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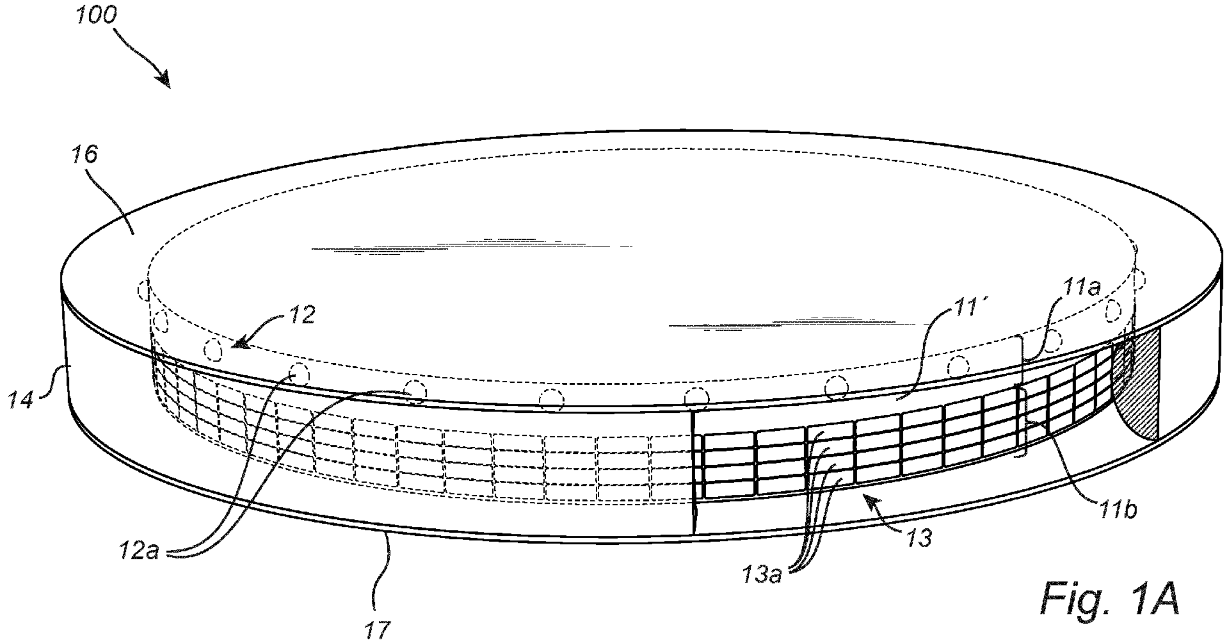

Fig. 1A

(57) Abstract: An arrangement for an outdoor luminaire comprising a substrate having a first area and a second area on a same side of the substrate, a light source arranged on the first area, a solar cell module arranged on the second area, and an optical element configured to direct light emitted from the light source in a direction in a fist angular range, and to direct light incident on the optical structure from a second angular range toward the second area and away from the first area. The optical element according to the invention ensures an improved light collection efficiency as a controlled intensity distribution.

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Arrangement including light source and solar cells

FIELD OF THE INVENTION

The present invention relates to an arrangement including a light source and a solar cell module, and a luminaire comprising one or several such arrangements.

BACKGROUND OF THE INVENTION

Photovoltaic cells also commonly known as solar cells are often used for luminaires in lighting applications such as outdoor lighting systems like garden lights which usually are on for a short period in the evening or only when people are passing by, triggered by a sensor. Usually, the photovoltaic cell is mounted as a totally separate component in electric connection with the luminaire for instance via electric wiring. In some of the common examples the photovoltaic cell is located on top of the luminaire for proper light exposure.

In other existing examples, the solar cells may be integrated into the luminaire, however there is still a requirement of electrically connecting the solar cells and the light sources which still retains the necessity of using different forms of electrical wiring, thus making the fabrication of these devices more complicated and costly. Further, electrical wiring adds reliability issues such as broken connections and short circuits to the lighting system, increasing maintenance costs and complexities.

In an improved solution disclosed in US 2010/0126549 a solar cell module with an integrally-arranged light emitting device is described. In this device a plurality of solar cells are arranged together for conversion of solar energy to electrical energy. The lighting devices which could be a plurality of LEDs or electro-luminescent devices. In this arrangement a space-optimized and integrated solution is proposed however numerous drawbacks are left unaddressed, such as the optical efficiency of the device, and the fact that the device is still dependent on a sort of electric wiring between the solar cells, the lighting devices and a control unit.

Therefore, there is a need in the field to further develop more appealing, versatile and cost effective integrated solar cell-lighting devices to achieve efficient lighting solutions.

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 arrangement with integrated solar cells for a luminaire.

According to a first aspect of the invention, this and other objects are achieved by an arrangement for an outdoor luminaire comprising a substrate having a first area and a second area on a same side of the substrate, a light source arranged on the first area, a solar cell module arranged on the second area, and an optical element configured to direct light emitted from the light source in a direction in a fist angular range, and to direct light incident on the optical structure from a second angular range toward the second area and away from the first area.

The light source may include one or several light emitting diodes (LEDs) and a luminaire comprising LEDs may be referred to as a LED-luminaire. Also a solar cell module generally comprises a plurality of individual photovoltaic or solar cells. The incident light is typically sunlight.

By arranging the LEDs and the solar cell modules on the same side of the substrate (i.e. facing generally the same direction) and providing an optical element according to the invention, an improved light collection efficiency by the solar cell modules as well as a controlled intensity distribution with high beam directability for the light emitted by the light source can be achieved simultaneously. Further, with light source and solar cells on the same substrate, the need for costly electrical wiring between the LEDs and solar cell modules is conveniently eliminated. The arrangement according to the first aspect may also provide an improved aesthetic appearance for the luminaries by integrating the solar cell modules together with the light sources.

The first area and the second area should be understood as designated and separated portions of the substrate surface, such that each designated portion comprises only the light sources or only the solar cell modules. It is noted that either the first area or the second area or both may include several different sub-areas. For example, the second area may include two sub-areas, each including a solar cell module.

The optical element may be a single component or may comprise a plurality of similar/different optical components with customizable optical properties. Preferably, the optical element is arranged such that the first angular range extends downwards from a horizontal reference plane.

In one embodiment, the optical element is a positive lens operable to direct light emitted from said light source in the first angular range and to collect and direct light incident on the lens from the second angular range toward the solar cell module. Arranged correctly, a positive lens is a simple way to achieve the desired functionality of the present invention.

In order to provide a straight exterior surface, e.g. to facilitate cleaning, the positive lens may have a convex surface facing the substrate and a flat surface facing away from the substrate. However, the positive lens may alternatively have a flat surface facing the substrate, or have two convex surfaces. In fact, the positive lens may even have a concave surface and a convex surface, as long as the total effect is that of a positive lens.

An optical element in the form of a positive lens will cause Fresnel reflections, especially for high elevation angles (large incident angle). Such Fresnel reflections will thus have a certain negative effect, especially when the sun is high and the skies are clear. In overcast (cloudy) conditions, such negative effects will be very minor.

In another embodiment, the optical element includes a first set of refractive prisms configured to direct light emitted from the light source in the first angular range, and a second set of refractive prisms configured to collect and direct light incident on the second grating from the second angular range toward said solar cell module. In principle, it may be sufficient with one prism adjacent to the light source, and one prism adjacent to the solar cell module. However, preferably each set includes several prisms.

In yet another embodiment, the optical element is a prism with a cross section in the shape of a right trapezoid, the prism having a light in-coupling surface facing the light source, a light out-coupling surface opposite to and parallel with the in-coupling surface, and an intermediate surface connecting the in-coupling surface and out-coupling surface, the intermediate surface facing the solar cell module. With this design, light emitted from the light source is at least partly coupled into the prism through the in-coupling surface, is guided through the prism by total internal reflection, and exits the prism via the out-coupling surface. Further, light incident on the out-coupling surface from the second direction is refracted by the prism and exits the intermediate surface towards the solar cell module.

Such a prism thus serves as both as a light guide and collimator, for light emitted by the light source, and also as a light-bending prism to concentrate the incident light e.g. sunlight, toward the solar cell modules. Therefore, a compact and easy to manufacture optical element creating the useful illumination out of the luminaire with enhanced light collection efficiency is achieved.

Optical elements including prisms may be more advantageous for conditions with clear sky and higher solar elevation for example 45 degrees or 55 degrees or 65 degrees.

The substrate may be curved, and for example form a cylinder, or a segment of a cylinder (e.g. a semi-cylinder). According to one embodiment, the substrate is cylindrical, preferably circular cylindrical, and the first and second areas are formed on an outside surface of the cylindrical substrate. In this case, the optical element is annular and arranged to surround the cylindrical substrate, e.g. an annular lens, an annular prism or an annular grating. With this design, the arrangement thus becomes substantially rotationally symmetric.

