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(71) Applicant: **Mass Technology (H.K.) Limited**
Kowloon, Hong Kong (CN)

(72) Inventor: **Lee,, Wing Tak**
Kowloon (HK)

(74) Representative: **Potter Clarkson LLP**
The Belgrave Centre
Talbot Street
Nottingham NG1 5GG (GB)

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(54) **REFLECTOR FOR LIGHTING SOURCE AND LIGHTING DEVICE COMPRISING THE SAME**

(57) The present invention provides a reflector (100, 400) intended for lighting source comprising a reflector body (110) having reflective side walls (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D), a top opening (120, 420) and a bottom opening (140, 440). An inner surface of the side wall (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) is configured to be a light-reflective parabolic surface (432), a parabola of the light-reflective parabolic surface (432) having two end points and a parabola vertex, the parabola vertex being closer to the top opening (120, 420) with respect to the bottom opening (140, 440), a height between a connection line connecting the two end points of the parabola and the parabola vertex being a height H of the parabola. A ratio h/L of a

height h of the side walls (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) to a length L of the bottom opening (140, 440) is between 0.4 and 0.7, a ratio h/H of the height h of the side walls (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) to the height H of the parabola is between 0.55 and 0.75, and a ratio h/l of the height h of the side walls (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) to a length l of the top opening (120, 420) is between 0.3 and 0.55. The present invention also provides a lighting device (500) comprising the above reflector (100, 400), which is able to reduce the Unified Glaring Rating (UGR) while maintaining high luminous efficiency.

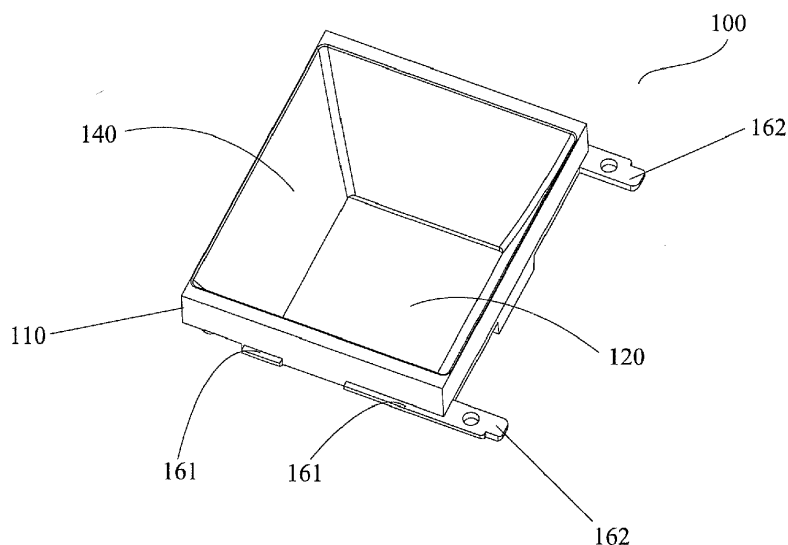


FIG. 1A

Description

Technical Field of the Invention

[0001] This invention relates to the field of lighting device. More specifically, this invention relates to a reflector for lighting source, and a lighting device comprising the reflector with low Unified Glaring Rating (UGR) while maintaining high luminous efficiency.

Background of the Invention

[0002] As a solid state light-emitting light source possessing huge development potential, the LED has been attracting more and more attention due to its advantages such as long lifespan, firm structure, low power consumption, flexible dimensions, etc., and has been gradually replacing the conventional fluorescent and high-pressure halogen lamp in various lighting fields. However, LEDs have characteristics of high lumen output and small luminous area, so that in an illumination space the LEDs are prone to cause problems as associated with glare and excessive difference in illumination uniformity, decreasing the degree of comfort in the space. Severe glare causes human eyes to have visual fatigue and discomfort, lowering production efficiency of workers.

[0003] Visual comfort is of utmost importance to the interior lighting design applications in an office or a commercial place due to the large number of people occupying such space for a prolonged period of time. To realize this, products of reduced direct glare and reflected glare are desirable. Glare's effect on people or glare's damage to human eyes can be reduced by placing a light fixture correctly in the work place and by using optical elements that can reduce direct glare and reflected glare.

[0004] The degree of discomfort glare is measured by "Unified Glare Rating" (UGR). The UGR usually ranges from 10 to 30. A high UGR value represents a high degree of discomfort glare; a low UGR value represents a low degree of discomfort glare. A UGR value lower than 10 represents no discomfort glare. The International Standard EN 12461-1: 2011-08 defines the following UGR standard for a lighting system.

UGR	Level of glare discomfort
10	Imperceptible
13	Just perceptible
16	Perceptible
19	Just acceptable
22	Just uncomfortable
25	Uncomfortable
28	Unacceptable

[0005] To obtain a low UGR, it is desirable to provide

uniform direct light beams and avoid light beams parallel to the horizontal plane of a lighting space whenever possible. For the existing ceiling lights, this is accomplished by use of a reflective plate or a shield to prevent the light beams towards an undesired direction, or by increasing the shielding angle of the lights (i.e. the angle between an illumination beam and the horizontal plane). Another method is to use diffusers to cover bright light beams. However, these installations are very expensive.

[0006] Apart from the above, Chinese patent application no. 201280040123.7 provides a lighting device for reducing the UGR. The lighting device is equipped with a lighting means comprising a plurality of laminated plates with air gaps formed therebetween. The reduction in the UGR is accomplished by providing a patterned layer formed with an adhesive material around the air gap to increase reflection efficiency and at the same time removing patterns of a specific structure.

[0007] Another Chinese patent application no. 201110299984.4 discloses a light device for reducing glare comprising a first prism plate and a second prism plate. The second prism plate is arranged so that a longitudinal direction of a prism pattern formed on the second prism plate and a longitudinal direction of a prism pattern on the first prism plate intersect, and the prism patterns of the first prism plate and second prism plate both have an equilateral triangular cross section having a height H and a bottom side length L with the relation $0.1 \leq H \leq 0.2L$.

[0008] The technical solutions of the above two Chinese patent applications both involve specific patterns formed on a lighting means, which is complicated and expensive to manufacture.

[0009] Thus, there is a need to improve the existing LED lighting devices for lighting purpose, simplify their structure and reduce their production costs. The improved lighting devices are able to reduce discomfort glare experienced by human eyes, avoid glare interference to people and possible damage to human eyes, and have increased light-emission efficiency and increased luminous flux.

Summary of the Invention

[0010] An object of the present invention is to overcome the aforementioned drawbacks of prior art by providing a novel lighting device that does not only have good light-emission efficiency and high luminous flux, but also reduces the UGR value, simplifies the structure and structurally solve the glare problem of the LED light sources, thereby preventing strong light emitted from the LEDs from causing discomfort and possible damage to human eyes.

[0011] The object of the present invention is achieved by providing a reflector intended for lighting source comprising a reflector body having a plurality of reflective side walls having a height h, a top opening formed by upper portions of the reflective side walls and having a length

l, and a bottom opening formed by lower portions of the reflective side walls and having a length L. An inner surface of the side walls is configured to be one or more parabolic surfaces able to reflect light, a parabola of the parabolic surface having two end points and a parabola vertex, the parabola vertex being positioned closer to the top opening with respect to the bottom opening, the parabola having a height H defined by a distance between a connection line connecting the two end points of the parabola and the parabola vertex; and a ratio h/L of a height h of the side walls to the length L of the bottom opening is between 0.4 and 0.7.

[0012] A ratio h/H of the height h of the side walls to the height H of the parabola is between 0.55 and 0.75; a ratio h/l of the height h of the side walls to a length l of the top opening is between 0.3 and 0.55.

[0013] In a preferred embodiment of the present invention, the ratio h/L of the height h of the side walls to the length L of the bottom opening is between 0.45 and 0.55, the ratio h/H of the height h of the side walls to the height H of the parabola is between 0.6 and 0.7, and the ratio h/l of the height h of the side walls to the length l of the top opening is between 0.4 and 0.5.

[0014] In an embodiment of the present invention, the reflector body is formed by four side walls bounding around, and the reflector body has a trapezoidal configuration in a longitudinal section thereof, wherein the bottom opening is greater than the top opening. Two opposite ones of the four side walls are symmetrically arranged relative to a centrally vertical axis of the reflector body, and the two opposite side walls have respective inner surfaces configured to correspond to two symmetrical halves of the light-reflective parabolic surface. The bottom opening is configured to be a rectangular opening or a square opening, and the length of the bottom opening comprises a length or a width of the rectangular opening or a side length of the square opening.

[0015] In certain situations, the inner surface of each of the side walls comprises the parabolic surface extending in a direction from the bottom opening toward the top opening, and one or more circular-arc-shaped surfaces of different radii, extending from the parabolic surface to the top opening. In an embodiment of the present invention, the inner surface of the side wall consists of one circular-arc-shaped surface and the parabolic surface, wherein the circular-arc-shaped surface extends from the top opening to between 1/5 and 1/3 of the height of the side wall, and the parabolic surface, which is the one mentioned above, extends from the circular-arc-shaped surface to the bottom opening.

[0016] A second aspect of the present invention provides a lighting device comprising
a light source unit comprising one or more LED light sources;
a wiring substrate on which the one or more LED light sources are mounted;
one or more diffusers for scattering light emitted from the light source unit;

characterized in that the lighting device further comprises a corresponding number of the reflectors of the present invention as the number of the diffusers, wherein each of the diffusers is mounted between the LED light sources and a corresponding reflector in a way such that the diffuser closes a top opening of the corresponding reflector to allow for reflection of the light scattered by the diffuser through the inner surface of the reflector to the outside of the lighting device.

[0017] Preferably, the diffuser is a sheet having a central portion of dome shape, the diffuser is mounted in such a manner that a central axis of the diffuser is coincident with a central axis of the corresponding reflector and the dome-shaped central portion projects toward an inner cavity bounded by the side walls of the corresponding reflector.

[0018] In an embodiment of the present invention, the reflector of the lighting device is configured in such a way that the reflector body is formed by four side walls bounding around and the reflector body has a trapezoidal configuration in a longitudinal section thereof, wherein the bottom opening is greater than the top opening; and two opposite ones of the four side walls are symmetrically arranged relative to a centrally vertical axis of the reflector body, and the two opposite sides walls have respective inner surfaces configured to correspond to two symmetrical halves of the light-reflective parabolic surface. Accordingly, the diffuser is configured as a quadrilateral designed to fit into the top opening, the quadrilateral having a central portion projecting to form a dome shape, wherein a constraint is provided at the top opening to securely clamp the diffuser on the top opening of the reflector.

[0019] Preferably, the constraint comprises a tab provided on each of two opposite edges of the top opening for clamping edges of two respective sides of the diffuser; and a wing extends from a respective one of the other two side edges of the diffuser toward the bottom opening of the reflector, the wing being configured to be attached to an outer surface of a respective side wall of the reflector, thereby to position and securely clamp the diffuser on the top opening.

[0020] Moreover, a vertical wall parallel to the central axis of the reflector extends from an edge of each of two opposite sides of the bottom opening of the reflector toward the top opening, and one or more lateral projecting portions are formed on each of the vertical walls and are engageable with respective apertures formed through a housing of the lighting device so as to position the reflector on the lighting device. The vertical wall has a height that is 0.25 to 0.35 times of a height of the reflector.

[0021] Preferably, a hook and a lug engageable with each other are provided respectively on edges of the other two opposite sides of the bottom opening of the reflector, through the engagement of the hook with the lug two of the reflectors that adjoin are coupled together. Moreover, the two vertical walls each have an extension portion extending toward a same side wall of the reflector, an insert hole being provided on each of the two exten-

sion portions; and a corresponding insert pin being positioned on each of the two vertical side walls and opposite to the side wall of the reflector toward which the extension portions extend, wherein insertion of the insert pin of one reflector into the insert hole of another reflector enables coupling of the two reflectors that adjoin.

