIG 8A

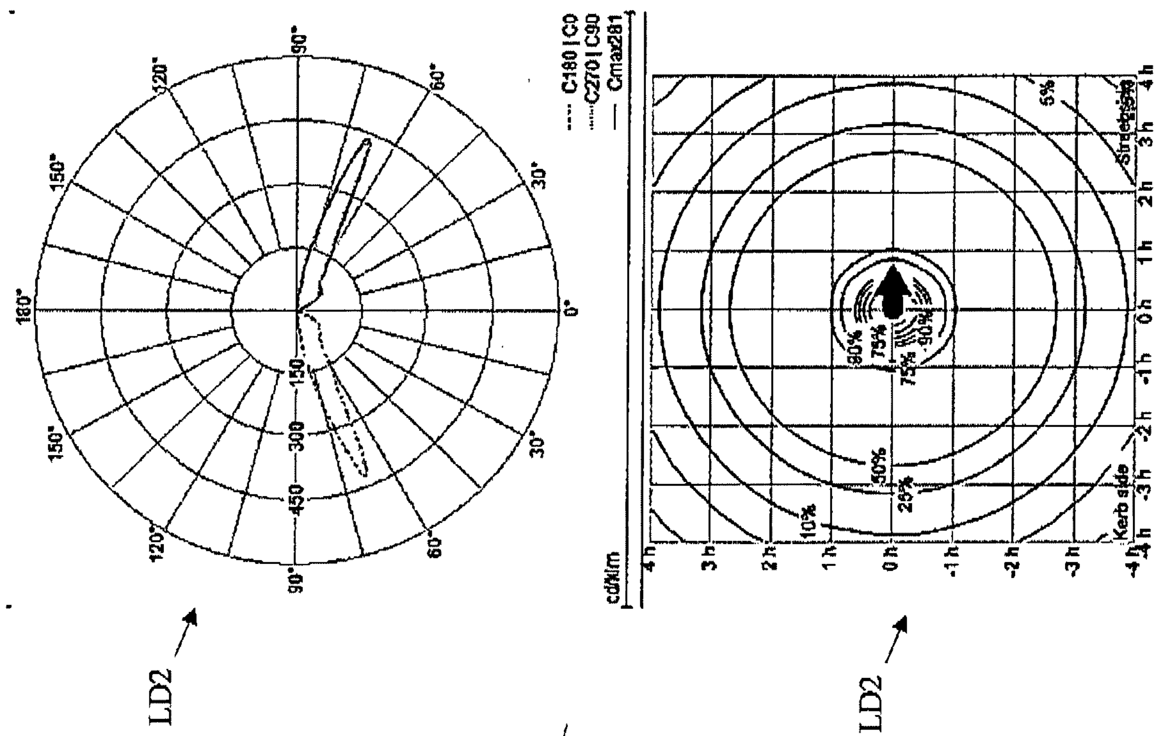
LD2
LD2
90°
120°
150°
180°
0°
30°
60°
150
300
450
C180 | C0
C270 | C90
Cmax281
cd/klm
Kerb side
Streetside
10%
25%
50%
75%
80%
90%
5%