A rotationally symmetric design allows for easy production of cylindrical or disc-shaped luminaires comprising disc-shaped modules. This configuration is typically useful for luminaires mounted on a cylindrical pole or post. Half-cylindrical (semi-circular discs) are typically useful for wall-mounted luminaires.

The arrangement and a luminaire including the arrangement may of course also be flat, cuboid, conical, polygonal or any other shape desired for the intended lighting solutions.

For example, the substrate may be substantially flat, and the optical structure having a flat substrate e.g. shaped like a flat plate may be installed in luminaries which are more suitable to be mounted on horizontal and/or vertical surfaces. The luminaire comprising the optical structure having a flat substrate may be a wall-mounted or floor-mounted luminaire. The flat plate could be readily installed in other different angled positions with respect to the vertical and/or horizontal orientations.

The arrangement may further comprise a plurality of additional solar cell modules arranged on a third area of the substrate, this third area being separate from said second area and being optically exposed to incident light, the plurality of additional solar cell modules being electrically connected to the solar cell module in the second area.

By devising an area dedicated for additional solar cell modules, the luminaire may collect incident light from different angular ranges, and thus have longer operation hours (i.e. as the sun moves).

According to a second aspect of the present invention, there is provided a luminaire comprising one or several arrangements according to the first aspect.

When combining several arrangements, it is noted that the first and second areas of each arrangement may be grouped together, in designated portions, such that all first areas are in the same designated portion. Alternatively, however, the first and second areas may be arranged in an alternating configuration.

A luminaire according to the second aspect of the invention may include a plurality of modules, each formed by a cylindrical arrangement according to the first aspect of the invention, the modules being aligned with each other in a stack. A light-reflecting plate may be arranged between each pair of adjacent modules, which reflective plate thereby prevents, or at least mitigates, cross-talk between adjacent modules in the stack.

A variety of optically translucent materials, for instance transparent materials such as glass or plastic could be used to manufacture the light-reflecting plate. The light reflecting plates may preferably be made of diffuse reflecting polymers. They may also comprise specular reflectors, prism reflectors, or comprise light-redirecting features, and surfaces with reflective coatings, etc.

The luminaire may further include a light-sensing element configured to detect the amount of ambient light and to generate an first signal indicative of the detected amount of ambient light; and a controller configured to control said at least one solid state light source based on said first signal.

The luminaire may also include a motion-sensing element configured to detect a motion in the vicinity of the luminaire, and to generate a second signal indicative of the detected motion, and a controller configured to control said at least one solid state light source based on said second signal.

The functionally different controllers may of course be implemented in one single controller.

The luminaire may also comprise an energy store for storing solar energy generated by the solar cell modules. Such energy store may be charged during daytime, when the sun is shining, and discharged during night-time to drive the light sources.

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 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 an arrangement according to a first embodiment of the present invention.

Fig. 1b shows an exploded view of the arrangement in Fig. 1a.

Fig. 2 illustrates a schematic perspective view of a luminaire including three arrangements as shown in Fig. 1a.

Figs. 3a-b illustrate an intensity distribution for light emitted from the luminaire of Fig. 2.

Fig. 4a illustrates a schematic side view of a luminaire according to a second embodiment of the present invention.

Figs. 4b-c illustrate schematic side views of two prismatic components of the optical structure of Fig. 4a.

Figs. 5a and 5b illustrate schematic side views of a luminaire according to a third embodiment of the present invention.

Fig. 5c illustrates an intensity distribution for light emitted from the light sources in Fig. 5a.

Fig. 6 illustrates a schematic side view of an arrangement in accordance with yet another embodiment of the present invention.

Fig. 7a shows the luminaire in Fig. 4a mounted on the ground and illuminating a wall.

Fig. 7b shows the luminaire in Fig. 4a mounted on a wall and illuminating the ground.

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.

Figure 1a and 1b illustrate an arrangement 100 for an outdoor luminaire 200 (see Figure 2). The arrangement 100 in this example has a cylindrical disc shape, and comprises a substrate 11 which is generally cylindrical, here a straight circular cylinder. However, in other embodiments the substrate 11 could e.g. be an oblique cylinder or have other geometrical shapes e.g. a conical shape, etc. The outward facing surface 11’ of the cylindrical substrate 11 includes a first area 11a and a second area 11b.

A light source 12 including a plurality of solid state light sources 12a such as LEDs, is mounted (electrically and mechanically) on a first area 11a of the surface 11’. The light source 12 is configured to emit light in a radial direction outward from the cylindrical substrate 11. The LEDs 12a may be individual LEDs as shown in this example or be LED modules, each module comprising a plurality of LEDs 12a.

A solar cell module 13, here comprising a plurality of solar cells 13a which may be connected serially or in parallel, is arranged on a second area 11b of the surface 11’.

In the illustrated example, the first area 11a containing the light source 12 is located above the second area 11b containing the solar cell module 13.

The first and second areas 11a, 11b may be physically separated by e.g. a gap/space. However, the physical separation of the first and second areas is not necessary and the areas may only be defined by the area 11a occupied by the LEDs 12a and the area 11b occupied by the solar cells 13a. In some embodiments the first 11a and the second 11b areas may be arranged on the substrate 11 in an alternating configuration. In other embodiments the first area(s) 11a may be arranged among several of the second areas 11b or vice versa.

The arrangement 100 further comprises an optical element 14, in this case an annular positive lens 14 surrounding the cylindrical substrate 11. The lens 14 here has a convex inner surface facing the LEDs 12a and solar cells 13a, and a flat outer surface 14’’. In other examples, the outer surface may also be convex, and the inner surface may then be flat. In fact, one of the surfaces may be concave, as long as the total optical effect is that of a positive lens. The annular lens 14 is arranged to extend around the complete circumference of the cylindrical substrate 11 such that the outer surface 11’ of the substrate 11 is enclosed by the annular lens 14. This way the first 11a and the second area 11b are arranged behind the concave surface 14’. The outer surface 14’’ faces the surrounding environment and is subject to incident ambient light (e.g. sunlight).

In other embodiments, the annular lens 14 may only partly extend around and surround the substrate 11.

The optical element here also includes a top and/or a bottom base plate 16, 17. The base plates 16, 17 are aligned with the cylindrical substrate 11. As illustrated most clearly in Figure 1b, the cylindrical substrate 11 and the annular lens 14 are here sandwiched by two top 16 and bottom 17 base plates. The base plates 16, 17 are at least partly made of light-reflecting materials, configured to reflect light emitted from the LEDs 12a and/or the incident light.

Turning to Figure 2, one or several, here three, disc-shaped arrangements 100 can be mounted on e.g. a post/pole 18 erected in areas intended to be illuminated. The post 18 is here a cylindrical post with a diameter corresponding to the diameter of the arrangements 100, and the arrangements 100 are mounted on top of the post. Alternatively (not shown), the arrangements 100 may be ring shaped and be mounted on the post 18 by sliding the ring-shaped arrangements along the post 18. Multiple arrangements 100 can be stacked on the post 18. Alternatively, the arrangement 100 is a flexible strip (not shown) which may be folded or wound around and secured to the post 18.

The luminaire 200 may additionally comprise a light-sensing element 31, configured to sense the ambient light e.g. amount of sunlight based on the time of the day and generate an output based on the amount of detected light. The luminaire 200 may also comprise a motion-sensing element 32 which is configured to detect a motion in the vicinity of the optical structure e.g. to detect the presence of a passerby. A controller 33 receives the outputs of the light-sensing element and the motion-sensing element. Depending on the amount of detected light by the sensing element, the controller is configured to control/operate the luminaire i.e. trigger the LEDs 12a to emit (turn-off) light if the output of the sensing element 31 is below (above) a threshold. The controller 33 may also operate the LEDs based on the output of the motion-sensing element 32 e.g. turn on the luminaire if presence of a passerby is detected.

The controller 33 may further charge battery or energy storage units (not shown) when there is energy inputted from the solar cells, however the controller may also discharge the energy storage units to power up the luminaire e.g. when there is no direct energy input from the solar cells. Optionally, the controller may be provided with a timer unit to alternate charge and discharge cycles of the energy storage unit and/or operate the luminaire during certain time periods.

The luminaire 200 may further include an energy store, such as a battery 34, to store energy generated by the solar cell modules 13. Such energy store may be used to collect energy during daytime, to energize the light source during nighttime.

In use, light 20 emitted substantially radially from the LEDs 12a is controlled i.e. shaped and redirected, by the annular lens 14 and the reflective base plates 16, 17 to be distributed within a first angular range A toward the ground 19 or other area be illuminated.

Further, light 28 incident on the lens 14 from a second angular range B, e.g. sunlight, is concentrated towards the solar cells 13a. Therefore, sunlight 28 is directed in directions away from the first area 11a and the LEDs 12.