[0022] The wiring substrate that the lighting device of the present invention uses can be a printed circuit board (PCB) or a metal core printed circuit board (MCPCB) on which a plurality of LED light sources are mounted, the plurality of LED light sources are respectively equipped with a plurality of the reflectors coupled to one another through the engagement of the hooks and the lugs to form a light source array. The light source array is selected from a group consisting of linear array, rectangular array, square array, triangular array, polygonal array and zigzag array.

[0023] The inner surface of the reflector of the present invention can be coated with a light reflecting material. The diffuser is made from a material having a transmittance in the range of 82% to 95%.

[0024] Unlike the lighting devices of prior art, the lighting device of the present invention is equipped with a reflector of unique structure according to the present invention, which is designed to fulfill a specific requirement in terms of dimensions of the side wall height, the length of the bottom opening and the length of the top opening. It has been found that the lighting device of the invention having the specific ratios among the above parameters allows the light that is emitted from an LED light source to pass through the diffuser and then get reflected by the inner surface of the reflector. The illumination light beam exhibits a cardioid or batwing illumination pattern having a beam width of around 90° to 120°. Thus, the lighting device of the present invention effectively reduces the UGR value to be equal to or smaller than 19 while maintaining the illumination intensity.

[0025] To have a better understanding of the objects, characteristics and effects of the present invention, the concepts, specific structure and technical effects thus produced of the present invention are further explained below in conjunction with the accompanying drawings.

Brief Description of the Drawings

[0026]

FIG. 1A is a perspective bottom view of a reflector constructed consistent with the first embodiment of the present invention.

FIG. 1B is a perspective top view of the reflector shown in FIG. 1A.

FIG. 2 is a bottom view of the reflector shown in FIG. 1A.

FIG. 3 is a front view of the reflector shown in FIG. 1A.

FIG. 4 is a cross-sectional view taken along line A-A in FIG. 2.

FIG. 5 is a cross-sectional view taken along line B-B in FIG. 2.

FIG. 6 is a front view showing two reflectors connected with each other.

FIG. 7 is a perspective view of a diffuser constructed according to the present invention.

FIG. 8 is a front view of the diffuser shown in FIG. 7.

FIG. 9 is a top view of the diffuser shown in FIG. 7.

FIG. 10 is a bottom view of the diffuser shown in FIG. 7.

FIG. 11 is a perspective top view of an assembly of the reflector shown in FIG. 1A and the diffuser shown in FIG. 7.

FIG. 12 is a plan cross-sectional view of the assembly shown in FIG. 11.

FIG. 13 is a perspective cross-sectional view of the assembly shown in FIG. 11.

FIG. 14 is a perspective view showing multiple reflector modules comprising a plurality of the reflectors constructed consistent with the present invention before they are assembled together.

FIG. 15 is a perspective view showing the reflector modules of FIG. 14 after they are assembled together.

FIG. 16 is a perspective bottom view of a reflector constructed consistent with the second embodiment of the present invention.

FIG. 17 is a bottom view of the reflector shown in FIG. 16.

FIG. 18 is a front view of the reflector shown in FIG. 16.

FIG. 19 is a cross-sectional view taken along line A-A in FIG. 17.

FIG. 20 is a cross-sectional view taken along line B-B in FIG. 17.

FIG. 21 is a view showing schematics of light reflection of the reflector shown in FIG. 16.

FIG. 22 is a perspective exploded view of a LED

lighting device constructed consistent with an embodiment of the present invention.

FIG. 23 is an illumination pattern of the light beam obtained from the LED lighting device shown in FIG. 16.

[0027] In the various figures of the drawings, like reference numbers are used to designate like parts.

Detailed Description of the Invention

[0028] While this invention is illustrated and described in preferred embodiments, the reflector and diffuser of the present invention may be produced in a number of various configurations, sizes and forms from many different materials.

[0029] Referring now to the drawings, FIG. 1A, FIG. 1B, and FIG. 2 to FIG. 5 show a reflector 100 constructed according to the first embodiment of the present invention. In this embodiment, the reflector 100 comprises a reflector body 110 comprising a top opening 120 and a bottom opening 140 provided respectively on its top and bottom. The reflector body 110 is formed by four side walls 130A, 130B, 130C and 130D bounding around, and the thus-formed reflector body has a longitudinal trapezoidal configuration in a longitudinal section thereof, wherein the bottom opening 140 is greater than the top opening 120. Two opposite side walls 130A and 130B are arranged symmetrically relative to a centrally vertical axis Z of the reflector body 110, and the two opposite side walls 130A and 130B have respective inner surfaces configured to correspond to two symmetrical truncated halves of the light-reflective parabolic surface formed by extension of parabolas. As shown in FIG. 5, the symmetrical halves respectively have end points extending from an edge of the bottom opening 140 to the top opening 120 to protrude beyond the top opening 120 until they intersect to form a parabola vertex. In this embodiment, a connecting line of the end points of each of the two symmetrical halves is located on a plane where the bottom opening 140 is located. Thus, the parabola has a height H defined by a distance between the plane of the bottom opening 140 and the parabola vertex.

[0030] Like the two side walls 130A and 130B, two opposite side walls 130C and 130D are arranged symmetrically relative to a centrally vertical axis Z of the reflector body, and the two opposite side walls 130C and 130D have respective inner surfaces configured to correspond to two symmetrical truncated halves of the light-reflective parabolic surface formed by extension of parabolas, which will not be elaborated herein.

[0031] As shown in FIG. 2 to FIG. 6, the top opening 120 is a square opening with a side length l ; the bottom opening is a rectangle with a length L and a width W. Of course, the top opening can also be in the form of a rectangular opening and the bottom opening is in the form of a square opening, or both openings can be of any

appropriate shape.

[0032] The inventor of the present application has found that, if the reflector is configured to have a ratio of a height h of the side walls of the reflector 100 to the length of the bottom opening 140 in a certain range, the light emitted from a light source enters from the top opening 120 into an inner cavity formed by the four side walls 130A, 130B, 130C and 130D bounding around, and is reflected by the reflective inner surfaces of the four side walls, the resultant light will have reduced UGR while maintaining uniform light intensity, i.e. the light beam exhibits an ideal illumination pattern. The length of the bottom opening can be the length L or the width W of the rectangle. Specifically, if the ratio of the height h of the side walls of the reflector 100 to the length of the bottom opening 140 (e.g. h/L) is set to around between 0.4 and 0.7, preferably around between 0.45 and 0.55, most preferably around 0.5, a more desirable illumination pattern will be obtained, as shown in FIG. 23.

[0033] The inventor of the present application has also found that, if the reflector is configured to have a ratio of the height h of the side walls to the height H of the parabola around between 0.55 and 0.55, preferably around between 0.6 and 0.7, most preferably around 0.65, and to have a ratio of the height h of the side walls of the reflector to the length l of the top opening between 0.35 and 0.55, preferably around between 0.4 and 0.5, most preferably around 0.45, the lighting beam distribution curve obtained will be a heart shape or a batwing shape (i.e. UGR lower than 19), which is more desirable, while relatively high light output, desired beam width and relatively high light-emission efficiency can be maintained.

[0034] The inner surfaces of the side walls 130A, 130B, 130C and 130D of the reflector 100 are glossy parabolic surfaces and can be coated with a light reflecting material to enhance the luminous efficacy. The light emitted from the light source is reflected to the inner surface of the reflector, and is then irradiated through the bottom opening 140 to the outside of the lighting device.

[0035] Referring to FIG. 1B and FIG. 4, a constraint is provided on the top opening 120 to constrain a diffuser of the lighting device on the top opening 120 of the reflector. As shown, the constraint comprises a tab 121 provided on each of two opposite edges of the top opening 120. The tab 121 is used for clamping edges of two respective sides of the diffuser, which will be described in details below.

[0036] Referring to FIG. 1A, FIG. 2 and FIG. 3, a vertical wall 160 parallel to the central axis Z of the reflector extends from an edge of each of two opposite sides 130A, 130B of the bottom opening 140 of the reflector 100 toward the top opening 120, and one or more lateral projecting portions 161 are formed on each of the vertical walls 160, the lateral projecting portions 161 are engageable with respective apertures formed on a side plate in a housing of the lighting device (see FIG. 22) so as to position the reflector 100 on the lighting device. In this embodiment shown, the height of the vertical wall 160 is

set to 0.25 to 0.35 times of the height of the reflector 100.

[0037] As shown in FIG. 1B, FIG. 2 and FIG. 5, a hook 151 and a lug 152 engageable with each other are provided respectively on edges of the other two side walls 130C, 130D of the bottom opening 140 of the reflector 100, through the engagement of the hook 151 with the lug 152 two of the reflectors 100 that adjoin are coupled together (as shown in FIG. 6). Moreover, two vertical walls 160 each have an extension portion 162 extending toward the same side wall 130D, an insert hole 163 being provided on each of the two extension portions 162; and a corresponding insert pin 164 being positioned on each of the two vertical walls and at a position close to the side wall 130C (as shown in FIG. 1B and FIG. 3), wherein the insert pin 164 and the insert hole 163 match each other so that the insertion of the insert pin 164 of one reflector into the insert hole 163 of another reflector enables coupling of the two reflectors together.

[0038] Now referring to FIG. 7 to FIG. 10, there is illustrated a diffuser 200 adapted to be used in cooperation with the reflector 100 described above. The base of the diffuser 200 is a piece of rectangular sheet, whose size can close the square top opening 120 of the reflector 100 to direct and scatter the light emitted from the light source to the inner cavity of the reflector body of the reflector 100 and reflect the light scattered by the diffuser through the side wall of the reflector body to the outside of the lighting device. As shown in FIG. 7, a central portion 210 of the diffuser 200 has a dome shape, the dome-shaped central portion 210 being bounded by four edges 220. The four edges 220 form a stand-off zone between a vertical side wall 212 of the dome-shaped central portion 210 of the diffuser 200 and the four side walls 130A, 130B, 130C, 130D of the reflector 100. Setting the stand-off zone reduces scattered light to be irradiated from the dome-shaped central portion 210 toward the reflector 100, which is advantageous to forming a desired illumination pattern. The stand-off zone and the height of the dome-shaped central portion 210 cooperate for fine-tuning a central area of an illumination pattern. Setting the stand-off zone either too large or too small will reduce the overall output of light intensity. Furthermore, there is a certain requirement for the height of the dome-shaped central portion 210. If the height is too high, the final UGR will be affected. For instance, in the case of the dome-shaped central portion 210 having an area of 20 x 20 mm and a height of 6.5 - 7 mm, it has been proven that a good illumination pattern can be obtained if the width of each stand-off zone is set to around 5 mm. A wing 230 extends from a respective one of the two opposite edges 240C, 240D of the diffuser 200 toward the dome-shaped central portion 210. The wing 230 is configured to be attached to an outer surface of a respective one of the two side walls 130C, 130D of the reflector 100, thereby to position and securely clamp the diffuser 200 on the top opening 120 of the reflector 100.

[0039] The diffuser 200 of the above embodiment is molded from translucent plastic having a transmittance

of between 82% and 95%. The selected plastic can have a scattering rate of between 5% and 15% at a thickness of 1 mm.

