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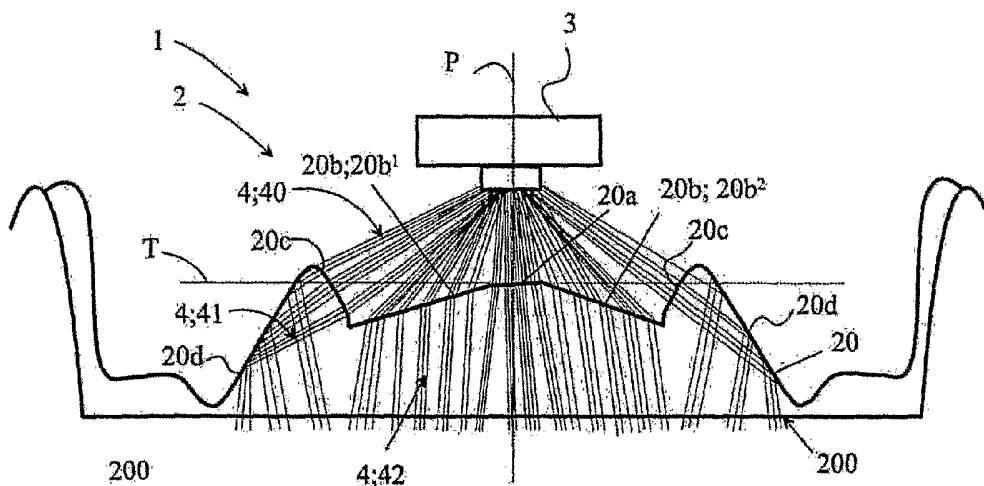
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(54) Title: ILLUMINATING DEVICE



(57) Abstract: The invention relates to an illuminating device (1) for a photographing means, in which the light source (3) is in the immediate vicinity of the lens (2), inside the photographing means, and the light (4; 40) emitted by the light source is adapted through said lens to illuminate an approximately rectangular area (5). The light source of the flashlight device (1) is a LED (3), which emits circular symmetrical light. The lens (2) comprises a light-refractive area and a totally light-reflective area, the lens being made of one monolithic piece.

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Illuminating device

The invention relates to an illuminating device, such as a flashlight, as defined in the preamble of claim 1.

- 5 When photographing in poor lighting conditions, one often uses a flashlight connected to the camera for illuminating the object. Current digital cameras often have a compact design such that, due to lack of space, the light source of the flashlight has necessarily been located within the camera, in the vicinity of the lens; such cameras include nearly all of the flashlights solidly connected to current
10 personal mobile stations equipped with digital cameras.

- Light sources used in photographing techniques emit light generally into all directions and their radiation intensity into different directions varies markedly. In current digital cameras, light is emitted from the light source and is incident on the area to be illuminated through a circular or at least circular symmetrical
15 orifice/lens, causing the illuminated area to assume a more or less circular shape as well. However, since films and most other image storing and viewing systems (i.a. television, LCD projectors) are based on more or less square, e.g. rectangular image areas (e.g. television 4:3), the corners of the illuminated area tend to receive less light than the other parts, thus naturally deteriorating the image
20 quality. Digital cameras connected to mobile stations such as mobile phones involve the special problem of low battery power, which limits the power of the light source used in the flashlight device. When the object is illuminated with a light source having low power, the image area tends to be irregularly illuminated, if excessive light is directed from the radiation of the light source outside the image
25 area.

- A number of lighting systems intended to solve the problem above are known in the state of the art. For instance, US patent specification 5,823,662 discloses a system in which the light emitted from a light source is collected on an appropriate, usually rectangular lens from one side of the light source and the light emitted from
30 the light source into the direction opposite to the area to be illuminated is collected on a separate reflective curved surface. The reference mentions that the system allows collection of over 50% of the light emitted by the light source into the desired rectangular area. However, considering current digital cameras, which are

mounted e.g. in mobile phones, the system disclosed by the US reference cited above has inadequate light collection power, given the relatively low power allowed by light sources of flashlights mounted within digital cameras. In addition, the US reference cited above discloses a lighting system whose design is too
5 complex and space requiring for it to be suitable as a flashlight focusing means in digital cameras.

The invention has the purpose of overcoming the drawbacks above appearing in the state of the art. Thus, the first objective of the invention is to provide a flashlight device to be disposed especially within digital cameras and allowing
10 focusing of the light emitted from a light source to a substantially rectangular (rectangle or square) area to be illuminated. The second objective of the invention is to provide a flashlight device whose light collection system allows focusing of the light from the light source nearly totally to the desired area. The third objective of the invention is to provide a flashlight device whose object area is illuminated as
15 evenly as possible.