Figure 3a shows an angular intensity distribution of the illumination from the LEDs 12a. It is clear that the first angular range extends downward from a horizontal reference plane (the line between the -90 and 90 degree marks in Figure 3a), the horizontal plane forming a cut-off plane. This horizontal plane is here to be understood as a plane parallel with the base of the cylindrical substrate 11 (and with the reflective base plates 16, 17). Hereby, for a luminaire 200 arranged on a pole which is shorter than an average person (such as a typical garden light), glare which can be dazzling and uncomfortable to the users can effectively be reduced.

The intensity distribution around the post 18 and in the area 19 illuminated by the luminaire 200 is shown in Figure 3b, exhibiting the intensity peak ‘P’ in the close vicinity of the luminaire 200 with a decreasing intensity in areas further away from the luminaire 200.

Computer simulations (not shown) have been carried out for the embodiment of Figures 1a-b to investigate the light collection efficiency (collection of sunlight by the solar cell modules) of the optical structure 100 in at least three different ambient light scenarios including: diffuse omnidirectional daylight, clear sky with solar elevation angle of 45 degrees and clear sky with solar elevation angle of 65 degrees.

The inventors have realized that the disc-shaped optical structure 100 having the annular lens 14 and reflective plate 16, 17 configuration is surprisingly effective (at least 22% increased light collection efficiency than the maximum efficiency achieved with no optical elements for the solar cell module area) for overcast/cloudy sky conditions with diffuse light compared to the more direct sunlight conditions at 45 or 65 degrees. One drawback with placing the solar cell modules 13 behind the optical element, here the annular lens 14, is that the efficiency drops with increasing sun elevation angle, which could be attributed to stronger Fresnel reflections off the surfaces of the annular lens 14. However, when the incident light is diffuse light, it is effectively concentrated on the solar cell area 11b and the optical efficiency of the solar cell modules 13 increases compared to arrangements lacking the optical elements.

Figure 4a illustrates another embodiment of an arrangement 101 designed as a flat structure (having a flat substrate 11), suitable for a luminaire 201 adapted to be mounted vertically on a support 46.

The support may be the ground 71, as shown in Figure 7a, and the luminaire 201 may be partly submerged in the ground. As shown in Figure 7a, the luminaire 201 receives sunlight 28 shining towards the ground 71 in front of the wall 72, and emits LED light 20 upwards, towards the wall 72 (or other object). The cut-off of emitted light 20 prevents glare in the eyes of nearby users.

Alternatively, the support may be a wall 72, as shown in Figure 7b. As shown in Figure 7b, the luminaire 201 receives sunlight 28 shining towards the wall 72, and emits LED light 20 downwards, towards the ground 71. Again, the cut-off of emitted light 20 prevents glare in the eyes of nearby users., and used to illuminate the ground 71.

Similar to the embodiment in Figure 2 the substrate 11 of the arrangement comprises the first 11a and the second 11b areas arranged on the same side 11' of the flat substrate 11. In this example the first 11a and the second 11b areas include several sub-areas, provided with light sources 12 and solar cell modules 13, arranged in an alternating configuration.

The optical element is here a set 41 of refracting prisms, including a first set 42 and a second set 43 arranged alternatingly facing the LEDs12 and solar cell modules 13, respectively. As shown most clearly in Figures 4b and 4c, the first set 42 includes refracting prisms 44 having a first orientation angle α, and the second set 43 includes prisms 45 having a second orientation angle β. The first set 42 (Figure 4b) is operable to bend and redirect light 20a emitted from the LEDs 12 in a direction within angular range A. The second set 43 (Figure 4c) is operable to concentrate incident light 28 toward the solar cell modules 13.

It is noted that a modular arrangement, more like the approach in Figure 1a-b, could be possible. Each "module" would then include a substrate with a light source and a solar cell module, and an optical element including two sets 42, 43 of prisms 44, 45.

It is noted that the set 41 of refractive prisms 44, 45 in Figure 4a may also be implemented in an annular shape, to surround a cylindrical substrate as shown in Figure 1a-b.

Figure 5a-c illustrate another luminaire 202 mounted on a support 46, similar to the luminaire 201 in Figure 4a. Also in this embodiment, the support may be the ground (as shown in Figure 7a) or a wall 72 (as shown in Figure 7b).

This example also has an alternating arrangement for the first and the second areas 11a, 11b. In this embodiment, unlike the embodiment of Figure 4, the optical element of the optical arrangement 102 is formed by a set of wedge-shaped prisms 22 having a cross-section in the form of a straight trapezoid. A first, inner flat surface 24 faces the light LEDs 12, while a second, outer flat surface 23, parallel to and larger than the first surface 24, faces away from the substrate. The first and second surfaces are joined by an upper surface 26, forming straight angles with the first and second surfaces 23, 24, and a lower surface 27, slanted upwards form the outer surface 23 towards the smaller inner surface 24. The prism is positioned so that the slanted surface 27 is located outside the solar cell module 13.

Each prism 22 is operable to both direct light emitted from the LEDs 12 (Figure 5a) and collect and direct sunlight towards the solar cell modules 13 (Figure 5b).

With reference to Figure 5c, the wedge-shaped prism 22 serves as a collimating light guide, with the inner surface serves as an in-coupling surface, and the outer surface serves as an out-coupling surface. Light 20a emitted from the LEDs 12 is in-coupled into the prism 22, guided by total internal reflection to the outer surface 23, and then coupled out. The direction of the out-coupled light 20b will be horizontal or directed downwards.

The prism 22 is generally arranged in front of the first 11a and second 11b areas such that a small air gap d is present between the light emitting surface of the LEDs and the in-coupling surface 24 of the prism 22. A majority, e.g. more than 90%, of the emitted light 20a is coupled into the prism 22. Further, a majority of the in-coupled light exits the prism 22 via the light-outcoupling surface 23 as light 20b. This way the intensity distribution and direction of the emitted light by the LEDs 12 can be effectively controlled by the prism 22. Due to the optical losses in the optical structure 300, particularly in arrangement of the LEDs 12 with respect to the prisms 22, a small percentage (<10%) of light may not couple into the prism 22 primarily due to Fresnel reflections off the surfaces of the prisms 22. These reflected light rays not coupled into the prisms 22 may couple into neighboring prisms 22 or may otherwise be transported by TIR without exiting the light-outcoupling surface(s) 23 (e.g. see light rays with reference sign 20c in Figure 5a).

The prisms 22 are configured to have a cut-off plane defined by the upper surface 26 of the prism 22, i.e. emitted light 20a is redirected by the prism 22 and exits the out-coupling surface 23 as light 20b in an angular range A oriented way from the surface 26 (i.e. downward in Figure 5a). The wedge-shaped prisms 22 thus serve as a collimator for collimating the emitted light from the LEDs 12 into the angular range A.

Similar to the luminaire 201 in Figure 4a, the luminaire 202 in Figure 5a-5b may be mounted on the ground 71 and used to illuminate a wall 72 (as shown in Figure 7a), or mounted on a wall 72 and used to illuminate the ground (as shown in Figure 7b). Similar to the luminaire 201 in Figure 4a, the cut-off plane serves to reduce glare in the eyes of people nearby.

In the illustrated embodiment, the surface 26 (and thus the cut-off plane) is perpendicular to the plane of the substrate 11. The corresponding intensity distribution is shown in a so called polar plot in Figure 5c. It shows the dependence of intensity value as a function of the polar angle, i.e. the angle between the direction of the intensity and the z-axis (the vertical direction). The magnitude of intensity is given in relative values (cd/lm), because the intensity (cd) is normalized to the LED flux (lm). The four different intensity plots in Figure 5c represent four different azimuthal angles, i.e. angle with respect to the plane for the substrate 11. The plot with the highest relative intensity is represents an azimuthal angle of 90 degrees (normal to the substrate 11).

With reference to Figure 5b, the prism 22 will also serve as a bending prism, refracting light incident on the outer surface 23 in the surfaces 23, 27, thereby concentrating and directing incident light on the solar cell modules 13.

The illustrated arrangement of the prisms 22 may increase the light collection efficiency for the area 11b comprising the solar cell modules 13 by at least 18% compared to no-optical element or having a flat glass/plastic cover in front of the solar cell modules 13 (verified by computer simulations for a scenario with clear sky and solar elevation angle of 55 degrees).

Again, a modular arrangement could be possible. Each “module” would then include a light source, a solar cell module and an optical element formed by one prism.

It is noted that the prism 22 in Figure 5a-b may also be implemented in an annular shape, to surround a cylindrical substrate as shown in Figure 1.