[0040] FIG. 11 to FIG. 13 show schematic views of an assembly of the reflector 100 and the diffuser 200. As shown, the diffuser 200 is mounted in such a manner that a central axis Y of the diffuser 200 is coincident with the central axis Z of the reflector 100; the diffuser 200 tightly closes the top opening 120 of the reflector 100 and its dome-shaped central portion 210 projects toward a reflective inner cavity of the reflector 100. The other two edges 240A, 240B of the diffuser 200 are clamped by the tabs 121 on the two opposite edges of the top opening 120 of the reflector 100 so that the entire diffuser 200 is securely clamped on the top opening 120. Referring to FIG. 9 and FIG. 10, the edges 240C, 240D of the diffuser 200 are also respectively provided with a lateral positioning groove 250, a lateral positioning block 122 (see FIG. 1B) mutually cooperating with the lateral positioning groove 250 is provided on a corresponding position of the top opening 120. Engaging the lateral positioning groove 250 with the lateral positioning block 122 is not only advantageous to the positioning of the diffuser 200, but also strengthens the secure clamping of the diffuser 200.

[0041] As discussed above, the structure of the reflector of the present invention allows a plurality of the reflectors to be assembled. FIG. 14 shows a top view of one reflector module 300 comprising four reflectors. The reflector module 300 is an integral prefabricated module, wherein a hook 151 is provided on the side wall 130C of the leftmost reflector and an insert pin 164 is provided at a position adjacent to the side wall 130C, while a lug 152 is provided on the side wall 130D of the rightmost reflector and an insert hole 163 is provided at a position adjacent to the side wall 130D. By engaging the hook 151 and the insert pin 164 of one reflector module 300 with the lug 152 and the insert hole 163 of another reflector module 300 respectively, the two reflector modules 300 can be coupled together, as the bottom view of the assembled reflector modules shown in FIG. 15. In this way, according to actual needs, a plurality of LED light sources equipped with the reflectors 100 can be flexibly assembled into various light source arrays, including but not limited to linear array, rectangular array, square array, triangular array, polygonal array, zigzag array, etc. In order to cooperate with the reflector module 300, preferably a plurality of diffusers 200 in number corresponding to the number of the reflector 100 of the reflector module 300 are prefabricated as one piece which is adapted to fit onto the prefabricated reflector module 300.

[0042] What is shown in FIG. 16 to FIG. 20 is a reflector 400 of the second embodiment of the present invention. The major difference between this embodiment and the first embodiment is that the inner surface of each side wall 430A, 430B, 430C, 430D consists of a circular-arc-shaped surface 431 and a parabolic surface 432. The

circular-arc-shaped surface 431 and the parabolic surface 432 are configured to have the same reflective material layer. The circular-arc-shaped surface 431 extends from the top opening 420 to around 1/5 of the height of the side wall; the parabolic surface 432 extends from the circular-arc-shaped surface 431 to the bottom opening 440. The structure of the parabolic surface 432 is basically the same as the parabolic surface of the first embodiment, the description of which can be made reference to the above and is not repeated here. The roundness or radius R of the circular-arc-shaped surface 431 is related to the size of the top opening: the smaller the top opening, the greater the roundness of the circular-arc-shaped surface 431; the bigger the top opening, the smaller the roundness of the circular-arc-shaped surface 431. A skilled person in the art should understand that two or more circular-arc-shaped surfaces can be arranged between the top opening 420 and the parabolic surface 432, depending on the height of the side wall of the reflector and/or the size of the top opening.

[0043] Provision of a circular-arc-shaped surface between the top opening of the reflector and the parabolic surface of the side wall is to cater for some scenarios. Under some circumstances, it is necessary to connect a plurality of reflectors together for a large light fixture which requires an enormous amount of reflectors; and under certain circumstances, it is desirable to reduce the number of reflectors for cost-effective purpose, which inevitably makes it necessary to increase the size of a reflector to meet the design goal. However, it is not possible for the light fixture to have a large height due to the limitation on ceiling mount while it is desirable to achieve a low UGR. If the dimension ratio of the reflector as discussed above is to be kept, the length of the bottom opening of the reflector has to be increased, which necessarily increases the height of the reflector. In order to keep the ratio of the height of the side walls of the reflector to the bottom opening within the range mentioned above, it is necessary to structurally modify the reflector around the top opening thereof, i.e. by configuring the parabolic surface of the side wall of the reflector at a level higher than 1/5 to 1/3 of the height of the side wall from the top opening, and providing one or more circular-arc-shaped surfaces between the parabolic surface and the top opening for connecting the parabolic surface and the top opening. The greater the curvature of the circular-arc-shaped surface is, the shorter the distance between the parabolic surface and the top opening becomes. The reflective zone defined by the circular-arc-shaped surface only occupies around 20% to 25% of the area of the entire inner surface of the reflector. The advantage of such an arrangement is that the circular-arc-shaped surface is able to reflect more light emitted from the dome-shaped central portion 210 of the diffuser 200 to a center of the light beam. However, since the area of the circular-arc-shaped surface is limited and the light source basically emit the light toward the central portion of the diffuser 200, the reflected light from the circular-arc-shaped sur-

face has little effect on the entire illumination pattern which remains the preferred cardioid or batwing shape, as shown in FIG. 23.

[0044] FIG. 21 is a view showing schematics of light reflection of the reflector constructed consistent with the second embodiment of the invention. FIG. 21 clearly illustrates that the light emitted from the light source 520 is scattered by the dome-shaped central portion 210 of the diffuser 200 to the reflective inner surface of each side wall of the reflector 100, with a small portion of the light scattered onto the circular-arc-shaped surface 431 and a major portion of the light scattered onto a shallow parabolic surface 432 of the reflector. As shown, both the light from the circular-arc-shaped surface 431 and the light from the shallow parabolic surface 432 fall onto the zone between the light beam center and the shielding angle. Therefore, the lighting device produces substantially reduced glare.

[0045] FIG. 22 shows a perspective exploded view of an LED lighting device 500 constructed consistent with a preferred embodiment of the present invention, comprising the reflector 100 and the diffuser 200 of the first embodiment of the present invention. As shown, the LED lighting device 500 comprises a plurality of the reflectors 100 connected to form a linear array, a plurality of diffusers 200 corresponding to the number of the reflectors 100, a wiring substrate 510, a plurality of LED light sources 520 mounted on the PCB substrate 510, a power supply unit 530, a lower half housing 540, an upper half housing 550, a support block 560, screws 570, a heat sink and a control circuit.

[0046] The lower half housing 540 and the upper half housing 550 are coupled to form a housing of the lighting device 500, in which various electronic and mechanical elements are accommodated. The lower half housing 540 is provided with a longitudinal through slot 542 that is able to allow for emission of the reflected light to the outside. On both sides of the through slot 542 are respectively provided side panels 541 extending inward from an inner surface of the lower half housing 540 to engage with the lateral projection 161 on the respective side wall of the reflector 100 so as to position the reflector 100 inside the housing. The lower half housing 540 can be colored to match the ceiling to blend the lighting device better with the indoor environment in which the lighting device is located. The power supply unit 530 can be the one which is conventional in prior art. The support block 560 is provided for supporting and fixing the power supply unit 530.

[0047] The control circuit of the lighting device 500 is not shown. The control circuit can be mounted on the wiring substrate 510 integrally with the lighting device 500, or separately from the lighting device 500. In the latter case, the control circuit has a pluggable connector to connect with the lighting device 500. The control circuit and the heat sink are not essence of the present invention and are not described in details.

[0048] The LED light sources 520 can be in the form

of LED chips, LED packages or LED arrays. All LED light sources 520 can be connected in series and/or in parallel, but are mounted on the wiring substrate 510 axially in linear manner. Such a linear arrangement of the LED light sources is cost-effective and may result in increased heat dissipation capacity of the heat sink and improved light output efficiency of the lighting device. In this embodiment, each LED light source 520 consists of four to five LED chips and is mounted inside the cavity bounded by the dome-shaped central portion 210 of the diffuser 200. The LED light sources 520 may be provided in the form of LED packages (COB) in some scenarios requiring high power luminous output.

[0049] The wiring substrate 510 is formed by electrically coupling two printed circuit boards (PCB). The copper foil of the printed circuit board has good heat dissipation capacity, on which mounting of the LED light sources 520 allows heat generated from the LED light sources 520 to be transferred to a bigger area of the printed circuit board and then dissipated. The wiring substrate 510 can be a conventional FR4-type or CEM-type, or a metal core printed circuit board (MCPCB) having better heat management capacity. As shown, the wiring substrate 510 is mounted at the top opening 120 of the reflector 100, and the diffuser 200 is located between the top opening 120 and the LED light sources 520, so that the LED light sources 520 are completely inside the cavity bounded by the dome-shaped central portion 210 of the diffuser 200.

[0050] The coupling of the reflector 100 with the diffuser 200 is illustrated in FIG. 11 to FIG. 13 and described above. In the lighting device 500, the bottom opening 140 of the reflector 100 faces toward the lower half housing 540. The LED light sources 520 emit light toward the diffuser 200 where the light is scattered into the reflective cavity of the reflector 100 through the top opening 120 and is then reflected by the reflective inner surface of each side wall of the reflector to pass through the bottom opening 140 and the lower half housing 540 in succession to the outside of the lighting device 500.

[0051] It is well-known that glare control requires the manipulation of the light beam distribution of a lighting device, in particular the cut-off angle of the light beam. An excessively large beam angle not only generates direct glare to human eyes, but also results in decreased light intensity caused by illuminating a large illumination area. An excessively small beam angle, which illuminates a small area, is prone to become a point light source and causes uneven light distribution, accompanied by glare problems associated with a point light source. Thus, it is ideal for interior lighting that the light beam is distributed in a cardioid or batwing illumination pattern, which has a beam angle of around 90° to ensure that the light beam is directed to a target area while there is adequate light intensity in the target area and its surrounding areas. In general, the cut-off angle of the light beam is around 120° to satisfy the requirement for the shielding angle. The high luminous output obtained in the two wing zones of

the cardioid or batwing illumination pattern substantially intensifies the light reflection from the surrounding walls and the floor, which in turn increases the intensity of background light of the indoor space to make it possible that the overall illumination in the indoor space becomes more uniform. Therefore the cardioid or batwing illumination pattern is an ideal pattern for interior lighting.

[0052] FIG. 23 shows an illumination pattern of the light beam obtained from the LED lighting device 500. As shown, the light beam produces a cardioid or batwing illumination pattern, with two wing zones having high light intensity. The light beam center is positioned at around 500 cd/klm, the two wing zones are positioned around 650 cd/klm with a wing vertex around 15° in the respective wing. The half power beam angle is within around 45°.

[0053] According to a tabular method (CIE 117-1995) established by the International Commission on Illumination (CIE), it has been found that the LED lighting device 500 of the present invention achieves a UGR lower than 19 in all standard combinations of room sizes, ceiling, wall and floor reflection indexes.

[0054] This reveals that the lighting device, which comprises the reflectors of the present invention and is provided with the diffusers cooperating with the reflectors, produces a cardioid or batwing illumination pattern while maintaining the illumination intensity. Namely, the lighting device according to the invention is able to maintain a high luminous efficiency and achieve a low Unified Glare Rating (UGR), providing comfortable lighting.

[0055] Having sufficiently described the nature of the present invention according to some preferred embodiments, the invention, however, should not be limited to the structures and functions of the embodiments and drawings. It is stated that insofar as its basic principle is not altered, changed or modified it may be subjected to variations of detail. Numerous variations and modifications that are easily obtainable by means of the skilled person's common knowledge without departing from the scope of the invention should fall into the scope of this invention.

