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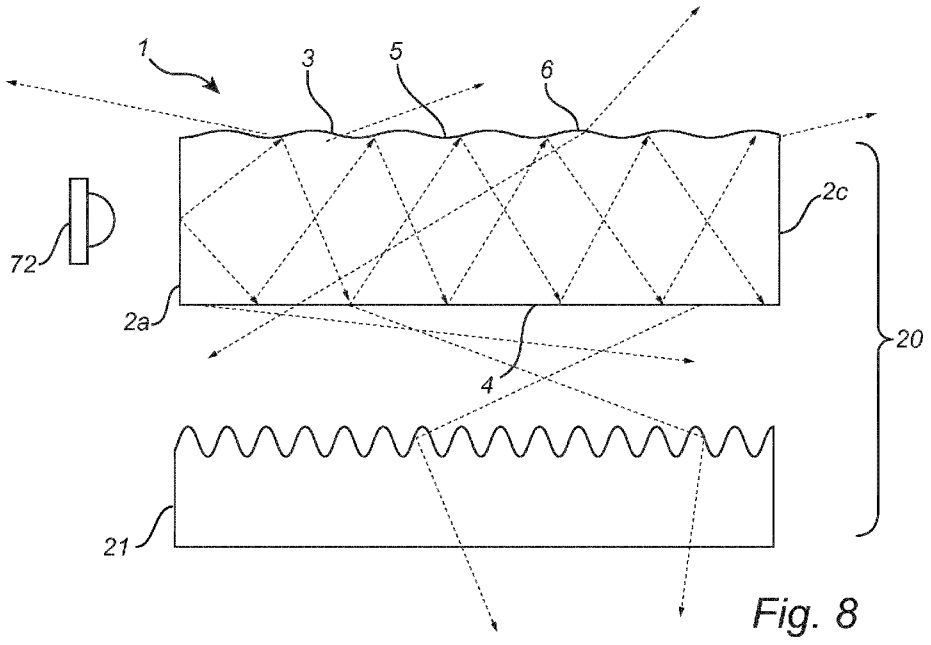


Fig. 8

(57) Abstract: The present invention relates to an optical structure (20) for an edge-lit luminaire (70), said optical structure comprising a light guide (1), said light guide comprising: an edge (2a) for light to enter said light guide; and a surface (3) comprising a plurality of at least partly light-extraction features (5, 6), wherein the at least partly curved light-extraction features have a minimum radius of curvature of at least 0.2 mm, and wherein the at least partly curved light-extraction features have a maximum slope relative to the light guide's plane (8), which maximum slope is less than 30 degrees. The present invention also relates to an edge-lit luminaire (70) comprising such an optical structure, and to a method of manufacturing such an optical structure.

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Optical structure for edge-lit luminaire

FIELD OF THE INVENTION

The present invention relates to an optical structure for an edge-lit luminaire. The present invention also relates to an edge-lit luminaire comprising such an optical structure, and to a method of manufacturing such an optical structure.

BACKGROUND OF THE INVENTION

The main optical architectures for indoor general lighting luminaires include direct-view (light sources aimed at the illuminated area), indirect-view (sources aimed at a reflector), and edge-lit (sources at the edge of a light guide). An advantage of the edge-lit architecture is the slim design, which allows for a low built-in depth for recessed luminaires, and elegant looks for surface-mounted, suspended or free floor standing luminaires. In the edge-lit architecture, the light guide may be illuminated from at least one of its edges by means of at least one light emitting diode (LED), and light is transported over the full area of a light guide by total internal reflections (TIR). Light is extracted from the light guide by extraction features counteracting the TIR.

These extraction features may be created by several processes including printing white paint and etching rough surfaces. However, printed and etched extraction features usually produce diffuse light with a Lambertian intensity distribution, or with an uncontrolled, broad light distribution.

The intensity distribution may be better controlled with specular reflecting extraction features. However, a problem with specular reflecting extraction features is that any deviation from the intended shape will be visible in the intensity distribution. High-quality beam control therefore requires precise control of the shape of the extraction features, with edges and tips being as sharp as possible. The manufacturing of detailed shape features usually requires an expensive process (complex tooling and/or long process times), such as an injection molding or hot embossing process at high pressure and temperature.

SUMMARY OF THE INVENTION

It is an object of the present invention to overcome or at least alleviate one or more of the aforementioned problems, and to provide an improved optical structure for an edge-lit luminaire.

According to a first aspect of the invention, this and other objects are achieved by an optical structure for an edge-lit luminaire, the optical structure comprising a light guide, the light guide comprising: an edge for light to enter the light guide; and a surface comprising a plurality of at least partly curved light-extraction features, wherein the at least partly curved light-extraction features have a minimum radius of curvature of at least 0.2 mm, and wherein the at least partly curved light-extraction features have a maximum slope relative to the surface's plane, which maximum slope is less than 30 degrees.

The invention is based on the insight that surprisingly, a light guide having only smooth light-extraction features (at least partly curved; minimum radius of curvature at least 0.2 mm; maximum slope less than 30 degrees) can produce a sharply defined intensity distribution, which distribution may be shaped into a light beam that is suitable for indoor lighting. The light guide with such light-extraction features can easily be manufactured by a low cost method like extrusion, low pressure/temperature injection molding, or embossing.

Here 'radius of curvature' may be and preferably is defined as the radius of a circle that best fits a normal section of the light-extraction feature. That the at least partly curved light-extraction features have a minimum radius of curvature of at least 0.2 mm should be construed as no light-extraction feature of the light guide has a radius of curvature smaller than 0.2 mm. The aforementioned 'surface's plane' may be a "reference" plane of the surface of the light guide, defined as the plane of the surface excluding variations due to the light-extraction features. In use or operation, the surface's plane is often horizontal. Furthermore, the surface's plane may be parallel to an opposing surface of the light guide.

According to one exemplary embodiment of the present invention, the at least partly curved light-extraction features have a minimum radius of curvature of at least 0.5 mm. This can make production methods even easier and cheaper.

According to one exemplary embodiment of the present invention, the maximum slope may be less than 20 degrees. This provides for a well-controlled light beam.

According to one exemplary embodiment of the present invention, the at least partly curved light-extraction features may comprise alternating concave and convex surfaces. In this way, the at least partly curved light-extraction feature may form a wavy (undulating) structure on the surface of the light guide. Each at least partly curved light-

extraction feature may include a cylindrical segment shape or include a spherical cap shape or include a rounded triangular prismatic shape or be cosine-shaped (e.g. have a contour that approximates a cosine curve). The minimum radius of curvature is not necessarily the same for the concave and the convex surfaces. Furthermore, the slopes on two sides of a bottom (concave surface) or a top (convex surface) need not be the same in value; hence an individual at least partly curved light-extraction feature of the plurality of at least partly curved light-extraction features can have a steeper and a less steep side.

According to one exemplary embodiment of the present invention, the at least partly curved light-extraction features may be linear and extend parallel to the edge of the light guide. Furthermore, in operation, a main (propagation) direction of light inside the light guide may be perpendicular to the linear at least partly curved light-extraction features. An advantage of linear light-extraction features is that they may be manufactured by extrusion, which may be regarded as a relatively simple process. Furthermore, all (linear) light-extraction features of the light guide preferably extend in one direction. The linear light-extraction features may for example include cylindrical segment shapes or be cosine-shaped.

Alternatively, the at least partly curved light-extraction features may be point-like features, such as local bumps and/or indentations. This may provide for a more symmetric intensity distribution. The point-like light-extraction features may for example include convex spherical cap shapes with smooth concave transitions, or be cosine-shaped.

According to one exemplary embodiment of the present invention, the surface of the light guide may have intermediate flat areas, which flat areas are parallel to, or positioned in, the aforementioned plane of the surface. The intermediate flat areas may be used to control or tailor the extraction efficiency (probability of extraction per meter distance) of the light guide. Each intermediate flat area may for example be provided between two concave surfaces or between two convex surfaces of the at least partly curved light-extraction features. Furthermore, the length of the intermediate flat areas may vary along the surface of the light guide from the edge of the light guide.

According to one exemplary embodiment of the present invention, at least one of the amplitude and the pitch of the at least partly curved light-extraction features may vary along the surface of the light guide from the edge of the light guide. The amplitude may be the height or the depth of the at least partly curved light-extraction feature(s). The pitch may be the (lateral) distance between the tops or peaks of two adjacent at least partly curved light-extraction features. Varying the amplitude and/or pitch of the at least partly curved light-extraction features may be used to control or tailor the extraction efficiency of the light guide,

whereby a balance between uniform looks (luminance) and a sharply defined intensity distribution may be achieved. In an example, an area close to the edge of the light guide may have shallow light-extraction features (low amplitude and/or long pitch), whereas a center area of the light guide has steeper light-extraction features (higher amplitude and/or shorter pitch) and thereby higher extraction efficiency (but a less controlled (wider) intensity distribution). In this way, the overall optical efficiency may be improved (a low fraction of the light in the light guide is absorbed at the opposite edge) and still a controlled overall intensity distribution can be obtained. The amplitude and/or pitch of the curved light-extraction features may vary stepwise or continuously. The latter may provide for a more smooth and uniform appearance of the light distribution coming out of the light guide.

