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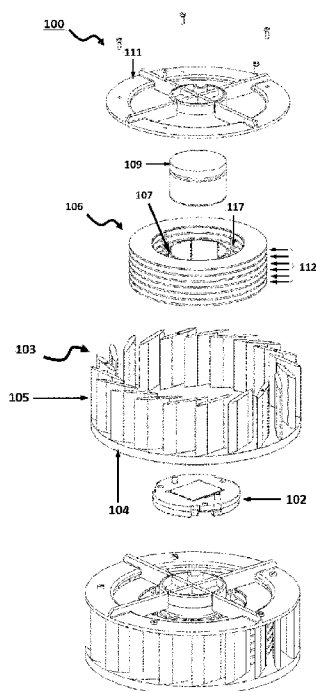


FIG. 1C

(57) Abstract: It is an object of the invention to provide an improved lighting device. The lighting device (100, 200) comprises: a light source (102); a plurality of planar discs (106) stacked apart parallelly on a common shaft (107) extending over a rotation axis (108), wherein each disc comprises an aperture (117) for enabling a fluid flow (110) along the common shaft (107) and at least partly outward in-between the plurality of planar discs (106); an electromotor (109) for rotating, during operation via the common shaft (107), the plurality of planar discs (106) with a rotational speed to induce said fluid flow (110); a heat sink (103) in thermal contact with the light source (102) and comprising a plurality of fins (105); wherein the plurality of fins (105) is arranged at least partly around the circumference of the plurality of planar discs (106) for enabling the fluid flow (110) to convectively cool the light source (102) via the heat sink (103).



A LIGHTING DEVICE

FIELD OF THE INVENTION

The invention relates to a lighting device. The invention further relates to a method of cooling a lighting device. The lighting device may be a spot light, preferably a pixilated spot light, or a TLED-luminaire.

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BACKGROUND OF THE INVENTION

A lighting device, when operated, is often associated with a generation of heat, which heat may affect the performance and the lifetime of the lighting device negatively. Therefore, a lighting device often requires cooling. Therefore, heat sinks and/or fans are commonly used.

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Furthermore, the lighting industry experiences a general push towards more compact and more reliable lighting devices. For example, in retail lighting and/or entertainment lighting. The available space / volume within such lighting devices becomes thus more and more limited. This defines a clear challenge for e.g. cooling: A heat sink needs to take a larger share in said available space of such a more compact lighting device, in order to maintain a similar cooling performance. A cooling fan needs to be operated at higher rotational speeds to transfer the accumulated heat away from such a more compact lighting device.

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The solution of a larger heat sink is undesired and often impossible due to the requirements set for achieving a more compact lighting device. For example, spot lights in retail become even smaller in diameter and depth to facilitate a less cumbersome installation and/or less bulky system, which limits the application of a larger heat sink, since the other electronic components also require their share in the housing of such spot lights. The solution of an increase in rotational speed of a cooling fan is undesired due to an increase in noise levels, which is especially undesired in office, retail and/or entertainment lighting.

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SUMMARY OF THE INVENTION

It is an object of the invention to provide an improved lighting device, which at least alleviates the problems mentioned above. Thereto, the invention provides a lighting

device comprising: a light source; a plurality of planar discs stacked apart parallelly on a common shaft extending over a rotation axis, wherein each disc comprises an aperture for enabling a fluid flow along the common shaft and at least partly outward in-between the plurality of planar discs; an electromotor for rotating, during operation via the common shaft, the plurality of planar discs with a rotational speed to induce said fluid flow; a heat sink in thermal contact with the light source and may comprise a plurality of fins; wherein the plurality of fins may be arranged at least partly around the circumference of the plurality of planar discs for enabling the fluid flow to convectively cool the light source via the heat sink; wherein the common shaft is hollow and accommodates the electromotor.

