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(54) **LIGHTING SYSTEM BASED ON SIGHT BLOCKING AND MULTIPLE REFLECTION FOR POINT AND DIRECTIONAL LIGHT SOURCES**

(57) This invention is related to a high level of energy efficient modular lighting system based on multiple reflection and sight blocking, developed particularly for point/directional light emitting LEDs and other light sources of the same characteristics, generating convenient light properties (e.g. with respect to glare , color rendering , homogeneity) and providing light distribution control in line with the standards required by all applicable industrial lighting fields (indoor / office-school-hospital-supermarket etc. lighting, road and tunnel lighting, park and garden lighting, architectural lighting etc.) where point/directional light sources / LEDs are used.

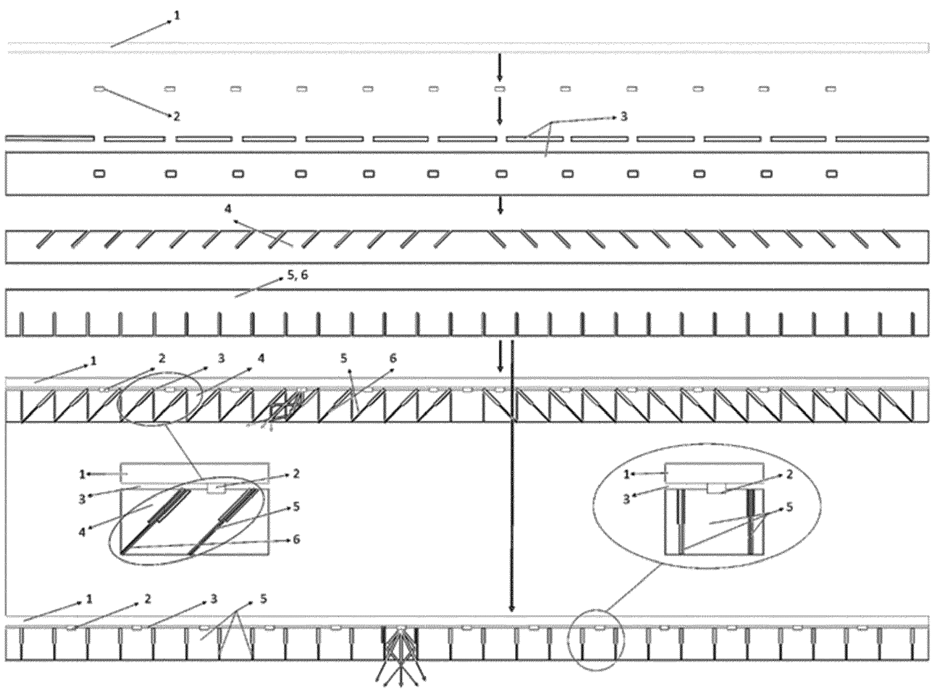

Figure 1

EP 3 537 037 A1

Description

Technical Field

[0001] This invention is related to a high level of energy efficient modular lighting system based on multiple reflection and sight blocking, developed particularly for point/directional light emitting LEDs and other light sources of the same characteristics, generating convenient light properties (e.g. with respect to glare , color rendering , homogeneity) and providing light distribution control in line with the standards required by all applicable industrial lighting fields (indoor / office-school-hospital-supermarket etc. lighting, road and tunnel lighting, park and garden lighting, architectural lighting etc.) where point/directional light sources / LEDs are used.

[0002] The invention has particularly been developed for ***point*** (emitting intensive light from a small surface) and ***directional*** (emitting light in one direction) light sources. The industrially applicable forms of the mentioned point/directional light sources currently used in artificial lighting are the LED light sources. Point/directional light sources and consequently LED light sources are used in the subject system of our invention.

Prior Art

[0003] The distinctive forms of artificial light sources preceding LED (light emitting diode), which has been reinforcing its position as the primary light source in lighting industry, are:

- Being surface - extended - spherical light sources / having wide light emitting surfaces
- Being omni-directional.

The lighting fixtures and components adopting the distribution and characteristics of the light sources in these physical forms in line with the target lighting type and area objectives, have naturally been developed in accordance with their mentioned forms and characteristics.

[0004] Light emitting diodes (LEDs), which emit point (not surface), directional (not all or omni-directional) and highly intensive light, have made most of the conventional luminaire optical components (opal diffusers - prismatic diffusers - parabolic aluminum reflectors - metalized plastic louvers...) functionless due to their unsuitability and incapacity for controlling light sources of these forms.

[0005] In this field, where industry is working continuously to develop new solutions for still unresolved and interrelated; efficiency, glare and light distribution control problems, there exist industrially applicable 4 main systems. Product and/or application details, specifications / weak and strong points of these existing systems can be summarized as follows:

1. Back-Lit Panel:

[0006]

- Efficiency: Weak. 25-30% light loss
- +19 UGR - high glare / over industry limits except very limited applications
- Light distribution / beam control : none
- Production cost: low / economical

2. Edge-Lit Panel:

[0007]

- Efficiency: Weak. 30-35% light loss
- ±19 UGR - upper limit of industry acceptable (for certain applications) glare level
- Light distribution / beam control : none
- Production cost: low / economical

3. Spotlight and parabolic aluminum louver reflectors

[0008]

- Efficiency: High / 85-95% power efficiency
- ±17 UGR - acceptable glare level
- Light distribution / beam control : high
- Fields of Application: limited / Main applications : shop - corridor - supermarket - accent lighting
- Production / application cost: high

4. Optic Lenses - TIR Lenses

[0009]

- Efficiency: reasonable. 80-85%
- UGR : medium - acceptable - (lenses: for high bay - outdoor lighting applications)
- Light distribution / beam control : good - particularly very high in TIR lenses
- Fields of application: limited / shop - decorative - accent lighting for TIR lenses and high bay - highway - stadium etc. lighting for optic lenses
- Production / application cost: high

[0010] The method of blocking the sight and re-directing the light by means of flat or parabolic reflective lamellas, consecutively parallel or non-parallel positioned at a certain fixed or various different angles to light source, have been implemented in different shapes and forms since very early ages. The oldest and the most common application is the "venetian blind" system used to control daylight. There also exist patented applications of the method developed for artificial light sources in lighting industry.

One of them is the patent application US5008791A. This patent discloses a room lighting system comprised of intersecting first and second sets of parallel elongated parabolic louvers. In the system depicted in the patent abstract, the louvers of at least one of the first or second sets are angularly oriented to nadir and spaced apart to confine light passing downwardly therethrough to an asymmetrical candlepower distribution curve. One quadrant of the curve, termed a "wall washing quadrant" is on one side of the curve and a "low direct glare quadrant" is oriented to an opposite side of the curve. According to the depicted lighting system, the light and light grid are said to be placed adjacent the wall such that the wall washing quadrant is oriented toward the wall to illuminate the wall and the low direct glare distribution quadrant is said to be oriented toward the interior of the room. The wall washing quadrant was supposed to eliminate the "cave effect" at the juncture of the adjacent wall and the ceiling while the low direct glare quadrant was supposed to provide desired illumination directed into the adjacent room. It is also claimed in the said patent document that variations of the grid arrangement allowed for uniform lighting of corners as well as end and side walls within a room.

The industrial embodiments of this specific product described in the said patent and alternative similar products subsequently introduced have verified the claims to a certain extent.

[0011] However:

- Although said application reduces the glare as claimed by blocking the light beam directed straight downward and by eliminating the "cave effect"; the loss of light in return (the blocking angular lamellas described in the system absorbs minimum 14% of the light emitted in each reflection) is far from justifying the overall benefits claimed. As a matter of fact, the suggested system failed to find much means of industrial application. Particularly aluminum vacuum metalized plastic types have been used merely in very specific decorative lighting applications such as gallery wall lighting, lobby, front desk top, elevator lighting etc.
- Although the claim of eliminating the "cave effect" by installing the luminaires adjacent to the wall of the room, is theoretically correct, the product has failed to find much possibility of industrial application. Industry has preferred to eliminate the problem by using local spot lights and/or lighting fixtures with opal / prismatic diffuser adjacent to the walls due to cost and technical reasons.
- As clearly specified in the said document, the system presumes wide surface - spherical - omni-directional tabular fluorescent lamps as the light source and specular louver / lamella finishes, so the foreseen and claimed results are inevitably based on these assumption. Even if certain adaptations and revisions are applied, operating the recommended system with directional and point light emitting LEDs, as the light source, *is definitely not feasible* and far from obtaining the claimed results. Furthermore, it will not be functional with point/directional light sources because of the optical problems to arise inevitably, as explained in detail in forthcoming pages of this patent application.

[0012] Another patent application which claims controlling the light distribution at high angles with a similar technique by means of angular bright finish lamellas, is CN103148454B. The document describes a lighting system with louvers comprising lengthwise and crosswise intersecting lamellas jointed to each other perpendicularly at right angles and positioned against the upper light source at 15-25°. This system claims that it would emit a glare-free soft light into the target lighting area by blocking and re-directing the beams oriented towards high angles *without any light loss* in spite of clearly indicated reflections from angular bright finish lamellas depicted as the main component of the system in the said patent (no test results have been presented to support this claim in the patent text). It was clearly indicated that the light source of the system was a metal halide lamp installed horizontally in the luminaire body and positioned parallel to the underlaid louver grid. The drawings in the patent text also depicts a metal halide (or similar) lamp as the light source of the system. However:

- Reducing glare by blocking the light beams oriented towards high angles is not a novelty but a widespread method being practiced through different means since very old ages.
- The system depicted in the patent presumes a laterally positioned omni-directional light emitting spherical metal halide lamp as its light source. There looks to be no possibility of applying / adopting it for directional / point light sources (LED) so as to achieve the claimed results in the said patent.

[0013] Although above mentioned products / systems display some formal similarities, there exist no affinity between these products and our invention in terms of utilized light forms & sources, operation principles, functions and claims. There exist no means of applying the mentioned products in the indicated forms with point - directional (LED) light sources. In other words, the technical problems, being claimed to be resolved by the subject system of the invention are valid specifically for industrially existing lighting systems (of which, the working principles / weak and strong points of the industrially existing systems were detailed above) utilizing, "point" (emitting intensive light from a very small surface) and "directional" (emitting light in a certain direction) light sources.

[0014] On account of this, the technical problems to be resolved with the subject system of the invention are applicable for and according to the systems which are already available / industrially implemented and the operating principles as well as strengths and weaknesses of which were detailed above (these are the existing LED and/or generally point/directional light source systems).

[0015] As a result, a development was required in the related technical field due to the negative aspects and inadequacy of the existing solutions / systems described so far.

Objective of the Invention

[0016] Inspired by the existing state of the technique, the invention intends to present solutions for following problems:

• PROBLEM 1: High glare / UGR

[0017] In the first two LED based general lighting systems depicted above, (back-lit panel and edge-lit panel) problem is particularly evident and high. In the invention, glare / UGR control, is achieved by:

a. Blocking the direct radiation at high angles (considered to be the main reason of the glare) from the source through all-vertical lamella louvers in all 4 directions or vertical and cross lamella combination louvers in 3 directions completely and at high angles in the 4th.direction.
b. Dispersing the light beams (through reflection from specifically chosen lamella surface finishes) over a certain degree and re-directing them towards the target lighting area in intended intensity and angles.

UGR levels much lower than those of acceptable limits for general lighting (cross jointed version: 15-16 UGR at 0°-180° axis / 11-12 UGR at 90°-270° axis / perpendicular jointed version: 15-16 UGR in all directions) can be achieved while maintaining high efficiency.

• PROBLEM 2 : Low efficiency / High light losses

[0018] Again, in the first two LED based general lighting systems depicted above, (back-lit panel and edge-lit panel), the light losses are very high (opal diffusers: 25-35% / transparent micro-prismatic diffusers: 12-18%) due to plastic diffusers inevitably needed as integral part of the system to decrease intensity and reduce glare. As these plastic diffusers are not needed in the invented system in order to solve the above mentioned (1st) problem of glare, the operational light losses are considerably low. Especially in the cross jointed louver system, the PCB surface is coated with white reflective film having +98% total reflection, in order to minimize the possible losses due to substantial back reflections mainly from sight blocking cross jointed 1st. reflection lamella and partly from the other lamellas forming the louver cell walls. According to the definitive lighting laboratory test results, the luminous efficacies achieved with the first prototypes are:

- ➢ Cross jointed louver type: 129.3 lumen/watt (=>+93% power efficiency)
- ➢ Perpendicularly jointed louver type: 132.5 lumen/watt (=>+95% power efficiency)

wherein, 139 lumen/watt efficiency bare PCB is used.

• PROBLEM 3 : Distribution control of the point light (LED) radiation:

[0019] In the first two LED based general lighting systems depicted above, (back-lit panel and edge-lit panel), there exist no control of light distribution at all. Due to their principles of operation, these systems direct the light, emitted by a number of point and directional LED sources onto opal or prismatic diffuser panels so as to transform this primary LED light source into another, less intense and more diffuse light source spread over a wider planar surface and as expected from a (still) raw light source, light is dispersed into the target lighting area without any directional control. Further / secondary optics / lighting fixtures are actually required to control the light distribution after this stage in these systems.

[0020] The 3rd. group of industrially accepted, LED based lighting systems depicted above, (Spotlight and parabolic aluminum louver reflectors) are able to achieve light distribution control in a wide range of beams (8° - 65°) while maintaining the efficiency at considerably high levels. However, this performance can be realized only in certain lighting applications and at high unit costs. Due to their high lumen output emitted from a rather small luminous area in this family of luminaires, their application areas are technically restricted with high ceiling areas and/or certain specific applications. These optical restrictions coupled with high cost components of this group of luminaires (spun or segmented reflectors , aluminum cast or profile body, necessity of using COBs as light source , cob holders , coolers ...) constrain them (as actually practiced in the market) in:

a. spot/object lighting named as "accent lighting" and/or
b. lighting of high ceiling areas / applications (5 meters and higher) so as to justify their high units costs by obtaining sufficiently wide illuminated surfaces for each luminaire in the target lighting area and decrease light intensity down to levels acceptable for human eye. In case they are intended to be used in lower ceiling areas (covers the biggest segment of the artificial lighting market) a further optics / diffusers would be needed and this would mean additional light loss (up to 35%) and inevitably higher UGR levels. High costs and these technical restrictions actually confine this group of luminaires into almost only high ceiling "shop lighting" in the market.

[0021] The 4th.group of industrially accepted, LED based lighting systems depicted above, (optic lenses - TIR lenses), provide angular light distribution control at acceptably good levels and maintain relatively high efficiency levels. However, in the same way as above mentioned 3rd. group of LED based lighting systems, this performance can be realized only in certain lighting applications and at high unit costs.

[0022] With the potential of applicability in almost all areas of lighting, our system with its modular structure, provides light distribution control in a wide range of beams, without the above mentioned disadvantages of the existing systems.