According to one exemplary embodiment of the present invention, the optical structure may further comprise a beam-shaping structure adapted to shape light extracted from the light guide by the plurality of at least partly curved of light-extraction features, wherein the beam-shaping structure has a surface facing the light guide, and wherein the surface of the beam-shaping structure comprises a plurality of at least partly curved light-redirecting features that are steeper than the at least partly curved light-extraction features of the light guide. An advantage of using such a beam-shaping structure is that the sharply defined intensity distribution produced by the light guide may be transformed into a useful luminaire intensity. Light extracted from the light guide may enter the at least partly curved light-redirecting features and then be redirected by the at least partly curved light-redirecting features through TIR. Like the light-extraction features, the at least partly curved light-redirecting features may comprise alternating concave and convex surfaces, form a wavy (undulating) structure on said surface facing the light guide, include cylindrical segment shapes or include spherical cap shapes or include rounded triangular prismatic shapes or be cosine-shaped, be linear and extend parallel to the edge of the light guide, be point-like features, etc. The at least partly curved light-redirecting features for example may have a minimum radius of curvature of at least 0.1 mm or at least 0.15 mm or at least 0.2 mm.

According to one exemplary embodiment of the present invention, the surface of the light guide may be a top surface, wherein the surface of the beam-shaping structure may be a top surface. ‘Top surface’ may be construed as a surface facing upwards when the edge-lit luminaire is installed in its intended use position. Here, the beam-shaping structure is positioned under (below) the light guide and predominantly shapes light exiting the bottom of the light guide, for example to an intensity distribution which is limited to small angles with respect to the normal in downward direction, whereas light exiting the top surface of the light

guide may have a very wide distribution in the upward direction (applicable for direct-indirect lighting in indoor workplaces). In variants, the surface of the light guide may be a bottom surface or the light guide can have at least partly curved light-extraction features (minimum radius of curvature at least 0.2 mm; maximum slope less than 30 degrees) on both its top and bottom surfaces. Furthermore, the beam-shaping structure could be positioned above the light guide.

According to one exemplary embodiment of the present invention, the at least partly curved light-redirecting features may have a maximum slope relative to the (beam-shaping structure) surface's plane, which maximum slope is in the range 50-75 degrees, preferably in the range 60-70 degrees. By selecting the maximum slope in this range, the shape of the shaped light may be optimized or a desired up/down ratio may be achieved. In one example, a (maximum) slope of 55 degrees, resulting in a top angle of 70 degrees, may produce a more narrow and peaked downward distribution than a top angle of 50 degrees. In a different example, a top angle of 120 degrees may reflect most of the light exiting the bottom of the light guide upwards.

According to one exemplary embodiment of the present invention, the optical structure may further comprise a perforated specular reflector arranged over the surface of the light guide comprising the plurality of at least partly curved light-extraction features, wherein the perforated specular reflector is adapted to reflect part of the light extracted from the light guide. By means of such a perforated specular reflector, a desired up/down ratio may be achieved. The perforated specular reflector may for example reflect some of the (up)light exiting the top surface of the light guide in downward direction. For a downlighting (edge-lit) luminaire with no uplight, the specular reflector is not perforated.

According to a second aspect of the present invention, there is provided an edge-lit luminaire comprising: an optical structure according to the first aspect invention; and at least one solid-state light source arranged at the edge of the light guide. This aspect may exhibit the same or similar feature and technical effects as the first aspect, and vice versa. The luminaire could also be referred to as a (light) fixture or light fitting.

According to a third aspect of the present invention, there is provided a method for manufacturing an optical structure according to the first aspect, wherein the light guide of the optical structure is made by one of: extrusion, injection molding, and embossing. This aspect may exhibit the same or similar feature and technical effects as the first and/or aspects, and vice versa.

It is noted that the invention relates to all possible combinations of features recited in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the present invention will now be described in more detail, with reference to the appended drawings showing embodiment(s) of the invention.

As illustrated in the figures, some features (including the slopes) are or may be exaggerated for illustrative purposes and, thus, are provided to illustrate the general structures of embodiments of the present invention. Like reference numerals refer to like elements throughout.

Fig. 1a shows a schematic perspective view of a light guide of an optical structure in accordance with at least one embodiment of the present invention.

Fig. 1b shows a schematic side view of the light guide in fig. 1.

Fig. 1c shows an intensity distribution of light exiting a light guide according to the embodiment shown in figs. 1a-b.

Fig. 2 shows a schematic side view of the light guide of figs. 1a-b and a beam-shaping structure of the optical structure.

Figs. 3a-c show intensity distributions of light from optical structures in accordance with embodiments of the present invention.

Fig. 4a shows a side view of the optical structure in accordance with another embodiment of the present invention;

Fig. 4b shows an intensity distribution of light from an optical structure according to the embodiment shown in fig. 4a.

Figures 5a-c are schematic side views of light guides according to various embodiments of the present invention.

Fig. 6a shows a schematic side view of the optical structure in accordance with yet another embodiment of the present invention.

Fig. 6b shows a schematic side view of the optical structure in accordance with yet another embodiment of the present invention.

Fig. 7a shows a schematic cross-sectional side view of the optical structure in accordance with a further embodiment of the present invention;

Fig. 7b shows a schematic top view of the optical structure in fig. 7a.

Fig. 7c shows intensity distribution of light from an optical structure according to the embodiment shown in figs. 7a-b.

Fig. 8 shows a schematic side view of a luminaire in accordance with at least one embodiment of the present invention.

DETAILED DESCRIPTION

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which currently preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided for thoroughness and completeness, and fully convey the scope of the invention to the skilled person.

Figs. 1a-b illustrate a light guide 1 of an optical structure 20 according to the invention. The optical structure 20 is intended for an edge-lite luminaire 70, see fig. 8. The light guide 1 is generally shaped like a flat plate. Hence the light guide 1 can be referred to as a light guide plate. The light guide 1 may for example be a rectangular cuboid (with a low height (z-direction), for example in the range of 2-6 mm, preferably 3-4 mm). The light guide 1 may be translucent, for example transparent (clear). The light guide 1 can be made of PMMA (Poly(methyl methacrylate)), PC (Polycarbonate) or PS (polystyrene), for example. In case the light guide 1 is flexible, it could be made of silicone or PVC (polyvinylchloride).

The light guide 1 comprises two opposing (here rectangular) surfaces 3 and 4. The surfaces 3 and 4 may generally be parallel. The (xy) plane of the surface 3 is designated by reference sign 8. The plane 8 is parallel to the (opposite) surface 4. The light guide 1 further comprises four edges 2a-d connecting the surfaces 3 and 4. Light is intended to enter the light guide 1 through at least one edge, here edge 2a, which is one of the short edges of the light guide 1. To this end, at least one light source 72 may be arranged at the edge 2a, see also fig. 8. Light that enters the light guide 1 at the edge 2a during operation may generally be transported over the full area of the light guide 1 by total internal reflection (TIR) at the surfaces 3 and 4.

At least one of the surfaces 3 and 4, in figs. 1a-b only the top surface 3, comprises a plurality of light-extraction features 5, 6, whereas the other surface 4 is (completely) flat. Hence, the light-extraction features 5, 6 here face upwards. The light-extraction features 5, 6 are generally adapted to counteract the TIR conditions and extract (out-couple) light from the light guide 1. The light-extraction features 5, 6 preferably cover the complete or substantially the complete surface 3, except any intermediate flat areas 9 (see figures 5a-c). It should be noted that even in case both surfaces 3 and 4 comprise light-

extraction features, the light guide 1 may nevertheless be a cuboid or at least comprise a cuboid portion extending from edge 2a to the opposing edge 2c between the surfaces 3 and 4.

According to the present invention, the light-extraction features 5, 6 are at least partly curved light-extraction features 5, 6 having a minimum radius of curvature (ROC) of at least 0.2 mm (millimeter) or at least 0.5 mm and having a maximum slope (relative to the plane 8) which is less than 30 degrees, as illustrated by β. This allows the light guide 1 to be easily manufactured by a low cost method like extrusion, low pressure/temperature injection molding, or embossing. At the same time, a sharply defined intensity distribution can be produced, as will be discussed further below.

The light-extraction features 5, 6 are preferably integrated with the rest of the light guide 1, i.e. made in one piece with the rest of the light guide 1. The light extraction features 5, 6 are preferably made of the same material as the rest of the light guide 1. Furthermore, the light guide 1 has no sharp light extraction features.