Such a lighting device comprises a light source and a heat sink. The light source is in thermal contact with the heat sink for transferring heat from the light source to the heat sink. The heat sink comprises a plurality of fins for increasing the surface area of the heat sink for improving convective heat transfer. The lighting device moreover comprises an active cooling means for inducing a convective fluid flow to cool said heat sink and its fins, thereby cooling any heat generated by the light source. Namely: The lighting device comprises a plurality of planar discs stacked apart parallelly on a common shaft, whereby the common shaft extends over a rotation axis, and whereby said plurality of fins is arranged at least partly around the circumference of the plurality of planar discs. As each disc of said plurality of planar discs comprises an aperture, a fluid flow (or a fluid to flow) is enabled along the common shaft and at least partly outward in-between the plurality of planar discs. Said fluid may for example be air.

Said fluid flow is forced by rotation of the common shaft. That is: The lighting device further comprises an electromotor for rotating the common shaft with a rotational speed, and thereby for rotating the plurality of planar discs via said common shaft. This rotation may induce said fluid flow, which enables the fluid to be distributed in spaces in-between consecutive planar discs, and which enables the fluid in such spaces to be forced outward. Thus, since the plurality of fins is arranged at least partly around the circumference of the plurality of planar discs, the resulting fluid flow may convectively cool the light source via the heat sink.

Thus, the lighting device implements active cooling. The fluid flow is thereby not forced by means of blades transferring momentum to the fluid; which is common for e.g. a fan, a compressor or a pump; which may often be turbulent flow and therefore noisy. Instead, the concept of a Tesla turbine is implemented, but in its reverse modality of a compressor (i.e. action of the fluid does not force the turbine into motion, but action of the

turbine forces the fluid into motion, as in a compressor). That is: The fluid flow according to the present invention is forced by (surface) friction forces caused by the very rotation of said plurality of planar discs stacked apart parallelly on the common shaft; which may often be Couette flow. Said planar discs may thereby be stacked apart parallelly densely.

5 Thus, the very configuration of the plurality of planar discs enables a fluid to be distributed amongst the spaces in-between said planar discs, and subsequently enables said fluid to be forced outward through said spaces in-between said planar discs, which outward (spiraling) force is caused by the friction forces of the surface of each planar disc acting on the fluid, alike the Tesla turbine concept. Hence, the space in-between two planar discs may
10 establish a channel, which renders a flow in-between parallel plates.

 The advantage of the lighting device according to the invention is that said occurring fluid flow convectively cools the light source via the heat sink, of which the plurality of fins is arranged at least partly around the plurality of discs, from in-between the fluid flow is forced out; while at the same time said occurring fluid flow may not be
15 turbulent, hence providing noise-reduction. Thus, undesired noise production associated with the lighting device is prevented, while thermal performance of the lighting device is maintained or improved.

 Moreover, as said fluid flow may enter the lighting device axially (in respect to axis of rotation) and be forced out outwardly essentially perpendicular thereto, this change
20 in direction of the fluid flow may facilitate miniaturization of a lighting device. Namely: a heat sink and the cooling arrangement (i.e. said plurality of planar discs) may be integrated spatially, wherein the heat sink (or a plurality of fins of the heat sink) circumferences said cooling arrangement. Consequently, the perimeter of the cooling arrangement is efficiently and/or effectively utilized for cooling; whereas, if the direction of the fluid did not change,
25 the heat sink would have been separately required in the axial path to which the fluid is forced; like for example a fan. In spot lighting applications, for example, the height of a spotlight is often limited, hence not allowing a fan being placed in series with a heat sink during a miniaturization effort. In such conditions the present invention is particularly beneficial, as the heat sink may be positioned around the circumference of said cooling
30 arrangement, hence not requiring space in the height, but rather use the diameter of the spotlight.

 Provided with the present invention, it is expected that lighting devices in e.g. retail lighting and/or entertainment lighting will be actively cooled by implementing the present invention (and not e.g. a fan), because the thermal requirements in said lighting

domain are stringent, while also requirements are present to reduce noise levels of the active cooling means (e.g. in retail lighting, lighting devices remain in an on-state relatively long causing a high generation of heat, but still require the lighting devices to be silent due to customer-ergonomics; in entertainment lighting, lighting devices have a relatively high lumen output causing a high generation of heat, but still require the lighting devices to be silent due to their application in an entertainment setting wherein noise-pollution is undesired; in outdoor lighting or stadium lighting, similar conditions may apply). For example, the invention may be advantageously applied for specific lighting devices present within the portfolio of Signify such as e.g. retail lighting devices, pixilated LED spots, or more specifically the *EasyAim* spotlight. Furthermore, the use of this invention can be especially beneficial in beamers or projecting devices.