FIG 9B

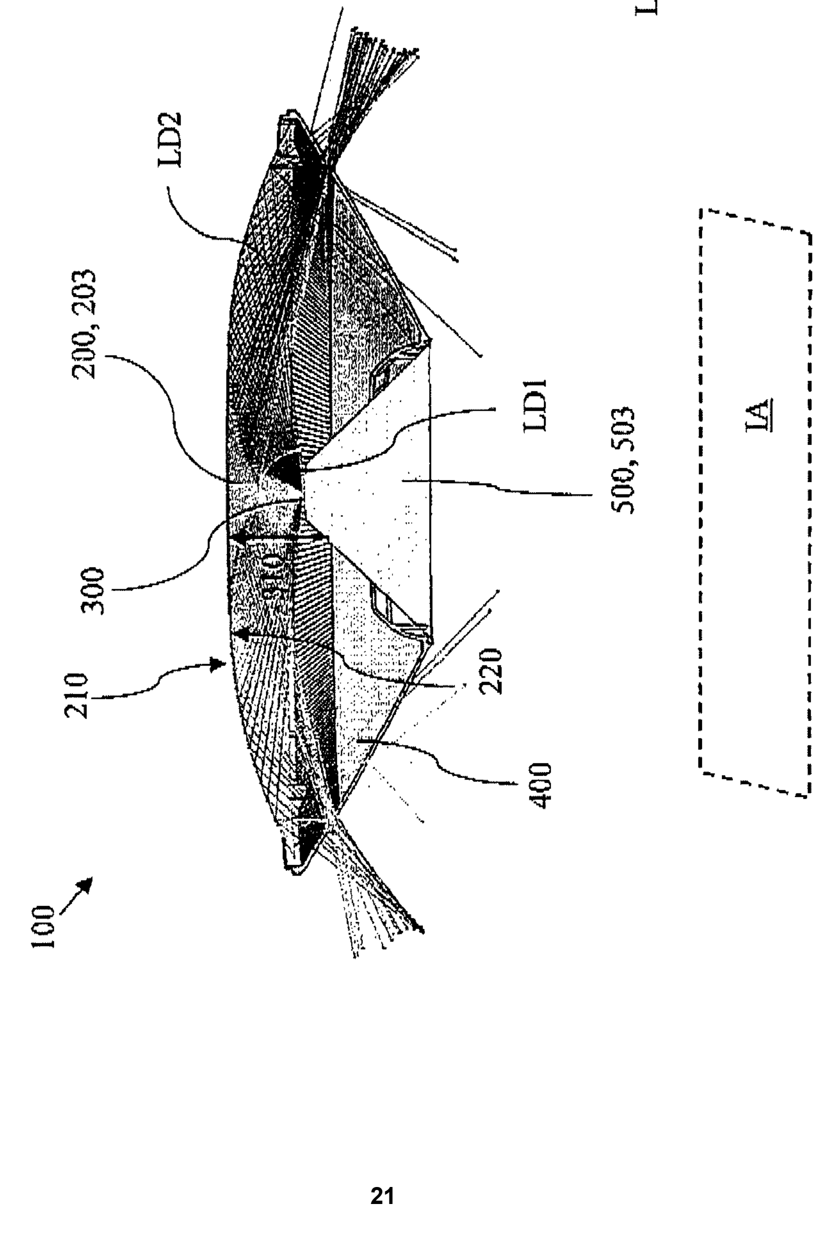
100
210
300
310
220
400
200, 203
LD2
LD1
500, 503
IA