[0023] The subject system of the invention offers:

a. Incomparably superior results with respect to the first two LED based general lighting systems depicted above, (back-lit panel and edge-lit panel), in :

I. Efficiency
II. Light / lighting quality (by reducing glare)
III. Light distribution control

b. Relatively better efficiency and glare control results with respect to the 3rd. (Spotlight and parabolic aluminum louver reflectors) and the 4th. (optic lenses - TIR lenses) LED based lighting systems depicted above, without the disadvantages of:

I. Applicability in limited lighting areas
II. High cost
III. Shorter life span and performance decrease due to high heat generation of the system

[0024] In order to realize the above mentioned objectives; as a high energy efficient modular lighting system based on multiple reflection and sight blocking, developed particularly for point - directional light emitting LEDs and other light sources of the same characteristics , generating convenient light properties and providing light distribution and glare control in line with the standards required by all applicable lighting fields where point/directional light sources / LEDs are used; is characterized in that:

- system cell walls are made up of the articulation of cross-blanked and/or perpendicularly blanked lamellas to each other in parallel, successive, angular and/or perpendicular sequences, said lamella surfaces providing a very high reflection in various types for the visible spectrum of electromagnetic radiation used in artificial lighting due to its perceptibility by the human eye;
- system louver cell top is entirely covered with PCB surfaces on which the point/directional light source units /LEDs are assembled;
- the PCB surface that constitutes the closed ceiling of the system is coated with a polymer-based reflective film having very high reflection values in visible spectrum of electromagnetic radiation (or other materials of the same properties) so as to leave uncovered only the point/directional light sources (LEDs) assembled on it, in order to reroute the light beams reflected back from the surfaces of the system cell lamellas, into the target lighting area with minimum possible losses;
- System comprises one or more than one cells , the walls of which are all closed except the one facing the target lighting area , each (cell) capable to functioning as an independent luminaire, and of which , the cell wall lamella finishes, sizes, forms, articulation angles, the positions of point / directional light sources assembled on PCB which forms the top cover of the system, all creating the functional parameters of the system, acting either individually or in interaction with each other in the system so as to contribute the system to function in line with the target lighting objectives to control light intensity , glare, beams and distribution.

[0025] The structural and characteristic properties of the invention and its advantages will more clearly be understood with the attached figures and detailed explanations referring to these figures, and therefore, the invention is required to be evaluated by taking these figures and detailed explanations into consideration.

Figures to Help Understanding of the Invention

[0026] The preferred embodiments of the invention is illustrated in the accompanying drawings, in which:

Figure 1 shows the elements which constitute the said system of the invention.

Figure 2, shows top and side view of PCB without reflective film, onto which point/directional light source (LED) units are assembled.

Figure 3, shows top and side view of reflective film laminated PCB onto which point/directional light source (LED) units are assembled.

Figure 4 shows the reflections of the light, back from highly reflective (+98% total reflection) white polymer (pet) film laminated on PCB surface.

Figure 5, shows vertical side wall cell lamella - cross blanked in two asymmetrical directions.

Figure 6, shows crosswise inserted lamella of the sight-block louver system or the lamella in both directions of the standard perpendicular louver system - lamella with perpendicular articulation blanks.

Figure 7.1, shows angularly jointed lamellas / louver system.

Figure 7.2, shows perpendicularly jointed lamellas / louver system.

Figure 8.1, shows the lighting louver system formed by angularly jointed lamellas.

Figure 8.2, shows the lighting louver system formed by perpendicularly jointed lamellas.

Figure 9, shows table giving reflection type and values from perpendicular and cross lamella surfaces which are coated through PVD (positive vapor deposition) method either with pure aluminum (having +95% total reflection) or pure silver (having +98% total reflection) and the following graph shows the light losses after each reflection from surfaces of different reflection properties.

Figure 10, shows the images and light reflection characteristics of the PVD coated specular, semi-specular and luminal matte surfaced materials used for the perpendicular and cross (angular) cell wall lamellas of the system.

Figure 11.1, shows the layout of PCB in the form to entirely cover the top of the cell made up of angularly intersecting cross and perpendicular blanked lamellas so as to confine each point/directional light source in a separate cell.

Figure 11.2, shows the layout of PCB in the form to entirely cover the top of the cell made up of perpendicularly intersecting jointed lamellas so as to confine each point/directional light source in a separate cell.

Figures 12.1, 12.2, show intracellular reflections and extracellular light distribution of the cross jointed cell formations depicted at figure 11.1 and perpendicular jointed cell formations depicted at figure 11.2

Figures 13.1, 13.2, 13.3.1, 13.3.2, 13.3.3, 13.3.4, 13.3.5, show how the light distribution and beam angles directly and light intensity indirectly could be controlled by changing the assembly positions of the point/directional light sources (LEDs) on reflective film laminated PCB, covering the cell top, in directions towards either of the consecutive angled / cross jointed lamellas.

Figures 14.1, 14.2, 14.3, show the images related with shortening the width of the first cross lamella in the cell.

Figures 15.1, 15.2, 15.3, show the images related with shortening the width of the first cross lamella and extending the width of the opposite second cross lamella in the cell.

Figures 16.1, 16.2, 16.3, show the images related with the bending of the extended part of the second cross lamella in the cell at various angles at one or more points, to one or more angles towards the light source.

Figures 17.1, 17.2, 17.3, show the images related with creating asymmetrically light emitting luminaire by using only half of the two way cross blanked perpendicular cell wall lamellas and by shortening the width of the first cross lamella **in the cell system with cross jointed lamellas**.

Figures 18.1, 18.2, 18.3, 18.4, 18.5, show the images related with creating asymmetrically light emitting luminaire **in the cell system with perpendicularly jointed lamellas,** by bringing the light source in the diagonal center point of the cell top cover (PCB), closer towards one of the side walls (with an asymmetrical distribution in the direction opposite to this wall) and by extending and/or by bending this side wall in the direction of the light source either with or without extending this specific side wall and/or by shortening the opposite side wall.

[0027] The drawings are not necessarily needed to be scaled and the details that are not essential to understand the present invention may have been omitted. Additionally, the elements which are at least substantially identical or having at least substantially identical functions are shown with the same reference number.

Description of the References of the System Components

[0028]

1. PCB (printed circuit board)
2. Point/directional light source
3. Reflective film
4. Cross blanked - vertically jointed lamella
5. The first / perpendicularly blanked - cross jointed lamella (reflective surface facing angularly upwards / towards light source in the cell)
6. The second / perpendicularly blanked - cross jointed lamella (reflective surface facing angularly downwards / towards the target lighting area)

Detailed Description of the Preferred Embodiments of the Invention

[0029] In below detailed descriptions, the preferred embodiments of the invention are presented with the intention of facilitating a better understanding of the invention and in the way not to create any restrictions in the content.

[0030] This invention relates to a high level of energy efficient modular lighting system based on multiple reflection and sight blocking, developed particularly for point - directional light emitting LEDs (2) and other light sources of the same characteristics , generating convenient light properties (e.g. with respect to glare , color rendering , homogeneity) and providing light distribution control in line with the standards required by all applicable lighting fields (indoor / office-school-hospital-supermarket etc. lighting, road and tunnel lighting, park and garden lighting, architectural lighting etc.) where point/directional light sources / LEDs are used.

[0031] The invented lighting system includes:

- **a printed circuit board - PCB (1)** which creates the electrical-electronical infrastructure;
- **the point/directional light sources (2)** producing the light required for the system. These light sources are assembled on the PCB (1) and the position of them in the system as a controllable and variable

parameter in co-ordination with the other parameters of the system, provides the control of light distribution and beam angles directly and glare indirectly;

- **reflective polymer film (3)** providing a high (+98%) total reflection, laminated on PCB (1) surface so as to leave only the light emitting surfaces of assembled point/directional light sources (2) open and minimizing the possible high light losses by re-directing the light beams reflected backwards, onto the PCB (1) surface from the system cell lamellas (4,5,6) back to the lighting area with negligible losses.
- **lamellas (4, 5, 6),** :
    - forming closed cells by the parallel/consecutive, angular or vertical articulation to each other in one or two opposite directions;
    - the sizes, forms and the surfaces of which are the interrelated, variable parameters of the system used in the control of the distribution, beam angles, intensity and glare of the light emitted by the point/directional light sources (2) assembled on the PCB (1); (see figures 1, 2, 3, 4, 5, 6)

[0032] In the invented lighting system, top and bottom open grids/cells are constituted by the articulation of the cross-blanked lamellas (4) with the perpendicular-blanked lamellas (5,6) (see figure 7.1) or by the articulation of identical perpendicular-blanked lamellas (5) with each other (see figure 7.2) and the tops of these cells are completely closed with reflective film (3) laminated PCBs (1) on which proper point/directional light sources (2) are assembled in the position fitting for the purpose of the target lighting objectives , so that only the bottom surfaces of the cells facing the target lighting area remain open (see figures 11.1 , 11.2, 12.1, 12.2).

[0033] As the existing **general lighting** applications with LEDs (edge-lit panel / back-lit panel) do not provide a light distribution control, there, such a special layout is not required. In these systems, the required number and power of LEDs are mounted into the luminaires generally in equal intervals so as to provide sufficiently homogeneous target lumen output. In the invention, the light properties of each point/directional light source (2) confined in a separate cell, can be controlled as an independent lighting fixture. In this way, the lighting system composed of independently functioning cells / modules may consist of a single cell which may function as a low power but competent luminaire, or it may consist of hundreds and even thousands of cells / modules in accordance with the target lighting power, purpose and function simply by extending the lengths of lamellas (4,5,6) accordingly. (see figures 7.1, 7.2, 8.1, 8.2)

[0034] The mentioned lamellas (4, 5, 6) are utilized to control light distribution at high angles and to prevent the direct, uncontrolled and highly intensive emission of important part (+75%) of light generated by the point/directional light sources (2) towards the target lighting area in cross jointed louver type (see figures 7.1, 8.1). In the vertically jointed louver type, the intersecting identical lamellas (5) forming the cell walls, are used for restricting the light distribution at high angles and/or to canalize it towards the direction in accordance with the target lighting purposes (see figures 7.2 , 8.2).

In the subject lighting system of the invention, either pure aluminum (providing +95% total reflection) or pure silver (providing +98% total reflection) coated (through PVD - positive vapor deposition method) lamella (4, 5, 6) surfaces can be used (see figure 9). Alternatively, polymer films providing over 98% total light reflection can be used to achieve the same function.

[0035] As the invention provides light distribution control and light intensity / glare control by means of sight-blocking and multi-reflection, it generates a much higher number of reflections than all other existing LED lighting applications. As each reflection also means loss of light, it is critically important that all reflection surfaces (the cross and vertical lamellas (4, 5, 6) and PCB (1) surfaces) in the system should have a very low (<2%) light loss / absorption in each reflection. In the present state of the technology, this feature could be achieved with PVD pure aluminum and PVD silver coated surfaces or high reflection polymer films which have already been used extensively in some LED lighting systems (e.g. spot lights - parabolic reflectors - TIR lenses) as well as prior lighting systems using fluorescent or other discharge lamps. The chart (efficiency curve as per number of reflections) in figure 9 clearly shows that the efficiency may decrease dramatically unless such a high reflection is provided.

[0036] The subject lighting system of the invention may use specular, semi-specular, luminal matte and patterned PVD reflective materials as the lamella (4, 5, 6) surfaces, wherein:

a. Specular surfaces : provide point light reflection
b. Semi-specular surfaces : provide partly diffused light reflection
c. Matte / patterned surfaces : provide diffused light reflection

[0037] In this way, the distribution form (and beam angles) as well as UGR - glare values of the significant "reflected" part (+75%) of the total light emitted by the point/directional light source (2) of the system can be controlled (see figure 10).

[0038] As the main reflective surfaces of the system, the lamellas (4, 5, 6) can be defined:

- in 2 different ***forms*** according to the type of blanks on them:

    a. **cross blanked** lamella (4)
    b. **perpendicular blanked** lamella (5, 6)

- in 3 different ***status*** according to their ways of articulation into the system:

a. cross blanked / **vertically jointed** lamella (4)
b. perpendicularly blanked / **cross jointed lamella -** reflection surface faces diagonally upward, towards point/directional light source (2) ; perpendicularly blanked 1st. reflection lamella (5)
c. perpendicularly blanked / **cross jointed lamella -** reflection surface faces diagonally downward, towards target lighting area ; perpendicularly blanked 2nd. reflection lamella (6)

and the cells of the louvers can be constructed in different lamella surface finish combinations:

a. all lamellas (4, 5, 6) having the same surface finish (e.g. all semi-specular)
b. each lamellas (4, 5, 6) having different surface finishes (e.g. cross blanked-perpendicularly jointed lamella (4):matt / perpendicularly blanked-cross jointed 1st. reflection lamella (5): specular / perpendicularly blanked-cross jointed 2nd. Reflection lamella (6): semi-specular

so as to provide varied light characteristics and distributions according to the target lighting objectives. Although these surface elements belong to prior art, their ability to fulfill the above described functions within the subject system of the invention utilizing point/directional light sources (2), is absolutely dependent on the unique element of independently functioning closed cell system structure of the invention.

[0039] The light distribution and beam angles can directly be controlled and the light intensity can indirectly be controlled by shifting the positions of the point/directional light resources (2) assembled on the reflective film (3) laminated PCB (1) covering the cell top completely, from the center position, in the direction towards either of the perpendicular blanked cross lamellas (5, 6) in the system (see figure 13.1). By making this function utilizable, which does not exist / is not foreseen and used in any of the existing general LED lighting applications, a new parameter / factor has been put in use, in the direct control of light distribution and beam angles and indirect control of light intensity and glare. In the cross-jointed cell system, as the position of the point/directional light source (2) in the cell is shifted towards the perpendicularly blanked 1st.reflection lamella (5) (see figure 13.3.2), the beam angle in 0-180° axis becomes narrower while it tends to become wider in 90-270° axis, and as it is shifted in the reverse direction towards the perpendicularly blanked 2nd.reflection lamella (6), the distribution angles tend to become wider and converge towards each other in both axis (see figures 13.3.3 , 13.3.4). In the vertically jointed cell system, as the position of the point/directional light source (2) in the cell is shifted, from the central position towards the either of the side walls, a gradually more asymmetric light distribution (in the opposite direction of the convergence) can be obtained, in proportion to the convergence ratio (see figure 13.3.5). An important optical problem which was not foreseen in the previous technologies, and which would inevitably emerge when the prior-art cross-lamella louver systems are used with point/directional light sources (2) is resolved in the invented lighting system with cross-jointed lamella through various system configurations made up of extending or extending and bending (of the extended part) of the width of the perpendicularly blanked 2nd.reflection lamella (6), or shortening the width of the perpendicularly blanked 1st. reflection lamella (5) in interaction with the position of the point/directional light source (2) in the cell. The use of point/directional light sources (2) in a lighting system with cross-jointed lamellas, causes a critical optical / light distribution problem which does not occur with the usage of the surface / extended / spherical / omni-directional light sources: When the light of point and directional nature leaves the closed ***cross-jointed cell system*** formed by the lamellas (4, 5, 6) and distributed into the lighting area in 0 -180° main axis (and partially in the adjacent 30-210° and 60-240° axes as well), it splits into 3 independent and disconnected beams having optically problematic relationships with each other with respect to the lighting technique (see figure 13.2) and this situation causes the lighting problems described below:

a. **Beam 1**: 14-26° part (in the direction towards the 2nd.cross lamella (6)) of the light emitted from the point/directional light source (2) and reflected from the bottom end of the perpendicularly blanked, cross-jointed 1st.reflection lamella (5), forms an independent beam, split from the main light distribution body, in between 64-76° (amount of light and angle interval vary depending on the position of the point/directional light source (2) in the cell) from nadir without touching the reflective surface of the 2nd.cross lamella (see figure 13.2). This beam will be considered as a loss to a great extent as it is directed to a zone away from the target lighting area, and it also causes glare due to its high beam angle. (as used herein, nadir is a reference line or axis at the approximate center of the curve, that is perpendicular to the grid and vertical in relation to the room plane)
b. **Beam 2**: This light beam, emitted from the point/directional light source (2) towards the open surface of the cell in between the angles ±26 - 50°, confined by the two cross-jointed lamellas (5, 6) of the system, is detached both from Beam 1 (64-76°) and Beam 3 distributed in 0-17° range. Although the light distribution angle range (and the intensity of the part of it over 45°) does not cause a serious glare, it creates relatively darker, low light areas in 50-64° and 17-27° ranges.
c. **Beam 3**: It is the only problem-free piece of light on its own in this cell structure. This strong light beam is initially emitted from the point/directional light

source (2) towards the first vertically blanked cross lamella (5) in angles 0-14° in the direction towards the second vertically blanked cross lamella (6), on 0 - 180° axis, and there reflected over towards the opposed second vertically blanked cross lamella (6) and then finally rerouted from there, towards the target lighting area, in parallel to nadir.