The objectives mentioned above are achieved with the illuminating device defined in claim 1, such as a flashlight device, in which the light source is in the immediate vicinity of the lens within the photographing means and the light emitted by the light source is adapted via the lens so as to illuminate an approximately
20 rectangular area. The light source of the illuminating device is a LED, which emits roughly circular symmetrical light and the lens comprises a light-refractive area and a totally light reflective area, the lens consisting of one monolithic piece. The light-refractive area of the lens 2 is located in the central area K of the inner surface 20 of the lens and the light-reflective area of the lens is located in the
25 border area R of the inner surface 20 of the lens.

The major portion, preferably over 80% of the light intensity emitted by the LED, originates from light whose emission direction is scattered by maximally 60 degrees from the direction of the light beams directed perpendicularly through the front surface of the LED and the outer surface of the lens.

30 The invention is based on the idea that the circular symmetrical light distribution emitted by the LED placed within the cameras is adapted via a lens having a uniform inner and outer surface such that the illuminated area is substantially a square or a rectangle. The lens proper comprises two discrete areas: a light-refractive area of the lens located in the central area of the lens and a totally light-

reflective area of the lens located in the border area of the lens. The light-refractive area of the inner surface of the lens further comprises two different optical surfaces: a central surface forming as such a final rectangular (rectangle or square) illuminated area and a peripheral surface around the central surface
5 allowing equalisation of the light intensity reaching the area to be illuminated. The totally reflective border area of the lens usually consists of a first surface directing the light beams in parallel or almost in parallel to a second surface and a second totally reflective surface directing the light beams at an angle of 90 degrees relative to the their incidence angle.

10 Compared to the lighting system disclosed in US patent specification 5,823,662, such a lens has the advantage of a straightforward design (one single lens) and thus of small space requirement, being thus well suited as a flashlight focusing means in digital cameras.

In a preferred embodiment of the invention, the light source of the flashlight device
15 is placed inside a mobile station equipped with a digital camera, such as e.g. a mobile phone, near the camera lens. Especially in mobile phones, the flashlight device of the invention achieves a notable advantage over prior art flashlight devices, because in the flashlight of these, the total amount of light emitted by the light source tends to be low due to the limited service time and power of their
20 current source (battery). Should flashlight devices of mobile phones use a conventional flashlight device, the illuminated image area would risk to be poorly and irregularly illuminated, because they waste illuminating power by illuminating areas outside the image area. By contrast, the flashlight device of the invention, which comprises both a LED and a lens having a continuous inner lens surface
25 consisting of two different optical areas, the entire image area will be well and evenly illuminated despite the relatively low illuminating intensity of the LED.

The invention is also applicable to continual illumination of an object. e.g. in connection with a video imaging means.

The invention is depicted in further detail below with reference to the
30 accompanying drawings.

Figure 1 illustrates the intensity of the radiation emitted by the LED and the angular straight distance of the radiation gradually from the light source from the direction of the forwardly oriented light.

Figure 2 is a schematic view of the lens of the flashlight device of the invention and a cross-sectional lateral view of the light source (LED).

5 Figure 3A illustrates the light pattern provided by the central surface of the lens of the flashlight device of the invention.

Figure 3B illustrates the light pattern provided by the central faces of the lens of the flashlight device of the invention.

10 Figure 3C illustrates the light pattern provided by the totally reflective border area of the lens of the flashlight device of the invention.

Figure 3D illustrates the light pattern provided by the entire lens of the flashlight device of the invention.

15 Figure 4 is a partial sectional view illustrating the lens of the flashlight device of the invention.

20 Figure 5 is a cross-sectional view of an area illuminated with the flashlight device of the invention in the horizontal direction.

The diagram of figure 1 shows the light distribution provided by the LED 3 as such, without a lens. In this diagram, the vertical axis represents the relative light intensity (%) of the light emitted by the LED and the horizontal axis represents the
25 angle of difference of the radiation gradually relative to the direction of the radiation directed in the normal forward direction from the LED (the reference direction, i.e. zero direction being the radiation direction perpendicular to the plane of the outer surface of the LED). The light beams emitted from the LED are directed in their totality to the front of the LED, and they are scattered at a
30 maximum angle of 90 degrees from the front surface of the LED to the direction of the light emitted into the normal forward direction. Over 70% of the total intensity emitted by this particular LED is actually scattered by less than 60 degrees and barely 40% is scattered at an angle above 60 degrees from the direction of light beams directed straight forwardly. The light distribution of the radiation emitted by
35 the LED is circular symmetrical relative to the light beams passing from the LED into a perpendicular straight forward direction through the plane of the front surface of the LED.