As mentioned, said plurality of planar discs may be stacked apart parallelly densely. In embodiments, an axial spacing between two consecutive discs of the plurality of planar discs may be at most 0.5 centimeter. This axial spacing, which defines a maximum distance between two consecutive discs of the plurality of planar discs, will render consecutive discs closer together, thereby improving the friction forces induced onto the fluid therebetween and thereby improving inducing the (Couette) fluid flow. In alternative examples, said axial spacing may be at most 1 centimeter.

Hereby, in embodiments, a radius of the planar disc may be at most 20 centimeters. Such a diameter may be suitable for larger lighting applications, such as e.g. flood lighting, stadium lighting, spot lighting, façade lighting, or outdoor lighting. Alternatively, said radius of the planar disc may be at most 10 centimeter, at most 5 centimeter, or at most 3 centimeters, or at most 2 centimeters. Such a smaller radius of the planar disc may be more suitable for retail type of applications, such as miniaturized spot lights.

Hereby, in embodiments, when having an axial spacing between two consecutive discs of the plurality of planar discs being at most 0.5 centimeter, a radius of the planar disc may be at most 5 centimeters. Moreover, in examples, as a rule, when said axial spacing is being at most 0.N centimeter, the N being an integer [1 to 9], said radius of the planar disc may be at most N centimeter. Such a rule may facilitate manufacturing. Other rules may alternatively apply.

As mentioned, said electromotor is arranged for rotating, when in operation, the common shaft with a rotational speed. In an embodiment, the rotational speed may at least be 10 rad/sec. At this rotational speed, said friction forces induced onto the fluid

distance between two consecutive discs of the plurality of planar discs is improved, and thereby improving inducing the (Couette) fluid flow.

In an embodiment, the plurality of planar discs may comprise a disc material being at least one of: a metal, a ceramic, or a polymer; and wherein the heat sink may
5 comprise a heat sink material being at least one of: a metal, a thermally conductive plastic, such as a polymer with a thermally conductive filler or fiber, or a ceramic. Such materials may not only be advantageous in terms of manufacturing, weight-reduction, mechanical strength, and/or costs; but may also be advantageous for inducing said friction forces induced onto the fluid, thereby inducing the fluid flow, because the surface roughness of said
10 materials may influence said friction forces.

In some examples, said planar discs may e.g. comprise a texture for improving surface roughness, thereby improving inducing said fluid flow. In this way, the friction forces induced onto the fluid are increased and thereby improving inducing the fluid flow according to the invention, which fluid flows in-between the plurality of planar discs at least partly
15 outward.

In some examples, said plurality of planar discs may comprise a disc material being transparent or translucent, such as glass. The light source may in such examples further be configured to output light source light through said plurality of planar discs (i.e. along the rotation axis). As a result, the build-up or assembly of the lighting device may be more
20 compact, because the cooling arrangement, which constitutes of the plurality of planar discs, may be integrated in the line of light emission of the light source.

In an embodiment, each planar disc may comprise at least one further aperture for enabling a fluid flow along the common shaft and at least partly outward in-between the plurality of planar discs. Hence, such a planar disc may comprise for example two apertures
25 for enabling a fluid flow along the common shaft and at least partly outward in-between the plurality of planar discs. Said apertures may be holes, for example circular holes. Said apertures may moreover be any other shape such as rectangular, slot-shaped, triangular, perforated, etc. The aperture and the at least one further aperture advantageously enables a fluid to be distributed better amongst the spaces in-between said planar discs, because the
30 area through which the fluid can flow may be larger with more (alike) apertures.

Said rotation may be clockwise and/or counterclockwise. The mention of 'outward' in said phrasing of enabling a fluid flow at least partly outward in-between the plurality of planar discs may be defined as a fluid flow having at least one radial component in respect to the rotation axis. Often said fluid flow comprises a radial component as well as a

tangential component (e.g. spiraling outward). The mention of along the common shaft may not necessary mean (essentially) close to the common shaft, but may also mean in the direction of the common shaft, e.g. for distributing said fluid amongst the spaces in-between the plurality of planar discs stacked parallelly apart on the common shaft.