[0040] As one of the most important function of the subject system of invention, the solution to above described serious optical problem, is created by shortening the width of the first perpendicularly blanked cross lamella (5) in a manner and at the extent to prevent the formation of beam 1 (see figure 14.1) The extent /size of the shortening is directly interrelated with the position of the point/directional light source (2) in the cell: the more , the point/directional light source is brought closer to the second vertically blanked cross lamella (6), the less shortening will be needed (see: figure 13.1) and 2 important results will arise from this formation:

I. As the beam 1 never occurs, the emission / glare at high angles and the loss of light are eliminated, and eventually the dark area between Beam 1 and Beam 2 never comes out. In the same way, the dark area between beam 2 and beam 3 (in 17-27° range) naturally fails to occur as the bottom-end section of the first perpendicularly blanked cross lamella (5) which causes it, is cleared off.

II. In the absence of this element [shortening of the width of the first perpendicularly blanked cross lamella (5)], the inevitable minimum 2% light loss due to minimum one more reflection of the system light emission within 15-27° range directed towards the shortened part of the first perpendicularly blanked cross lamella (5) is avoided and this angularly problem free beam reaches directly to the target lighting area without any reflection, contributing the total system efficiency.

[0041] As a result, when the light distribution details in figure 14.2 is analyzed in comparison with figure 13.2, it is clearly understood that a healthy and solid distribution is achieved with light control in high angles and without dark areas, in terms of lighting technique and practice.

[0042] In the alternative embodiments of the invented lighting system with cross-jointed lamellas, the function / benefit obtained by shortening the width of the first perpendicularly blanked cross lamella (5) can also be achieved by shortening the width of the first perpendicularly blanked lamella (5) less than required (to achieve the function mentioned above properly), and compensating this deficiency by extending the width of the opposed second perpendicularly blanked cross lamella (6) (see figure 15.1). In this new form of the grid cell structure, not only the cut-off for the undesired beam at 64-76 degrees could be obtained, but as new parameter / function to control the distribution of point/directional light sources (2), this modification also expands the light distribution beam angles of the system.

In alternative embodiments of the invented lighting system with cross-jointed lamellas; by bending the extended part of the second perpendicular blanked cross lamella (6), from one or more points, in one or more angles, in direction to the first perpendicular blanked cross lamella (5) (see figure 16.1), on the one hand, the same functionality of blocking the undesired light emission at 64-76 degrees by the shortening of the first perpendicular cross lamella (5), could be obtained, while on the other hand, light distribution beam angles are narrowed (see 16.2 - 16.3) in line with intended target light distribution, as a new parameter/factor in the control of the point/directional light sources (2).

[0043] In alternative embodiments of the invented lighting system with cross-jointed lamellas, while the width of the first perpendicularly blanked cross lamella (5) is shortened so as to prevent an emission, split at 64-76° degrees from the main body of the light distribution, and no modification is done on the second perpendicularly blanked cross lamella (6), by using only the half of the cross blanked perpendicular lamella (4) (see figure 17.1), having normally blanks in 2 different directions (+X and -X) from its midpoint (see figure 5), the form and the size of the luminaire is designed so as to emit light in one direction and an asymmetrical / wall washing light distribution (see figure 17.2 , 17.3) is obtained. This type of light distribution is required/utilized in specific lighting applications like "supermarket shelf lighting" as well as in eliminating "cave effect" coming out almost all louver grid lighting systems (including the subject lighting system of this invention).

[0044] In alternative embodiments of the invented lighting system with ***perpendicular cell structure***, where the vertically blanked lamellas (5, 6) are articulated with each other perpendicularly to form the cell walls all parallel to each other and perpendicular to the lighting plane, an asymmetric light distribution could be obtained in various distribution forms and angles by converging the point/directional light source (2) towards one of the perpendicular cell walls and:

a. extending the width of the wall lamella (5) towards which the point/directional light source (2) is converged (see figure 18.1)

b. extending the width of the wall lamella (5) towards which the point/directional light source (2) is converged and additionally shortening the width of the opposite parallel lamella (5) (see figure 18.2)

c. bending the wall lamella (5), (the width of which is either extended or not extended) towards which the point/directional light source (2) is converged , in direction towards the light source (2), at the angle required by the target light distribution and additionally by shortening the width of the opposite parallel lamella (5) (see figures 18.3, 18.4, 15.5>)

[0045] This type of light distribution is required/utilized in specific lighting applications like "supermarket shelf lighting" as well as in eliminating "cave effect" coming out almost all louver grid lighting systems (including the subject lighting system of this invention).

Claims

1. A modular lighting system based on sight blocking and multiple reflection, which is capable of controlling the light generated by point and directional light emitting sources (2), in accordance with the target lighting specifications of: distribution, beam angle, intensity and glare, while maintaining high level of energy and light efficiency at the same time; wherein:

   a. the lateral walls of the cells of the system formed by the articulation of cross-blanked (4) and/or perpendicularly blanked lamellas (5,6) to one another in parallel, successive, angular and/or perpendicular sequences, ***have very high and diverse reflection properties*** in the visible (perceivable by human eye) spectrum of electromagnetic radiation which can be used for artificial lighting;
   b. the ***tops of the cells of the system are entirely covered*** with PCB (1), on the surface of which, point/directional light sources (2) are assembled, so light therefrom will pass through the grid;
   c. the LED inserted PCB (1) surface, covering the tops of the cells of the system, is ***laminated with a polymer film (3) or other materials with similar / high reflection properties,*** in the way to allow open, only the light emitting surfaces of point/directional light sources (2) assembled on PCB (1), so as to reroute the beams diverted upwards from the system cell lamella (4,5,6) surfaces, back into the cell and consequently to the lighting area with minimum losses;

   So that:

   I. each cell or each group of cells with (a) ***single open surface***(s) facing the target lighting area, is a closed , self-contained, modular lighting system, meaning , every single cell or any number of physically combinable cells can operate as an industrially functioning independent luminaire.
   II. the variable factors, elements and parameters provided by the system:

   - ***reflection properties*** of the cell wall lamellas (4,5,6);
   - the ***sizes, forms and articulation angles*** of the cell wall lamellas (4,5,6);
   - the ***positioning*** of the point/directional light sources (2) on PCB (1) which is forming the top cover of the system;

   each, can function singly or in interaction to control the distribution, beam angle, intensity and glare of the light in line with the intended lighting objectives.

2. A modular lighting system according to Claim 1, **characterized by** the vertical or cross blanked lamella (4, 5, 6) surfaces forming the cell structure of the system and used in controlling the light distribution, beam angles and consequently the UGR of the reflected 75%-90% part of the total light dispersion, ***being made of materials with specular and/or semi-specular and/or luminal matte/patterned surface reflection properties,*** depending on the intended / required target lighting specifications.

3. A modular lighting system according to Claim 1, **characterized by** comprising the point/directional light sources (2) whose ***positions in the cell / on the PCB (1) can be shifted*** in direction towards either of the perpendicularly blanked cross lamellas (5, 6) of cross articulated cell system or towards one of the vertical wall lamellas (5) of the perpendicularly articulated cell system, for the purpose of controlling (at various levels) the distribution, beam angles, intensity and glare of the light generated by point/directional light sources (2).

4. A modular lighting system according to Claim 1, **characterized by** comprising perpendicularly blanked, cross-jointed first reflection lamellas (5), the reflective surfaces of which face ***upwards*** / PCB (1) and the ***widths of which can be shortened*** as required in interaction with the position of the point/directional light sources (2) on the PCB (1), for the purpose of controlling the distribution, beam angles, intensity and glare of the light generated by point/directional light sources (2) in the cross articulated cell system.

5. A modular lighting system according to Claim 1, **characterized by** comprising perpendicularly blanked, cross-jointed, second reflection lamellas (6), the reflective surfaces of which face ***downwards*** / the lighting area and the ***width of which can be extended*** in interaction with the other two light control parameters of the system:

   I. The position of the point/directional light source assembled on PCB (1), forming the closed ceiling of the system,
   II. The width of the perpendicularly blanked, cross-jointed first reflection lamella (5),

for the purpose of controlling the distribution and beam angles of the light generated by point/directional light sources (2) in the cross articulated cell system.

6. A modular lighting system according to Claim 1, **characterized by** comprising perpendicularly blanked, cross-jointed, second reflection lamellas (6), the reflective surfaces of which face downwards / the lighting area and the ***extended*** (for the purposes explained at claim 6) ***widths of which can further be bended*** in the direction of the point/directional light sources (2) of the system, at one or more points and in various angles in line with the needs of intended lighting objectives and specifications.

7. A modular lighting system according to Claim 1, wherein, an asymmetric light distribution can be obtained through utilization of only one half (cross blanks facing either +X / center left or -X / center right direction) of the cross blanked, vertically jointed lamellas (4) in the formation of the cross-jointed cell system.

8. A modular lighting system according to Claim 1, in the version of vertically jointed cell system which is formed by the articulation of perpendicularly blanked lamellas (5) to each other, wherein, the point/directional light source (2) is converged towards one of the perpendicular lateral cell walls (5) and:

- The width of the wall lamella (5) closer to the light source (2) is extended or,
- The width of the wall lamella (5) closer to the light source (2) is extended and the width of the opposite wall lamella (5) is shortened or,
- The width of the wall lamella (5) closer to the light source (2) is either extended or not extended but bended towards the light source (2), and/or the opposite wall lamella (5) is shortened,

thus an asymmetric light distribution can be obtained in various levels, distribution forms and beam angles.