The light source of the flashlight device of the invention comprises particularly the LED 3 shown in figure 2 and a lens 2 having a continuous inner surface 20 and a continuous outer surface 200. The light beams 4; 40 emitted by the LED 3 pass through the lens 2 of the flashlight device 1 of the invention, as shown in figure 2, passing first through the refractive and reflective inner surface 20 of the lens and then through the outer surface 200 of the lens located at level with the body casing (not shown in the figure). The LED 300 is disposed in the vicinity of the inner surface 200 of the lens, e.g. within the body of a mobile phone equipped with a digital camera. The lens 2 is then made either of the same material as the body casing of the mobile phone (e.g. transparent plastic, such as acryl) or is a separate lens embedded in the body casing of the mobile phone. The outer surface 200 of the lens 2 is substantially in the same plane as the surface of the body casing (not illustrated). The inner surface 20 of the lens 2 consists of a central area 20; K refractive to light beams 4 as explained in further detail below and of a border area 20; R reflecting light beams around the central area. All the optical surfaces of the lens 2 are "surfaces of unlimited shapes", which consist of various geometrical curves and surfaces. A surface of unlimited shapes is a surface which is not limited to mere conventional analytic shapes, such as conical surfaces, and which is defined as a surface passing through specific control points (such as Bezier, B-Spline and NURBS surfaces). The optically active area of the lens has a square general shape. The exact shape of the refractive and totally reflective inner surfaces of the lens is based on the well-known Snell's law and its implementation in the lens material under consideration. Regarding the implementation of the Snell's law, we refer to the known literature in this domain, such as e.g. Warren J. Smith "Modern Optical Engineering" or Born & Wolf, "Principles of Optics".

The optically active inner surface 2; 20 of the lens 2 comprises a centre 20a of the central area K having a relatively small area, through which a major portion of the light 4; 40 emitted by the LED nevertheless passes. Said centre 20a is rectangular and it has been designed as a light-refractive surface. A lateral face is associated with each side of the centre 20a, the faces forming together a peripheral surface 20b of the light-refractive central area K. The peripheral surface 20b thus consists of four lateral faces inclined towards the outer surface, the figure showing the lateral face 20b³ and partly the lateral faces 20b¹ and 20b², these faces being connected with different sides of the central area and interconnected by their flanks. In the lens 2 shown in figure 2, the central surface or centre 20a of the

central area K of the inner surface 20 has been drawn closer to the LED 3 used as a light source than the lateral faces of the peripheral surface 20b associated with said central surface 20a, the faces being abruptly inclined away from the LED 3 used as the light source. With the relatively planar, straight front surface 200a of the outer surface 200 of the lens used as the reference plane, the distance of the central surface 20a from this reference plane 200a is greater than that of the lateral faces of the peripheral surface 20b associated with the central surface and inclined towards the outer surface 200.

Usually over 60%, frequently even 80 - 90% of the light 4; 40 emitted by the LED 3 used as a light source passes through the light-refractive central area K of the inner surface 20 of the lens 2, depending on the distribution of the light emitted by the LED or any other light source and on the shape of the area to be illuminated with the present flashlight device 1. Said light-refractive surfaces, i.e. the central surface 20a and the lateral faces of the peripheral surface 20b associated with its edges, have been formed by combining curve sections to form a curve of unlimited shapes. Each curve section has been calculated so as to refract the light 4 incident on the surface defined by the curve section at a specific angle. After this, the curves of unlimited shapes have been interconnected to form a continuous, uninterrupted surface of unlimited shapes.

The area of the inner surface associated with the lateral faces of the light-reflective peripheral surface 20b of the inner surface 2; 20 of the lens, which is referred to as border area R in this context, has been designed so as to reflect substantially all the light 4; 40 incident on it (in other words, the area has been designed to be totally reflective). The first surface 20c of said light-reflective border area R is curved upwardly (with the plane of the front surface 200a of the outer surface 200 of the lens as the reference surface in this case as well), rising to a level higher than the horizontal level T parallel with the outer surface and passing through the apex of the central surface 20a. The first surface 20c of the light-reflective area, i.e. the border area R shown in figure 2, has an approximately symmetric shape relative to the central axis P passing through the lens 2. Thus the parts of the first surface located at the same distance from the central axis P have the same shape and are located at the same distance from the front surface 200a of the outer surface of the lens. The surface of the second, i.e. totally reflective area 20d of the totally reflective border area R is directly associated with said first surface 20c, at the apex of said surface 20c viewed from the front surface 200a of the outer