The light-extraction features 5, 6 in figs. 1a-b comprises linear and uniform alternating concave surfaces 5 and convex surfaces 6, forming a smooth and continuous wavy (undulating) structure on the surface 3. The waves (i.e. light-extraction features) of the wavy structure "propagate" along the surface 3 from the edge 2a in the x-direction and "oscillate" in the z-direction. As can be seen from the side of the light guide 1, the light-extraction features 5, 6 hence have a rising and falling height profile. All the light-extraction features 5, 6 extend in one direction parallel to the edge 2a of the light guide 1. Furthermore, the light-extraction features 5, 6 extend and are elongated in a direction perpendicular to a main direction of light 7 inside the light guide 1. Each light-extraction feature 5, 6 may here include a cylindrical segment-shape. Alternatively, each light-extraction feature could be cosine-shaped (e.g. have a contour that approximates a cosine curve, as seen in the side view of fig. 1b), in which case each light-extraction feature includes at least one concave surface and at least one convex surface.

In operation, light from the at least one light source 72 enters the light guide 1 through the edge 2a and is transported in the light guide 1 by total internal reflection. The light transported inside the light guide 1 is extracted from the light guide 1 by means of the light-extraction features 5, 6, whereby light exits the light guide 1 from both the (top) surface 3 and the (bottom) surface 4 (see fig. 1b).

For the light guide 1 of figs. 1-b, wherein the minimum radius of curvature of the light-extraction features 5, 6 is 4 mm, and wherein the maximum slope of the light-extraction features 5, 6 is seven degrees with respect to the plane 8 of the surface 3, the

resulting intensity distribution is shown in fig. 1c. The intensity distribution has sharp intensity peaks, limited to about 10-30 degrees with respect to the plane 8.

Fig. 2 illustrates the optical structure 20 with the light guide 1, and further comprising a beam-shaping structure 21. The beam-shaping structure 21 is adapted to shape light extracted from the light guide 1 by the plurality of light-extraction features 5, 6. The beam-shaping structure 21 may be a beam-shaping plate, and it may generally be positioned parallel to the light guide 1, preferably at a distance from the light guide 1.

The beam-shaping structure 21 has a surface 22 facing the light guide 1. Here the surface 22 is a top surface 22 facing the (flat) bottom surface 4 of the light guide 1. The surface 22 of the beam-shaping structure 21 comprises a plurality of at least partly curved light-redirecting features 23, 24 that are steeper than the light-extraction features 5, 6 of the light guide 1. The at least partly curved light-redirecting features 23, 24 may for example have a maximum slope relative to a plane 26 of the aforementioned surface 26 of the beam-shaping structure 21 (as illustrated by θ), which maximum slope is in the range 50-75 degrees, preferably in the range 60-70 degrees.

By using the beam-shaping structure 21, the sharply defined intensity distribution of the light guide 1 in fig. 1c can easily be transformed into a useful luminaire intensity. In an example, the at least partly curved light-redirecting features 23, 24 are linear and includes rounded prisms 24 (rounded triangular prismatic shape), with a minimum radius of curvature of 0.3 mm and a top angle α of 50 degrees. This results in an intensity distribution that is limited to small angles with respect to the normal 25 in downward direction, and a wide distribution in the upward direction, as shown in fig. 3a. This distribution is typically applicable for direct-indirect lighting in indoor workplaces. The up/down ratio may be varied by adding a perforated specular reflector 26 over the surface 3 to reflect part of the uplight in downwards direction.

The shape of the downward beam may be optimized by varying the top angle α of the beam-shaping features (rounded prisms) 24. For instance, as shown in fig. 3b, a top angle of 70 degrees instead of 50 degrees may produce a narrower and peaked downward distribution. The top angle α may be defined as the angle between the two slopes at the position where the curvature changes sign (from convex to concave).

In a different example shown in fig. 3c, the beam-shaping structure 21 may be used to change the up/down ratio. Here, rounded prisms 24 each with a top angle of 120 degrees may reflect most of the light exiting from the bottom surface 4 of the light guide 1 upwards. A similar beam-shaping structure 21 could be used to reflect light downwards when

applied above the top surface 3 of the light guide 1, in which case the optical structure may comprise a further beam-shaping structure with a "wavy" surface below the light guide 1 to shape the downwards beam (not shown). The further beam-shaping structure could for example have a top angle of about 65 degrees.

Fig. 4a shows another embodiment, wherein the light-extraction features 5, 6 are provided on the bottom surface 4 of the light guide 1 instead of on the top surface 3, and wherein the top surface 22 of the beam-shaping structure 21 faces the light-extraction features 5, 6. In this embodiment, the at least partly curved light-redirecting features (rounded prisms) 24 of the beam-shaping structure 21 may have a top angle α of 55 degrees. The resulting intensity distribution is shown in fig. 4b.

Figures 5a-c show light guides 1 according to various embodiments of the present invention wherein the surface 3 of the light guide 1 have intermediate flat areas 9. The flat areas 9 may be parallel to the surface's plane 8. In fig. 5a, each flat area 9 is provided between two concave surfaces 5 of the light-extraction features. In fig. 5b, each flat area 9 is provided between two convex surfaces 6 of the light-extraction features. In fig. 5c, the length of the intermediate flat areas 9 varies along the surface 3 from the edge 2a of the light guide 1.

In yet another embodiment according to the present invention, at least one of the amplitude 51 and the pitch 52 of the at least partly curved light-extraction features 5, 6 may vary along the surface 3 of the light guide 1 from the edge 2a of the light guide 1, see fig. 6a. In this way, the extraction efficiency (probability of extraction per meter distance) may be varied. The extraction efficiency usually requires careful engineering. If it is too high, the luminance may be highly non-uniform (concentrated at the edge). If it is too low, the luminance is uniform, but the optical efficiency is low (a large fraction of the light crosses the light guide 1 and is partly absorbed at the opposite edge 2c).

In fig. 6a, areas 53 of the light guide 1 close to the opposing edges 2a and 2c have shallow light-extraction features 5, 6 (lower amplitude 51) resulting in a narrow intensity peak coming out of the light guide 1, whereas a center area 54 of the light guide 1 has light-extraction features 5,6 with relatively steep slopes (higher amplitude 51 but the same pitch 52 as in the peripheral areas 53) resulting in a broader intensity peak. In a simulated example, the optical efficiency improves significantly (from 83% with only shallow light-extraction features 5, 6 to 95% when the steep light-extraction features 5, 6 are replacing the shallow ones in the center area 54) and still a controlled intensity distribution may be obtained. The steep light-extraction features 5, 6 in the center area 54 may produce a

bright center line. This can be used intentionally as an aesthetic feature, or the brightness difference may be tuned to zero by carefully balancing the extraction efficiencies of the different areas. Instead of the stepwise variation in amplitude 51 and/or pitch 52 as in fig. 5, the amplitude 51 and/or pitch 52 of the light-extraction features 5, 6 may vary continuously along the surface 3 of the light guide 1 from the edge 2a of the light guide 1.

Figure 6b shows yet another embodiment wherein the shape at least partly curved light-extraction features 5, 6 varies along the surface 3 from the edge 2a. At the left, the left slopes are steeper than the right slopes, in the center the light-extraction features (waves) are symmetric, and at the right the right slopes are steeper than the left slopes.

In a further embodiment, shown in figs. 7a-b, the light-extraction features of the light guide 1 are point-like features, rather than linear. Specifically, the light extraction features comprise local (smooth and wavy) bumps 61 arranged in a hexagonal grid pattern. The bumps 61 in are circular symmetrical, each with a cosine-shaped cross section (as seen in the view of fig. 6a). In an example, the bumps 61 of the light guide 1 have a diameter of 4 mm and a height of 0.3 mm at the edge 2a (minimum radius of curvature is 2.7 mm), and a height of 0.6 mm in the center area 54 (min radius of curvature is 1.4 mm). The beam shaping structure 21 also has a hexagonal grid of (smooth and wavy) circular symmetrical cosine-shaped bumps 62 acting as the light-redirecting features (diameter of 2.5 mm, height of 1.9 mm, and minimum radius of curvature of 0.17 mm). This embodiment may produce a downward intensity distribution which is almost circular symmetric, as shown in Fig. 6c. Instead of being arrange in a hexagonal grid pattern, the bumps 61 (and 62) could be arranged in some other patter, such as a square grid pattern.

In fig. 8, an edge-lit luminaire 70 according to an aspect of the present invention is shown. The luminaire 70 comprises the optical structure 21 with a light guide 1 and the beam shaping structure 21 according to various embodiments explained above. The luminaire 70 further comprises at light source 72 arranged at least the edge 2a of the light guide 1. The at least one light source 72 may be one or more Lambertian sources. The at least one light source 72 can be at least one solid state light source, such as at least one light emitting diode (LED). The at least one LED may for example be 3x3 mm mid-power LEDs. At least one further light source (not shown) may be arranged at the opposite edge 2c of the light guide 1.