In yet another embodiment illustrated in Figure 6 the arrangement 104 further comprises a plurality of additional solar cell modules 25 in addition to the at least one solar cell module 13. The additional solar cell modules are arranged on an area 11c of the substrate 11 which is different from the second area 11b. In this example the arrangement 104 is again a flat structure like the embodiment of Figure 4a with the optical element being sets of refractive prisms, however the skilled person will understand the other optical elements such as optical elements of Figure 1a or Figures 5a and 5b may also be arranged facing the first 11a and second 11b areas. In the example of Figure 6 the upper part 104a of the arrangement comprises the light sources 12 while the lower part 104b, which in comparison to the upper part has a larger footprint, comprises the area 11c of additional solar cell modules 25 to increase the energy storage capacity of the luminaire.

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. For example, the substrate is not necessarily one single piece, may be formed of two or more pieces. In some embodiments the substrate may be a substrate made at least partly of flexible materials. The substrate can be bent or formed into various shapes. In such embodiments the light sources and solar cell modules may be mounted on different areas of the substrate, e.g. on different parts of a bent substrate. This in turn adds another degree of flexibility in forming the luminaire in various customizable shapes and configurations.

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 arrangement (100; 101; 102, 104) for an outdoor luminaire, said arrangement comprising:

a substrate (11) having a first area (11a) and a second area (11b) on a same side of said substrate;

a light source (12) arranged on said first area (11a);

a solar cell module (13) arranged on said second area (11b); and

an optical element (14; 22) configured to direct light emitted (20, 20a) from the light source (12) in a direction in a fist angular range (A), and to direct light incident (28) on said optical structure from a second angular range (B) toward said second area,

wherein the optical element (41) includes:

a first set (42) of refracting prisms configured to direct light emitted (20) from said light source in the first angular range (A), and

a second set (43) of refracting prisms configured to direct light (28) incident on the second set from the second angular range (B) toward said solar cell module 13), or

wherein said optical element is a prism (22) with a cross section in the shape of a right trapezoid, said prism (22) having a light in-coupling surface (24) facing said light source, a light out-coupling surface (23) opposite to and parallel with the in-coupling surface (24), and an intermediate surface connecting said in-coupling surface (24) and said out-coupling surface (23), said intermediate surface facing said solar cell module (13), such that

light emitted from said light source (12) is at least partly coupled into said prism (22) through said in-coupling surface (24), is guided through the prism by total internal reflection, and exits the prism (22) via the out-coupling surface (23), and

light incident on said out-coupling surface (23) from said second direction (B) is refracted by said prism and exits said intermediate surface towards said solar cell module (13).

2. The arrangement according to claim 1, wherein said optical element is arranged such that said first angular range (A) extends downwards from a horizontal reference plane.

3. The arrangement (100) according to claim 1, wherein said substrate (11) is curved, and wherein said first and second areas (11a, 11b) are formed on a convex surface of the curved substrate.

4. The arrangement (100) according to claim 3, wherein said substrate (11) is cylindrical, preferably circular cylindrical, and wherein said first and second areas (11a, 11b) are formed on an outside surface of the cylindrical substrate, and wherein said optical element (14; 22) is annular and arranged to surround the cylindrical substrate (11).

5. The arrangement according to claim 4, wherein the optical element is an annular prism.

6. The arrangement (101; 102; 104) according to claim 1 or 2, wherein said substrate (11) is a flat substrate and wherein said first and second areas (11a, 11b) are formed on a surface of the said flat substrate.

7. The arrangement (104) according to any of preceding claims, further comprising a plurality of additional solar cell modules (25) arranged on a third area (11c) of said substrate (11), said third area (11c) being separate from said second area (11b) and being optically exposed to incident light (28), said plurality of additional solar cell modules being electrically connected to said at least one solar cell module in the second area (11b).

8. A luminaire (200; 201; 202) comprising at least one arrangement (100, 300) according to any one of the preceding claims.

9. The luminaire (200) according to claim 8, including a plurality of modules, each formed by a cylindrical arrangement according claim 3 or 4, said modules being aligned with each other in a stack,

wherein a light-reflecting plate (16, 17) is arranged between each pair of adjacent modules, said reflective plate preventing cross-talk between adjacent modules.

10. The luminaire according to claim 8 or 9, further comprising:

a light-sensing element (31) configured to detect the amount of ambient light and to generate an first signal indicative of the detected amount of ambient light and/or a motion-sensing element (32) configured to detect a motion in the vicinity of the luminaire, and to generate a second signal indicative of the detected motion; and

a controller (33) configured to control said at least one solid state light source (12) based on said first signal and/or said second signal.

11. The luminaire according to one of claims 8 - 10, further comprising an energy store (34) for storing solar energy generated by the solar cell modules.