FIG 9A

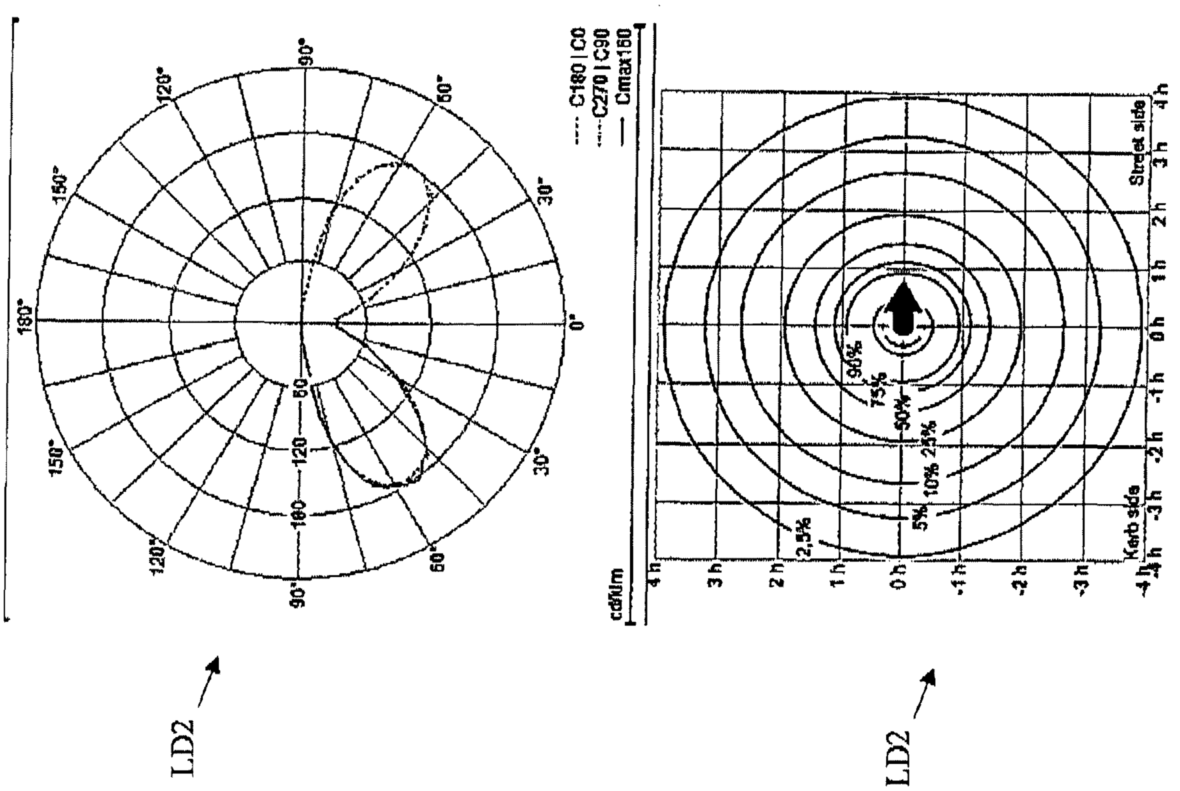

FIG 10B

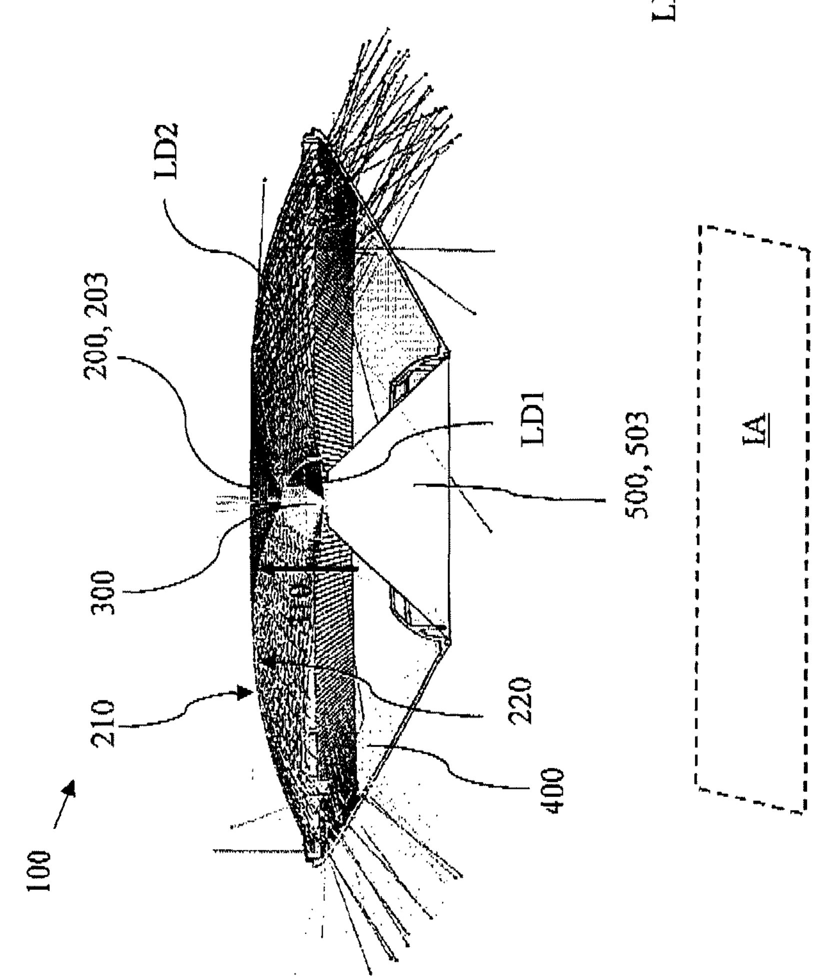

FIG 10A

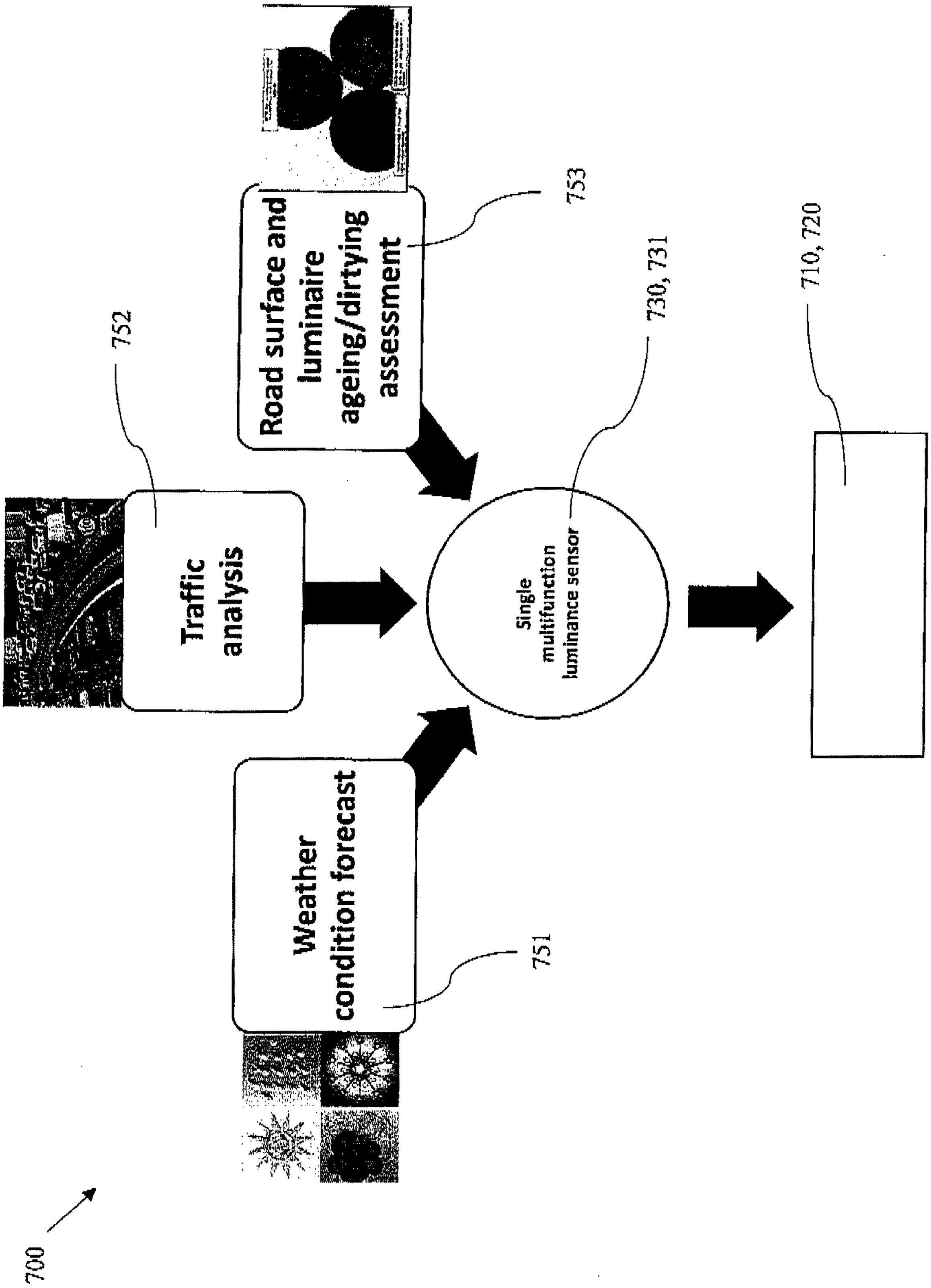
Road surface and luminaire ageing/dirtying assessment
753
752
Traffic analysis
730, 731
Single multifunction luminance sensor
710, 720
Weather condition forecast
751
700