Claims

1. A reflector (100, 400) intended for lighting source, comprising:

a reflector body (110) having a plurality of reflective side walls (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) having a height h , a top opening (120, 420) formed by upper portions of the reflective side walls (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) and having a length l , and a bottom opening (140, 440) formed by lower portions of the reflective (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) side walls and having a length L ;

characterized in that the plurality of reflective

- side walls (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) have an inner surface configured to be one or more light-reflective parabolic surfaces (432) formed by extension of parabolas, each of the parabolic surfaces (432) having two end points and a parabola vertex and arranged such that the parabola vertex is positioned closer to the top opening (120, 420) with respect to the bottom opening (140, 440), and the parabola has a height H defined by a distance between a connection line connecting the two end points of the parabola and the parabola vertex; and a ratio h/L of the height h of the side walls (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) to the length L of the bottom opening (140, 440) is between 0.4 and 0.7.
2. The reflector (100, 400) of claim 1, **characterized in that** a ratio h/H of the height h of the side walls (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) to the height H of the parabola is between 0.55 and 0.75, and / or **in that** a ratio h/l of the height h of the side walls to the length l of the top opening (120, 420) is between 0.3 and 0.55.
 3. The reflector (100, 400) of claim 2, **characterized in that** the ratio h/L of the height h of the side walls (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) to the length L of the bottom opening (140, 440) is between 0.45 and 0.55, the ratio h/H of the height h of the side walls (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) to the height H of the parabola is between 0.6 and 0.7, and the ratio h/l of the height h of the side walls (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) to the length l of the top opening (120, 420) is between 0.4 and 0.5.
 4. The reflector (100, 400) of any one of claims 1 to 3, **characterized in that** the reflector body (110) is formed by four side walls (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) bounding around, and the reflector body (110) has a trapezoidal configuration in a longitudinal section thereof, wherein the bottom opening (140, 440) is greater than the top opening (120, 420), preferably two opposite ones of the four side walls (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) are symmetrically arranged relative to a centrally vertical axis Z of the reflector body (110), and the two opposite side walls have respective inner surfaces configured to correspond to two symmetrical halves of the light-reflective parabolic surface (432).
 5. The reflector (100, 400) of claim 3, **characterized in that** the bottom opening (140, 440) is configured to be a rectangular opening or a square opening, and the length of the bottom opening (140, 440) comprises a length or a width of the rectangular opening or a side length of the square opening.
 6. The reflector (100, 400) of claim 3, **characterized in that** the inner surface of each of the side walls (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) comprises the parabolic surface (432) extending in a direction from the bottom opening (140, 440) toward the top opening (120, 420), and one or more circular-arc-shaped surfaces (431) of different radii, extending from the parabolic surface (432) to the top opening (120, 420).
 7. The reflector (100, 400) of claim 6, **characterized in that** the inner surface of the side wall (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) consists of one circular-arc-shaped surface (431) and the parabolic surface (432), wherein the circular-arc-shaped surface (431) extends from the top opening (120, 420) to between 1/5 and 1/3 of the height of the side wall (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D), and the parabolic surface (432) extends from the circular-arc-shaped surface (431) to the bottom opening (140, 440).
 8. A lighting device (500), comprising:
 - a light source unit comprising one or more LED light sources (520);
 - a wiring substrate (510) on which the one or more LED light sources (520) are mounted;
 - one or more diffusers (200) for scattering light emitted from the light source unit;
 - characterized in that** the lighting device (500) further comprises a corresponding number of the reflectors (100, 400) according to any one of claims 1 to 7 as the number of the diffusers (200), wherein each of the diffusers (200) is mounted between the LED light sources (520) and a corresponding reflector (100, 400) in a way such that the diffuser (200) closes a top opening (120, 420) of the corresponding reflector (100, 400) to allow for reflection of the light scattered by the diffuser (200) through the inner surface of the reflector (100, 400) to the outside of the lighting device (500).
 9. The lighting device (500) of claim 8, **characterized in that** the diffuser (200) is a sheet having a central portion (210) of dome shape, the diffuser (200) is mounted in such a manner that a central axis Y of the diffuser (200) is coincident with a central axis Z of the corresponding reflector (100, 400) and the dome-shaped central portion (210) projects toward an inner cavity bounded by the side walls (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) of the corresponding reflector (100, 400), preferably the reflector (100, 400) is provided as the reflector (100, 400) according to any one of claims 4 to 9, and the

diffuser (200) is configured as a quadrilateral designed to fit into the top opening (120, 420), the quadrilateral having a central portion (210) projecting to form a dome shape, wherein a constraint is provided at the top opening (120, 420) to securely clamp the diffuser (200) on the top opening (120, 420) of the reflector (100, 400).

10. The lighting device (500) of claim 9, **characterized in that** the constraint comprises a tab (121) provided on each of two opposite edges of the top opening (120, 420) for clamping edges (240A, 240B) of two respective sides of the diffuser (200); and a wing (230) extends from a respective one of the other two side edges (240C, 240D) of the diffuser (200) toward the bottom opening (140, 440) of the reflector (100, 400), the wing (230) being configured to be attached to an outer surface of a respective side wall (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) of the reflector (100, 400), thereby to position and securely clamp the diffuser (200) on the top opening (120, 420).
11. The lighting device (500) of claim 9, **characterized in that** a vertical wall (160) parallel to the central axis Z of the reflector (100, 400) extends from an edge of each of two opposite sides of the bottom opening (140, 440) of the reflector (100, 400) toward the top opening (120, 420), and one or more lateral projecting portions (161) are formed on each of the vertical walls (160) and are engageable with respective apertures formed through a housing of the lighting device (500) so as to fix the reflector (100, 400) on the lighting device, preferably the vertical wall (160) has a height that is 0.25 to 0.35 times of a height of the reflector (100, 400).
12. The lighting device (500) of claim 11, **characterized in that** a hook (151) and a lug (152) engageable with each other are provided respectively on edges of the other two opposite sides of the bottom opening (140, 440) of the reflector (100, 400), through the engagement of the hook (151) with the lug (152) two of the reflectors (100, 400) that adjoin are coupled together.
13. The lighting device of claim 12, **characterized in that** the two vertical walls (160) each have an extension portion (162) extending toward a same side wall (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) of the reflector (100, 400), an insert hole (163) being provided on each of the two extension portions (162); and a corresponding insert pin (164) being positioned on each of the two vertical side walls (162) and opposite to the side wall (130A, 130B, 130C, 130D, 430A, 430B, 430C, 430D) of the reflector (100, 400) toward which the extension portions (162) extend, wherein insertion of the insert pin (164) of one

reflector (100, 400) into the insert hole (163) of another reflector (100, 400) enables coupling of the two reflectors (100, 400) that adjoin.

14. The lighting device (500) of claim 12, **characterized in that** the wiring substrate (510) is a printed circuit board or a metal core printed circuit board on which a plurality of LED light sources (520) are mounted, the plurality of LED light sources (520) are respectively equipped with a plurality of the reflectors (100, 400) coupled to one another through the engagement of the hooks (151) and the lugs (152) to form a light source array, preferably the light source array is selected from a group consisting of linear array, rectangular array, square array, triangular array, polygonal array and zigzag array.
15. A reflector module, comprising a plurality of the reflectors according to any one of claims 1 to 7 which are prefabricated integrally.