surface of said surface 20c, and is downwardly inclined from there and curved towards the outer surface 200a of the lens. The totally reflective second area (surface) 20d also has a roughly symmetrical shape and location; the surfaces of the totally reflective area 20d located at the same distance viewed from the central axis passing through the inner surface of the lens have the same shape and are located at the same distance from the plane of the front surface 200a of the lens. The first surface 20c of the border area R aligns the light beams 4; 40 incident on this surface at different angles from the LED 3 at an angle such that the light beams 4; 41 are incident on the second (totally) reflective area 20d at an angle such that substantially all the light beams 41 are reflected via the second surface 20d at an angle of 90 degrees relative to their direction of incidence. The critical angle of the total reflection can be derived from the well-known Snell's law. Said first surface 20c has been formed by combining curve sections so as to form a curve of unlimited shapes. Each curve section has been designed such that light beams incident on this are aligned. The curves of unlimited shapes have then been combined to form surface patches, which, again, have been interconnected to form a continuous uninterrupted surface of unlimited shapes. Said second totally reflective area 20d has been formed by combining curve sections so as to form a curve of unlimited shapes. Each curve section has been designed such that it reflects the light incident on it at a given angle in the desired area. After this, the curves of unlimited shapes have been combined to form surface patches, which, in turn, have been combined so as to form a continuous unbroken surface of unlimited shapes.

The exact shape of the inner surface 20 of the lens 2 depends on several facts: the distance between the lens 2 and the light source 3, the intensity of the light 4; 40 emitted by the light source and the intensity distribution, the desired shape of the illuminated area, etc. The lens-LED combination shown in figure 2 is intended to illuminate a square area, the front surface 200a of the lens used here having an approximately square general shape. If, for instance, one would aim at illuminating a rectangular 4:3 area, the front surface of the lens would also have a more or less rectangular general shape.

Figure 4 is a perspective and partly exploded view of the lens 2 of the flashlight device of the invention. The figure shows the lens and its points of connection to its operating environment, such as the casing of a mobile phone. The both surfaces of the lens 2 (inner and outer surface) are made of acryl or any other

transparent plastic and in this case the outer surface 200 is smooth, being thus adapted for use e.g. as the outer surface of a mobile phone. The lens 2 is associated with the other parts of the phone through extensions of the inner surface 20. The figure also shows the sprues 8 of the lens 2, through which plastic
 5 has been introduced into the mould during the injection moulding of the lens. The injection moulding preferably uses 2-component injection moulding for integrating a lens of one plastic quality into surrounding support structures of a second plastic quality, such as the mobile phone casing. The LED (not illustrated) can be positioned very close to the optically active inner surface 20 of the lens, allowing a
 10 very flat camera integrated in the mobile phone.

In a preferred embodiment of the invention, a hard protective film of transparent material is additionally moulded on top of the lens 2 during the injection moulding.

15 Figures 3A – 3D show how a lens-LED combination of the invention is used for forming a rectangular (square) light pattern 5; 50. This light pattern consists of light 4; 42 that has passed through the different optical areas (20a, 20b and 20c and 20d) of the inner surface 20 of the lens.

20 Figures 3A – 3C illustrate separately the light pattern generated on each optically active part of the lens and figure 3D shows the overall light pattern generated on the lens.

The numbers indicated in figures 3A – 3D imply the relative light intensity (%) of
 25 the peak light intensity in each case. Thus, 100 in the figure denotes the peak light intensity and 0 means that no light is incident on the surface.

While passing through the central light-refractive surface 20a of the inner surface of the lens, the light beams 4; 40 from the LED are refracted so as to generate at
 30 this stage the final rectangular illuminated area (figure 3A). However, in the light pattern 5; 51 generated through this part of the lens, the light intensity is not as yet regular within the illuminated rectangle, but the centre and the corners of the illuminated area are more illuminated than the other parts. In the light pattern, 5;
 51 A implies high illumination intensity, $I = 100 - 73\%$. B implies medium light
 35 intensity $I = 41 - 72\%$ and C low light intensity $I < 41\%$. In this case the peak intensity is 72.5116 cd.

On the other hand, the light beams 4; 40 incident on the area of the peripheral surface 20b surrounding the central surface 20a of the central area are refracted so that the light beams 4 emitted from this area generate a light pattern 5; 52. In the light pattern 5; 52, the highest intensity of incident light occurs in the immediate vicinity of the edges of the rectangular area (figure 3B). Hardly any light is emitted from this refractive area 20b of the inner surface of the lens to the centre of the rectangular area proper, because this area is already illuminated through the central surface 20a. In this light pattern, A implies high illumination intensity, in which $I = 73 - 100\%$. B implies medium intensity $I = 40 - 72\%$ and C low light intensity $I < 40\%$. The peak intensity in this case is 47.87 cd.