FIG 11

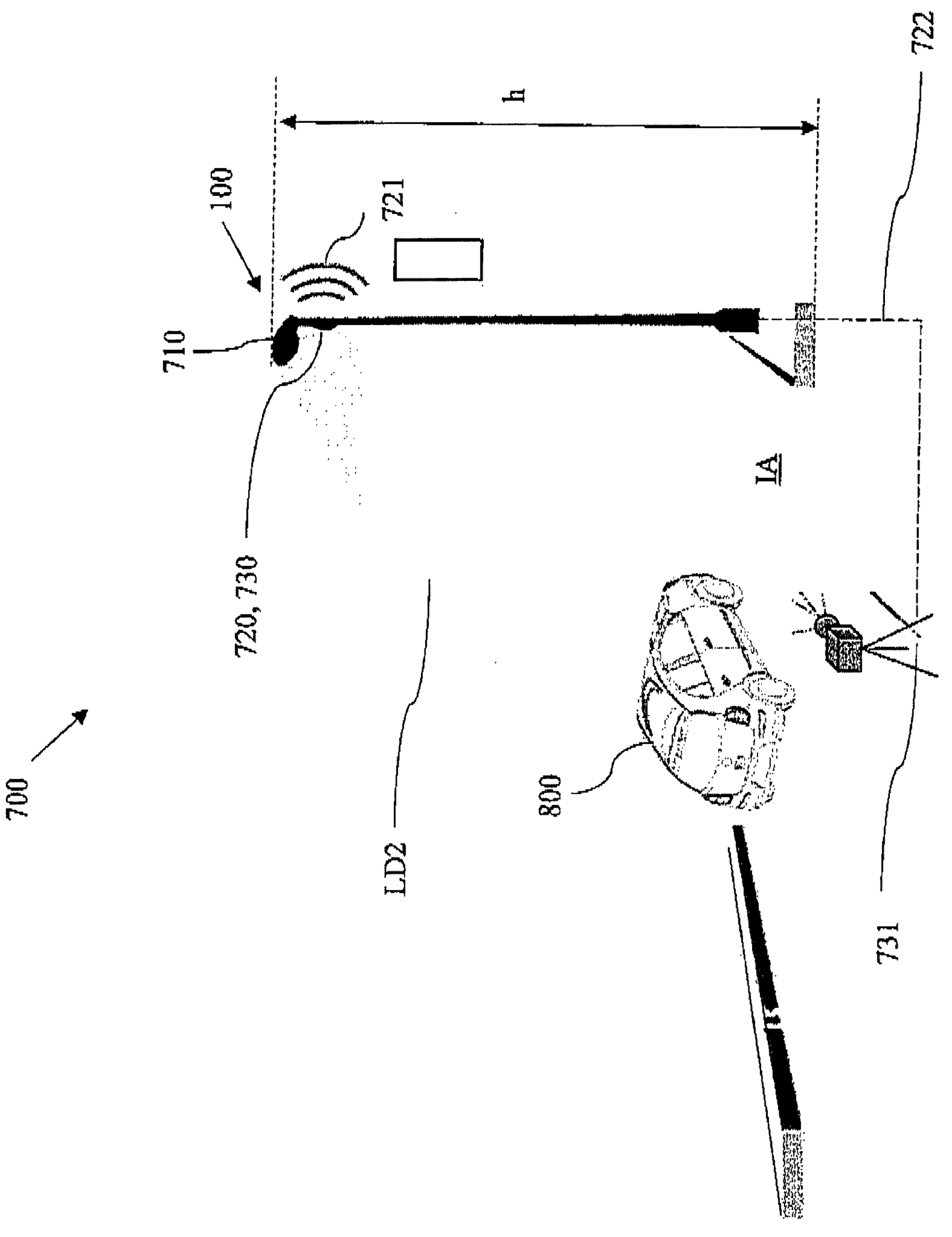

FIG 12

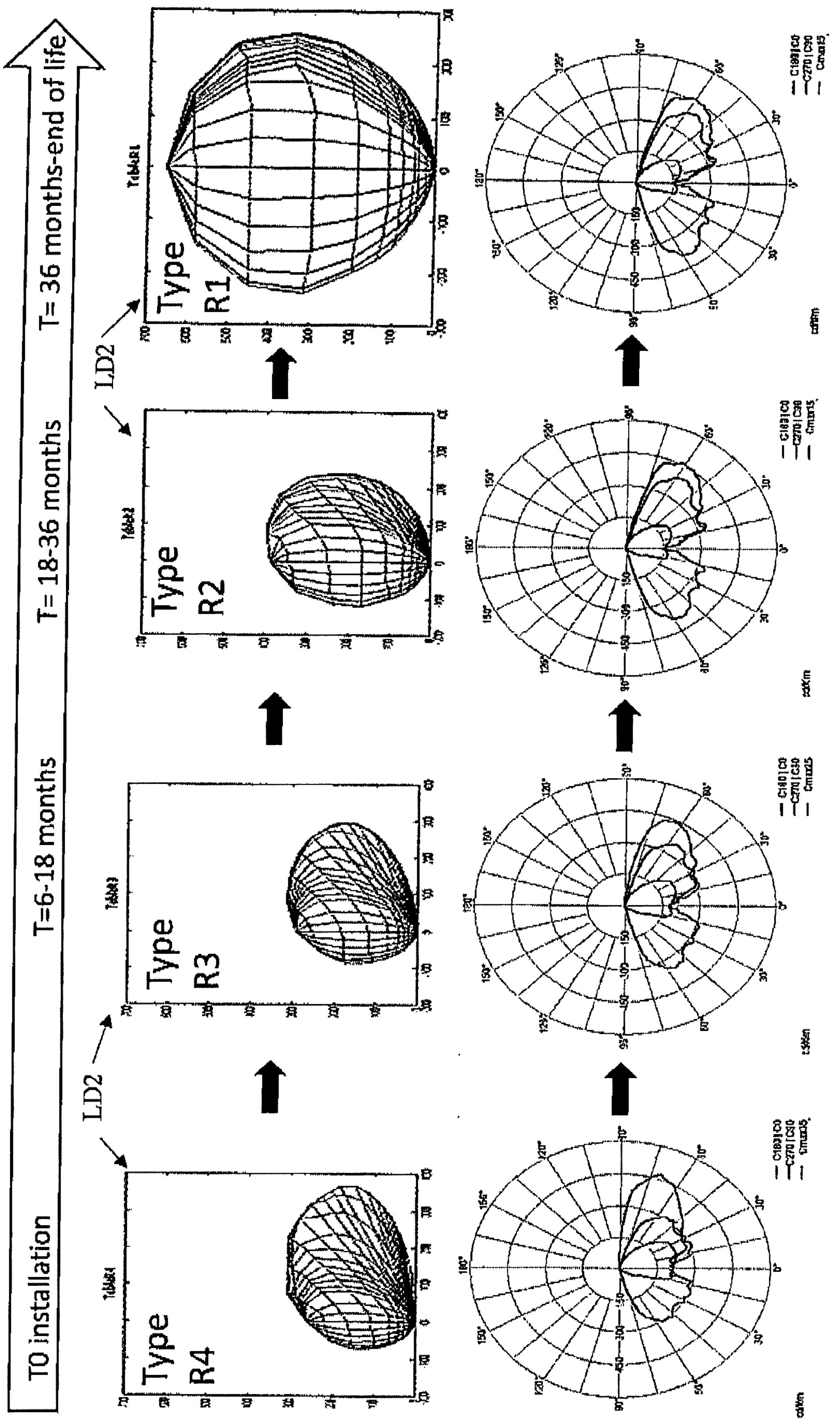

FIG 13A

FIG 13B

FIG 13C

FIG 13D

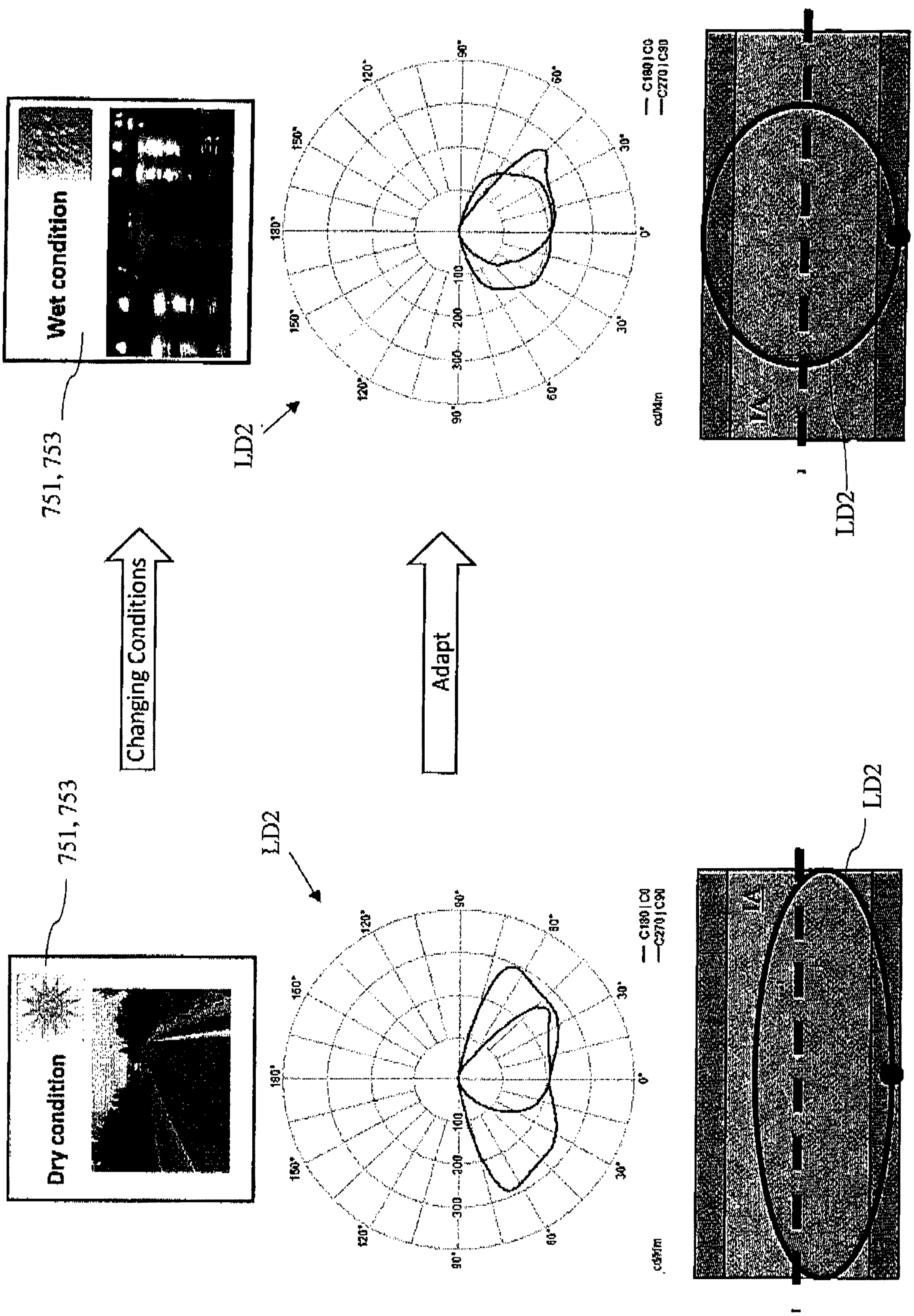

FIG 14A

FIG 14B

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 19 29 0030

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 2007/263388 A1 (LAI CHIEH-LUNG [TW] ET AL) 15 November 2007 (2007-11-15) * paragraphs [0049], [0084], [0087], [0089], [0093] * * figures 10-14, 18 * -----	1-15	INV. F21V7/00 F21S10/00 F21V23/04 F21V14/02
X	DE 20 2011 003261 U1 (HESS VERWALTUNGS GMBH [DE]) 28 April 2011 (2011-04-28) * paragraphs [0015], [0018], [0021] * * figures 4-9 * -----	1-5,8-15	
X	WO 2008/151801 A1 (LUXSOLI GMBH [DE]; MADES RALF [DE] ET AL.) 18 December 2008 (2008-12-18) * page 1, paragraph 5 * * page 3, paragraph 4 * * figures 3, 4 * -----	1-5,8,9, 11-15	
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