The edge-lite luminaire 70 may for example be used for direct-indirect lighting for indoor workspaces. The edge-lite luminaire 70 may be surface-mounted, suspended or free floor standing, for example.

The person skilled in the art realizes that the present invention by no means is limited to the preferred embodiments described above. On the contrary, many modifications and variations are possible within the scope of the appended claims. Additionally, variations to the disclosed embodiments can be understood and effected by the skilled person in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measured cannot be used to advantage.

CLAIMS:

1. An optical structure (20) for an edge-lit luminaire (70), said optical structure comprising a light guide (1), said light guide comprising:

an edge (2a) for light to enter said light guide; and

a surface (3) comprising a plurality of at least partly curved light-extraction features (5, 6), wherein the at least partly curved light-extraction features have a minimum radius of curvature of at least 0.2 mm, and wherein the at least partly curved light-extraction features have a maximum slope relative to the surface's plane (8), which maximum slope is less than 30 degrees.

2. The optical structure according to claim 1, wherein said at least partly curved light-extraction features have a minimum radius of curvature of at least 0.5 mm.

3. The optical structure according to claim 1 or 2, wherein said maximum slope is less than 20 degrees.

4. The optical structure according to any one of the preceding claims, wherein the at least partly curved light-extraction features comprise alternating concave (5) and convex surfaces (6).

5. The optical structure according to any one of the preceding claims, wherein the at least partly curved light-extraction features form a wavy structure on said surface (3).

6. The optical structure according to any one of the preceding claims, wherein each at least partly curved light-extraction feature includes a cylindrical segment shape or includes a spherical cap shape or includes a rounded triangular prismatic shape or is cosine-shaped.

7. The optical structure according to any one of the preceding claims, wherein the at least partly curved light-extraction features are linear and extend parallel to the edge of the light guide.

8. The optical structure according to any one of the preceding claims, wherein the at least partly curved light-extraction features are linear, and wherein in operation a main direction (7) of light inside the light guide is perpendicular to the linear at least partly curved light-extraction features.

9. The optical structure according to any one of the preceding claims, wherein said surface has intermediate flat areas (9), which flat areas are parallel to, or positioned in, said plane (8) of the surface.

10. The optical structure according to any one of the preceding claims, wherein at least one of the amplitude (51) and the pitch (52) of the at least partly curved light-extraction features varies along the surface of the light guide from said edge of the light guide.

11. The optical structure according to any one of the preceding claims, further comprising:

a beam-shaping structure (21) adapted to shape light extracted from the light guide by the plurality of at least partly curved light-extraction features, wherein the beam-shaping structure has a surface (22) facing said light guide, and wherein said surface of the beam-shaping structure comprises a plurality of at least partly curved light-redirecting features (23, 24) that are steeper than said at least partly curved light-extraction features of the light guide.

12. The optical structure according to claim 11, wherein said surface of the light guide is a top surface, and wherein said surface of the beam-shaping structure is a top surface.

13. The optical structure according to claim 11 or 12, wherein the at least partly curved light-redirecting features have a maximum slope relative to the surface's plane (26), which maximum slope is in the range 50-75 degrees, preferably in the range 60-70 degrees.

14. The optical structure according to any one of the preceding claims, further comprising a perforated specular reflector (26) arranged over the surface of the light guide comprising the plurality of at least partly curved light-extraction features, wherein the perforated specular reflector is adapted to reflect part of the light extracted from the light guide.

15. An edge-lit luminaire (70), comprising:
an optical structure (21) according to any of the preceding claims; and
at least one solid-state light source (72) arranged at the edge of said light guide.

16. Method of manufacturing an optical structure according to any one of the preceding claims 1-14, wherein the light guide (1) of the optical structure is made by one of: extrusion, injection molding, and embossing.