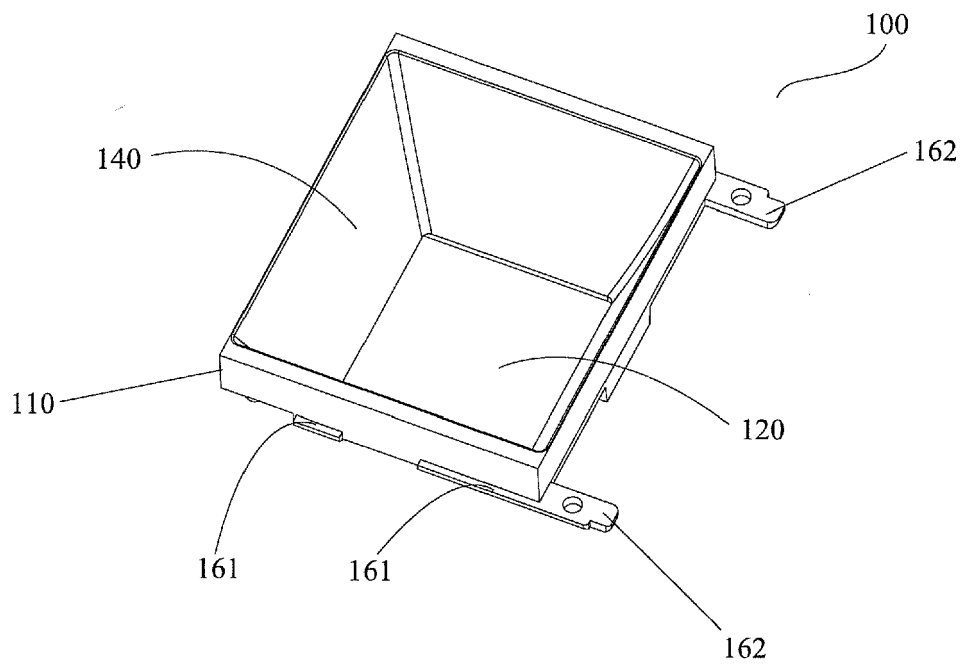


FIG. 1A

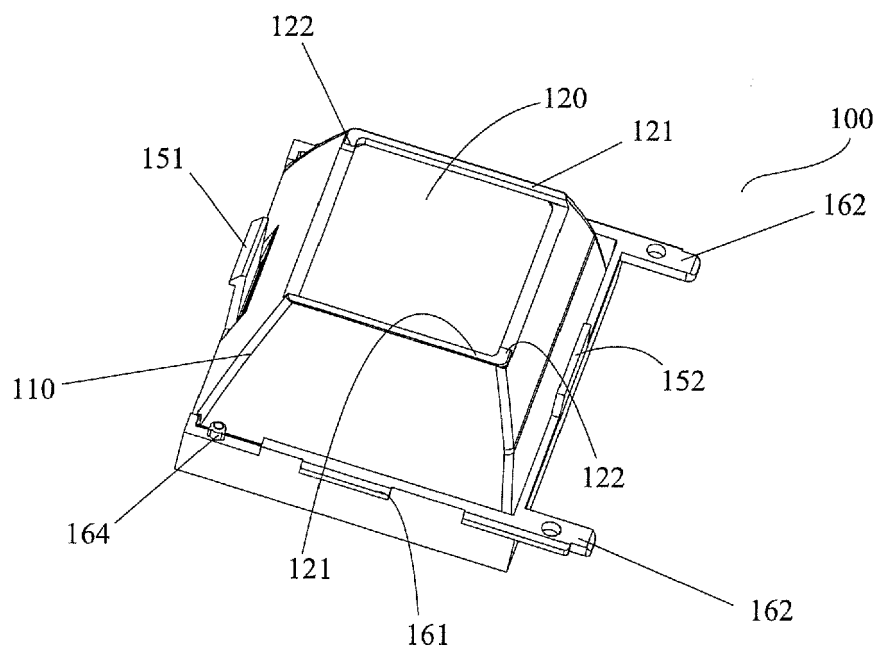


FIG. 1B

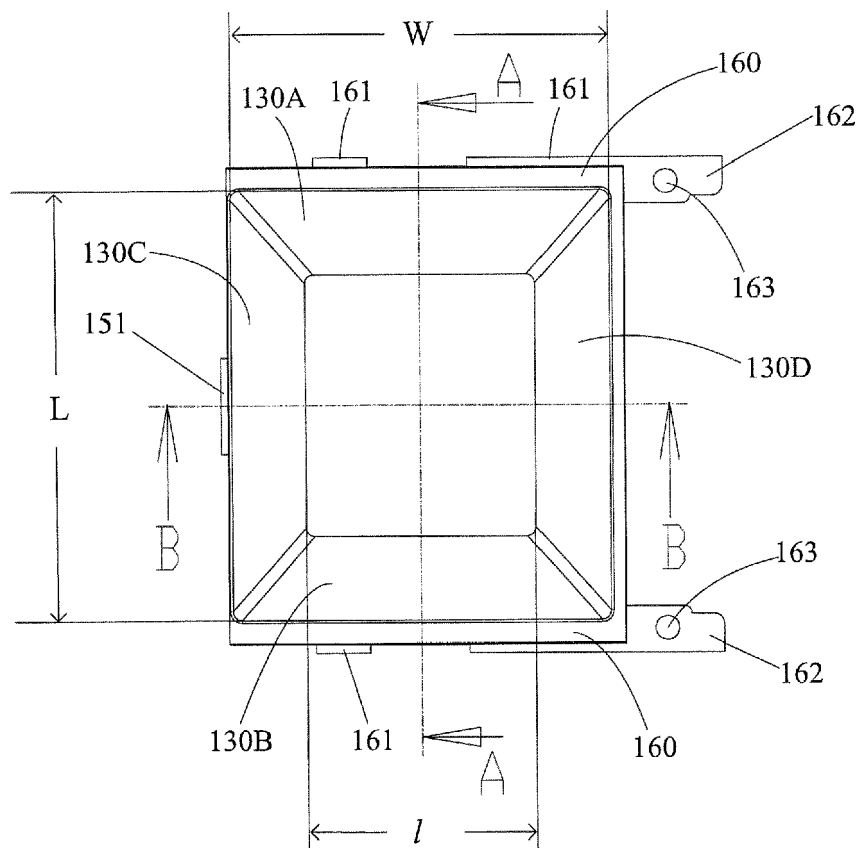


FIG. 2

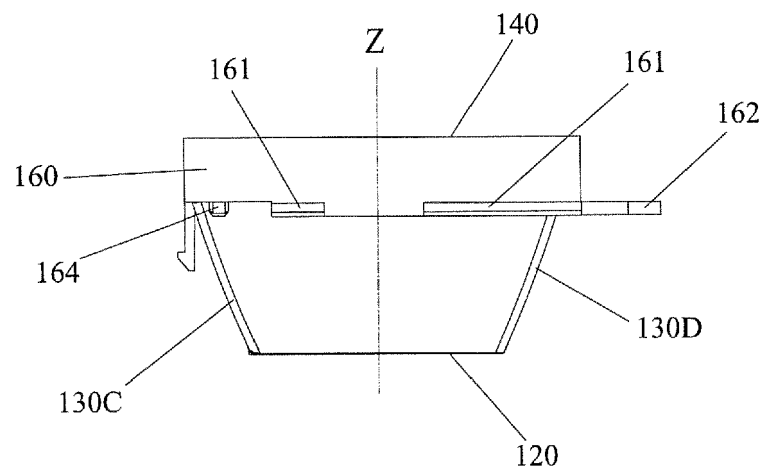


FIG. 3

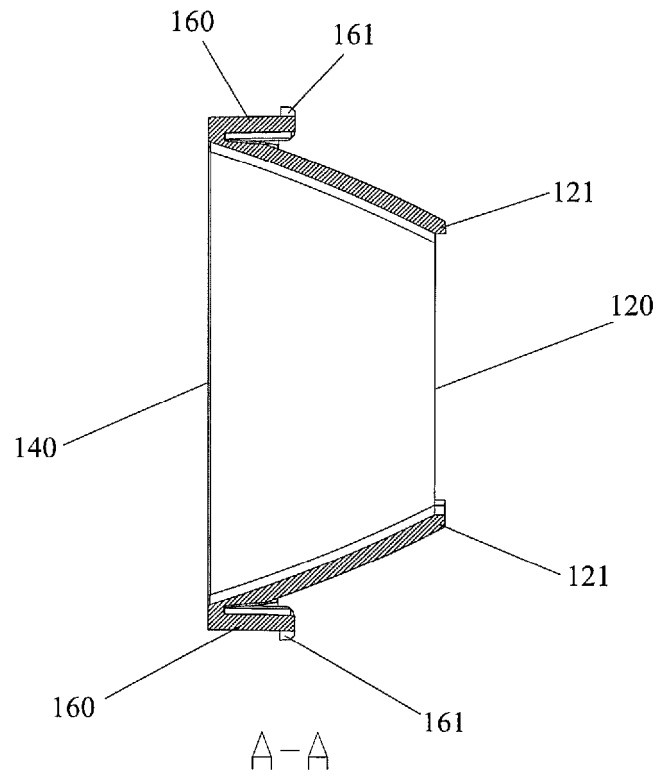


FIG. 4