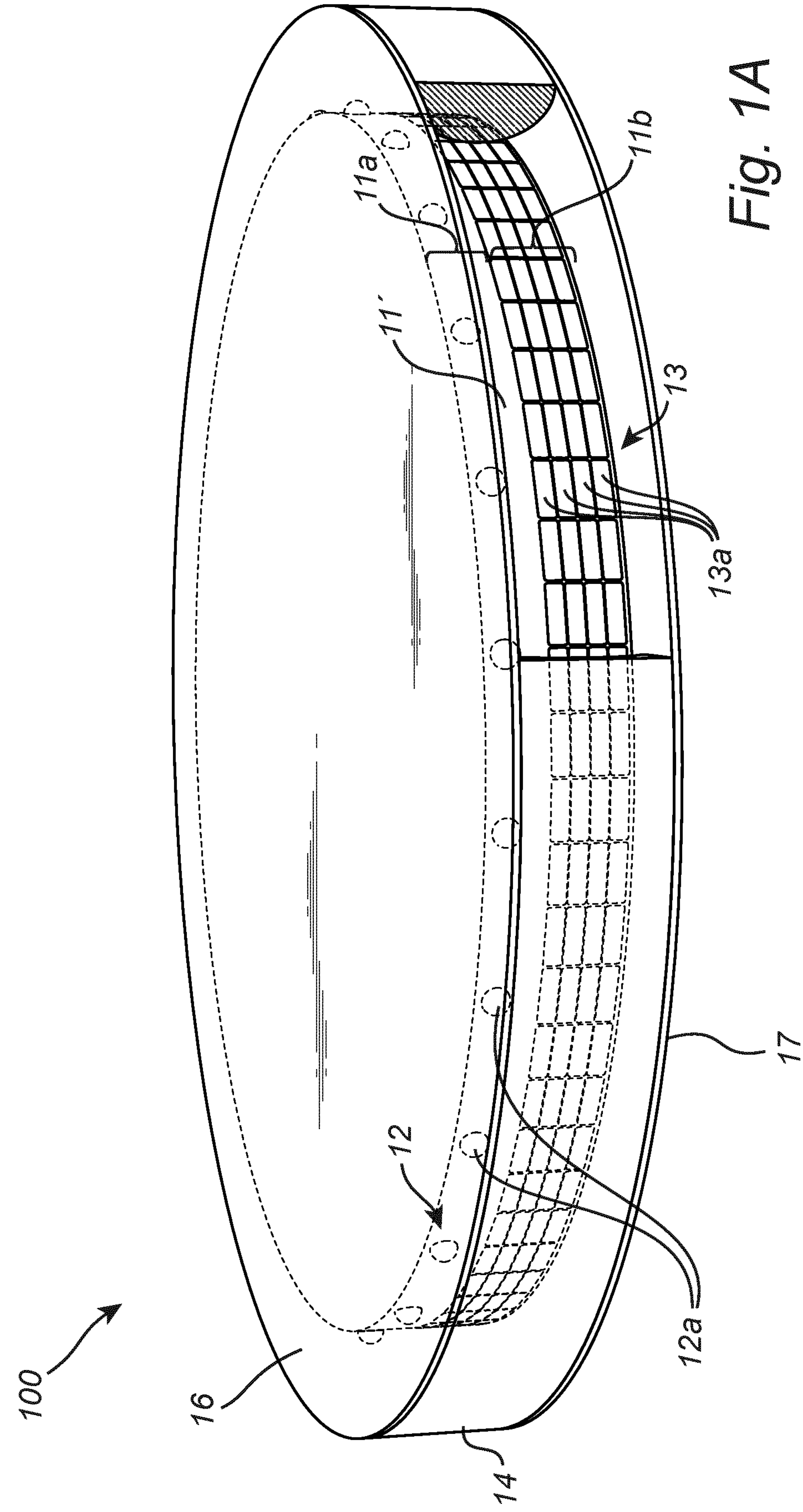

Fig. 1A

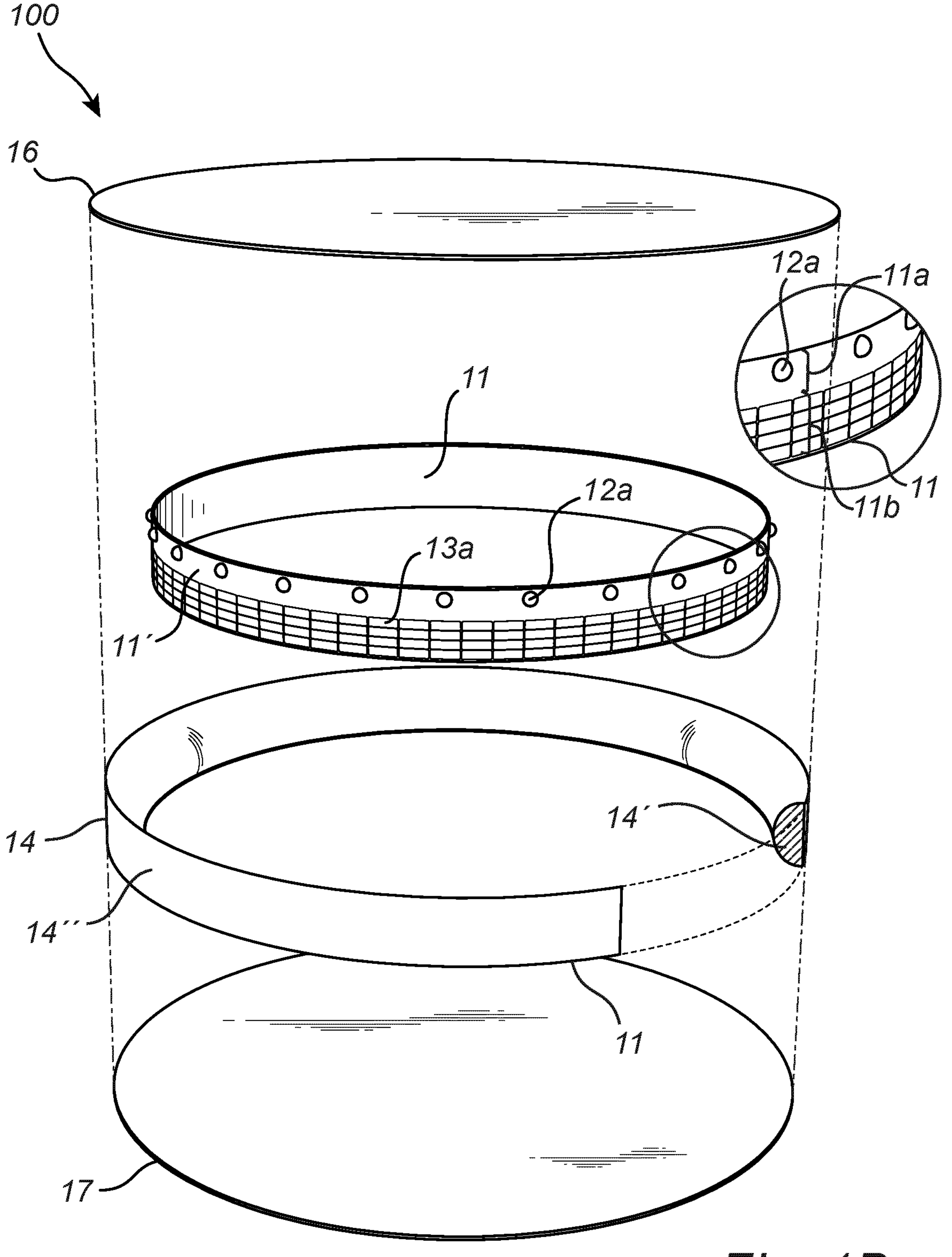

Fig. 1B

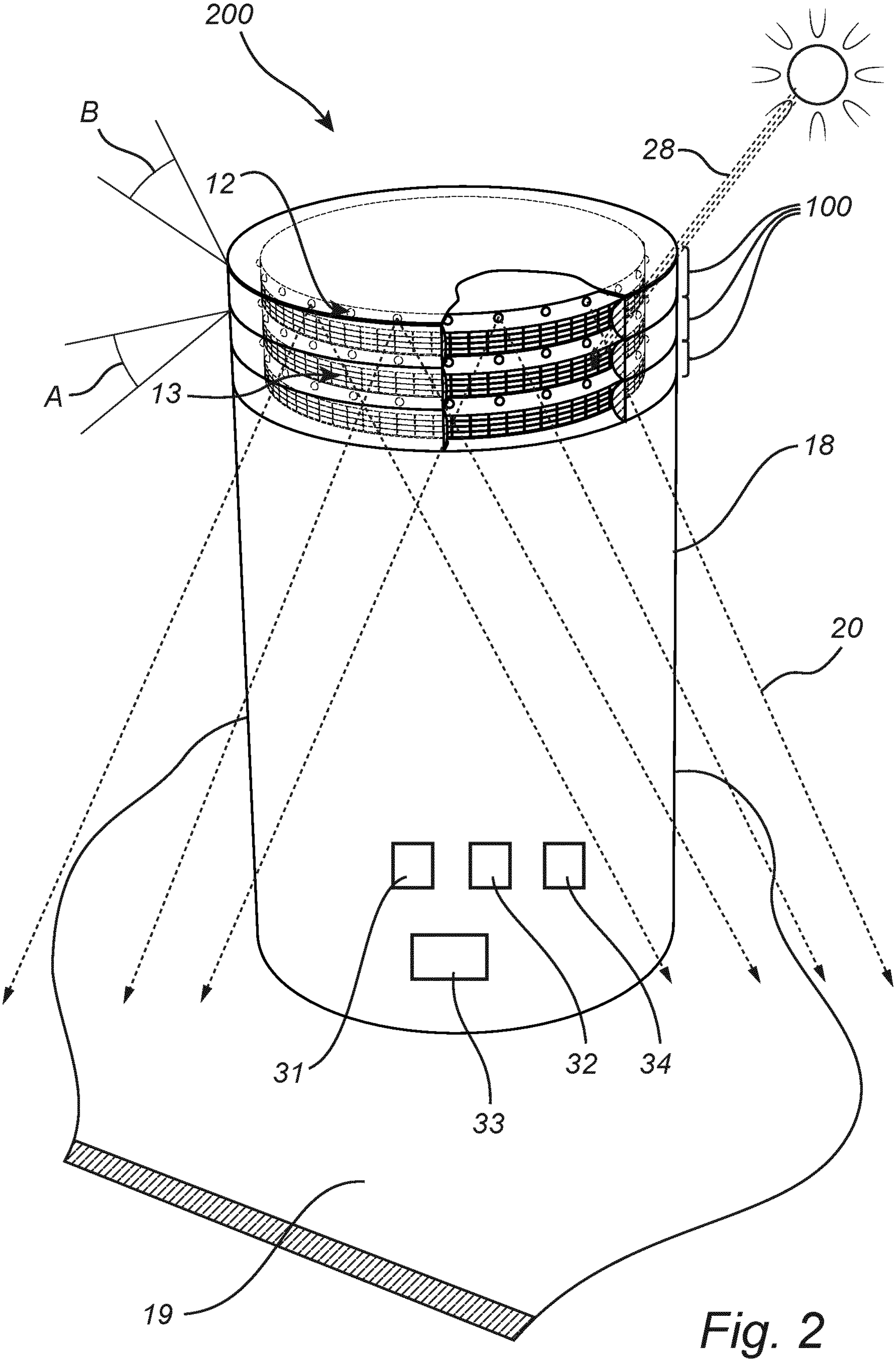

Fig. 2

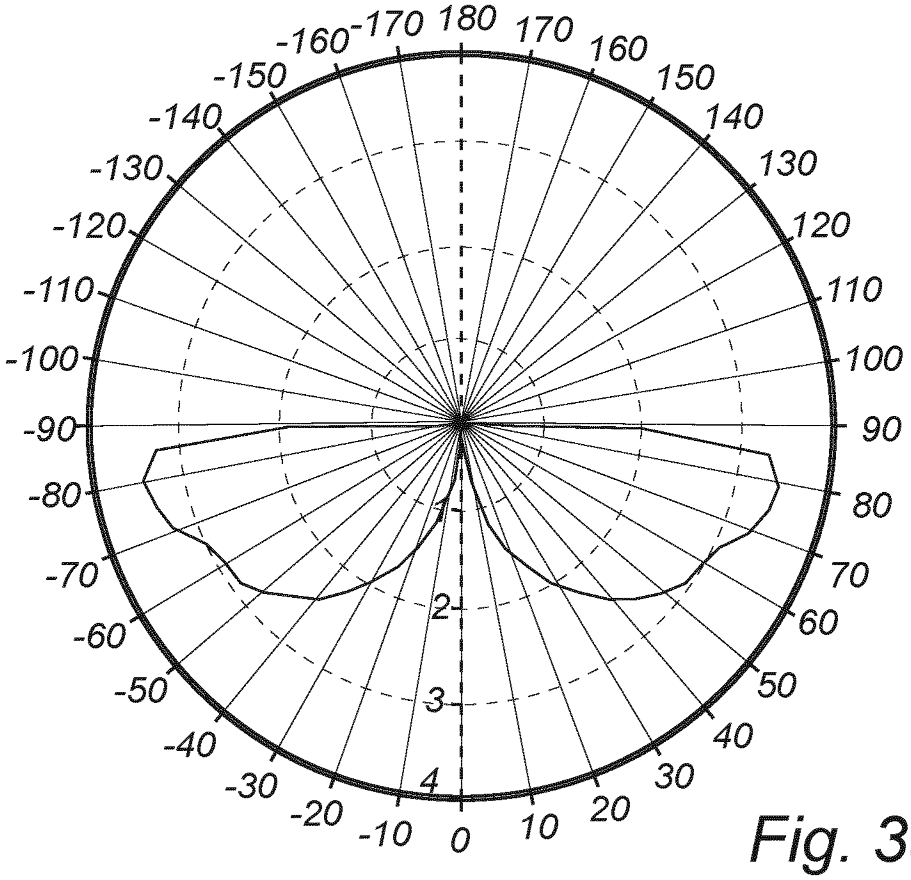
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Fig. 3a