5 Furthermore, as mentioned, substantially (or essentially) each disc may comprise an aperture for enabling a fluid flow along the common shaft and at least partly outward in-between the plurality of planar discs. Thus, for example, when said plurality of planar discs constitutes of N planar discs, a final planar disc (number N) of said plurality of planar discs may not comprise an aperture, as it may not be needed that said fluid flow leaves
10 said final planar disc, but fully flows outward in-between the final planar disc and a penultimate planar disc (being N-1) of said plurality of planar discs. Such examples may generally apply when substantially each disc may comprise an aperture.

 Furthermore, as partly mentioned, substantially each disc may comprise an aperture for enabling a fluid flow along the common shaft and at least partly outward in-
15 between the plurality of planar discs. Said mention of at least partly outward may be defined as for a major part outward. Hence, the fluid flow entering a space in-between a first planar disc (via an aperture of the first planar disc) and a second planar disc of the plurality of planar discs may for one part flow outward in-between the first and second planar disc, while for another part may flow to the space in-between the second planar disc and a third planar disc
20 (via an aperture of the second planar disc). Said one part may be a percentage, e.g. 70%, and another part may be a complementary percentage thereof, e.g. 30%. Or reversely, the one part being 30% while the another part being 70%. Such percentages may depend on the cross-sectional surface area of the aperture, a difference in diameter of the planar discs (as the diameter of the planar discs may in some examples either linearly or non-linearly
25 increase/decrease in axial direction), and/or a cross-sectional surface area of the area in-between two consecutive planar discs, i.e. the channel two consecutive planar discs established (essentially flow between two parallel plates). In some examples, the cross-sectional surface area of the aperture may be at least two times larger than the cross-sectional surface area (perimeter times distance between two consecutive adjacent planar discs) in-
30 between two consecutive adjacent planar discs.

 In an embodiment, said aperture and/or said at least one further aperture may be located between the rotation axis and halve the radius of the planar disc. Such an embodiment is advantageous, because said aperture and/or said at least one further aperture are located closer to the common shaft, thereby enabling a fluid to be distributed better along

the common shaft to the spaces in-between said planar discs, which are stacked apart parallelly on said common shaft. Another advantage is that a fluid particle closer to the common shaft has a larger distance (or path) to flow towards the circumference of the respective planar disc. Therefore, more kinetic energy can be transferred to said fluid particle by means of the surface of said respective planar disc and its rotating motion, hence rendering a higher fluid flow velocity at said circumference when cooling the heat sink (and/or its plurality of fins).

In an embodiment, a radius of the shaft may be smaller than halve the radius of the planar disc. Thus, a radius of the shaft may be smaller than a radius of the planar disc, which may ensure that the share of the shaft within the total surface area of a planar disc is limited, hence not taking unnecessary amount of surface area thereof. Said surface area may be more effectively used for adding kinetic energy to a fluid particle in a fluid flow associated with said surface area. Hence, a radius of the common shaft may be smaller than halve the radius of a planar disc of the plurality of planar discs.

As mentioned, the common shaft may be hollow and may accommodate the electromotor. This is advantageous, as it allows for further miniaturization of the lighting device, and/or enables to utilize space within the lighting device more effectively and/or efficiently.

In some examples thereof, wherein the electromotor is accommodated within a hollow common shaft, the electromotor may further be in thermal connection with said heat sink, such that the heat sink may also provide a cooling means for heat generated by the electromotor. This may also imply that the common shaft may be, on one end, accommodated with a bearing means within the heat sink.

The light source may be a conventional light source, such as a halogen spot, or incandescent lamp. Such light sources may provide more heat compared to more efficient light sources, and may require more cooling therefore.

In an embodiment, the light source is a semiconductor light source. Hence: the light source may be a LED light source or an OLED light source. Alternatively, the lighting device may comprise, or the light source may be: a high-power LED light source, or an array thereof, such as a pixilated LED array.