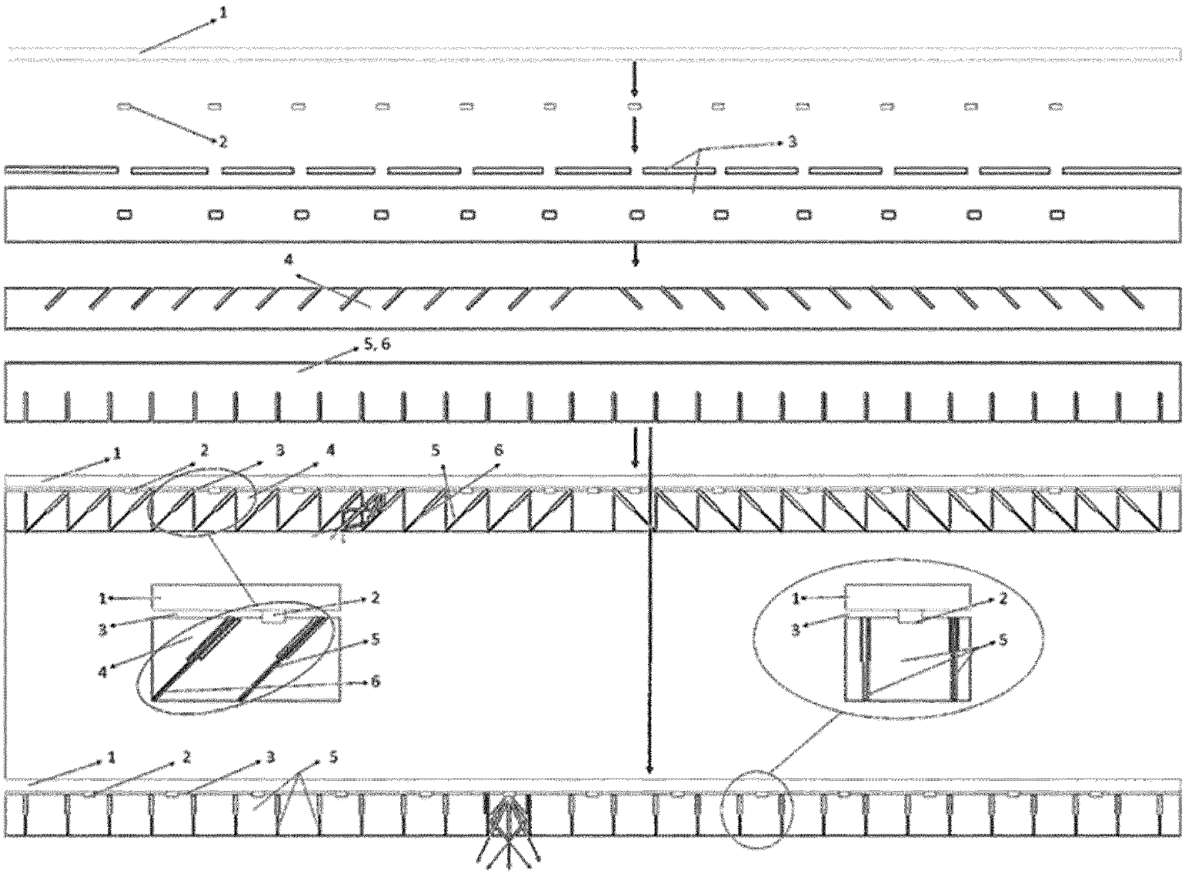

Figure 1

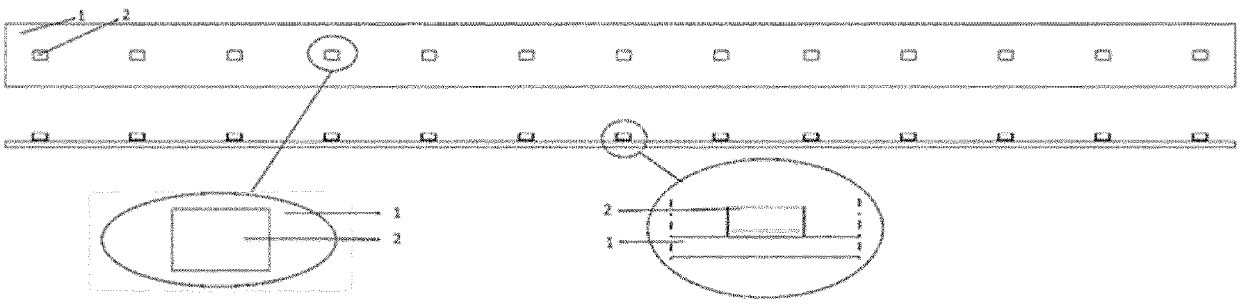

Figure 2

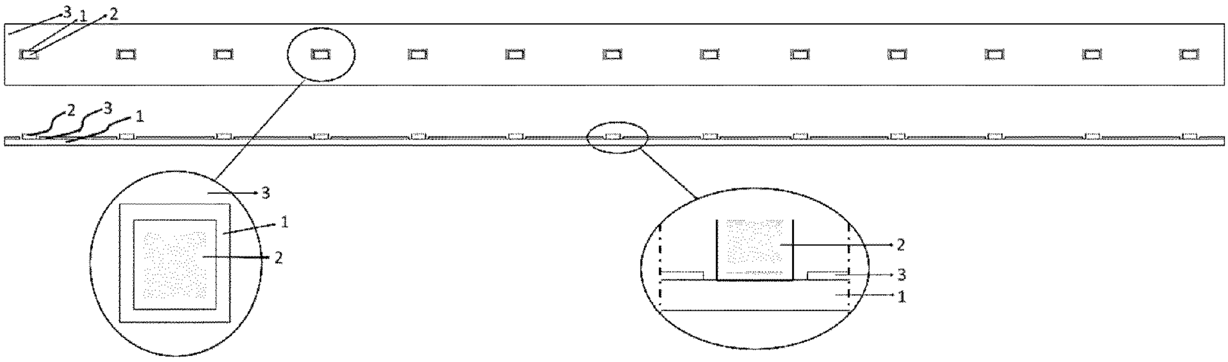

Figure 3

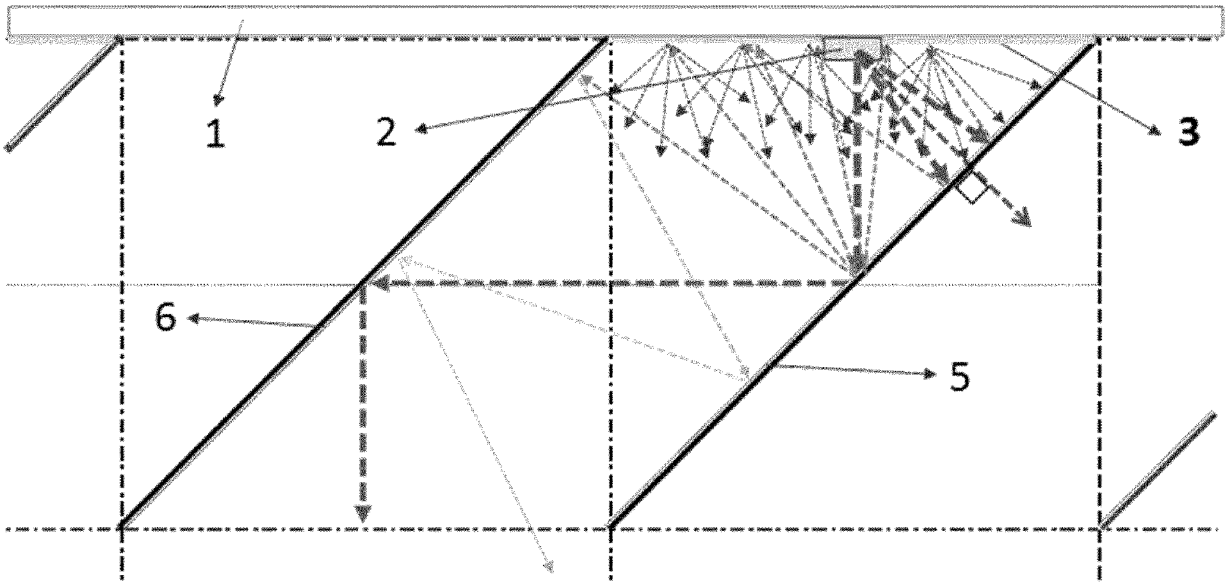

Figure 4

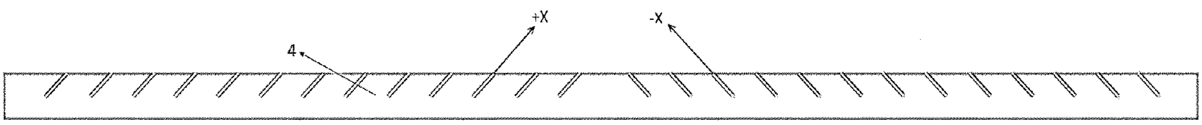

Figure 5

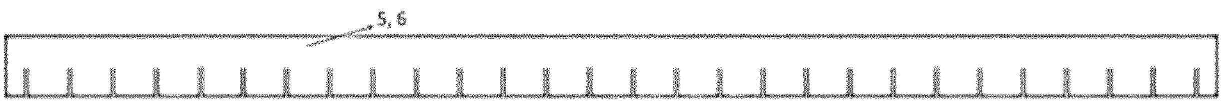

Figure 6

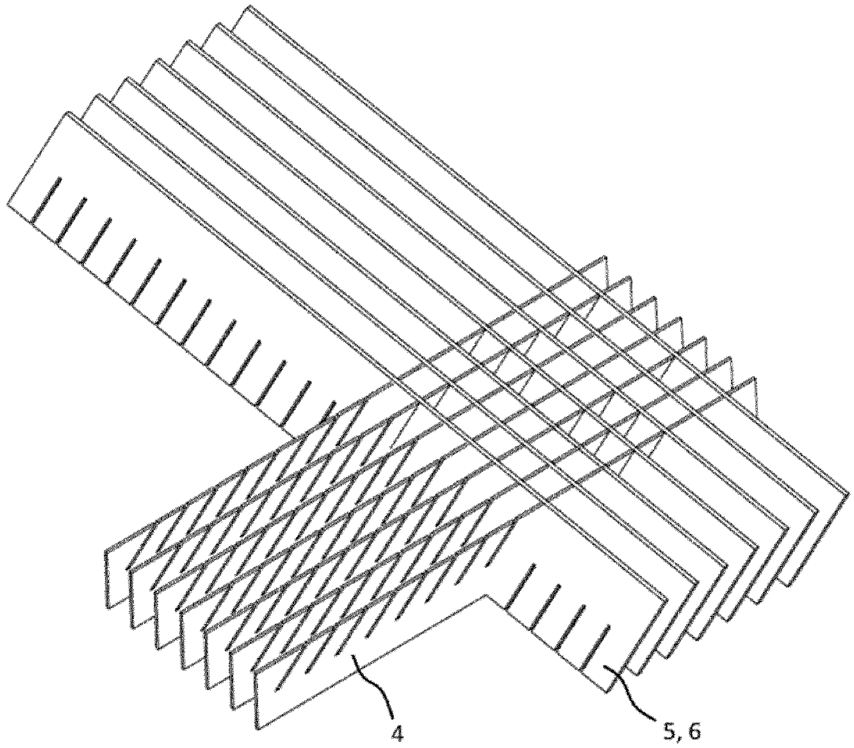

Figure 7

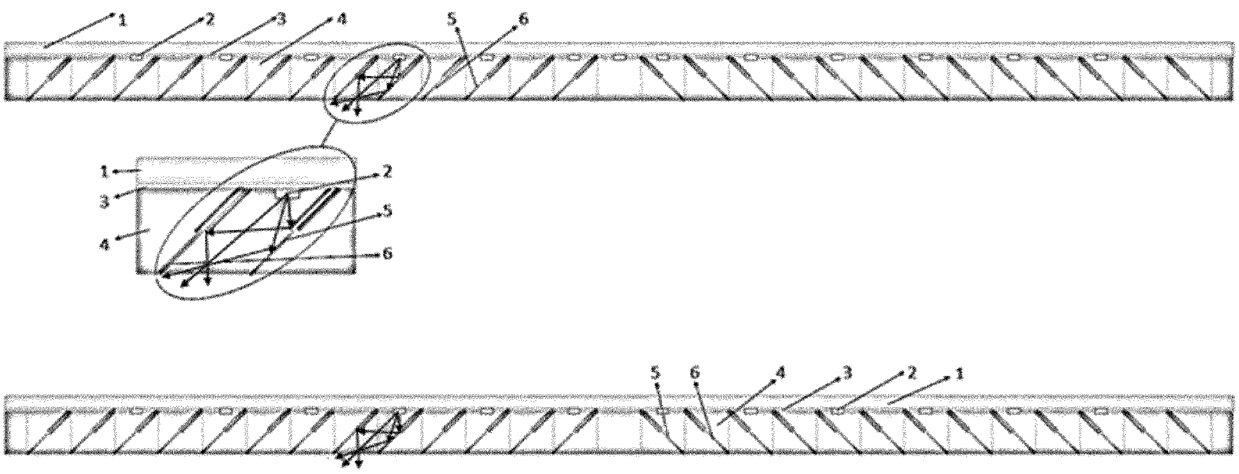

Figure 8

Product	Type	Reflection layer	Total reflectance [%]		Specular reflectance [%]		Diffuse reflectance [%]	Alloy	Temper (hardness)	Min. tensile strength [MPa]	Min. yield strength [MPa]	Min. [%] elongation A_5A_{10}	Class efficiency
			ASTM E 1651	DIN 5036-3	60° long	60° trans	DIN 5036-3						EN 1626[illegible]
V98100	specular	99.99% pure silver	≥ 98	≥ 98	93	93	< 11	1085	H18	125	105	2	A+
V98110	high specular	99.99% pure silver	≥ 98	≥ 96	94	94	< 7	1090	H18	125	105	2	A+
V98120	reflectormatt	99.99% pure silver	≥ 97	≥ 97	73 - 83	58 - 68	85 - 95	1090	H19	140	120	1	A+
V98125	lumenal matt	99.99% pure silver	≥ 98	≥ 98	83 - 87	83 - 87	65 - 75	1090	H18	125	105	2	A+
V98127	bright diffuse	99.99% pure silver	≥ 97	≥ 97	20 - 30	25 - 35	94 - 97	1090	H16	110	90	2	A+

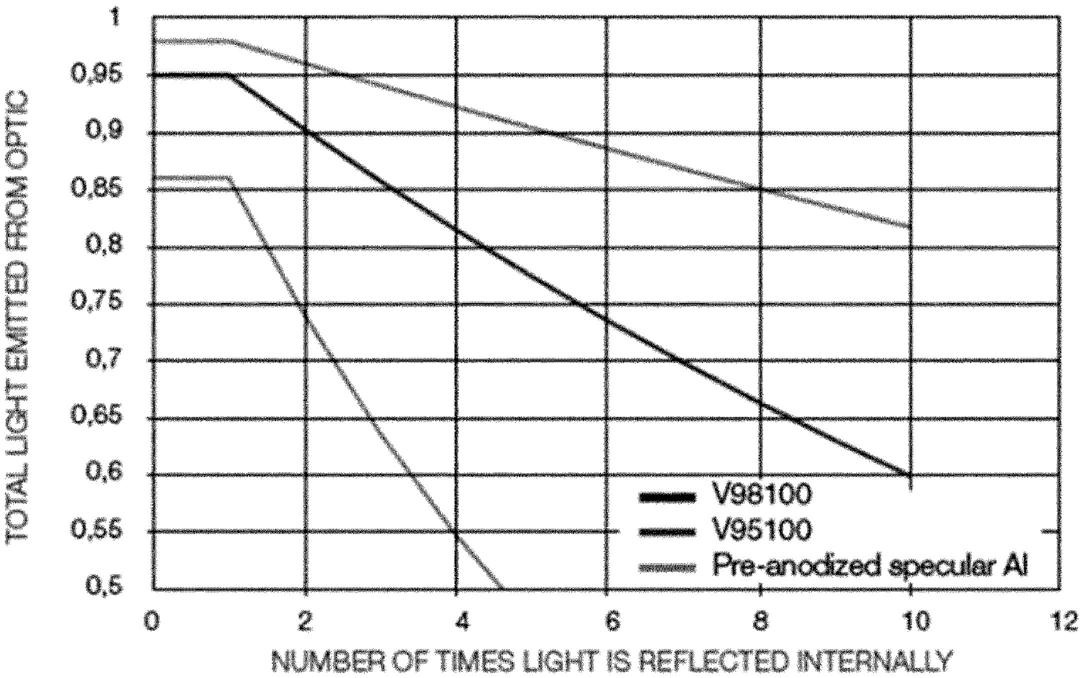

Figure 9

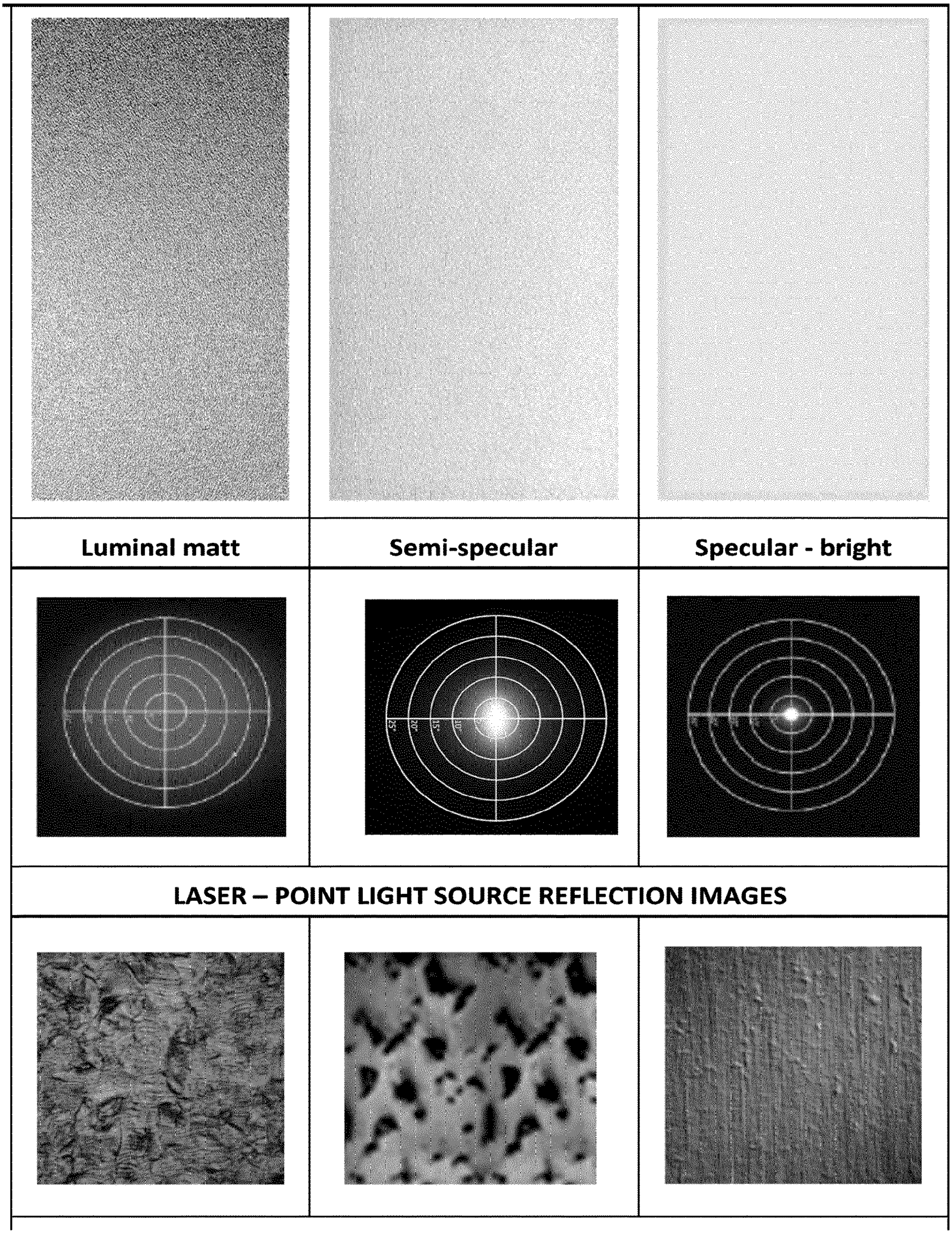
Luminal matt
Semi-specular
Specular - bright
LASER – POINT LIGHT SOURCE REFLECTION IMAGES