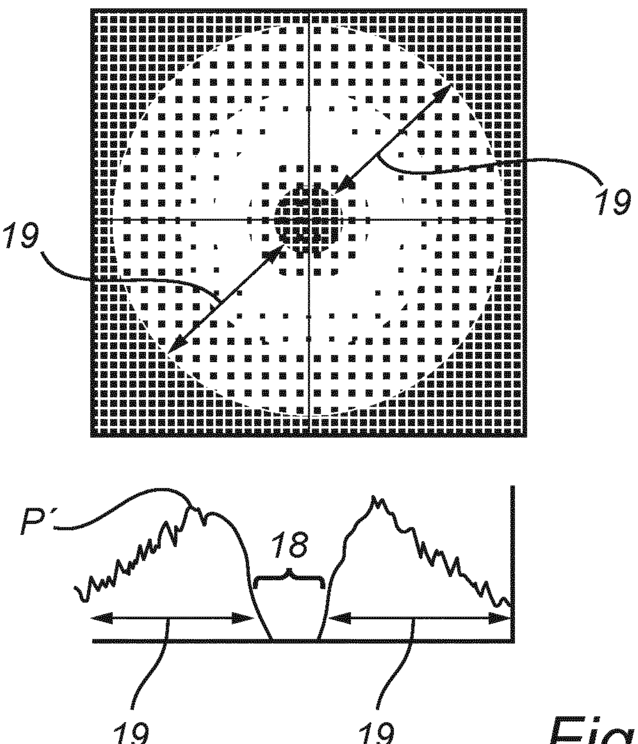
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Fig. 3b

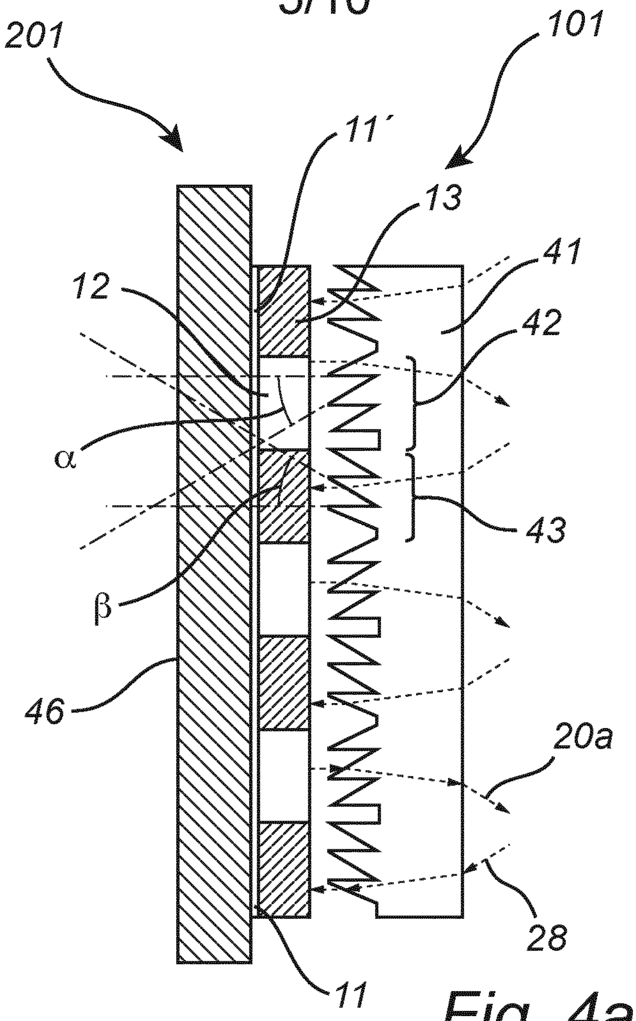

Fig. 4a

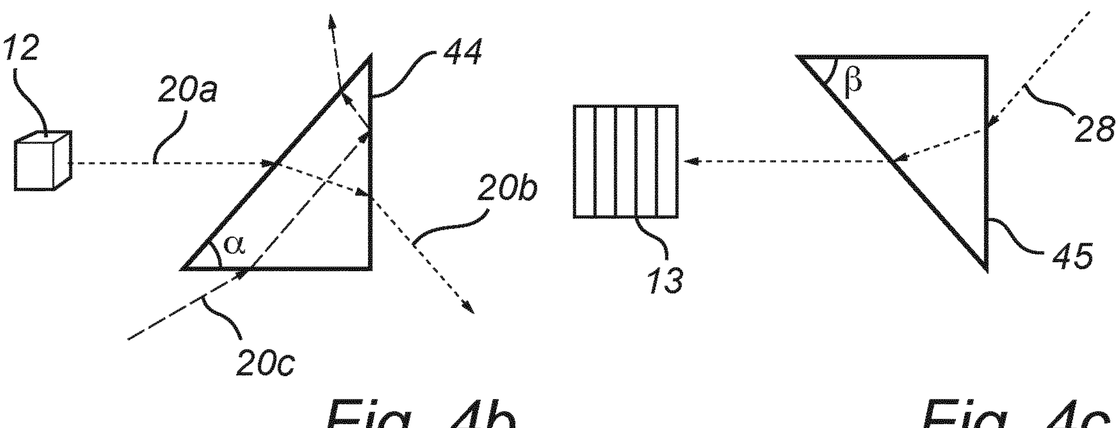

Fig. 4b

Fig. 4c

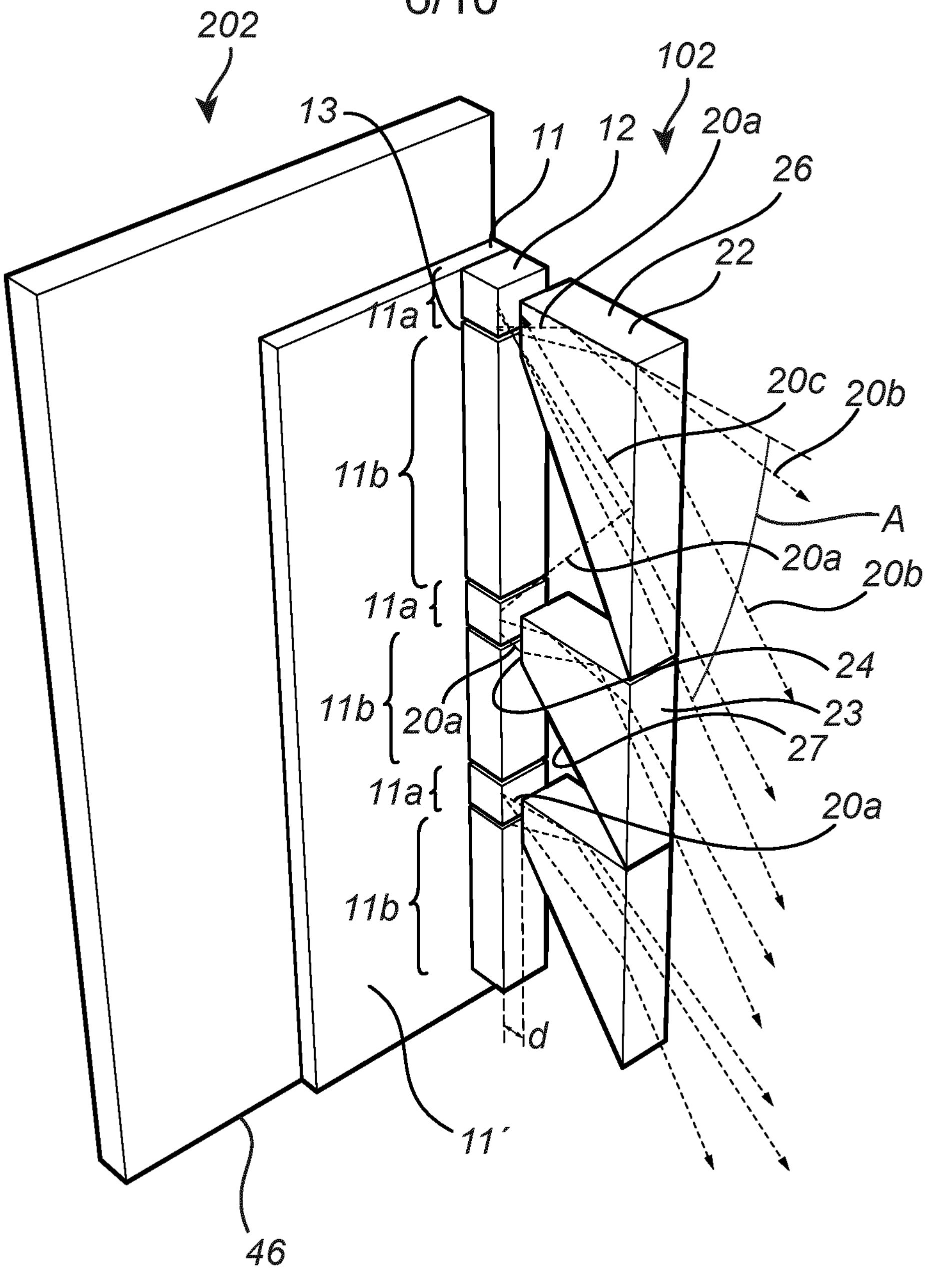
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Fig. 5a