In an embodiment, the lighting device may be a spot light, preferably a pixilated spot light. The present invention may be advantageous for a spot light, e.g. a pixilated spot light, because such spot lights may be prone to significant heat generation, also

partly due to their compact/miniaturized architecture, and their utilization (often in retail and/or entertainment) may have a requirement of reducing noise thereof.

As such a spot light often comprises a cylindrical housing, the very configuration of a plurality of planar discs stacked apart parallelly on a common shaft extending over a rotation axis, wherein the plurality of fins of the heat sink is arranged at least partly around the circumference of the plurality of planar discs, may therefore be particularly suitable to match (be compatible with) said shape of the cylindrical housing and therefore facilitate miniaturization of such spot lights.

In an embodiment, the lighting device may be a TLED-luminaire and the light source comprises a TLED. In a further embodiment, said TLED may be arranged in axial direction along the common shaft. Consequently, the elongated TLED luminaire may be integrated effectively with the plurality of planar discs stacked apart parallelly on a common shaft extending over a rotation axis, wherein the rotation axis may be in the elongated direction of the TLED.

As a TLED-luminaire may often comprise an elongated shape and may therefore be considered a line source of light, consequently generating a line of heat; the very configuration of a plurality of planar discs stacked apart parallelly on a common shaft extending over a rotation axis, wherein the plurality of fins of the heat sink is arranged at least partly around the circumference of the plurality of planar discs, may therefore be particularly suitable to match (or may be compatible with) said elongated shape of the elongated TLED-luminaire. As improved cooling means are provided by means of the present invention, while at the same time undesired generation of sound is reduced, such a TLED-luminaire may for example facilitate the luminaire to comprise a higher density LED light sources (e.g. more LEDs per meter); because the heat generated by a higher density LED light sources may e.g. be effectively transferred away without an increase in undesired noise levels.

Hence, in an embodiment, the heat sink may extend in axial direction along the rotation axis at least partly surrounding the plurality of planar discs.

Furthermore, different configurations are possible in respect to the plurality of fins comprised by the heat sink. The heat sink may comprise a heat sink base, and said plurality of fins may be protruding from this heat sink base. Said fins may be cylindrical protrusions. Hence, the surface area defining the contact of a fin with the heat sink base may be a circle. Alternatively, such a surface area defining the contact of a fin with the heat sink base may be one of: a square, a triangle, an ellipse, an airfoil (shape), a rectangle, blade

shape, etc. Thus, said fins may comprise a radial component, or an axial component, and/or a tangential component. In other words, said fins may be directed radially outward; or radially outward but with a tangential component, hence bend inwards or bend spirally.

In an embodiment, the fins may comprise a shape configured to guide the fluid flow in a radial direction away from rotation axis, in a direction spiraling away from the rotation axis, or in a direction parallel to the rotation axis.

In an embodiment, the heat sink may comprise at least one cooling disc, wherein said cooling disc may be concentric with said planar discs and be located in-between said planar discs. In some examples, said plurality of fins may comprise said cooling disc, i.e. the plurality of fins may be phrased as the cooling disc. This configuration may improve the cooling performance of the lighting device, because said cooling discs comprise a relatively high surface area and are positioned in the path of the fluid flow.

In an embodiment, the plurality of fins may extend in axial direction along the rotation axis at least partly surrounding the plurality of planar discs. For example: The heat sink may comprise a heat sink base. The heat sink base may be circular base with a height and diameter. Perpendicular to this circular base, at the edge (part) of said circular base, a plurality of fins may be present. These fins therefore surround a cylindrical area in-between them and above said circular base. Such a cylindrical area is well suited to accommodate a plurality of planar discs, which are stacked apart parallelly on a common shaft extending over a rotation axis, said rotation axis e.g. matching the center of the circular base. As a result, a very compact cooling arrangement is established, which may suck in air axially, and blow essentially with a radial component outward. As the plurality of fins is arranged around the circumference of the plurality of planar discs, the fluid flow may be enabled to convectively cool the light source via the heat sink.