A relatively small amount of light is incident on the totally light-reflective border area R of the lens 2 from the LED, in many cases only about 10 – 20% of the total amount of light 4; 40 emitted from the LED (figure 3C). The light passing through the border area R generates a light pattern 5; 53, which complements the light patterns 5; 51 and 5; 52. More light is incident on the centre of the illuminated area (area A) and less light on the edges (areas B and C). In this figure, A denotes high light intensity, in which $I = 76 - 100\%$. B denotes medium intensity $I = 41 - 75\%$ and C low light intensity $I < 41\%$. The peak intensity in this case is 65.221 cd.

The overall light pattern provided by the light having passed through the optical surfaces 20a, 20b, 20c and 20d of the lens in figure 3D is the sum of light patterns 5; 51, 5; 52 and 5; 53 and has an approximately square shape. In this light pattern, the rectangular or square area receiving maximum light in the area 5; 50 is in the centre and $I = 71 - 100\%$. At the edges of the illuminated area, there is a slightly less illuminated border area, in which the light intensity $I = 39 - 70\%$. Outside these illuminated areas A and B, there is a very poorly illuminated area C, in which $I < 38\%$. The peak intensity in this is 93.69 cd.

Figure 5 is a cross-sectional view of the illuminated area formed with the flashlight device of the invention in the horizontal direction. It can be seen in the figure that the light intensity (indicated as percentage of the peak intensity) drops abruptly outside the edges of the illuminated square area. In the figure, I implies the intensity as percentage of the peak intensity and X the point of observation.

Only a number of the embodiments of the invention have been described above, and it is obvious to those skilled in the art that the invention can be implemented in

many other ways as well without departing from the scope of protection of the claims.

5 Thus the general shape of the lens is usually square or rectangular, depending on the desired shape of the image area to be illuminated. By varying the shape of the front surface, border area and central area of the lens, the lens can be implemented with some other shape as well.

10 The totally reflective border area R can be formed also with the border area R partly or entirely metallised. In that case, the border area does no longer necessarily comprise a first surface 20c directing the light beams at a given angle to the second surface (area) 20d, because the border area reflects the emitted light beams at a given angle relative to the incidence angle of the light beams owing to its structure.

15 The distribution of the light emitted by the LED in figure 1 relates only to a given type of LED available on the market and the light distribution naturally changes as the type of LED is replaced. However, the light pattern provided by the LED is fairly typical for LED's currently available.

20 The flashlight device of the invention is applicable to photographing devices, especially to photographing devices intended for digital imaging. The photographing device may also be part of an apparatus primarily intended for some other application, such as e.g. in connection with mobile station devices used primarily for communication.

25 In conjunction with video imaging, among other things, a photographing device may use an illuminating device intended for continual illumination instead of a flashlight for illuminating the object. Such an illuminating device differs from the flashlight device exemplified above mainly by the fact that the light source (LED) is adapted to provide continual light.

30 The light density of the illuminated rectangular area obtained with each lens depends on the light source to a notable degree. Thus, in the example described above, the illumination intensity values indicated for the lens and its parts (both relative and absolute) may vary to a notable degree, depending on the shape of the lens and the power of the light source in each case.

Claims

1. An illuminating device (1) such as a flashlight device (1), intended for a photographing device, in which the light source (3) is in the immediate vicinity of the lens (2), inside the photographing means, and the light (4; 40) emitted by the light source is adapted by the lens to illuminate an approximately rectangular area, **characterised** in that
- the light source of the flashlight device (1) is a LED (3), which emits approximately circular symmetrical light,
 - the lens (2) comprises a light-refractive area and a totally light-reflective area, the lens consisting of one monolithic piece
 - the light-refractive area of the lens (2) is located in the central area (K) of the inner surface (20) of the lens and the light-reflective area of the lens is located in the border area (R) of the inner surface (20) of the lens.
2. An illuminating device (1) as defined in claim 1, in which the light source is a LED (3), the major portion of the light intensity emitted by the LED, especially over 60% and more advantageously over 80% originates from light beams directed from the light source to the lens with their direction of travel differing at the most by 60 degrees from the direction of the light beams passing through the front surface of the LED towards the lens (2).
3. An illuminating device (1) as defined in any of the preceding claims, **characterised** in that the lens (2) comprises a continuous inner surface (20) and a continuous outer surface (200) and the inner surface (20) of the lens comprises a light-refractive area and a totally light-reflective area and the outer surface of the lens is straight or double-curved.
4. An illuminating device (1) as defined in any of the preceding claims, **characterised** in that the light-refractive central area (K) of the inner surface (2; 20) of the lens comprises a central surface (20a), by means of which the major portion of the rectangular light pattern (5; 50) illuminated with the light source and of the peripheral surface (20b) surrounding the central surface is generated, and serving to balance the light intensity of the illuminated area.