Figure 10

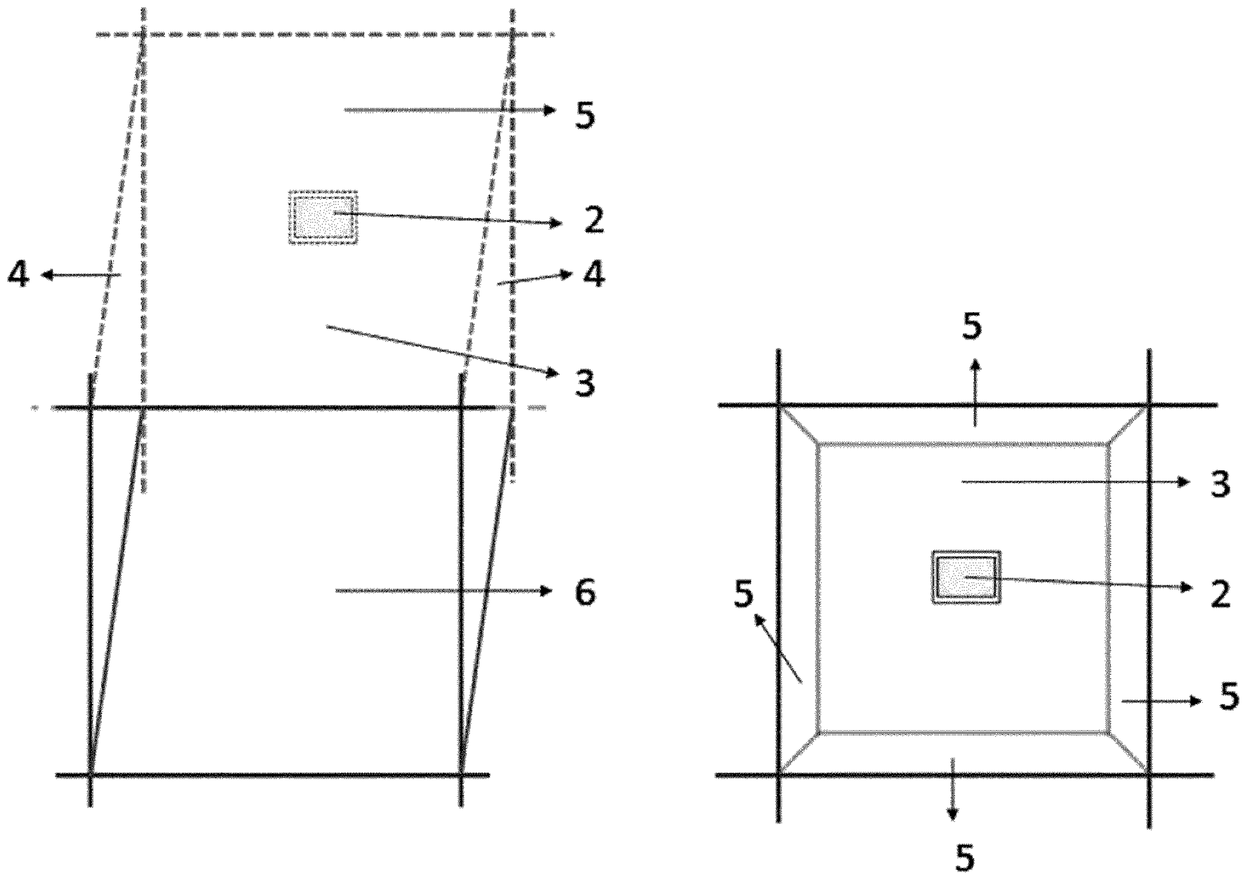

Figure 11

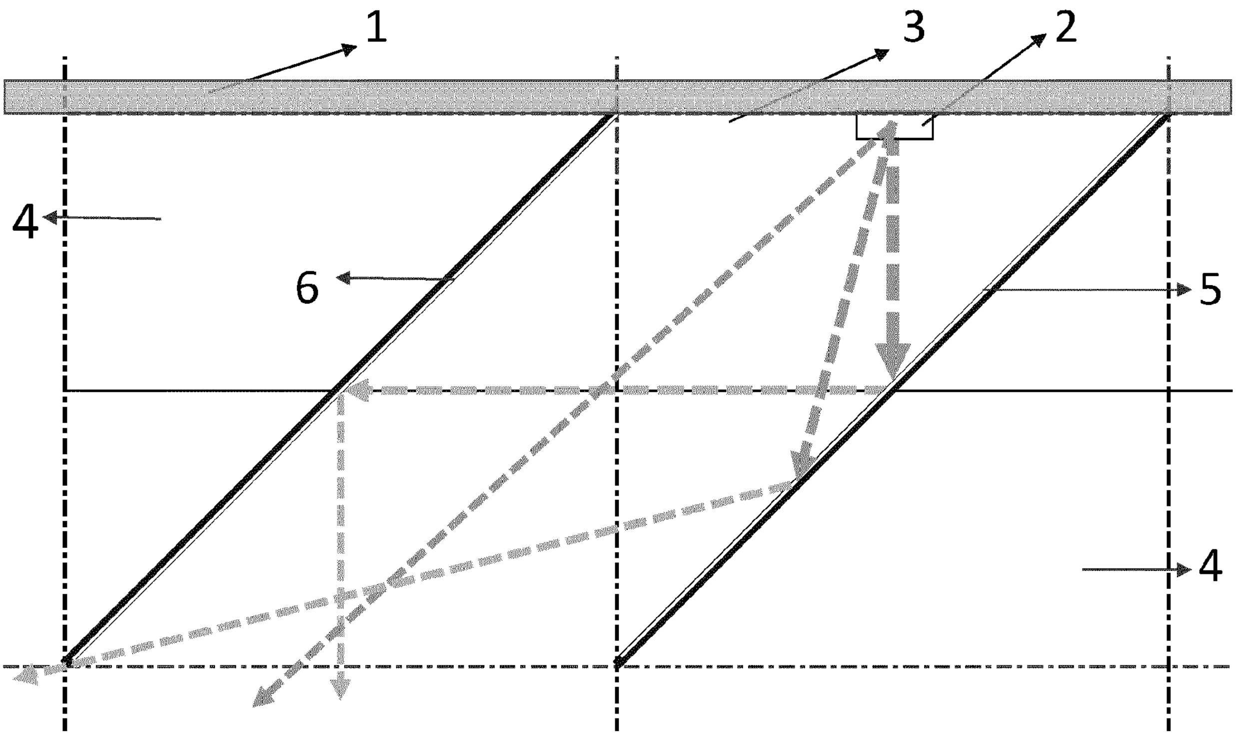

Figure 12.1

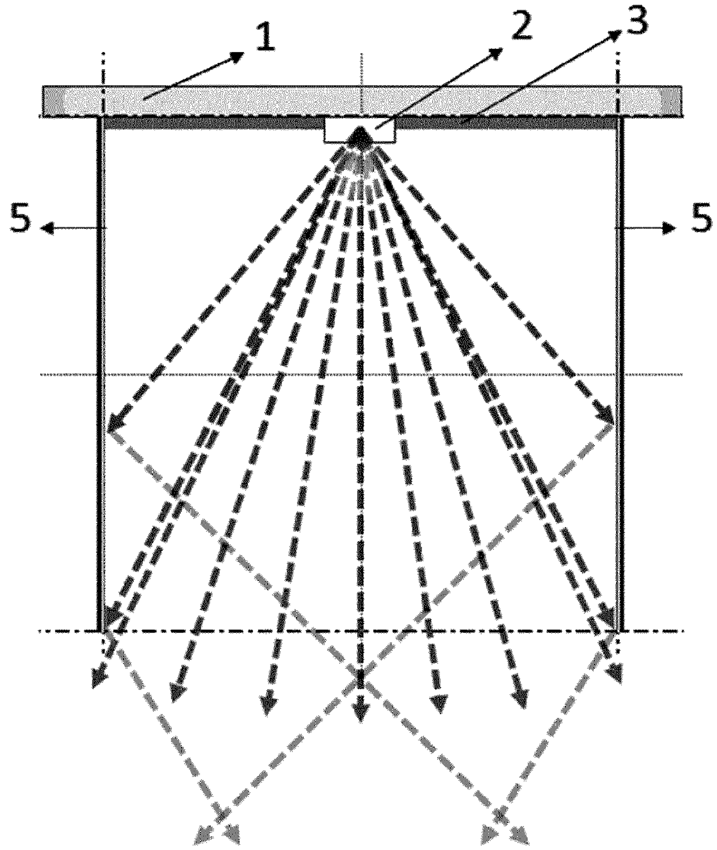

Figure 12.2

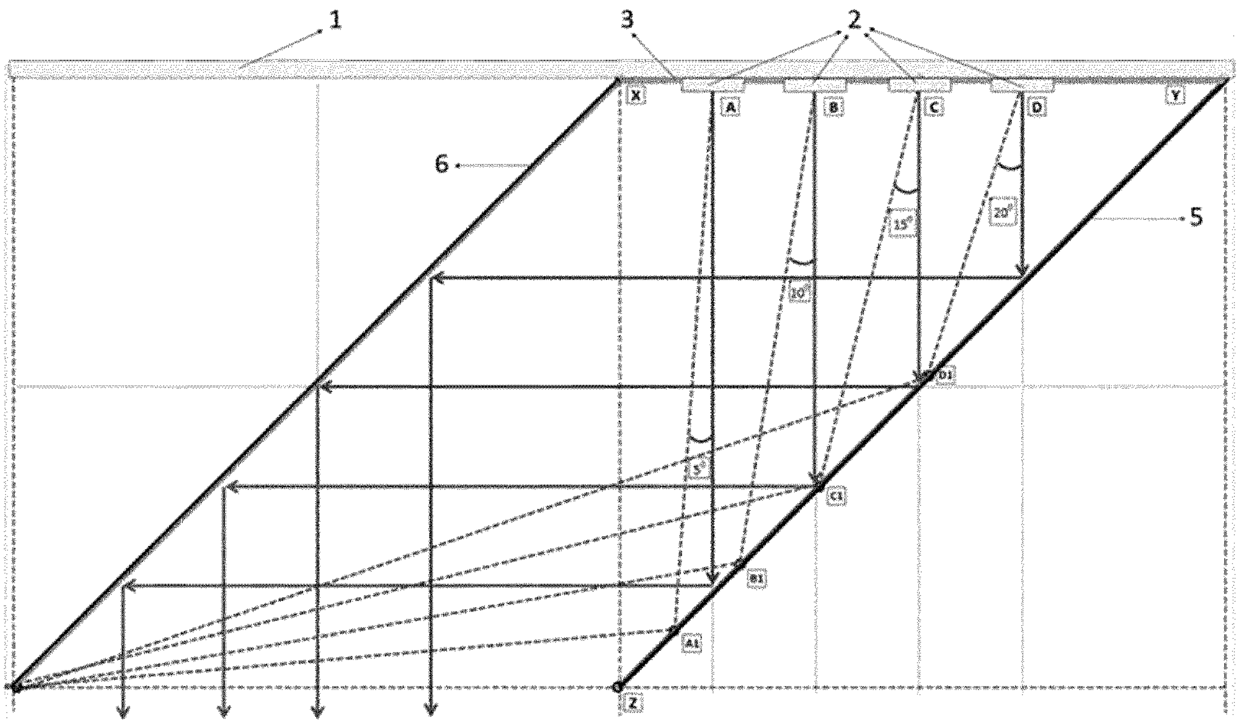

Figure 13.1

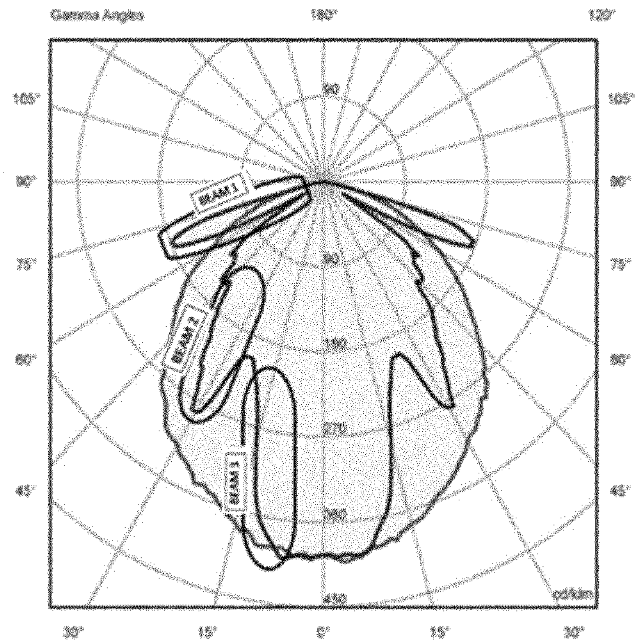

Figure 13.2

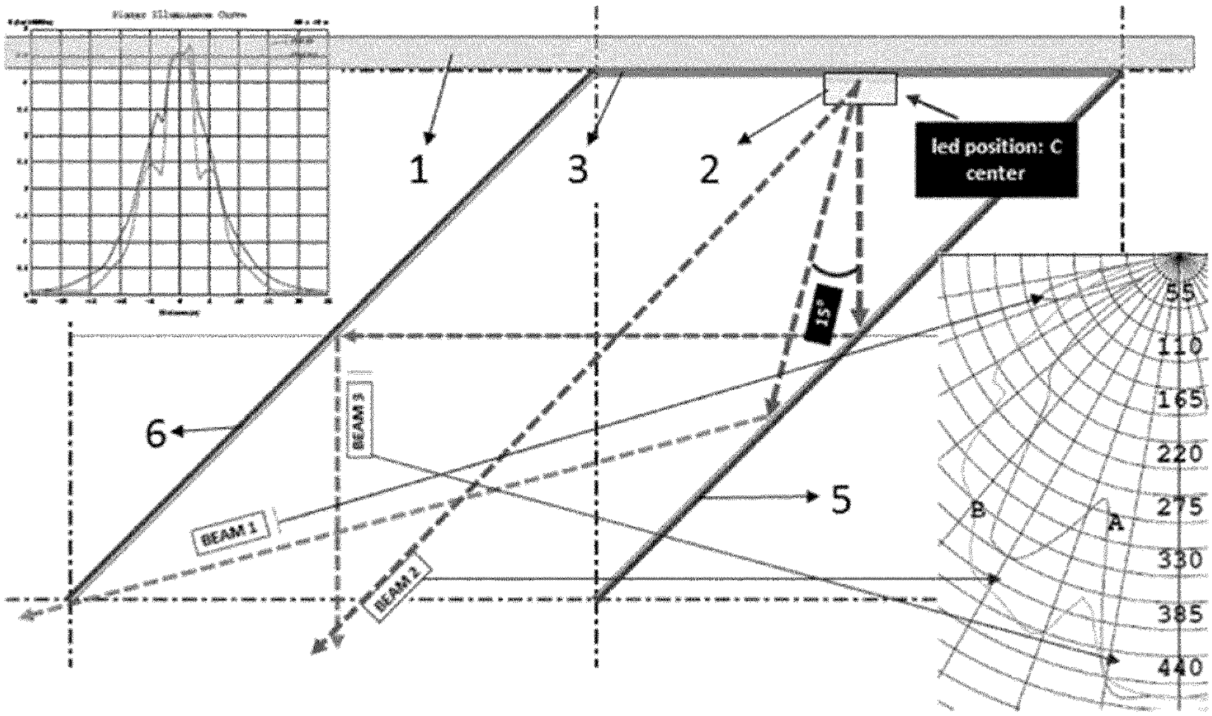

Figure 13.3.1

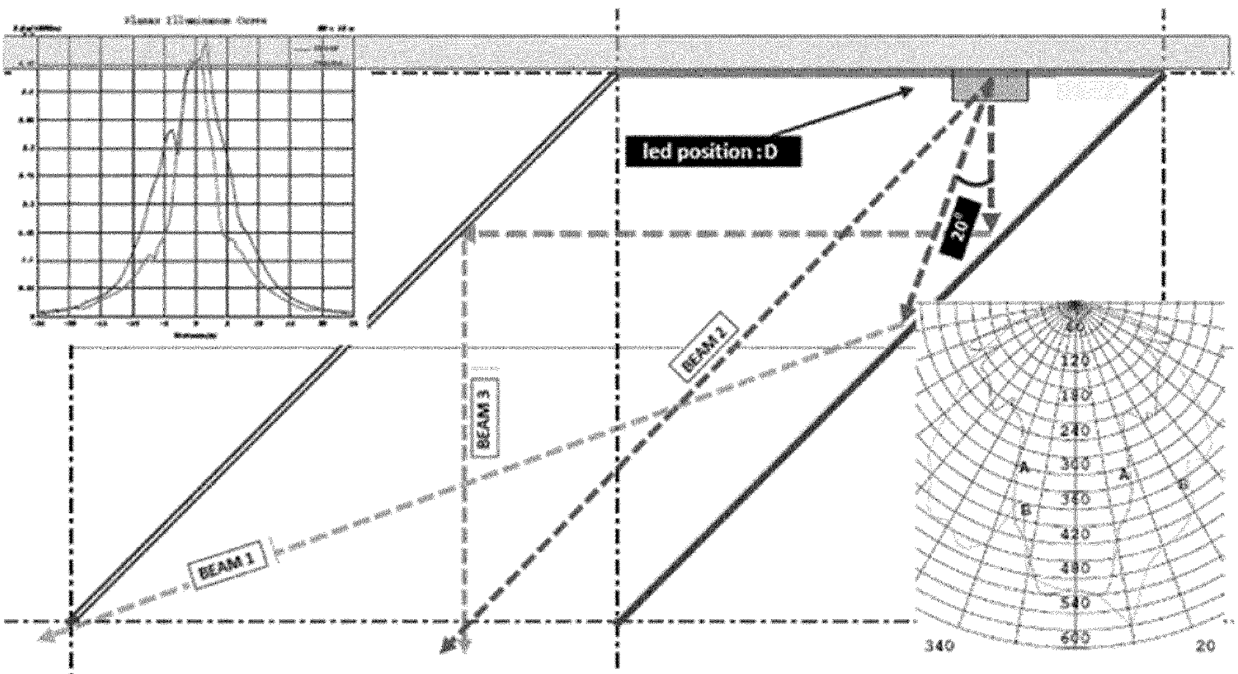

Figure 13.3.2

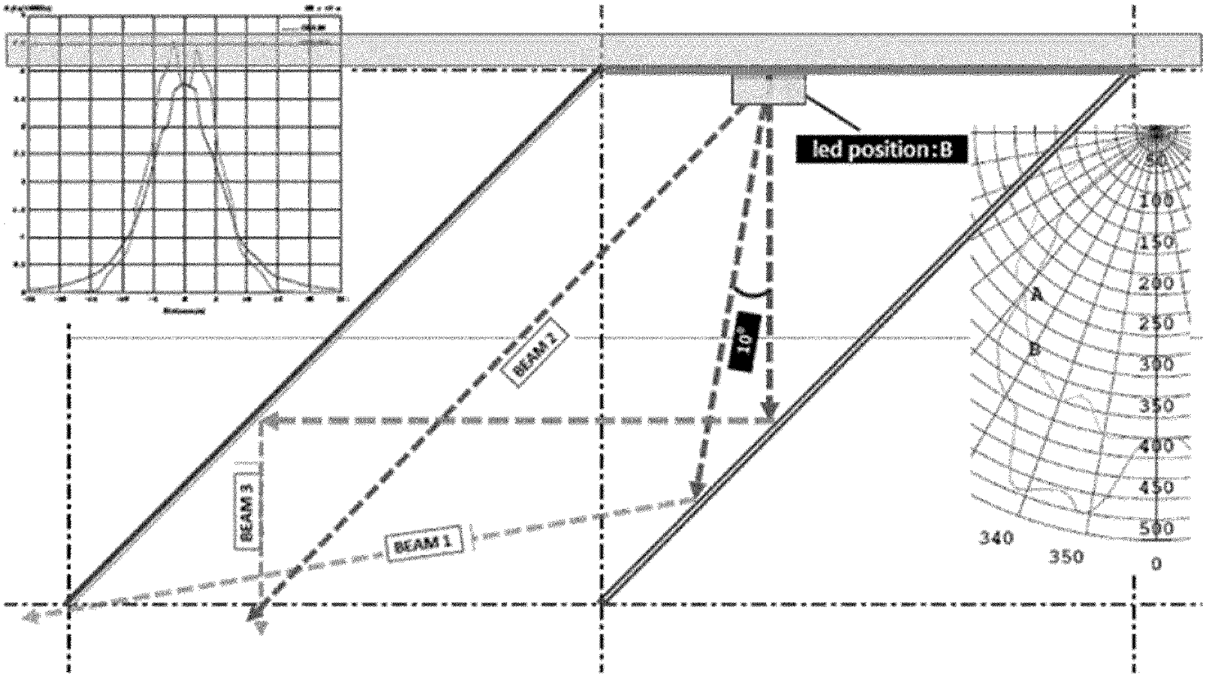