In an embodiment, the lighting device may further comprise a housing. Said housing may at least partly enclose the plurality of planar discs. The housing may comprise at least one entrance window for enabling a fluid to enter said housing and at least one exit window for enabling the fluid to exit said housing. As a result, the plurality of planar discs, i.e. the cooling arrangement, may be accommodated within a housing. Such housing may e.g. provide mechanical strength, or guiding means for the fluid flow (such as the entrance window so as to allow fluid to enter).

In an embodiment, said housing may comprise a front-plate, which is provided parallelly to said plurality of planar disc, and further essentially perpendicular to the rotation axis. Hence, essentially, a stationary front-plate may be provided upstream to the plurality of

planar discs. Such a front-plate may comprise means to accommodate the common shaft, such as bearings which may be provided in the front-plate. Similarly, said housing may comprise an end-plate, which is stationary and similar to the front-plate, but now located downstream (after the final disc of the plurality of discs).

5 Thus, the lighting device may further comprise a front-plate, wherein the front-plate is parallel to the plurality of planar discs and positioned in front of a first stacked planar disc of the plurality of planar discs perpendicular to the rotation axis. In examples, the heat sink may be part of the housing.

10 It is a further object of the invention to provide an improved method of cooling a lighting device comprising a light source, which at least alleviates the problems and disadvantages mentioned above. Thereto, the invention further provides, a method of cooling a lighting device comprising a light source, the method comprising: rotating, with an electromotor via a common shaft extending over a rotation axis, a plurality of planar discs stacked apart parallelly on said common shaft with a rotational speed, wherein each disc
15 comprises an aperture; inducing, by said rotating, a fluid flow along the common shaft and at least partly outward in-between the plurality of planar discs; convectively cool, with said fluid flow, the light source via a heat sink, wherein the heat sink is in thermal contact with the light source and may comprise a plurality of fins arranged at least partly around the circumference of the plurality of planar discs.

20 The advantages and/or embodiments applying to the lighting device according to the invention may also apply mutatis mutandis to the present method according to the invention.

25 In an aspect of the invention, there may be provided a pixilated LED spot comprising: a cylindrical housing; a carrier comprising a pixilated LED array; a plurality of planar discs stacked apart parallelly on a common shaft extending over a rotation axis, wherein each disc comprises an aperture for enabling a fluid flow along the common shaft and at least partly outward in-between the plurality of planar discs; an electromotor for rotating, during operation via the common shaft, the plurality of planar discs with a rotational speed to induce said fluid flow; a heat sink in thermal contact with the carrier comprising the
30 pixilated LED array and comprising a plurality of fins; wherein the plurality of fins may be arranged at least partly around the circumference of the plurality of planar discs for enabling the fluid flow to convectively cool the light source via the heat sink; wherein the carrier, the electromotor, the heat sink, and the plurality of planar discs are contained within the cylindrical housing.

Such a pixilated spot light according to the invention may be advantageous, because such pixilated spot lights may be prone to significant heat generation, also partly due to their compact/miniaturized architecture, and their utilization (often in retail and/or entertainment) may have a requirement of reducing noise thereof.

5 As such a pixilated spot light comprises a cylindrical housing, the very configuration of a plurality of planar discs stacked apart parallelly on a common shaft extending over a rotation axis, wherein the plurality of fins of the heat sink is arranged at least partly around the circumference of the plurality of planar discs, may therefore be particularly suitable to match (be compatible with) said shape of the cylindrical housing and
10 therefore facilitate miniaturization of such pixilated spot lights.

As better cooling may be achieved of the carrier comprising the pixilated LED array, the density of LED light sources of the pixilated LED array may be increased, which renders a pixilated LED spot with a higher resolution.

In an embodiment, the cylindrical housing comprises at least one entrance
15 window for enabling a fluid, such as e.g. air, to flow into the cylindrical housing and into the respective apertures (e.g. into the aperture of the first planar disc) of the plurality of planar discs. In an embodiment, the cylindrical housing comprises at least one exit window for enabling a fluid, such as e.g. air, to flow out the cylindrical housing.

The advantages and/or embodiments applying to the lighting device according
20 to the invention may also apply mutatis mutandis to the present pixilated LED spot according to the invention.