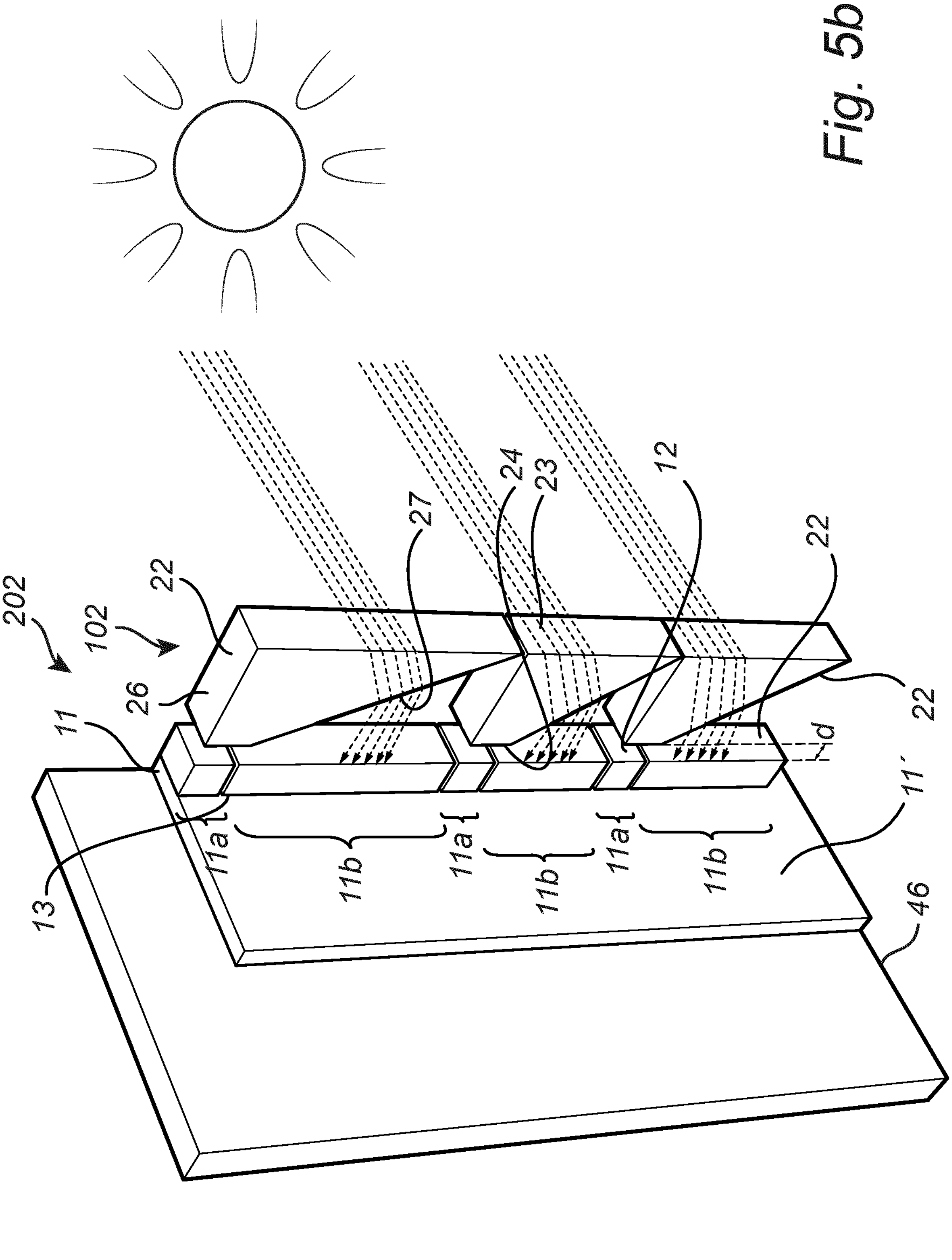

Fig. 5b

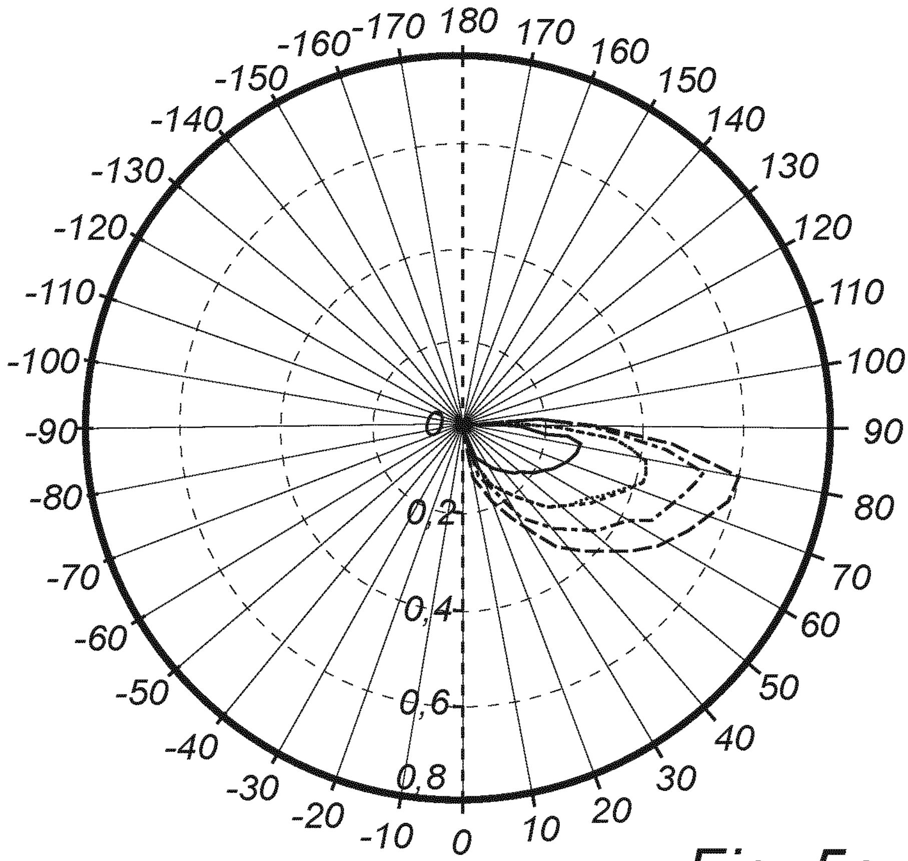
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Fig. 5c