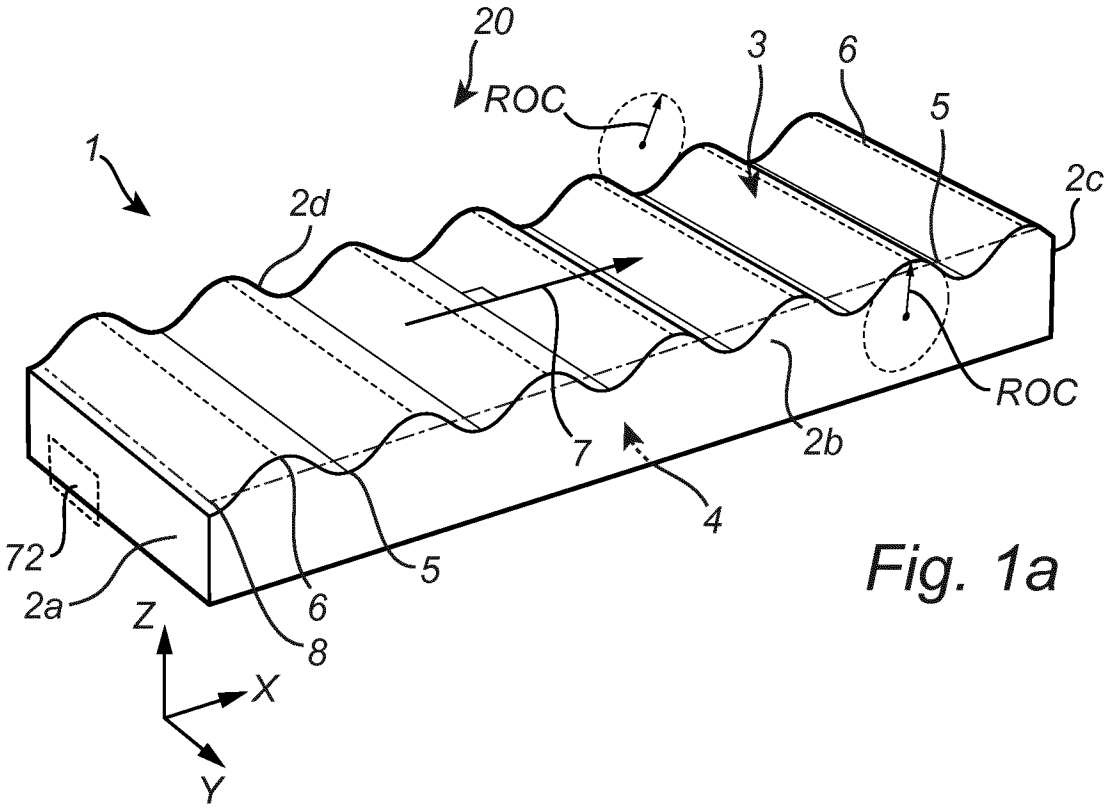


Fig. 1a

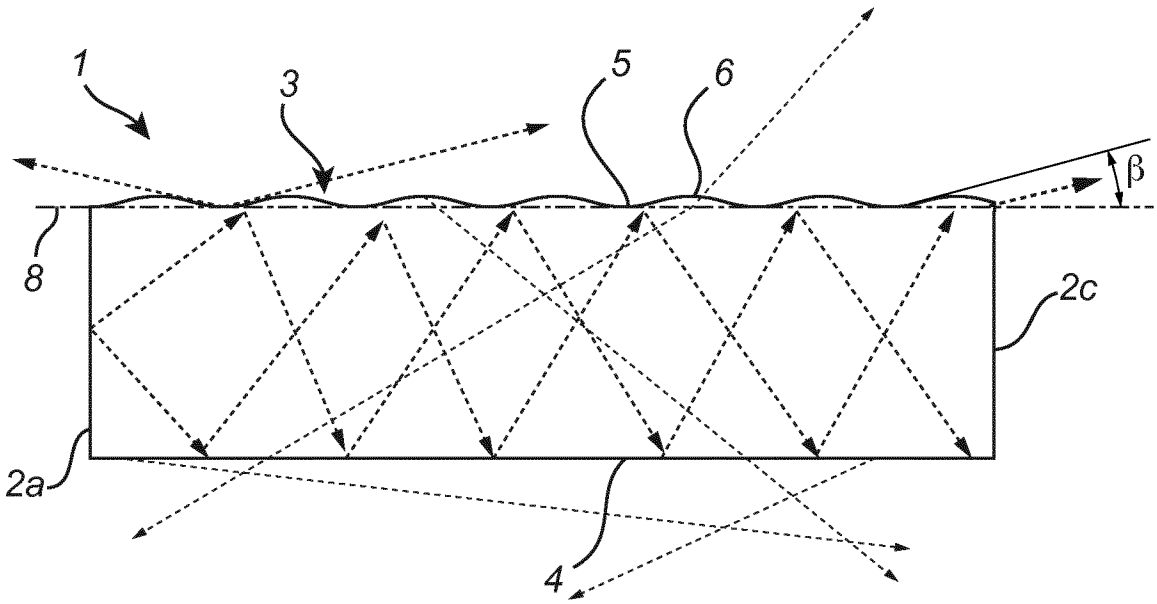


Fig. 1b

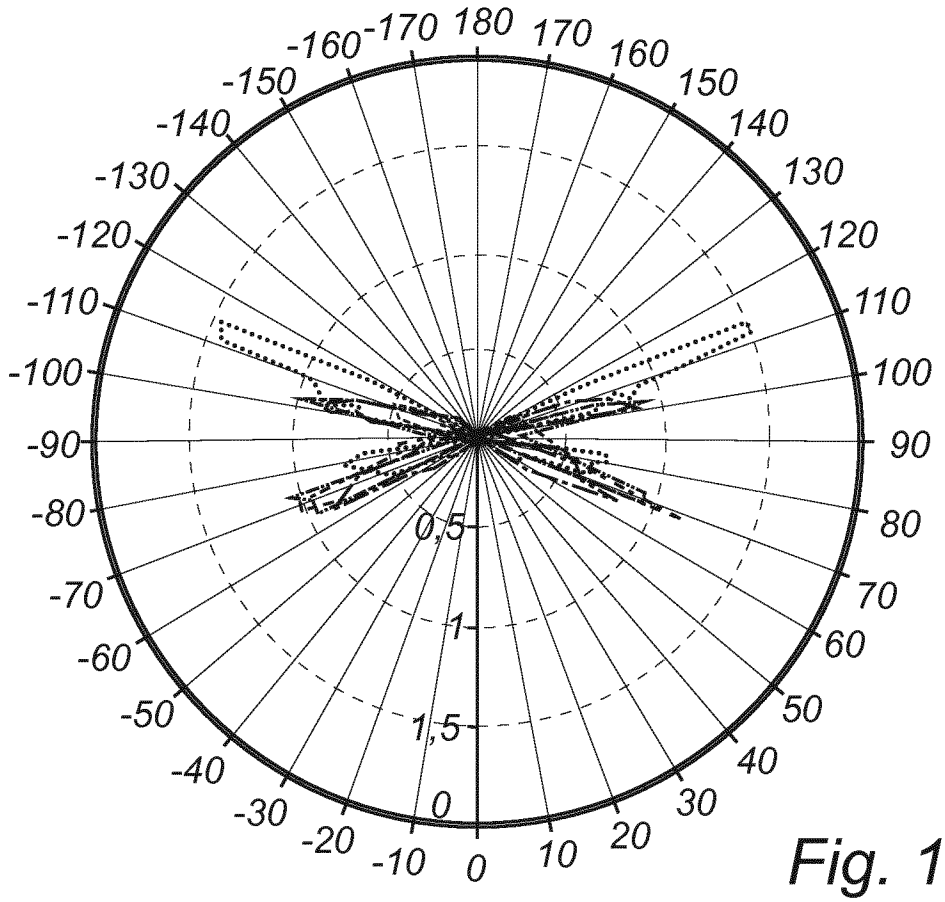

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Fig. 1c

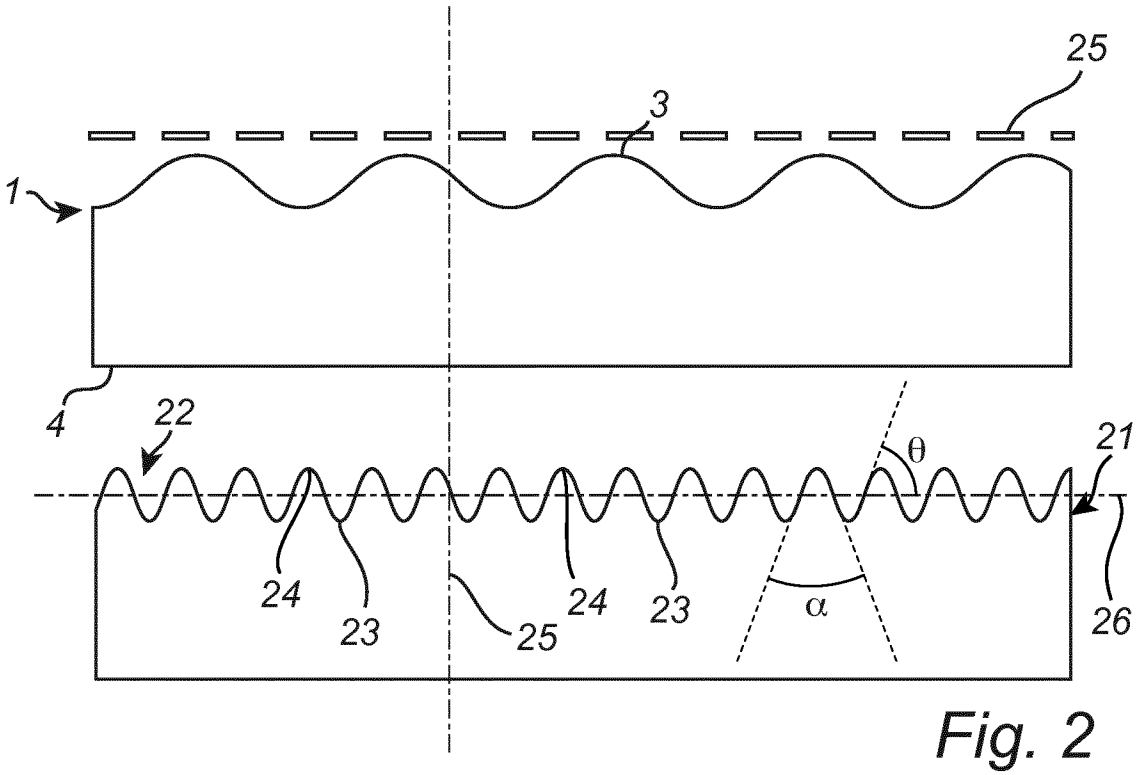

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Fig. 2

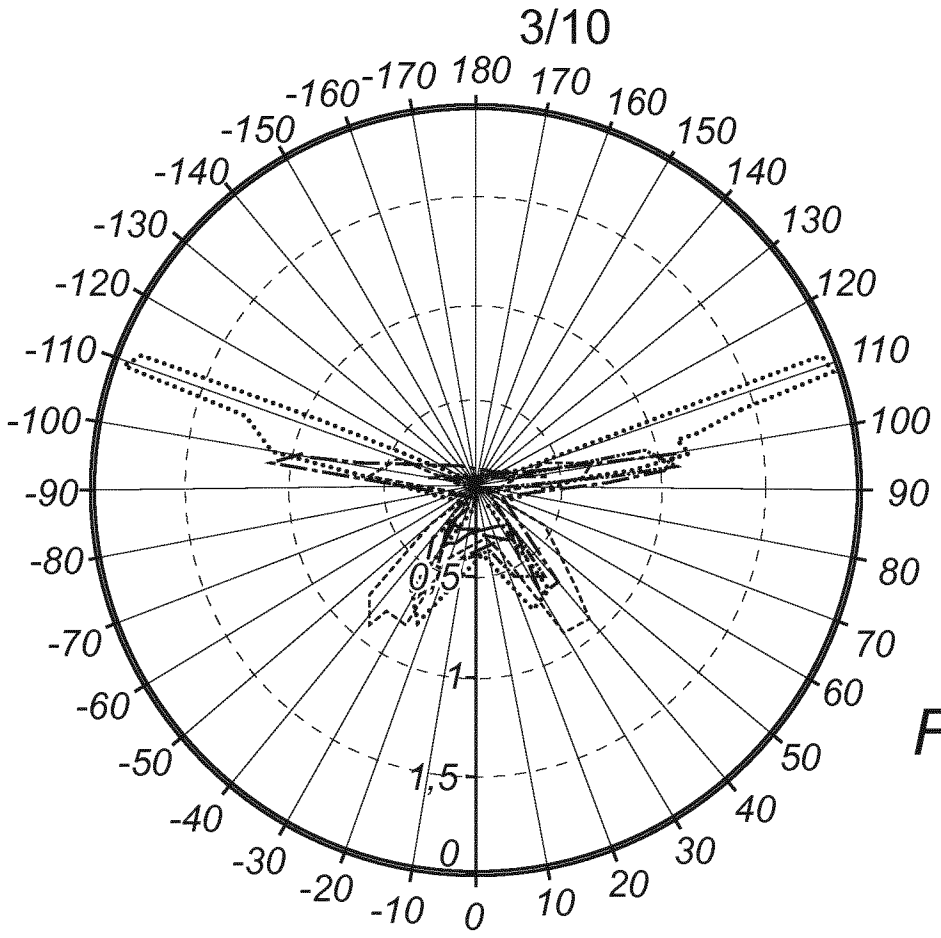