Figure 13.3.3

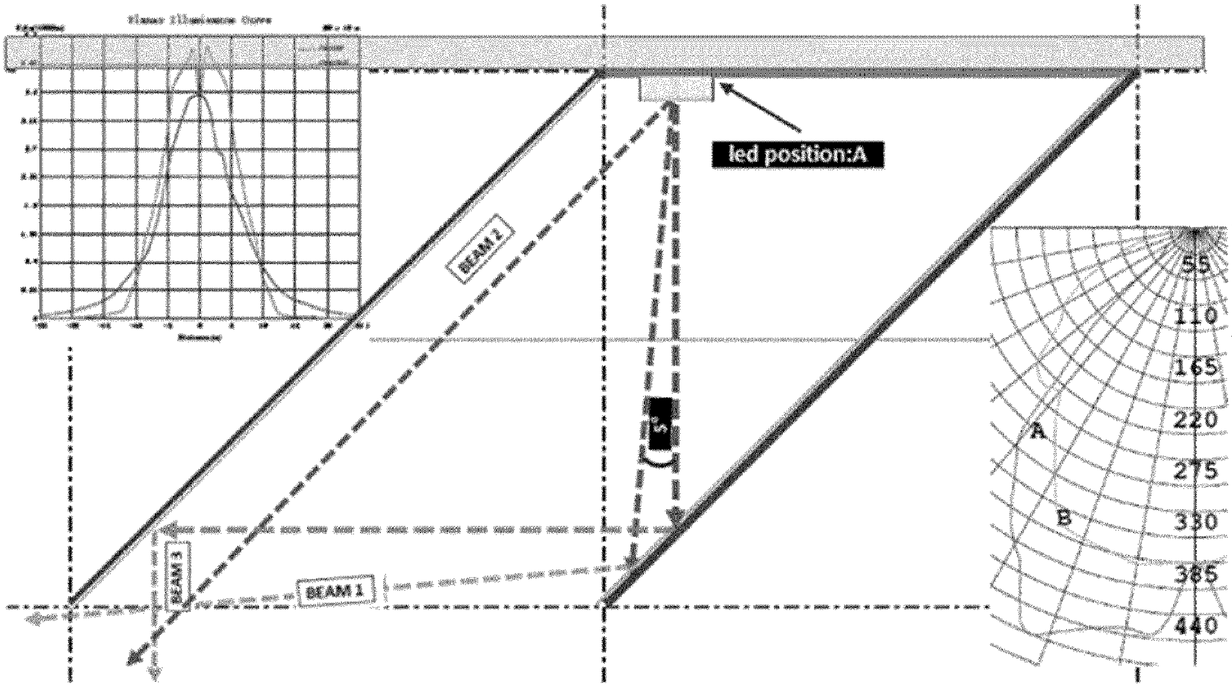

Figure 13.3.4

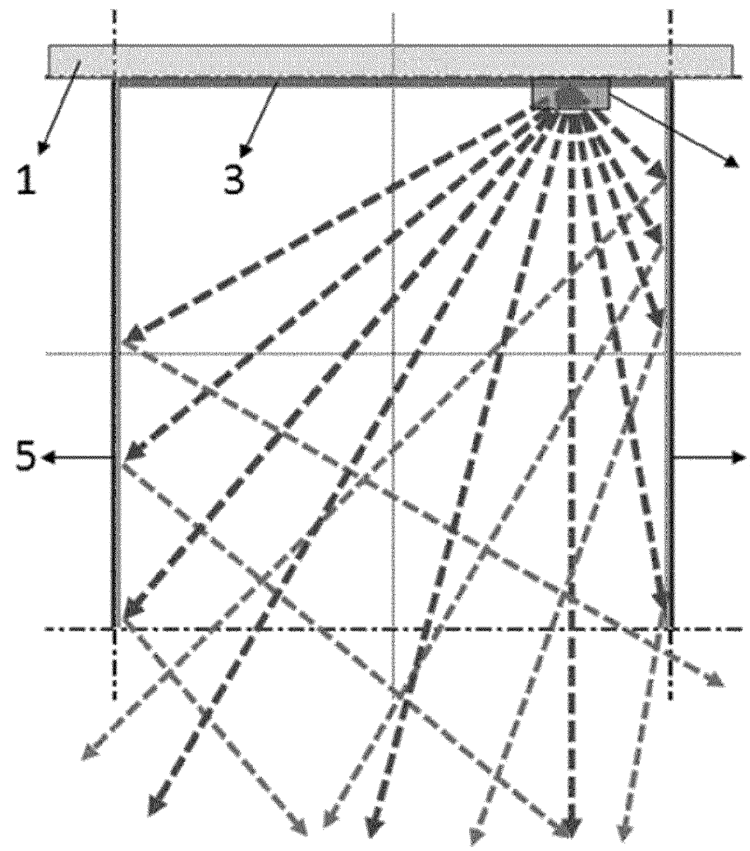

Figure 13.3.5

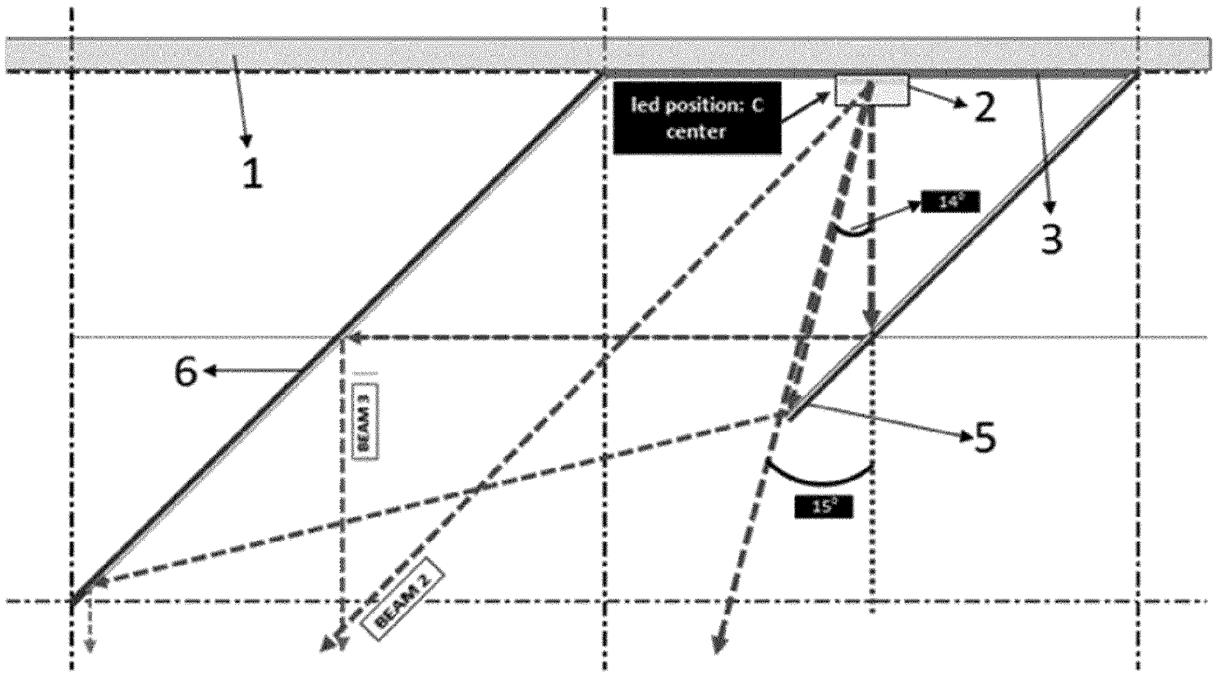

Figure 14.1

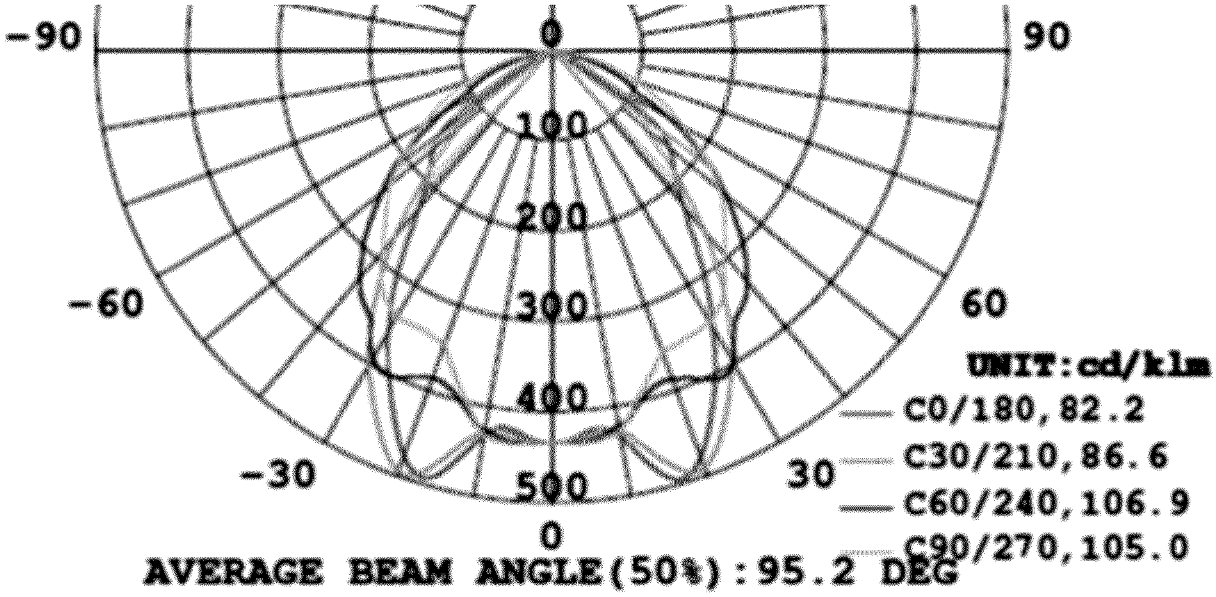

Figure 14.2

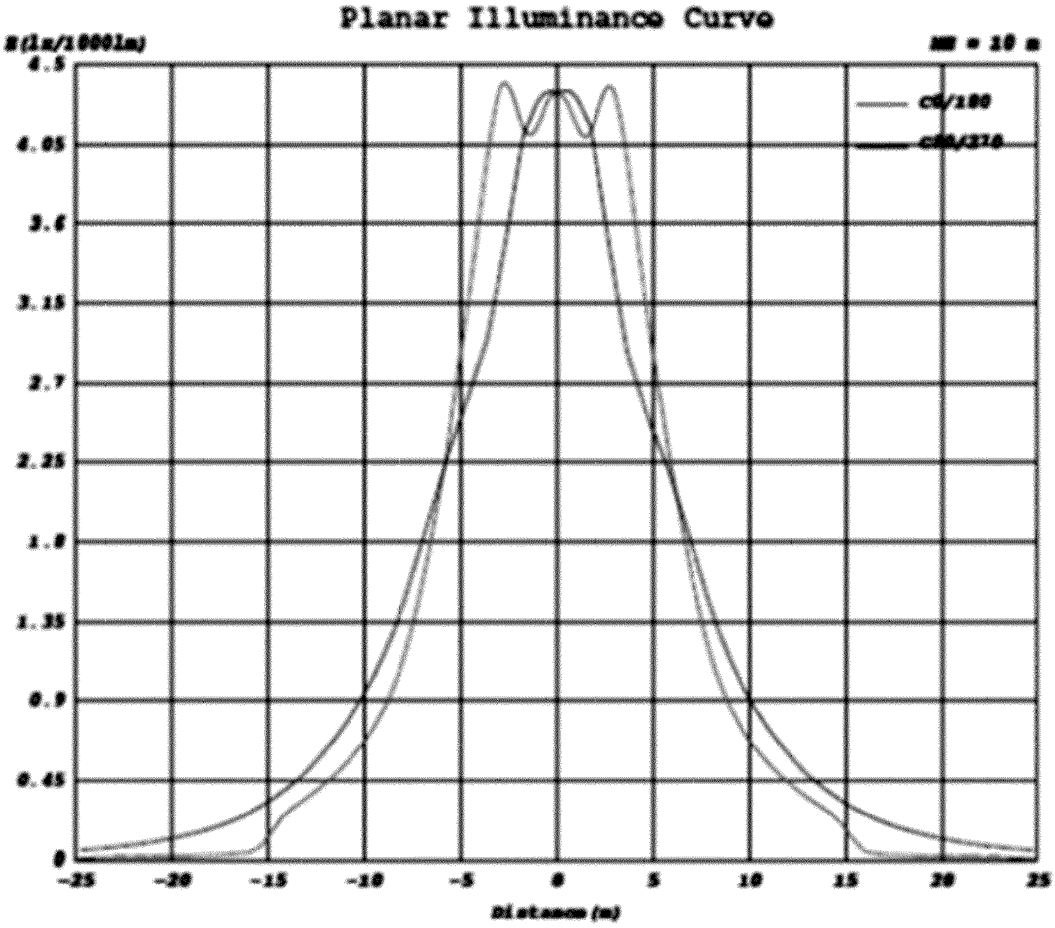

Figure 14.3

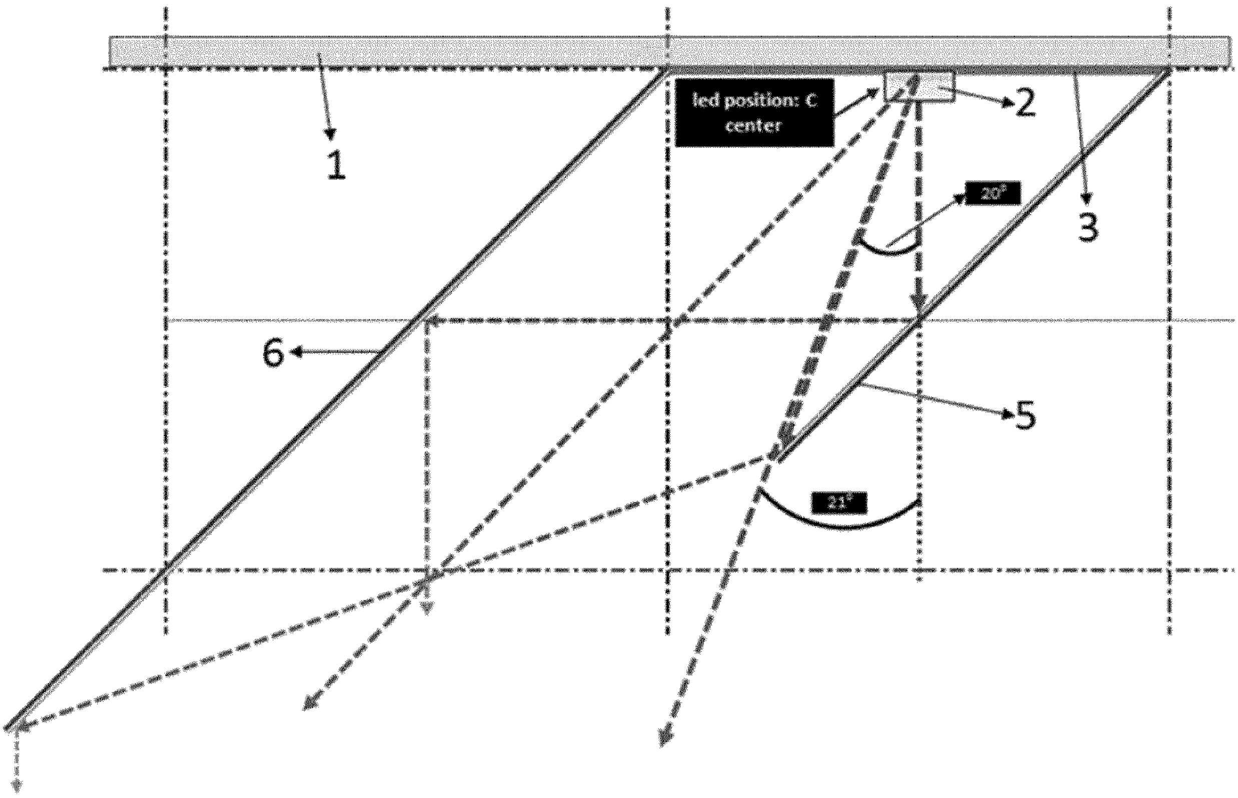

Figure 15.1

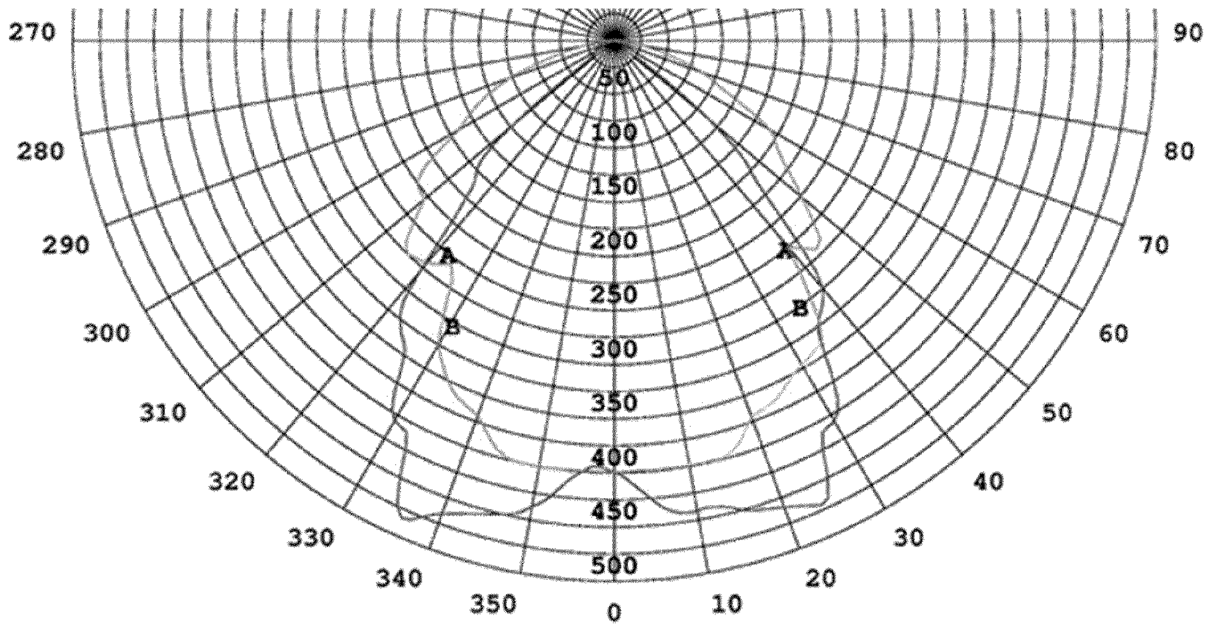

Figure 15.2

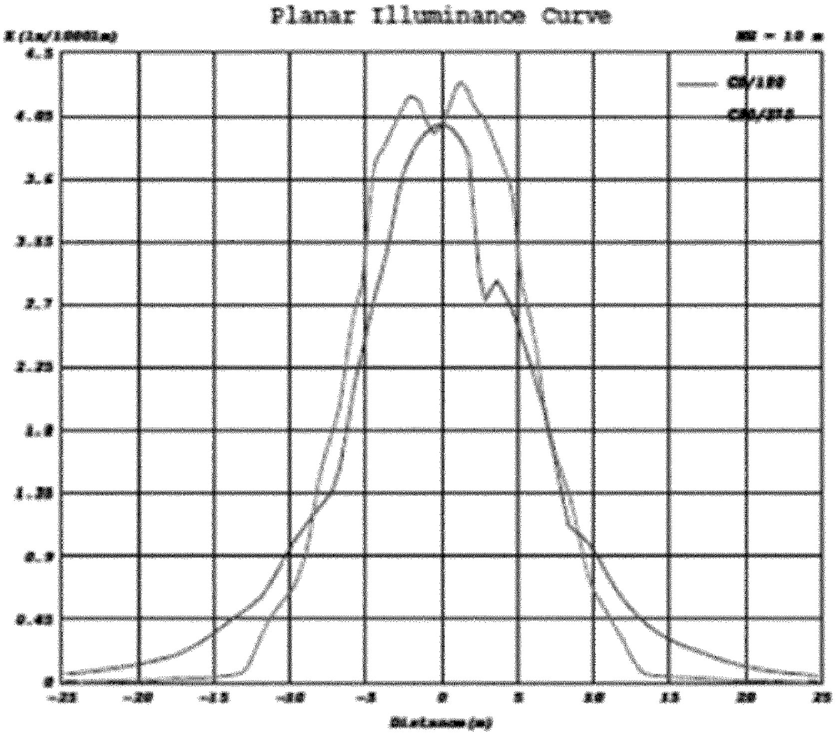