In some aspects, there may be provided a lighting device comprising: a light source; a plurality of planar discs stacked apart parallelly on a common shaft extending over a rotation axis, wherein the common shaft may be hollow and comprise one or more openings
25 for enabling a fluid flow along the common shaft and at least partly outward in-between the plurality of planar discs; an electromotor for rotating, during operation via the common shaft, the plurality of planar discs with a rotational speed to induce said fluid flow; a heat sink in thermal contact with the light source and comprising a plurality of fins; wherein the plurality of fins is arranged at least partly around the circumference of the plurality of planar discs for
30 enabling the fluid flow to convectively cool the light source via the heat sink. Hence, the fluid may enter the lighting device via said hollow shaft. The advantages and/or embodiments applying to the lighting device according to the invention may also apply mutatis mutandis to the present device according to the invention.

In some aspects, there may be provided a lighting device comprising: a light source; a plurality of planar discs (106) stacked apart parallelly on a common shaft extending over a rotation axis, wherein each disc comprises an aperture for enabling a fluid flow along the common shaft and at least partly outward in-between the plurality of planar discs, an
5 electromotor for rotating, during operation via the common shaft, the plurality of planar discs with a rotational speed to induce said fluid flow; a heat sink in thermal contact with the light source, wherein the heat sink is arranged at least partly around the circumference of the plurality of planar discs for enabling the fluid flow to convectively cool the light source via the heat sink. In a further embodiment thereof, the heat sink may comprise a plurality of fins
10 and/or a plurality of cooling discs. Said cooling discs may further be concentric with said plurality of planar discs and located in-between said plurality of planar discs. Such a cooling configuration may be advantageous, as a larger cooling surface area may be present in the fluid flow. The advantages and/or embodiments applying to the lighting device according to the invention may also apply mutatis mutandis to the present device according to the
15 invention.

Moreover, in some examples, said lighting device may be a kit of parts comprising a light source, a plurality of planar discs (according to the invention), an electromotor, and a heat sink, which in assembly form a lighting assembly and/or lighting device (according to the invention). Hence, in an aspect of the invention, in a paragraph,
20 there is provided: a kit of parts comprising a light source, a plurality of planar discs according to the invention (as described in the embodiments and examples above as comprised by the lighting device), an electromotor, and a heat sink according to the invention (as described in the embodiments and examples described above as comprised by the lighting device); wherein the kit of parts forms, in assembly, a lighting assembly and/or a lighting device.
25 Such a plurality of planar discs [which plurality of planar discs is stacked apart parallelly on a common shaft extending over a rotation axis, wherein each disc comprises an aperture for enabling a fluid flow along the common shaft and at least partly outward in-between the plurality of planar discs; wherein plurality of planar discs is arranged for inducing said fluid flow and thereby enabling the fluid flow to convectively cool a light source via a heat sink]
30 may also by itself be provided to cool a light source. The scope of the invention also encompasses such a plurality of planar discs with said cooling function in particularly in relation to cooling a light source of a lighting device.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be further elucidated by means of the schematic non-limiting drawings:

Fig. 1A depicts schematically, by non-limiting example, a first embodiment of a lighting device according to the invention, whereby Figure 1B depicts schematically a cross-sectional-view thereof, whereby Figure 1C depicts a blow-out assembly perspective of a part thereof;

Fig. 2 depicts schematically, by non-limiting example, a cross-sectional-view of a second embodiment of a lighting device according to the invention.

Fig. 3 depicts schematically, by non-limiting example, within a flowchart, an embodiment of a method of cooling a lighting device.

DETAILED DESCRIPTION OF THE EMBODIMENTS

As mentioned, the present invention provides a lighting device with an improved active cooling arrangement, wherein undesired noise production associated with the lighting device is prevented, while thermal performance of the lighting device is maintained or improved.

Figure 1A depicts schematically, by non-limiting example, an embodiment of a lighting device 100. Said lighting device 100 is a spot light comprising a cylindrical housing 101. Such spot lights are often used in retail lighting and/or entertainment lighting. Figure 1B depicts schematically a cut-through side-view of said lighting device 100 depicted in figure 1A. Said spot light 100 may be a pixilated LED spot light, wherein each LED light source of said pixilated spot light may be individually addressable for generating a lighting effect.