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Fig. 3a

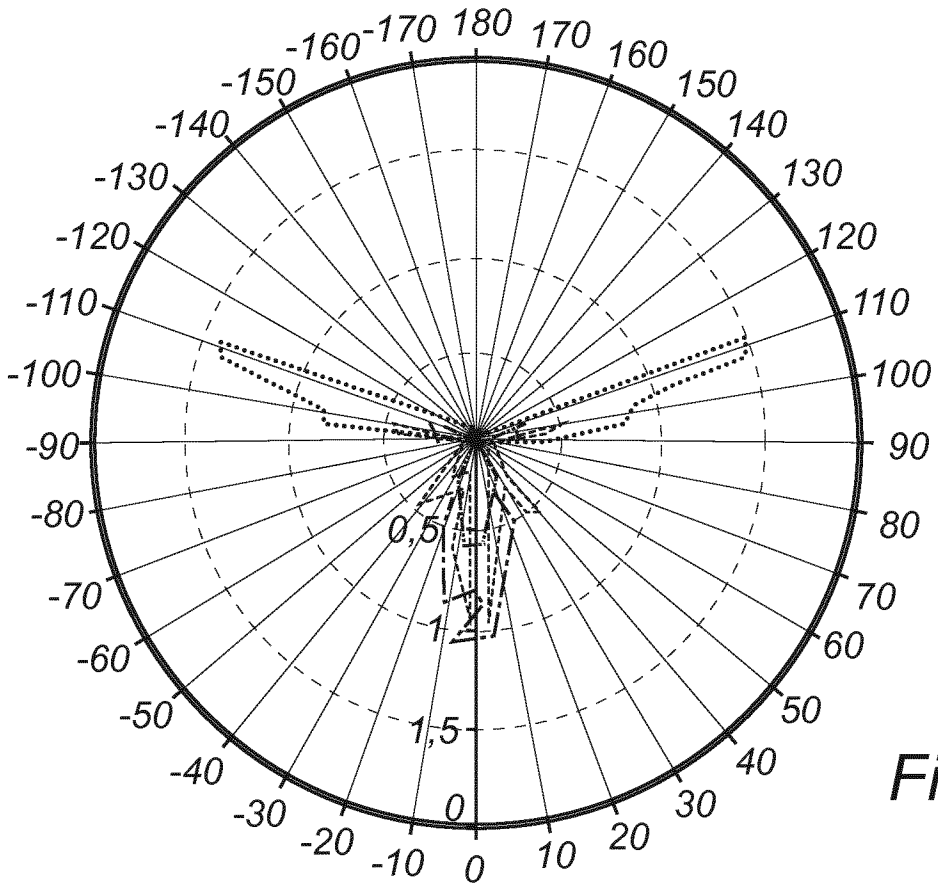

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Fig. 3b

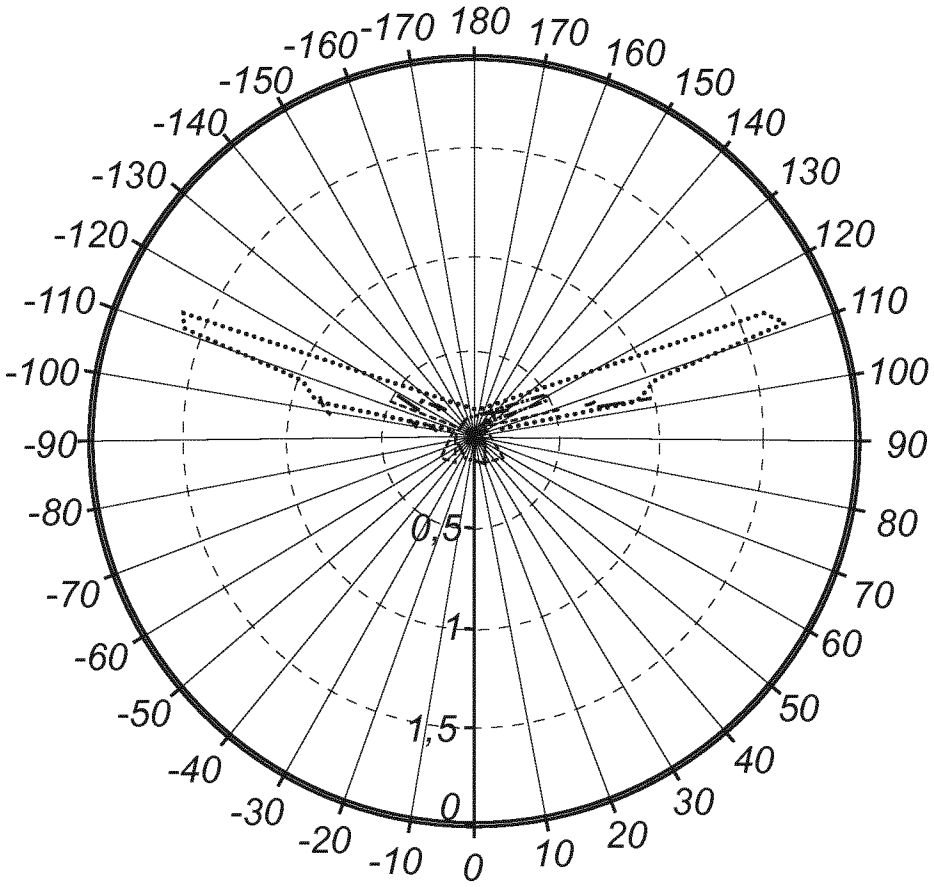

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Fig. 3c

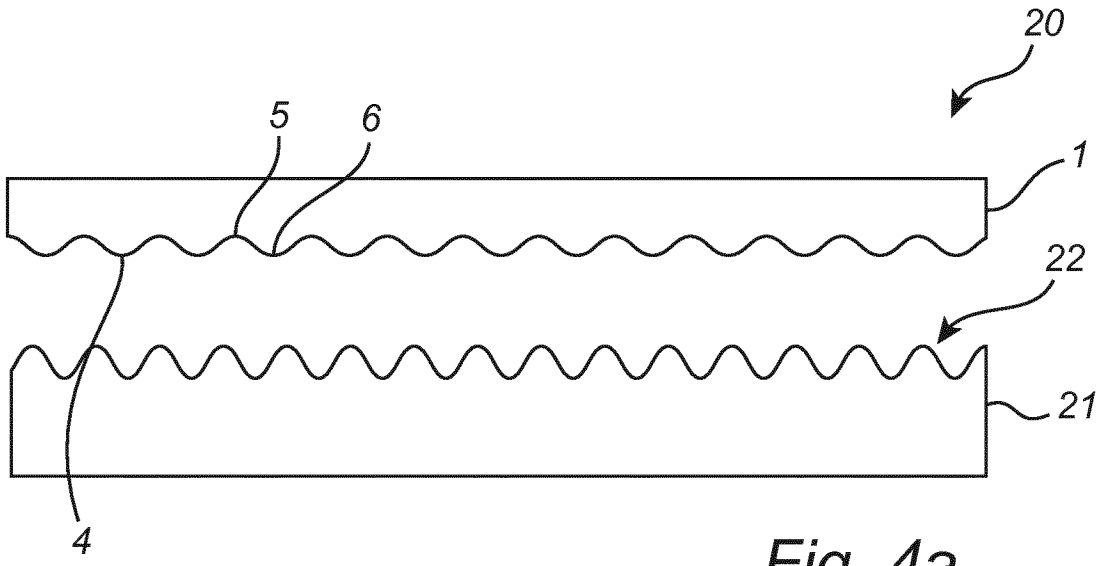

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Fig. 4a

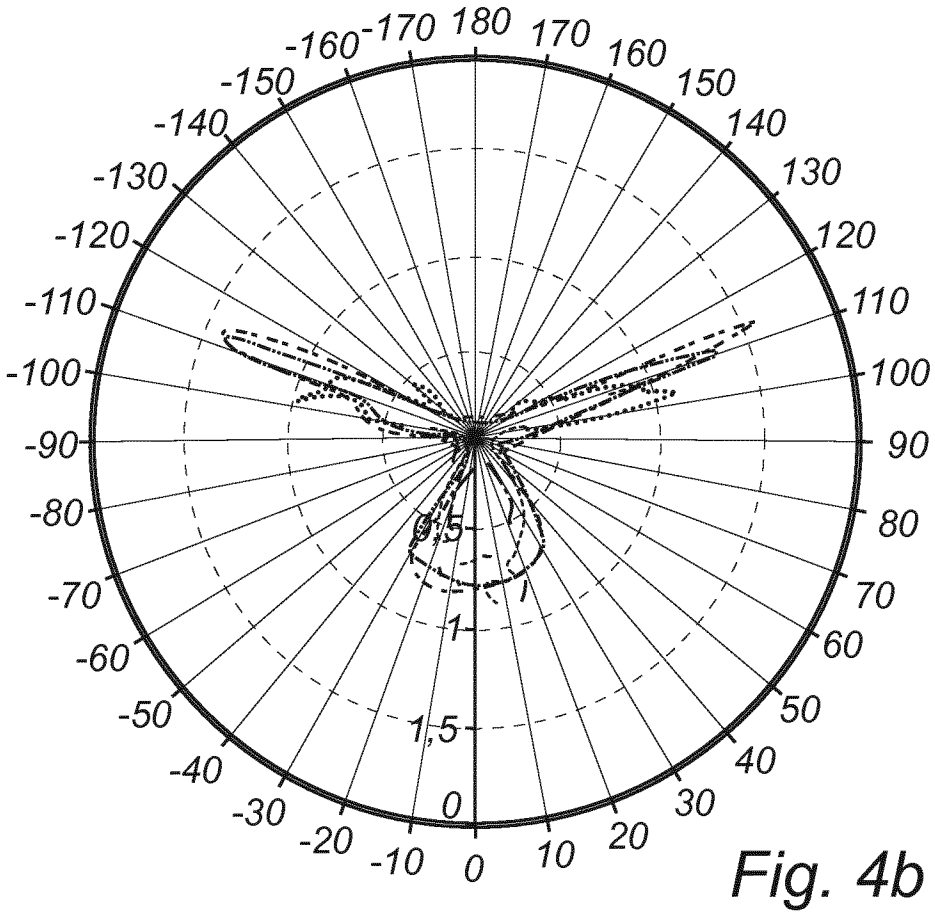