Figure 15.3

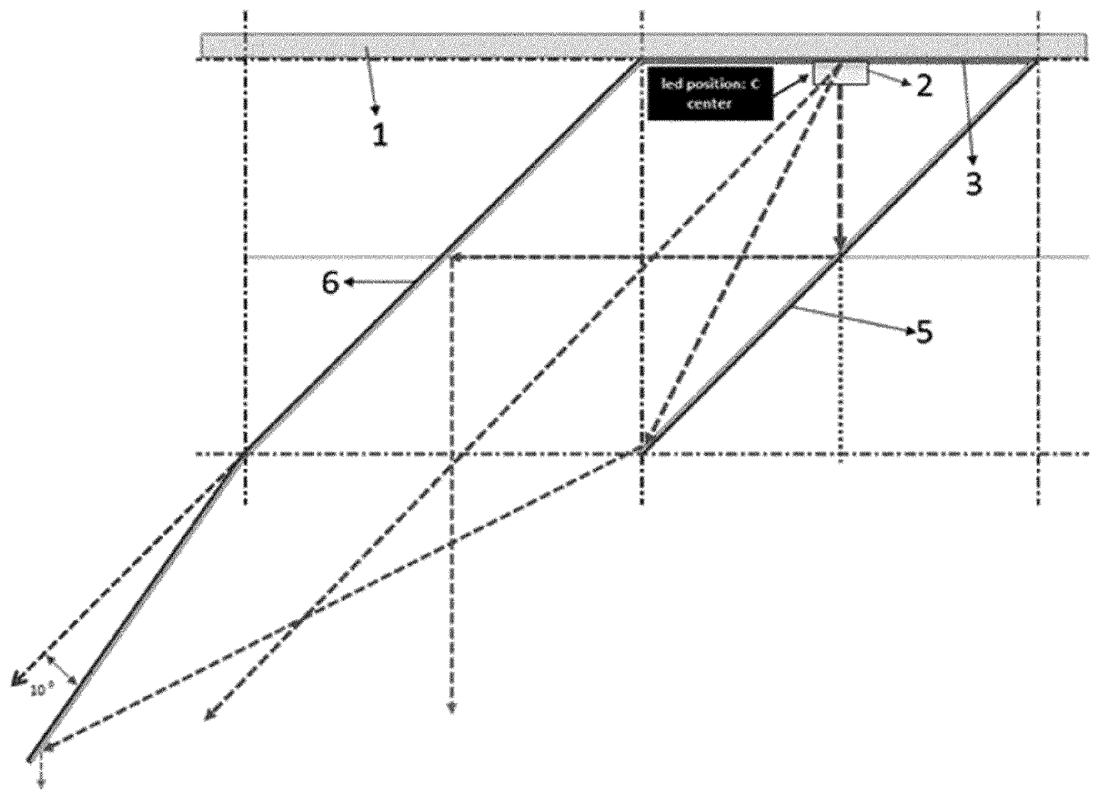

Figure 16.1

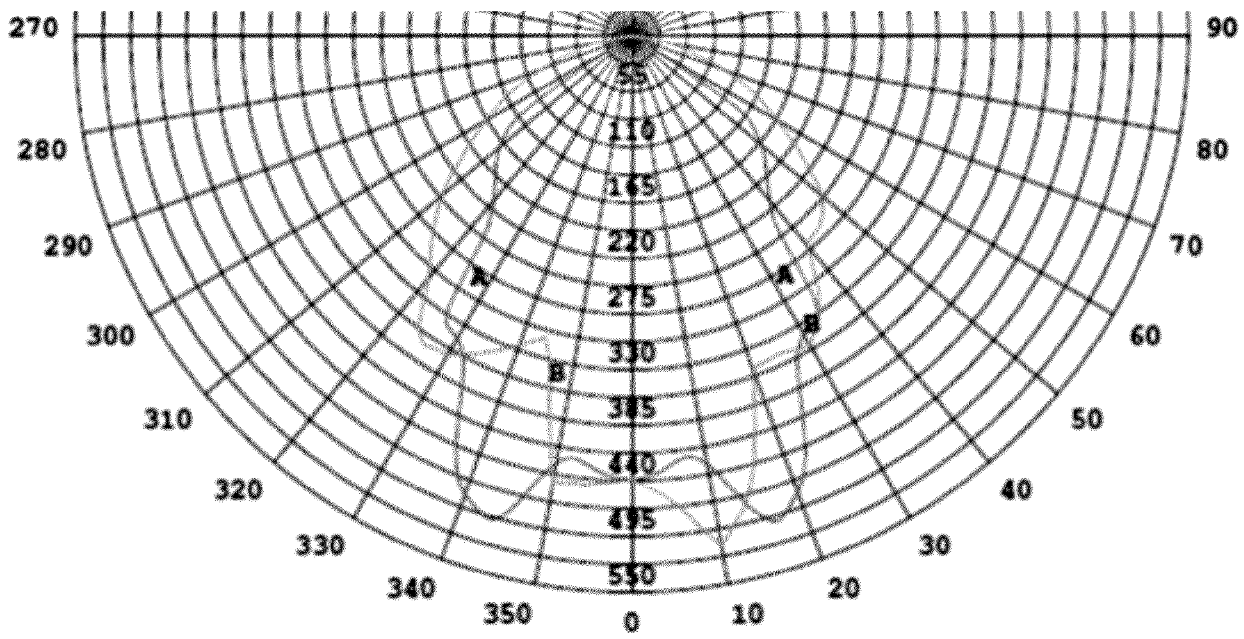

Figure 16.2

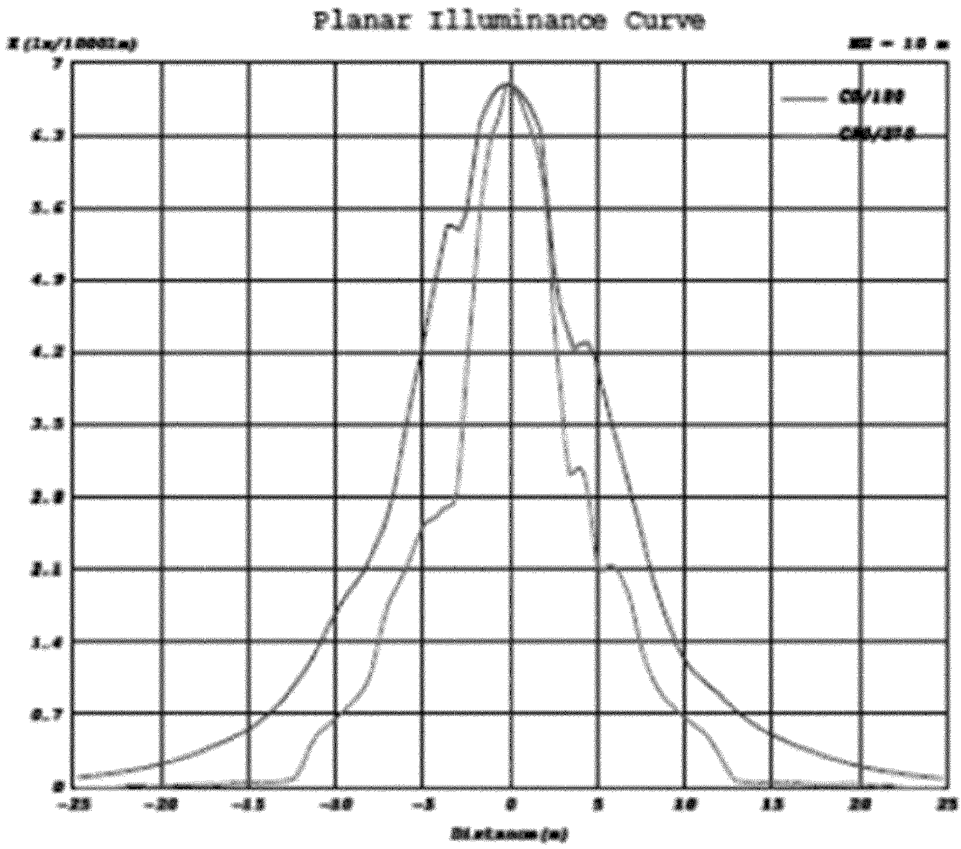

Figure 16.3

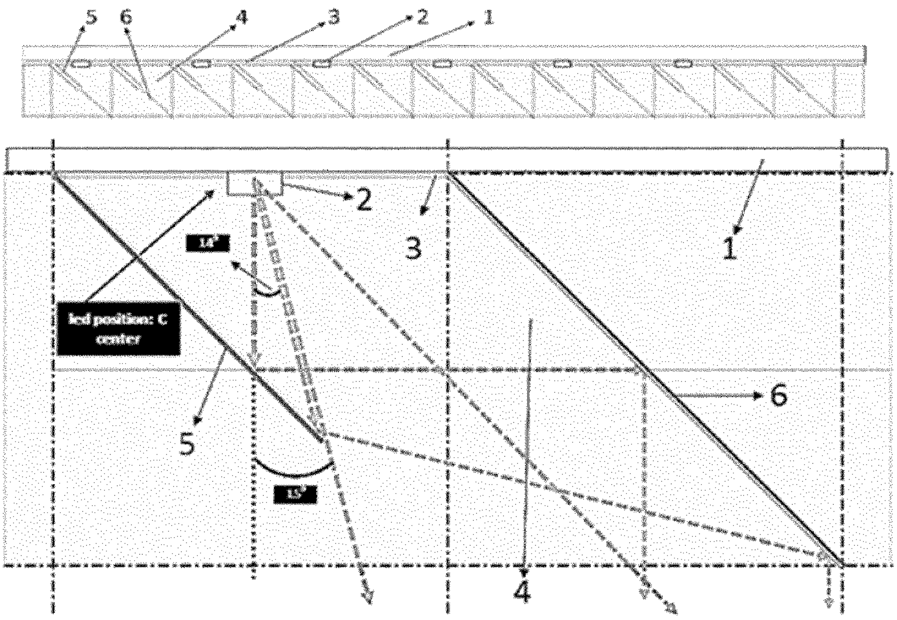

Figure 17.1

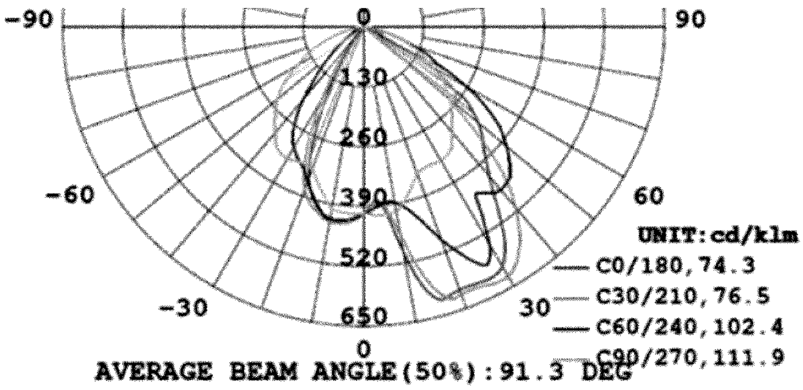

Figure 17.2

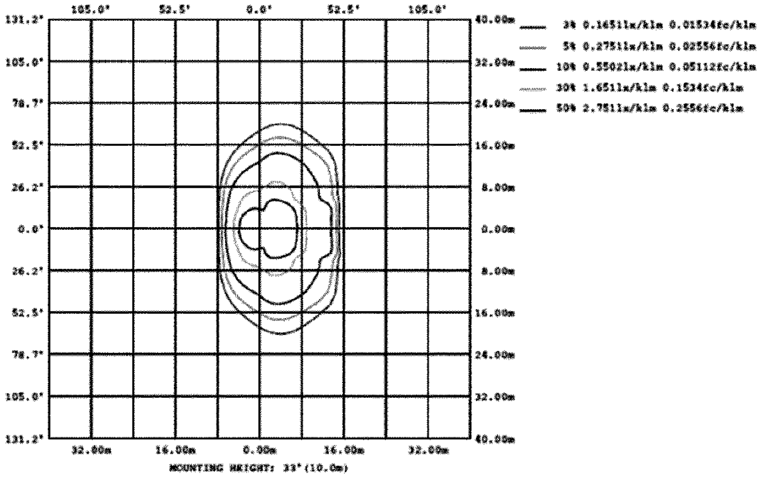

Figure 17.3

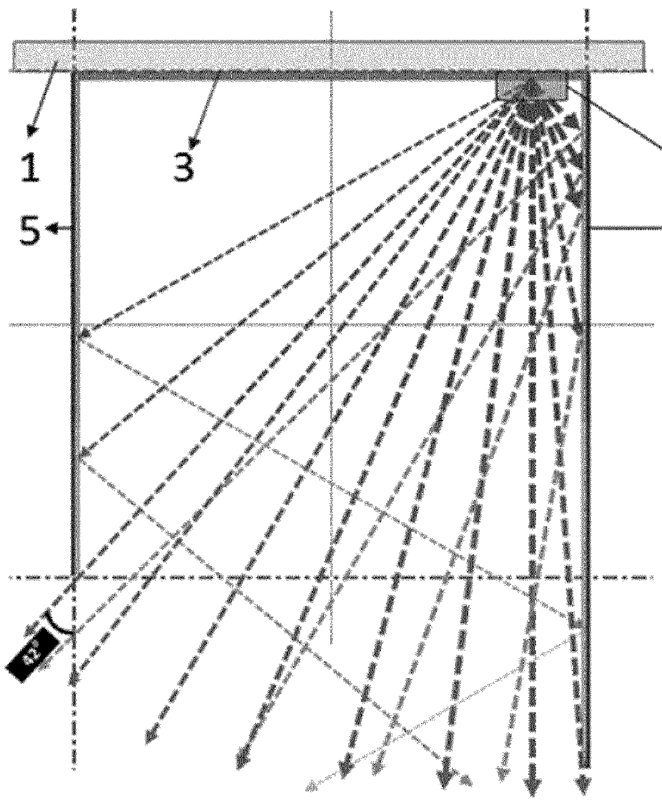

Figure 18.1

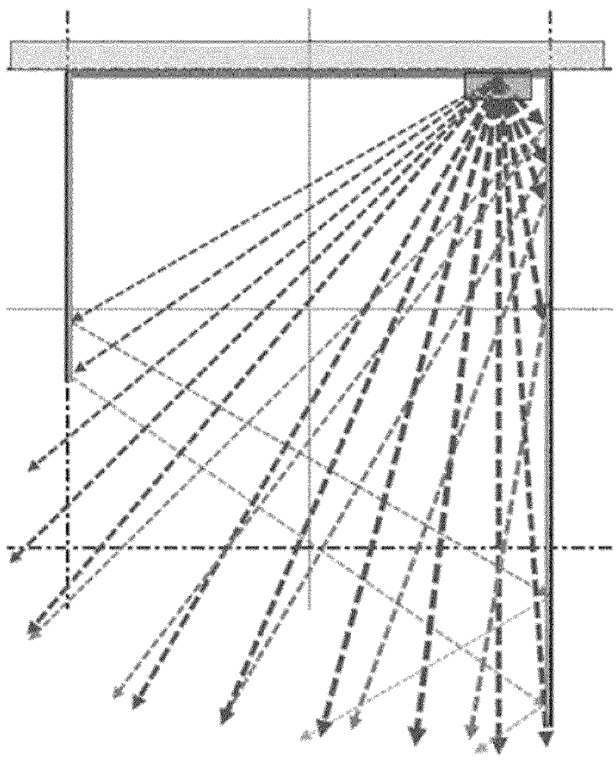