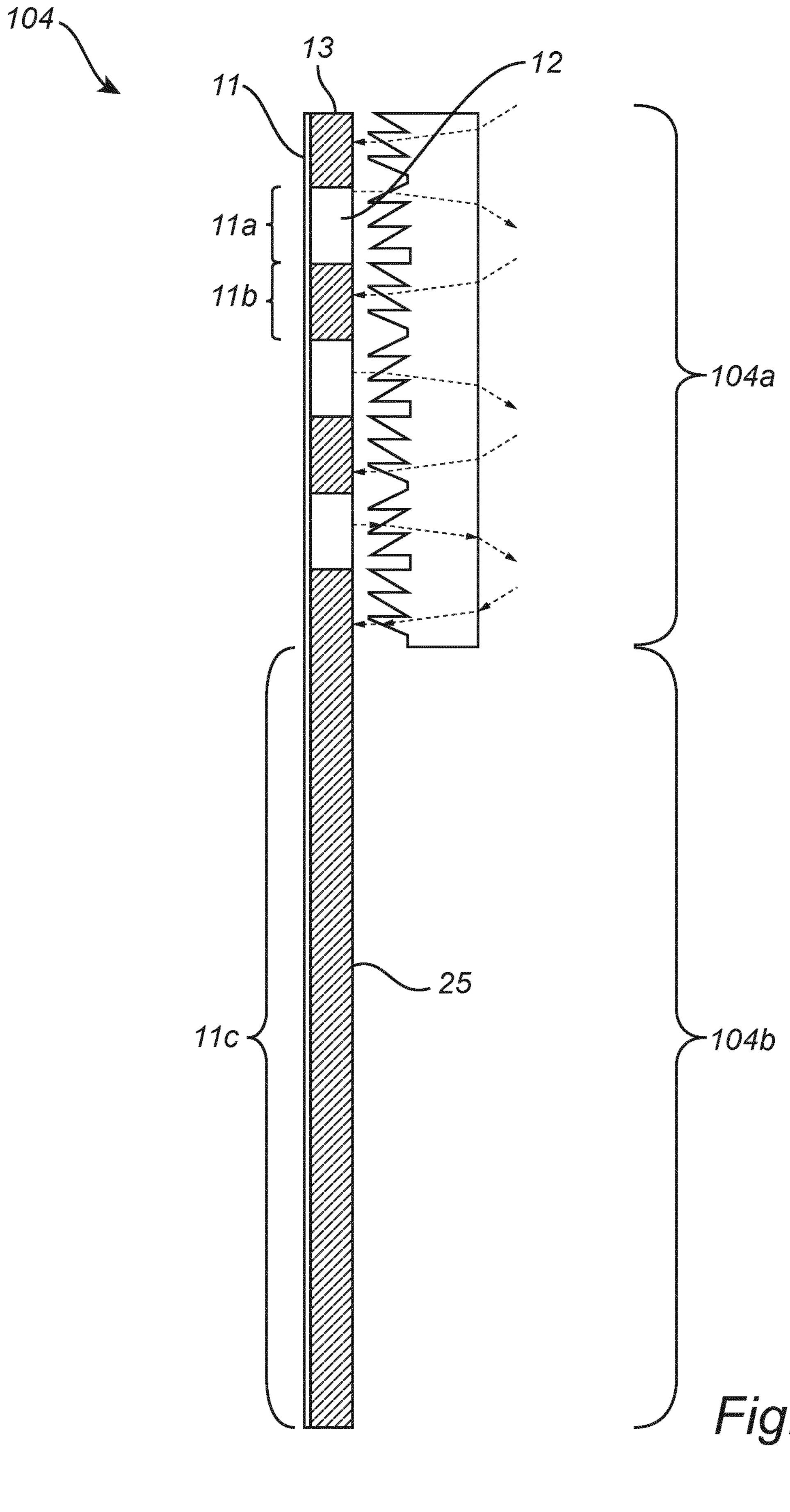

Fig. 6

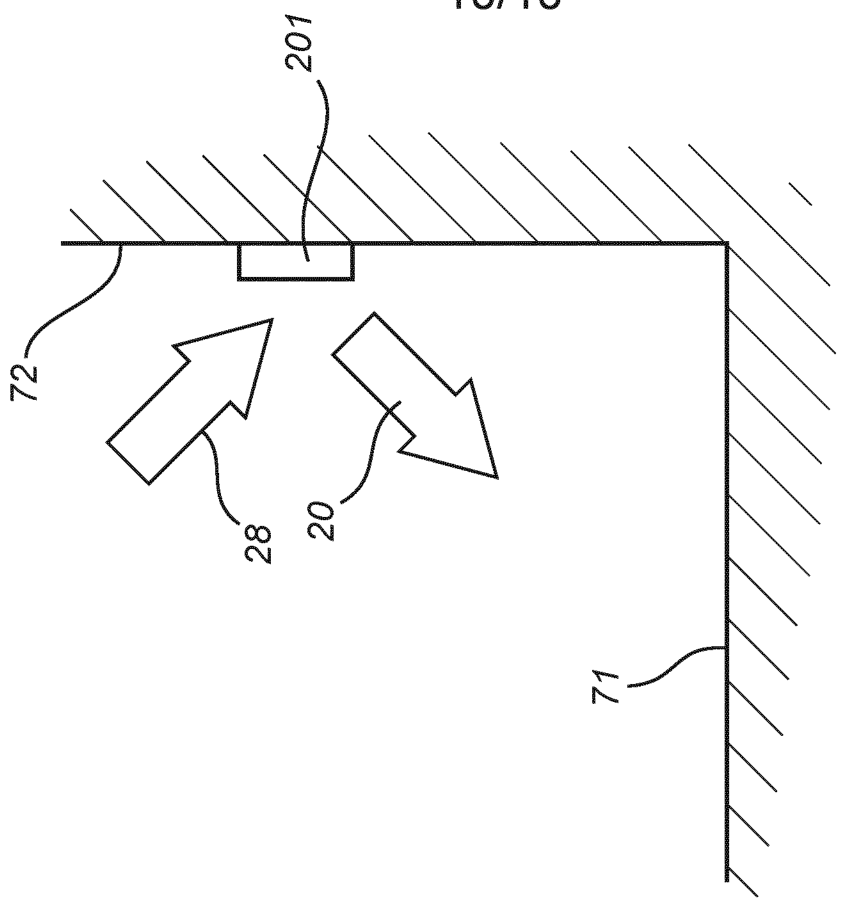

Fig. 7b

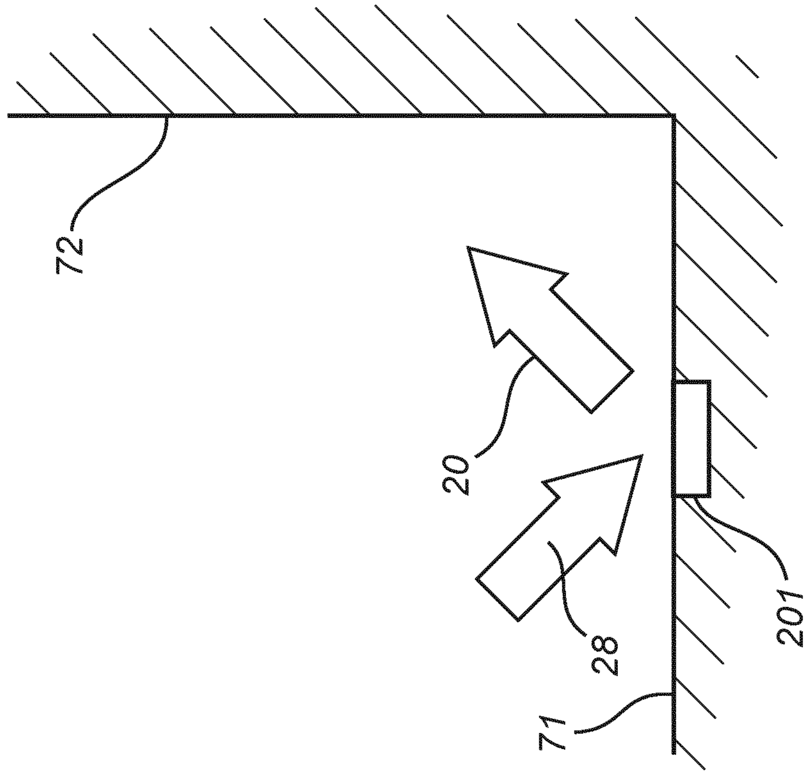

Fig. 7a

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/073374

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02S40/22 F21L4/08 F21S9/03
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)
H02S H01L F21V F21L F21S

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2011/156344 A2 (SEMPRIUS INC [US]; MEITL MATTHEW [US] ET AL.) 15 December 2011 (2011-12-15) abstract; claims 1-33; figures 1-23 page 1, line 10 - page 7, line 17 page 12, line 3 - page 15, line 27 page 17, line 1 - page 24, line 26 -----	1 2-11
Y	GB 2 528 742 A (WAKEFIELD RICHARD [GB]) 3 February 2016 (2016-02-03) abstract; claims 1-21; figures 7,8 page 4, line 10 - page 10, line 30 page 15, line 1 - page 16, last line -----	2-9
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 September 2020	21/09/2020

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	Hamdani, Fayçal

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	WO 2019/134818 A1 (SIGNIFY HOLDING BV [NL]) 11 July 2019 (2019-07-11) abstract; claims 1-13; figures 1-4 -----	1-11
A	EP 3 369 985 A1 (PHILIPS LIGHTING HOLDING BV [NL]) 5 September 2018 (2018-09-05) abstract; claims; figures -----	1-11
A	US 2008/041441 A1 (SCHWARTZMAN ZALMAN [IL]) 21 February 2008 (2008-02-21) abstract; claims; figures -----	1-11
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Information on patent family members

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