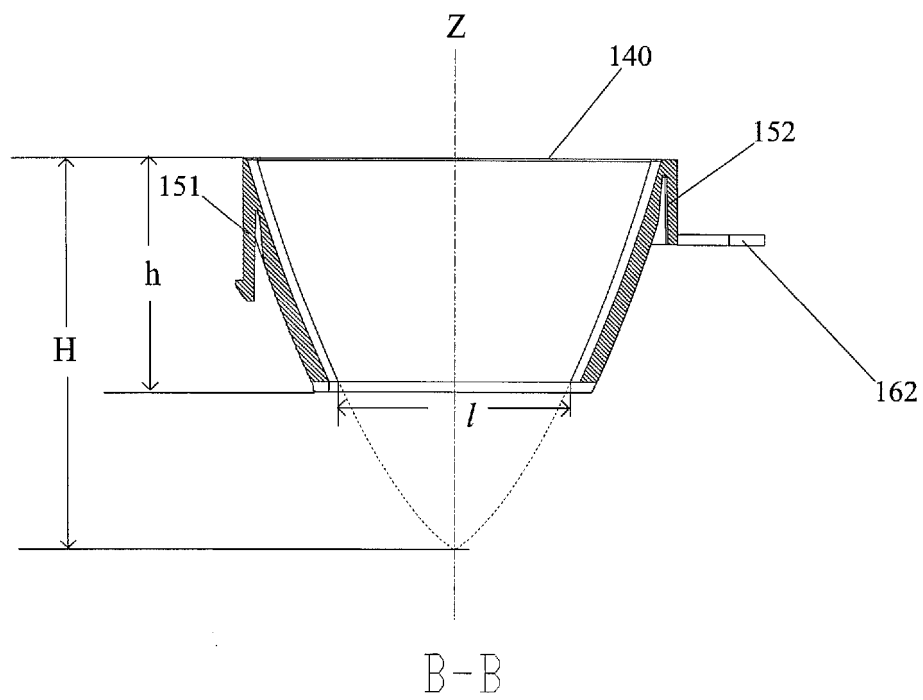


FIG. 5

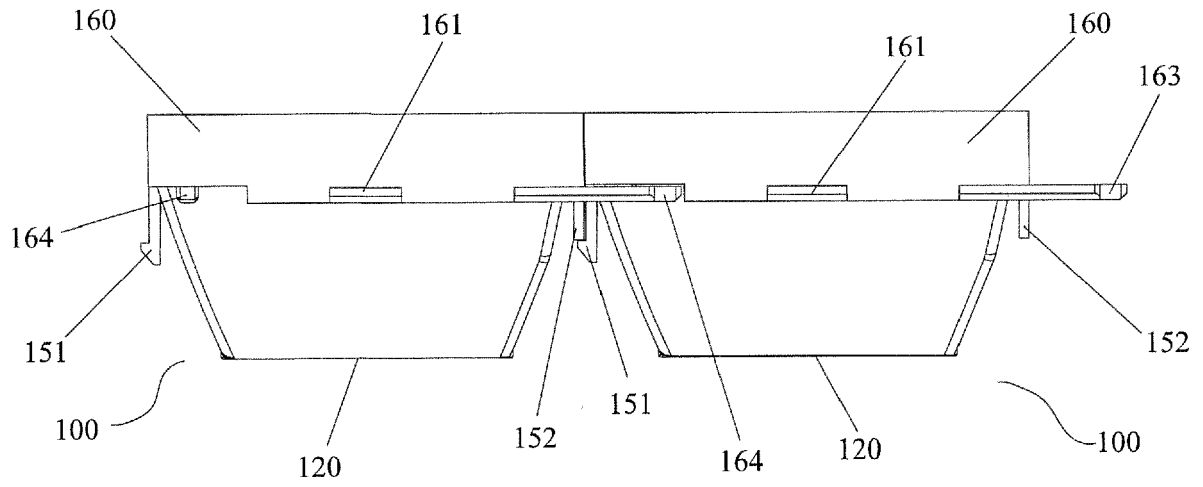


FIG. 6

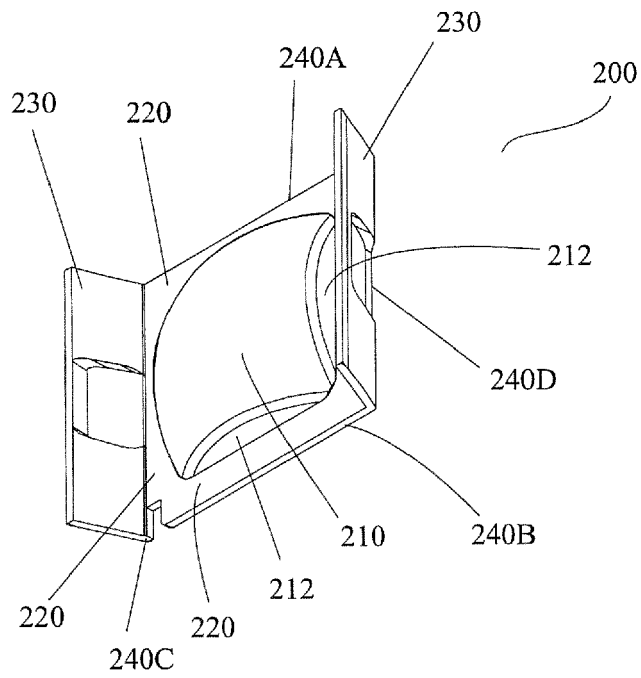


FIG. 7

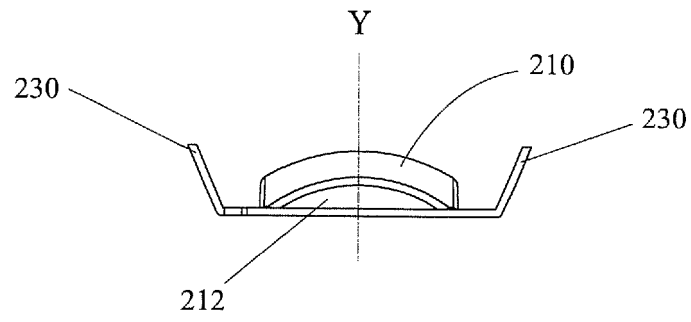


FIG. 8

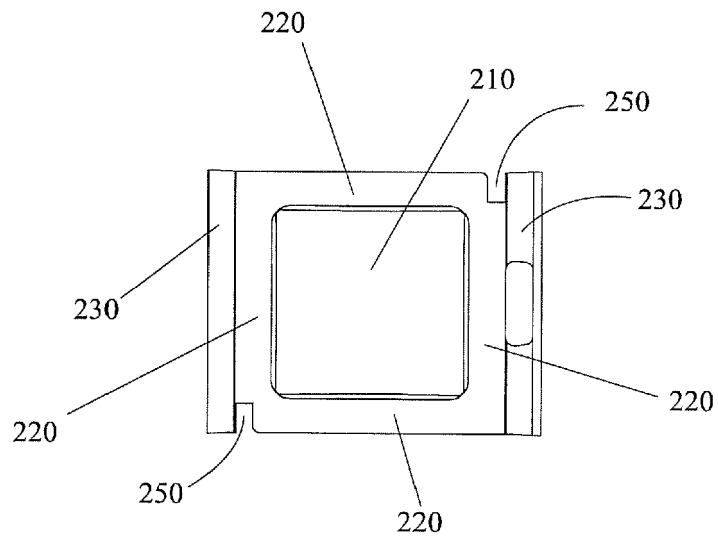


FIG. 9

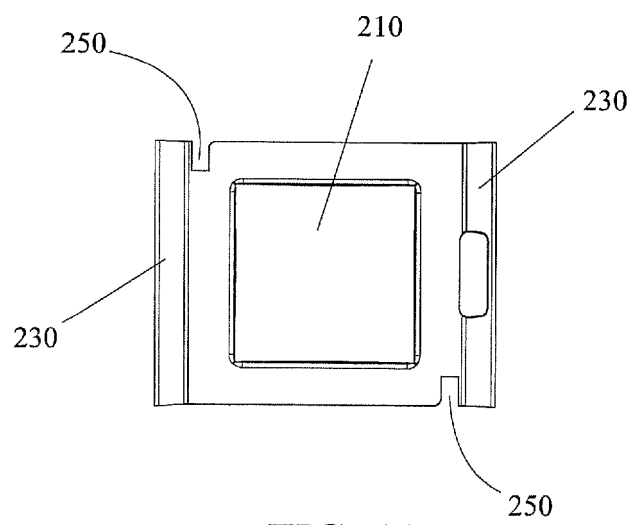