5. An illuminating device (1) as defined in any of the preceding claims, **characterised** in that the peripheral surface (20; 20b) consists of four lateral faces associated with the central surface and inclined from the point of connection
5 towards the outer surface (200) of the lens.

6. An illuminating device (1) as defined in any of the preceding claims, **characterised** in that the totally reflective border area (R) of the inner surface (20) of the lens (2) consists of a first surface (20c), which directs the light beams
10 incident on it to a second surface (20d) in alignment or almost in alignment, and of said second reflective surface (20d), which is at an angle to the first angle such that it reflects substantially all the light beams (4; 41) incident on it at an angle of about 90 degrees relative to its angle of incidence.

15 7. An illuminating device (1) as defined in any of the preceding claims, **characterised** in that over 60%, preferably over 80% of the light of the light source (3) reaches the rectangular or square area (5; 50) to be illuminated.

8. An illuminating device (1) as defined in any of the preceding claims, **characterised** in that all the optical surfaces of the inner surface (20) of the lens
20 (2) are appropriate polynomial curves by combining the obtained surfaces of unlimited shapes.

9. An illuminating device (1) as defined in any of the preceding claims, **characterised** in that the lens (2) is part of the outer casing of a camera.
25

10. An illuminating device (1) as defined in claim 8, **characterised** in that the lens (2) is made of the same material as the body of the photographing device surrounding the lens.
30

11. An illuminating device (1) as defined in any of the preceding claims, **characterised** in that the lens (2) has a rectangular or square general shape.

12. An illuminating device (1) as defined in any of the preceding claims, **characterised** in that the lens (3) is made by injection moulding one or more
35 plastic qualities.

13. An illuminating device (1) as defined in claim 12, **characterised** in that the lens (3) has been injection-moulded together with the body surrounding the lens, such as the casing of a mobile station.
- 5 14. Application of the illuminating device defined in any of the preceding claims to a mobile station device.