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Fig. 4b

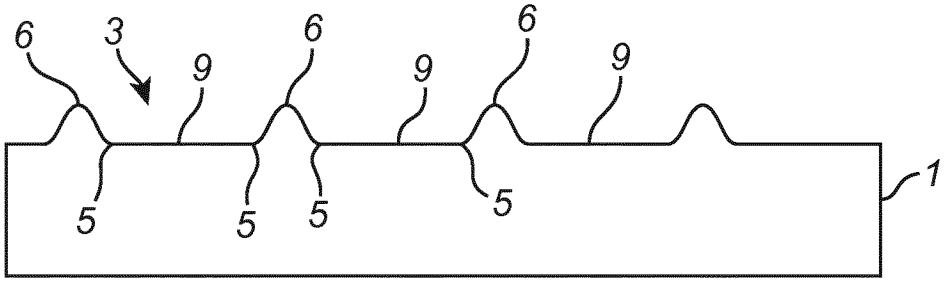


Fig. 5a

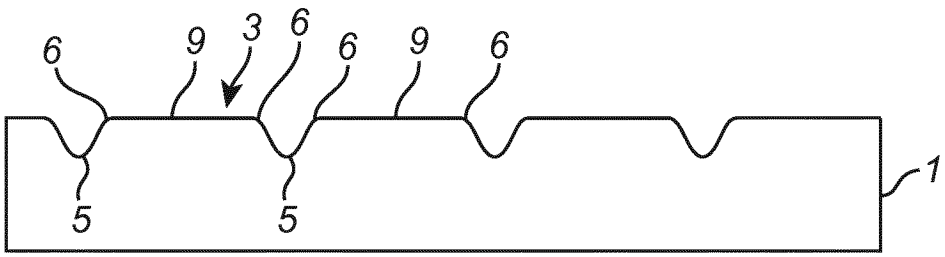


Fig. 5b

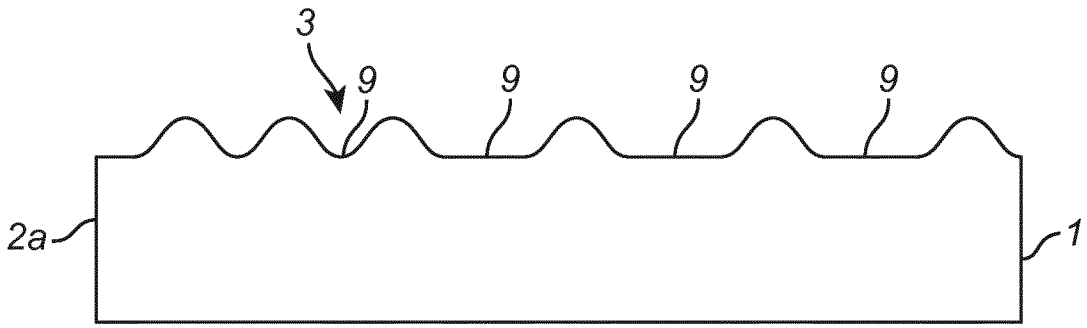


Fig. 5c

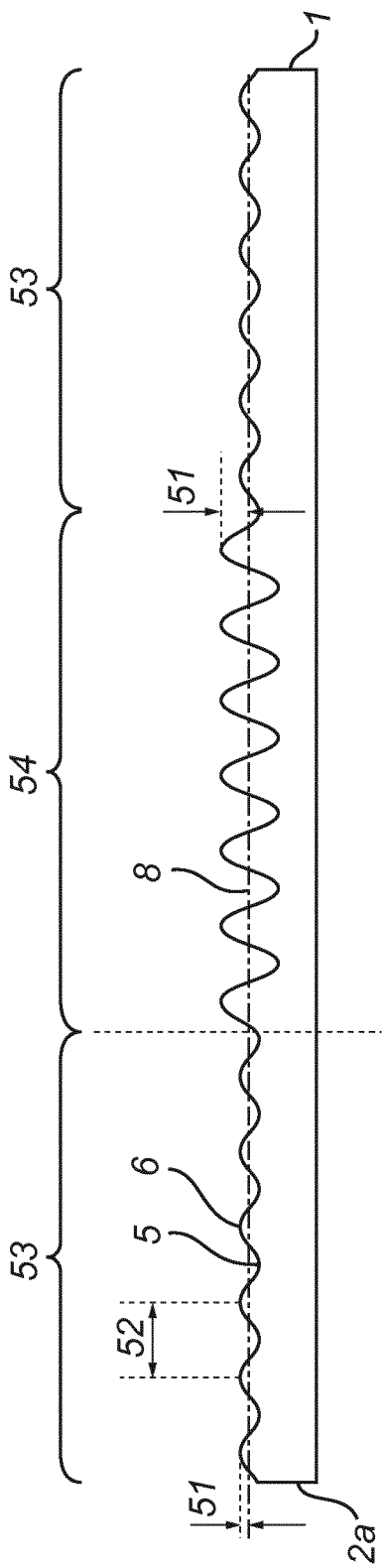


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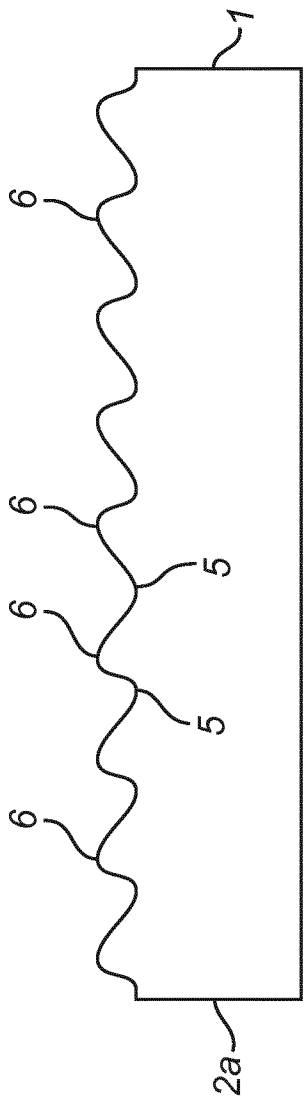