FIG. 10

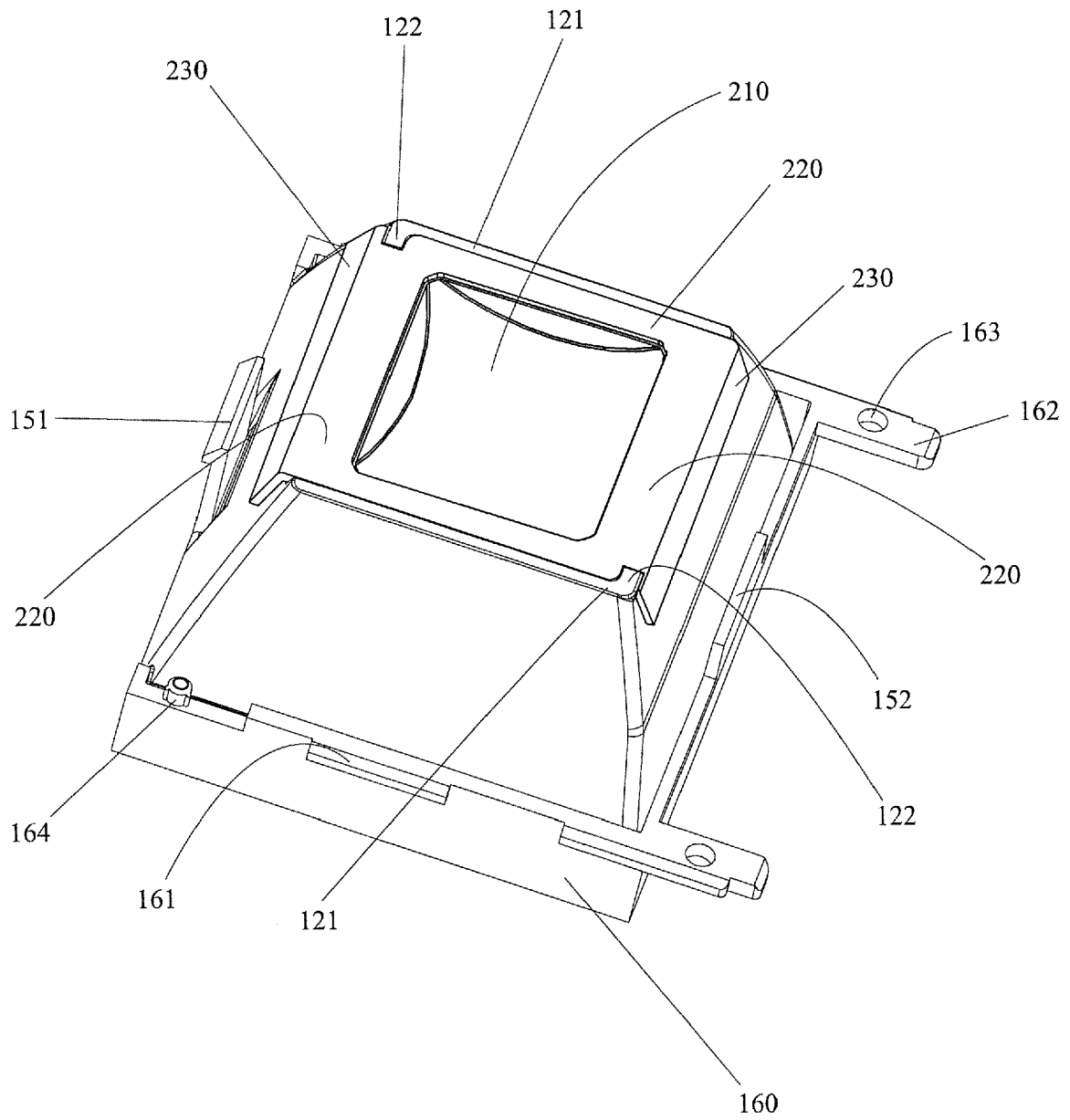


FIG. 11

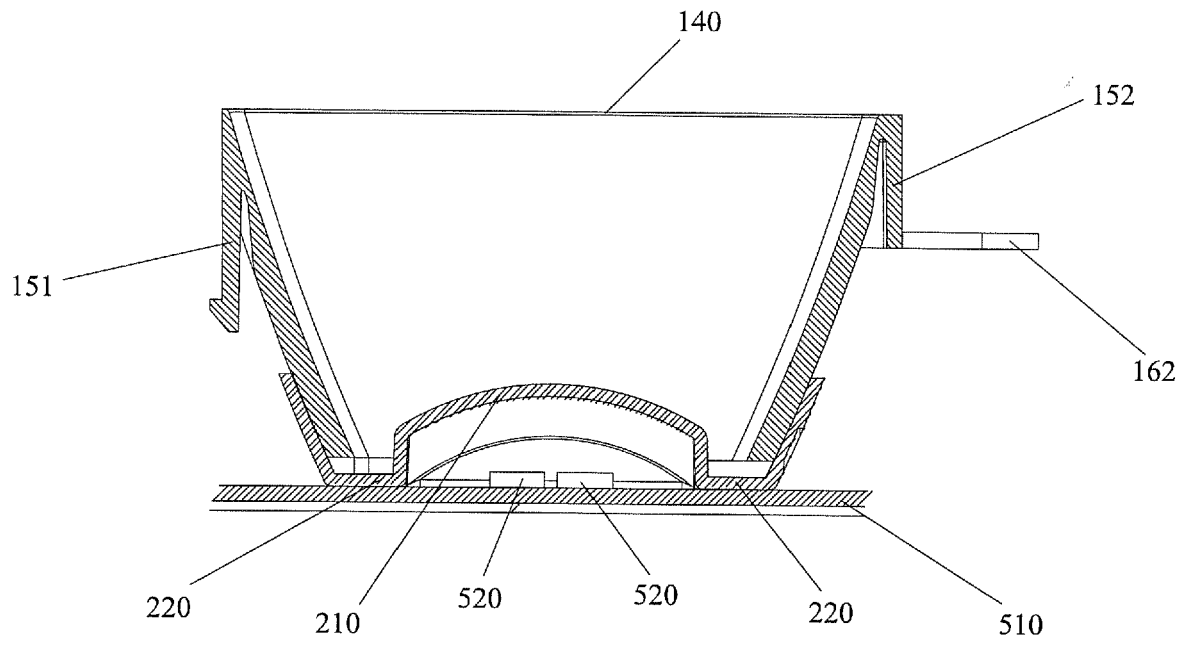


FIG. 12

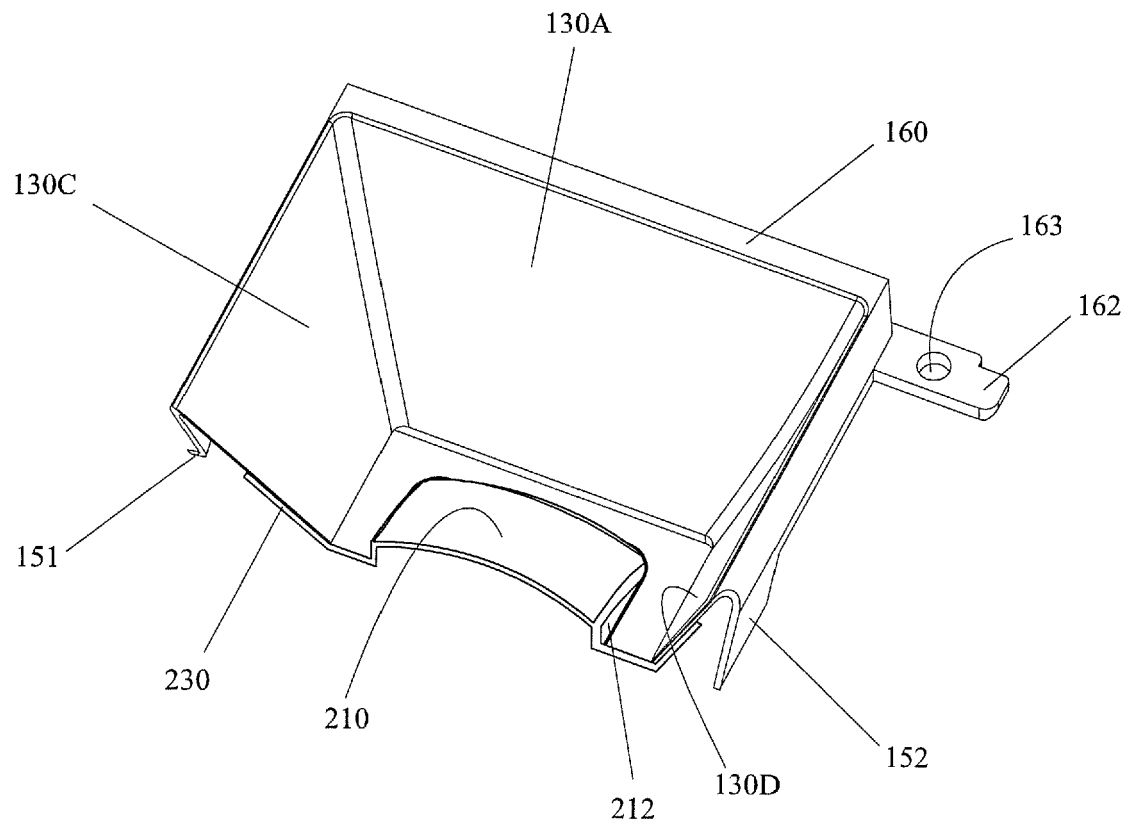
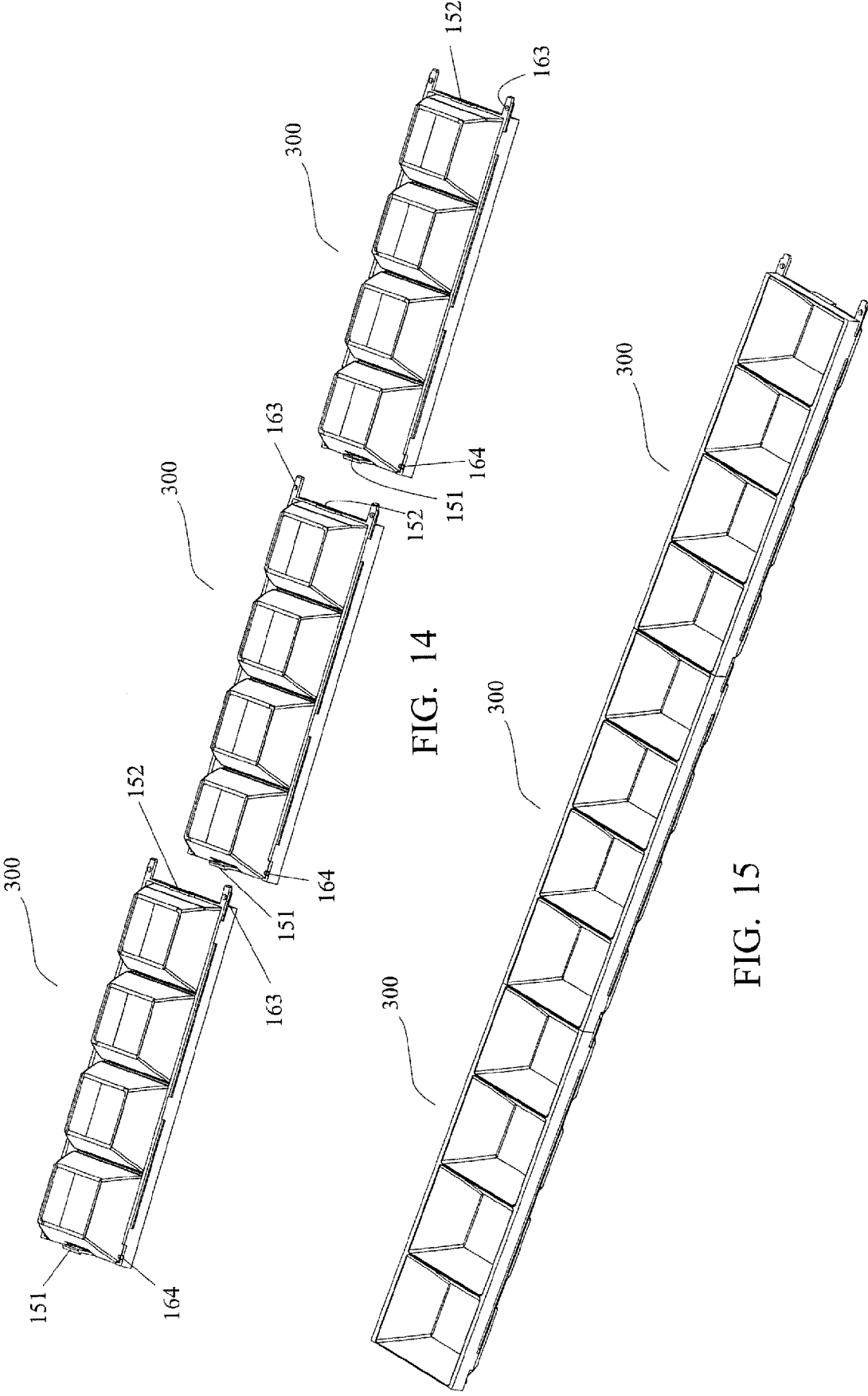
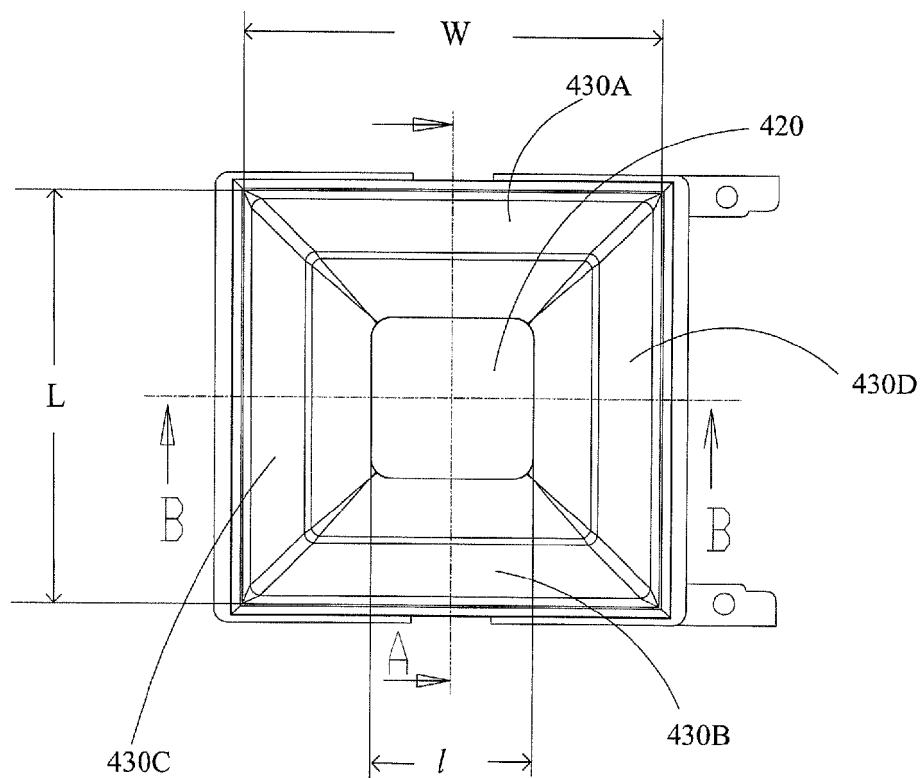
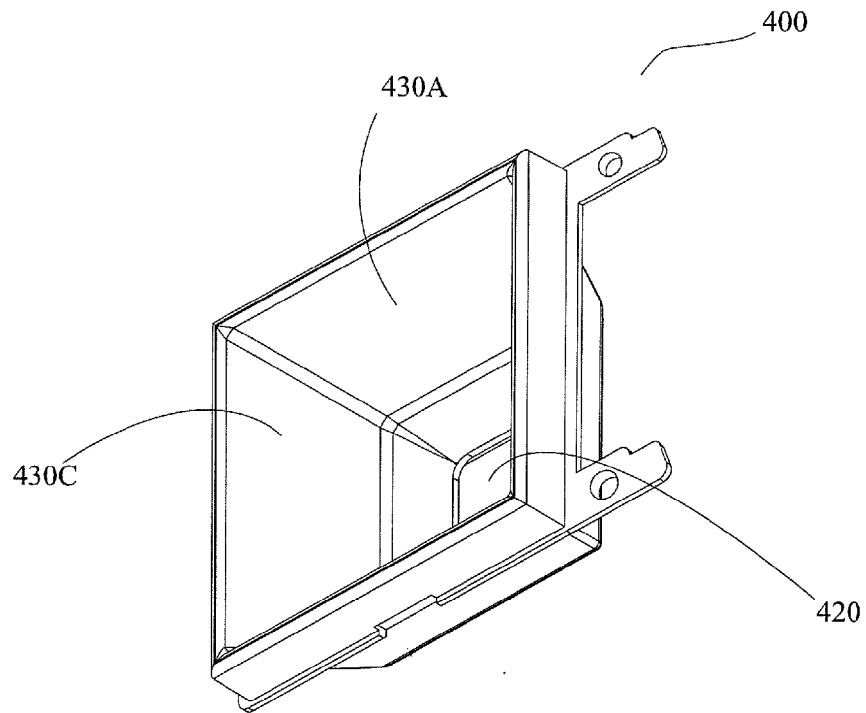