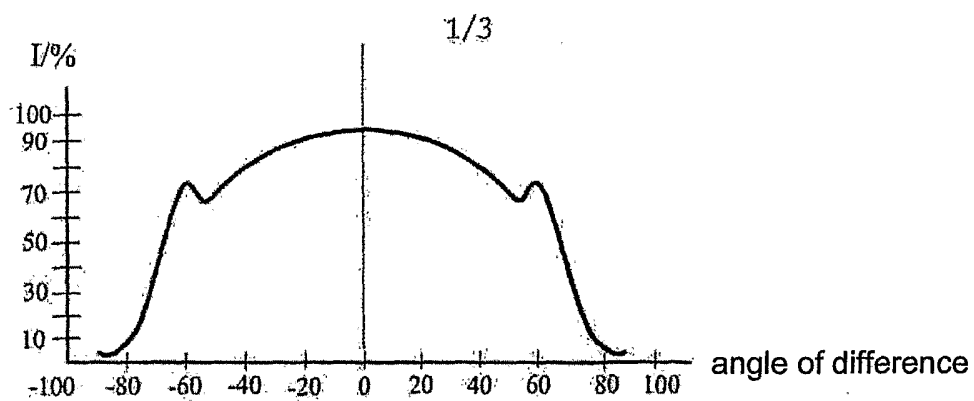


Fig. 1

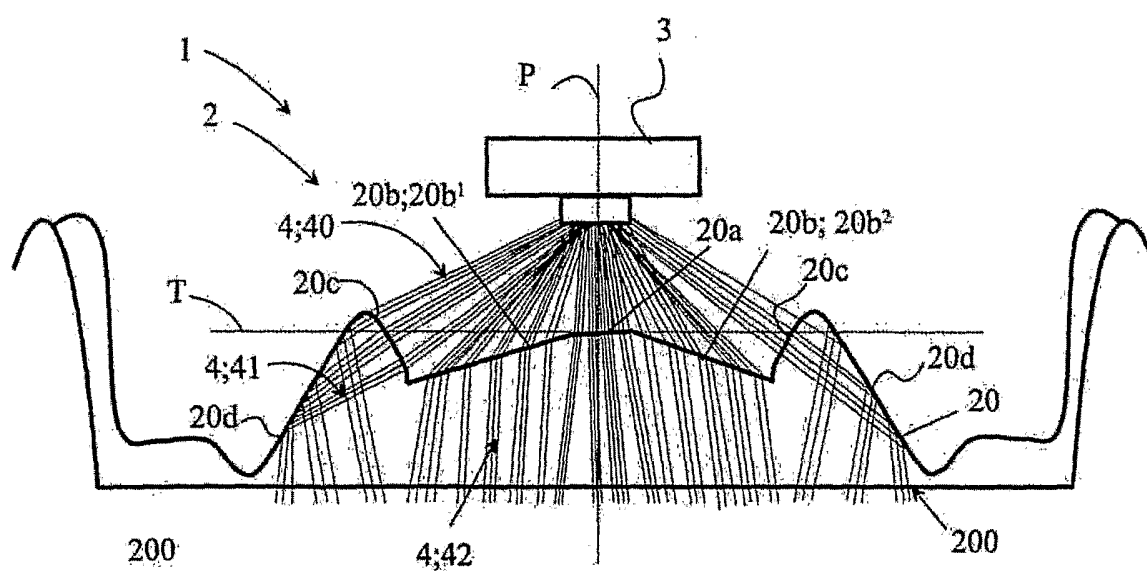


Fig. 2

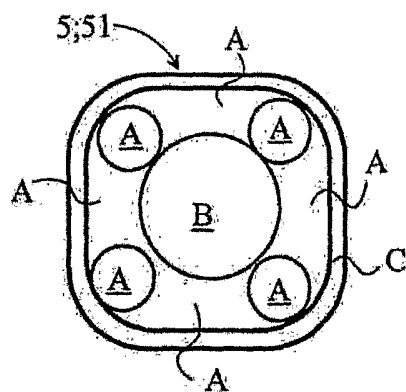


Fig. 3A

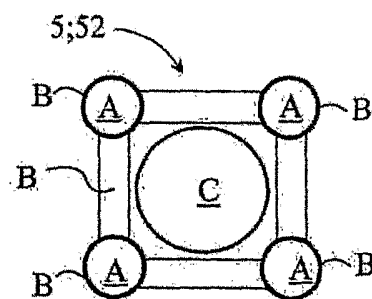


Fig. 3B

2/3

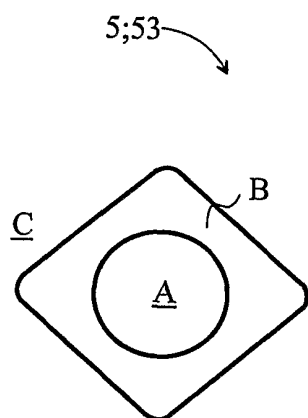