Figure 18.2

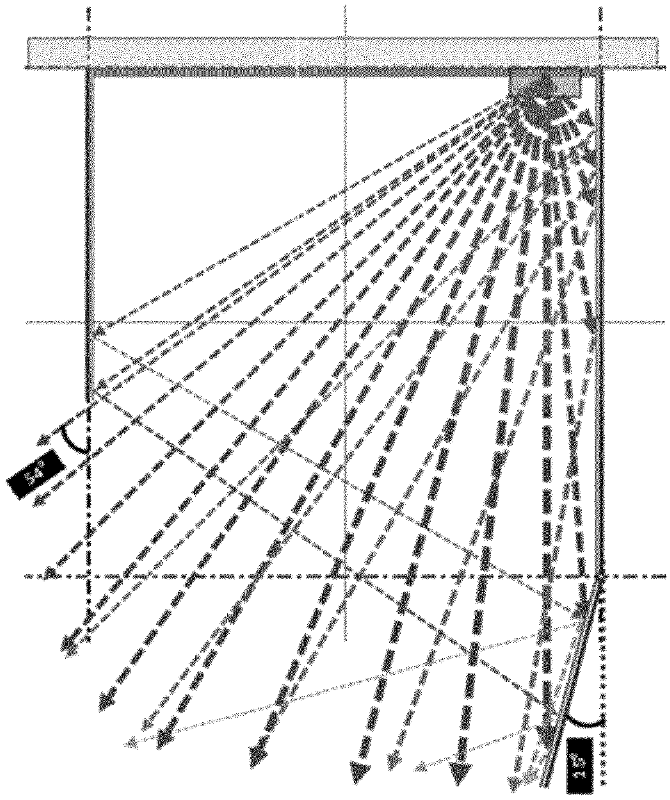

Figure 18.3

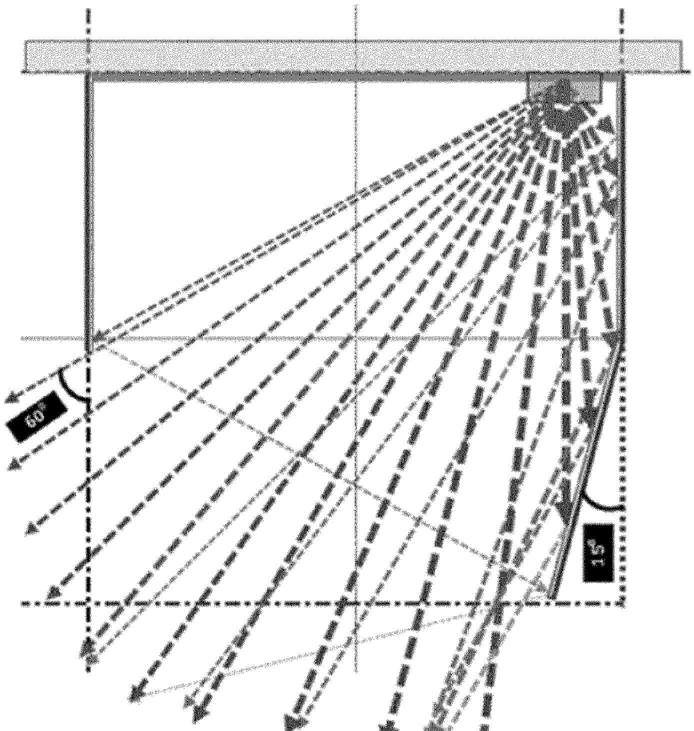

Figure 18.4

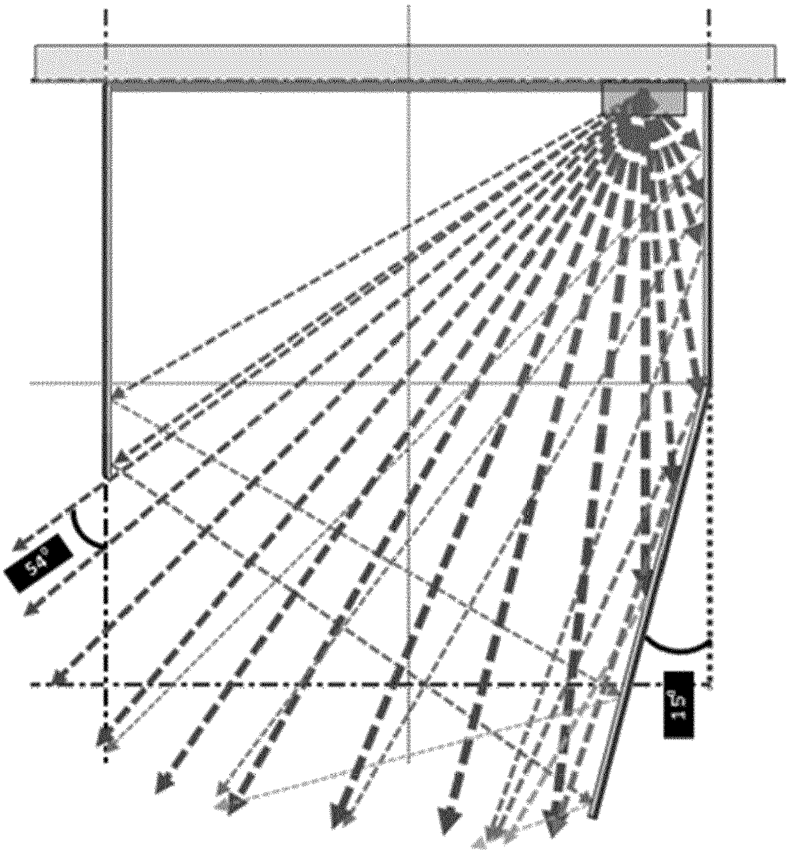

Figure 18.5

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EUROPEAN SEARCH REPORT

Application Number
EP 18 16 1042

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	6 June 2018	Dinkla, Remko

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