FIG. 13





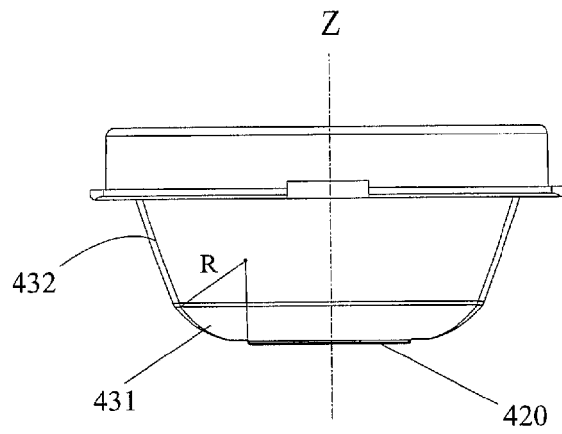


FIG. 18

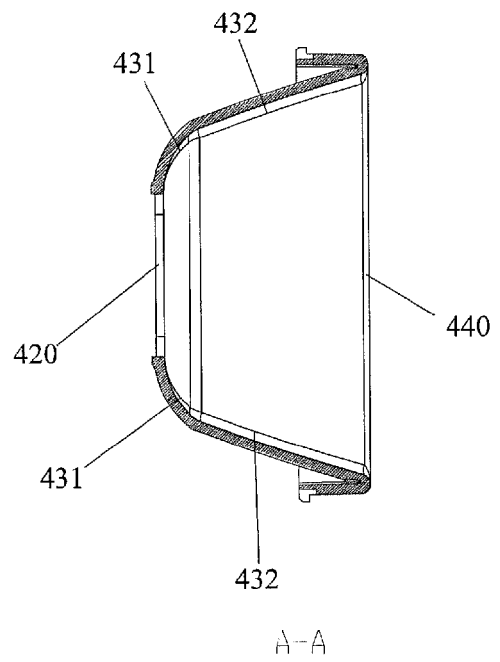


FIG. 19

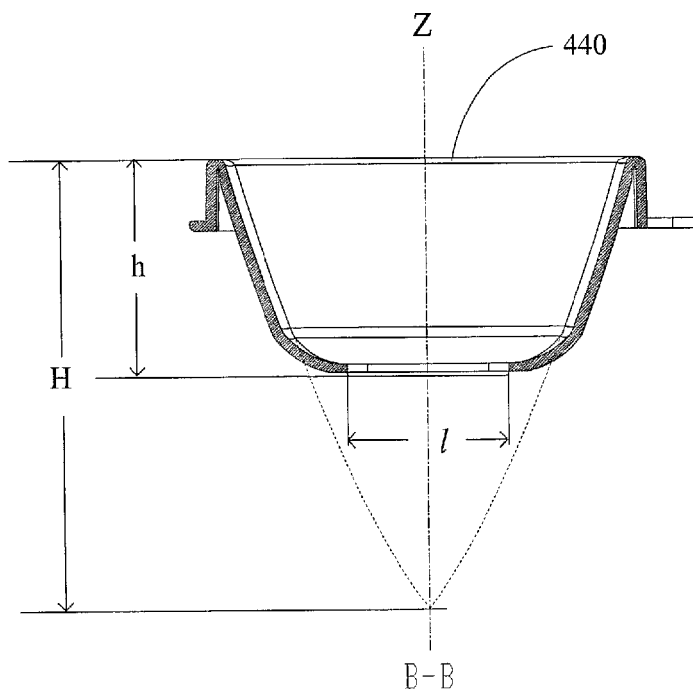


FIG. 20

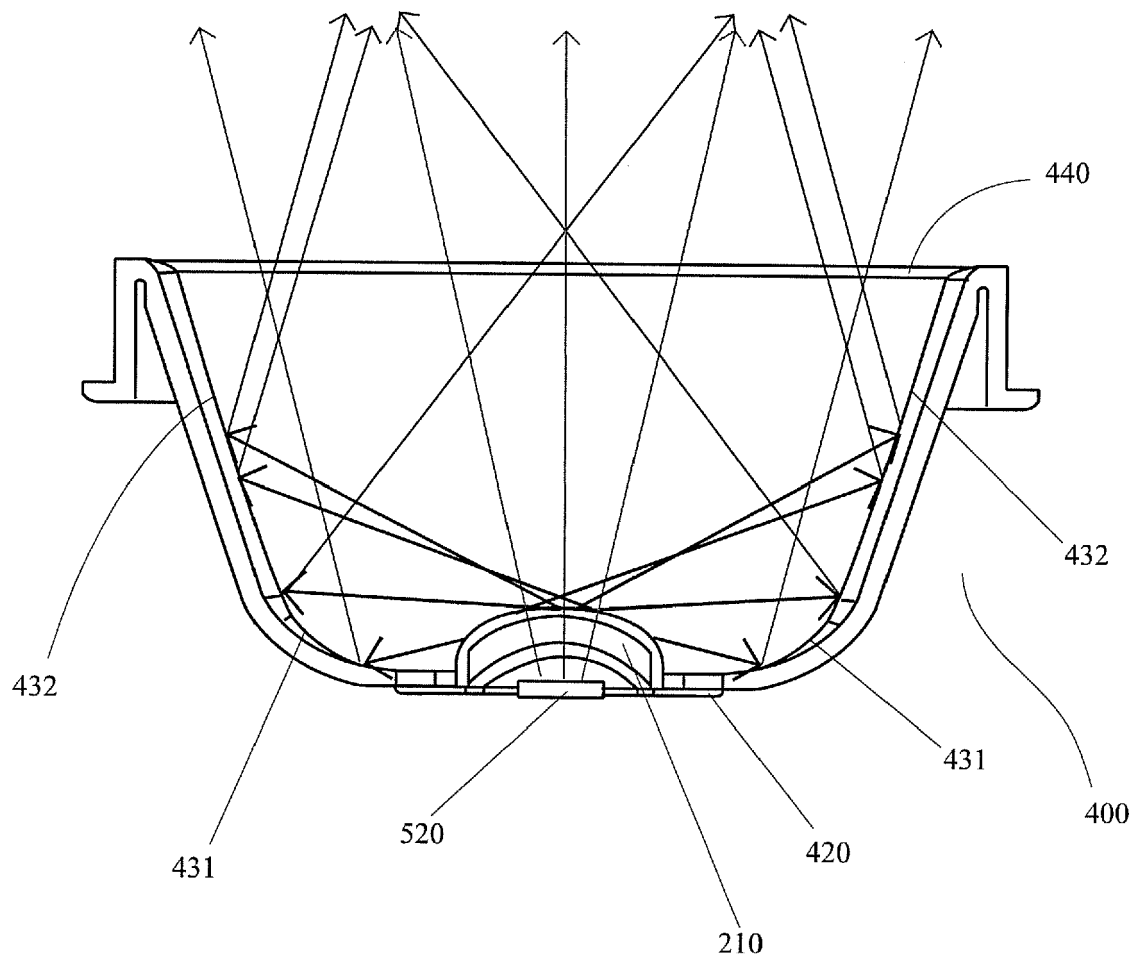


FIG. 21

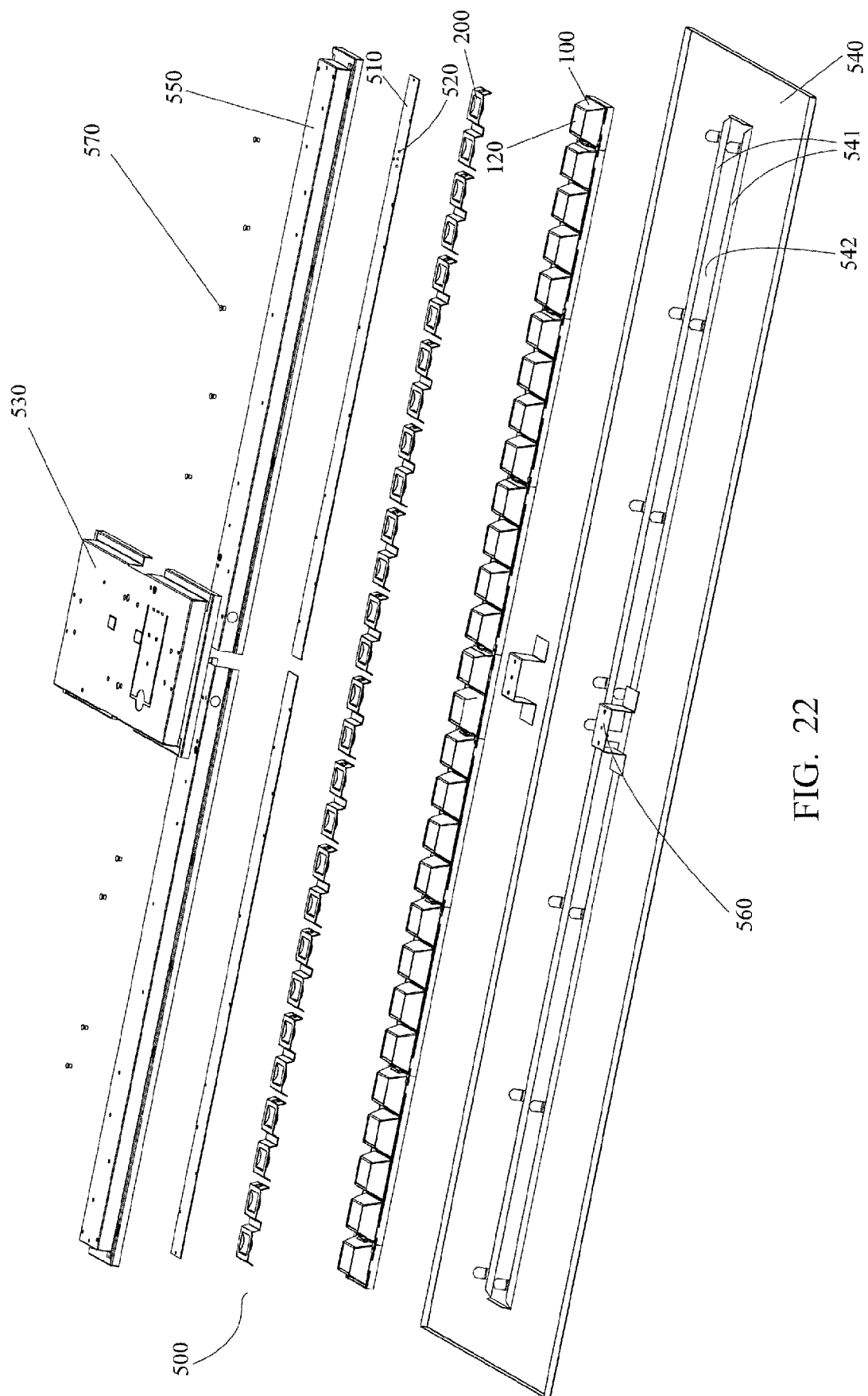


FIG. 22

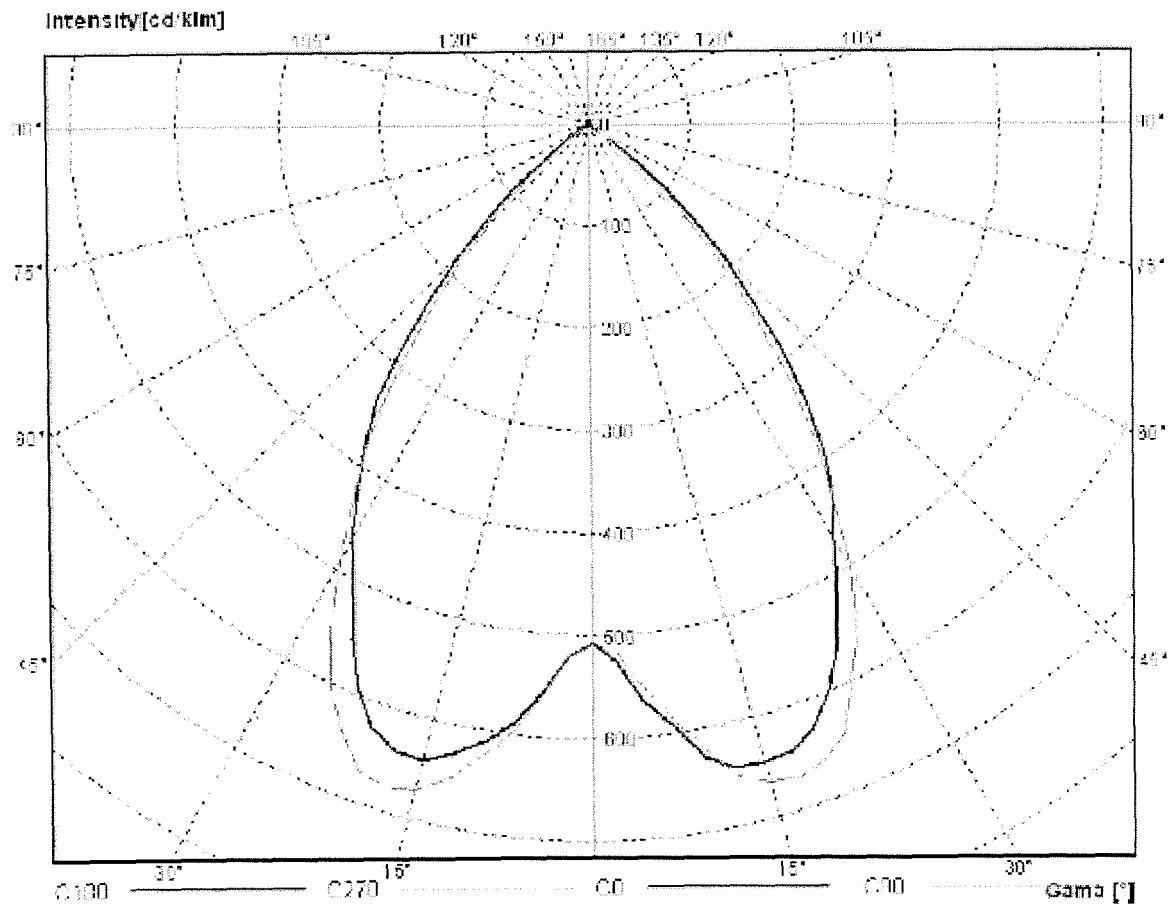


FIG. 23



EUROPEAN SEARCH REPORT

 Application Number
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 8 January 2018	Examiner Blokland, Russell
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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EUROPEAN SEARCH REPORT

Application Number
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Y	EP 2 713 094 A1 (TOSHIBA LIGHTING & TECHNOLOGY [JP]) 2 April 2014 (2014-04-02) * paragraph [0007] - paragraph [0074] * * figures 1-10 *	9	
Y		9	
A		1	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
Place of search The Hague		Date of completion of the search 8 January 2018	Examiner Blokland, Russell
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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Application Number

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CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).



LACK OF UNITY OF INVENTION
SHEET B

Application Number

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The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-7, 15

A reflector having as "special technical feature" that a ratio h/H of the height h of the side walls to the height H of the parabola is between 0.55 and 0.75, and / or in that a ratio h/l of the height h of the side walls to the length l of the top opening is between 0.3 and 0.55.

A reflector having as "special technical feature" that the reflector body is formed by four side walls bounding around, and the reflector body has a trapezoidal configuration in a longitudinal section thereof, wherein the bottom opening is greater than the top opening, preferably two opposite ones of the four side walls are symmetrically arranged relative to a centrally vertical axis Z of the reflector body, and the two opposite side walls have respective inner surfaces configured to correspond to two symmetrical halves of the light-reflective parabolic surface. A reflector having as "special technical feature" a plurality of the reflectors according to any one of claims 1 to 7 which are prefabricated integrally.

2. claims: 8-14

A reflector having as "special technical feature" (Rule 44(1) EPC) a light source unit comprising one or more LED light sources; a wiring substrate on which the one or more LED light sources are mounted; one or more diffusers for scattering light emitted from the light source unit; characterized in that the lighting device further comprises a corresponding number of the reflectors according to any one of claims 1 to 7 as the number of the diffusers, wherein each of the diffusers is mounted between the LED light sources and a corresponding reflector in a way such that the diffuser closes a top opening of the corresponding reflector to allow for reflection of the light scattered by the diffuser through the inner surface of the reflector to the outside of the lighting device.

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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