Fig. 6b

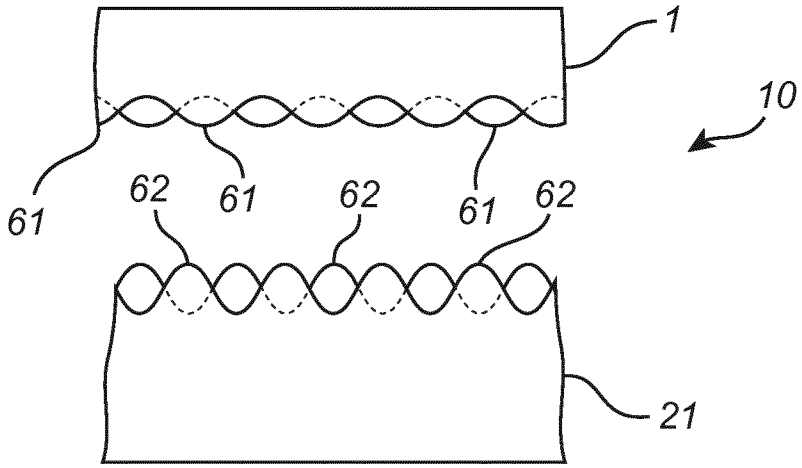


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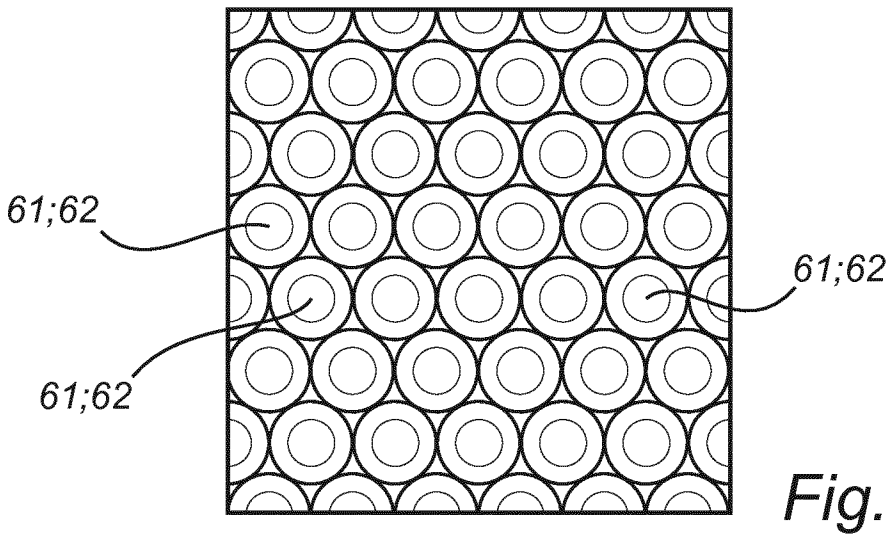


Fig. 7b

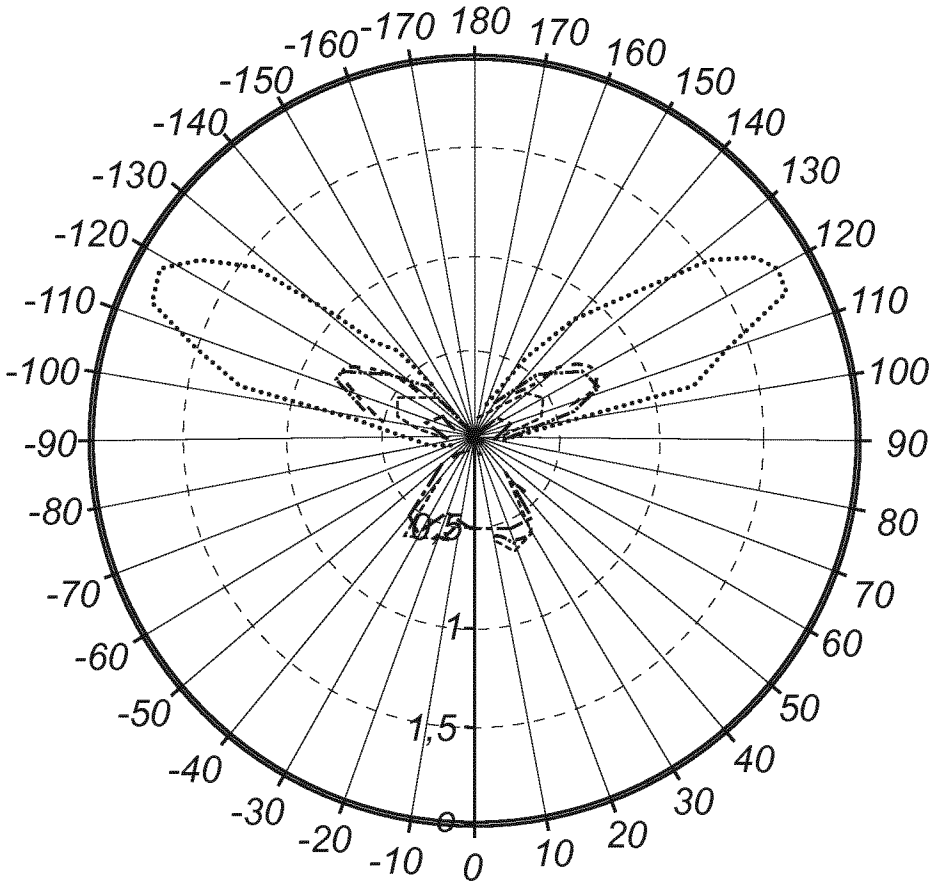

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Fig. 7c

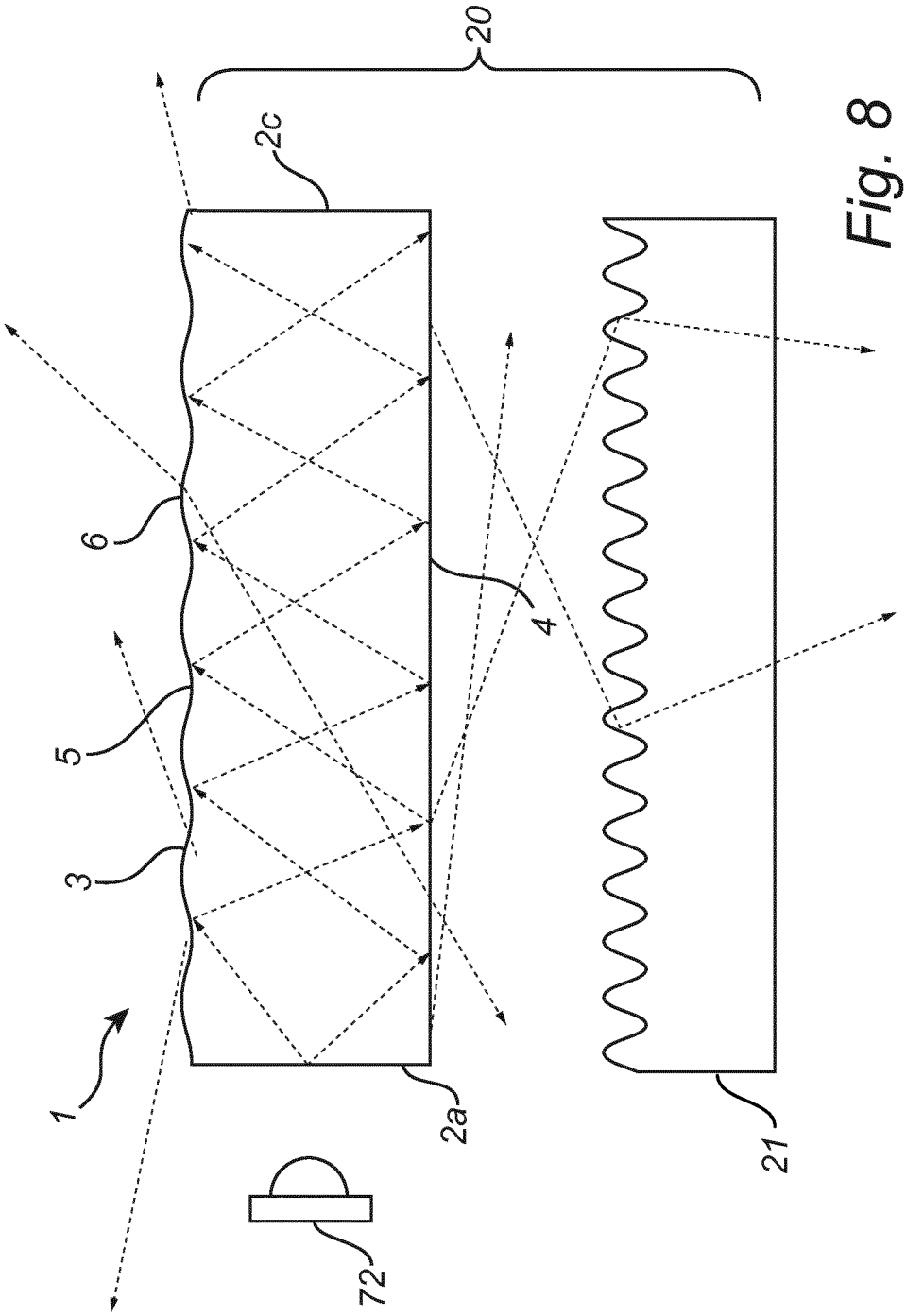


Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/080212

A. CLASSIFICATION OF SUBJECT MATTER
INV. F21V8/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/268404 A1 (CHIU WEN-YEN [TW] ET AL) 24 September 2015 (2015-09-24) figures 1A-1C, 6 paragraphs [0038], [0069], [0071], [0074], [0078]	1-16
X	JP 5 930729 B2 (SUMITOMO CHEMICAL CO) 8 June 2016 (2016-06-08) figures 1, 2, 4-6 paragraphs [0024], [0052] - [0054]	1-16
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

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Date of the actual completion of the international search	Date of mailing of the international search report
9 December 2019	17/12/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Zakynthinos, P

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/080212

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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