Fig. 3C

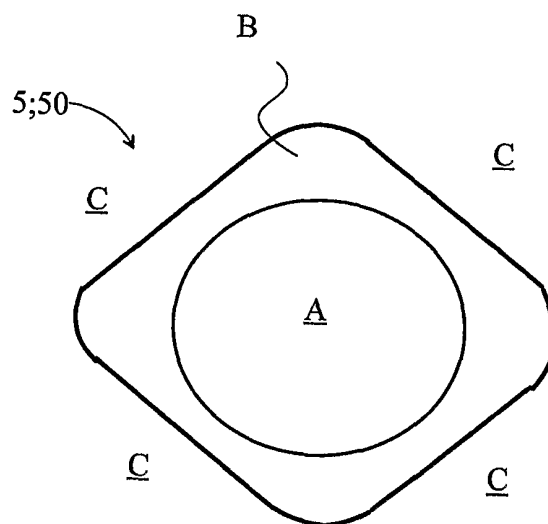


Fig. 3D

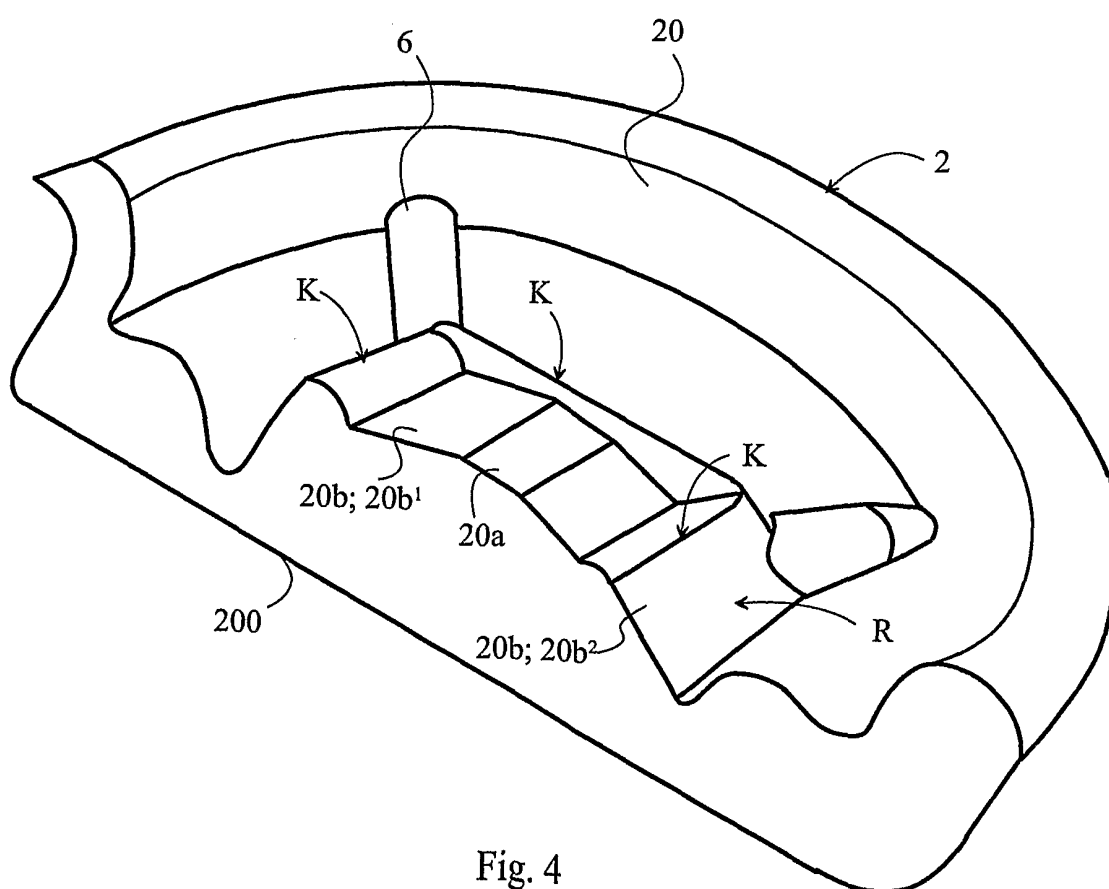


Fig. 4

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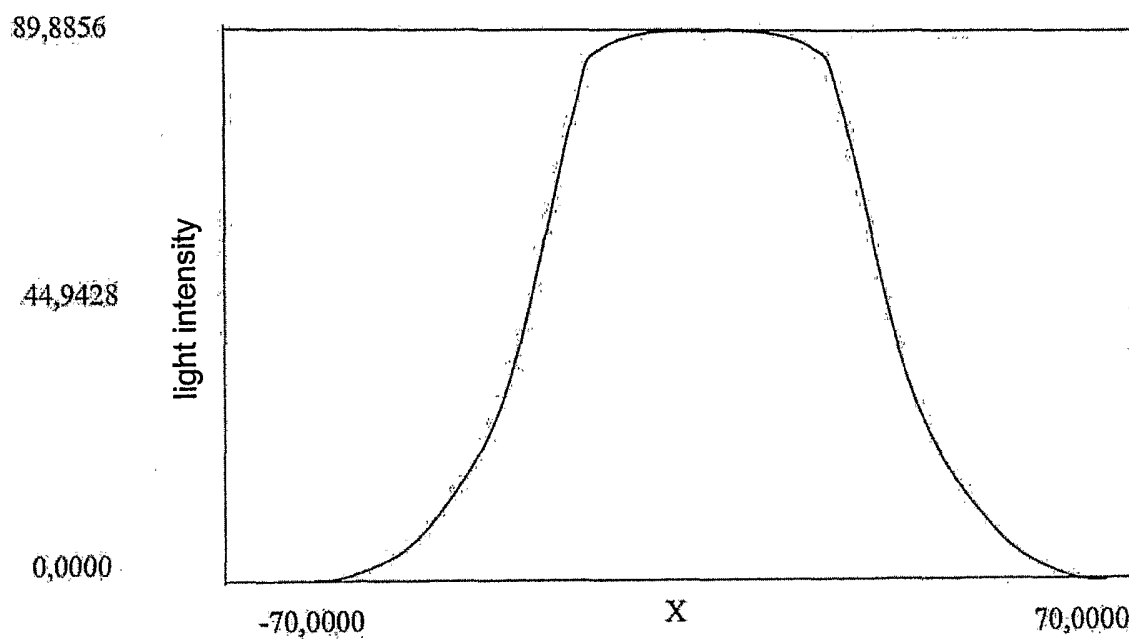


Fig. 5