The lighting device 100 comprises a LED module 102 serving as the light source. Said LED module 102 accommodates an array of LED light sources. This may for example be a plurality of RGBW LED light sources. The LED module, i.e. light source, generates undesired heat in operation. Alternatively, said light source may be a conventional or incandescent light source, which may e.g. still be used in specialized entertainment spot lights. Yet alternatively, said light source may be any other semiconductor lighting device, such as an OLED light source.

Referring to figure 1B and figure 1C, the lighting device 100 comprises a heat sink 103 in thermal contact with said LED module 102 for transferring heat from the LED module 102 to the heat sink 103 in operation. The heat sink 103 comprises a plurality of fins

105 for increasing the surface area of the heat sink 103 for improving convective heat transfer. The heat sink 103 comprises a heat sink base 104 onto which the plurality of fins 105 is arranged. Alternatively, not depicted, the lighting device and/or the heat sink does not comprise said plurality of fins, but instead the heat sink is arranged at least partly around the circumference of the plurality of planar discs for enabling the fluid flow to convectively cool the light source via the heat sink. The heat sink base 104 is essentially a circular plate. The plurality of fins 105 of the heat sink 103 protrude from said heat sink base 104. The plurality of fins 105 comprise a blade shape.

The lighting device further comprises a plurality of planar discs 106 stacked apart parallelly on a common shaft 107. The common shaft 107 extends over a rotation axis 108. The mechanical fixation of the common shaft, e.g. with bearings, may be with known means in the art. The LED module and heat sink 103, and/or the heat sink base 104, are also centered in respect to said rotation axis 108; hence allowing a symmetrical cylindrical spot light 100 in a cylindrical housing 101. The plurality of fins 105 is arranged around the circumference of the plurality of planar discs 106. Such a configuration facilitates miniaturization of such spot lights, because the plurality of planar discs fit well within the area surrounded by the plurality of fins 105 of the heat sink 103, which may be surrounded by the cylindrical housing 101. In alternative examples, said plurality of fins may be arranged at least partly around the circumference of the plurality of planar disc, for example, keeping 60 degrees of the 360 degrees circumference open.

Each planar disc of the plurality of planar discs 106 comprises an aperture 117. Alternatively, in other embodiments said planar discs may comprise at least one further aperture. The aperture 117 enables a fluid flow 110 along the common shaft 107 and at least partly outward in-between the plurality of planar discs 106. Figure 1B only depicts the flow on one side of the symmetric cut trough for convenience. Here, said aperture 117 is a 360 degrees circular slit. This slit is enabled in this embodiment since the common shaft is accommodating the plurality of planar discs 106 via a bottom flange serving as the bottom planar disc, upon which the other discs are stacked. Alternatively, more commonly, the planar discs may be stacked upon the common shaft more traditionally by directly mounting the planar discs thereto. The aperture, or the at least one further aperture, may alternatively be any other shape as indicated before. The aperture 117 enables a fluid to be distributed amongst the spaces 112 in-between planar discs of the plurality of planar discs 106. In alternative embodiment, said planar discs may comprise a plurality of apertures, or at least one further aperture. Furthermore, said plurality of planar discs may alternatively have a

surface roughness for improving the friction forces between the planar disc and any fluid in contact therewith. Said surface roughness may e.g. be established by a patterned relief on the planar discs, or material choice. The plurality of planar discs 106 comprises a disc material being aluminum, but may alternatively be copper, glass, another ceramic, or a polymer.

5 The lighting device 100 further comprises an electromotor 109. The electromotor 109 rotates, during operation via the common shaft 107, the plurality of planar discs 106 with a rotational speed. Here, the common shaft 107 is hollow and accommodates the electromotor 109. Alternatively, other structural arrangements with a solid common shaft and an externally gripping electromotor may be envisioned according to known architectures
10 in this field. The rotating of the plurality of planar discs 106 forces/induces a fluid flow 110. The fluid here is air. In closed systems said fluid may alternatively be a refrigerant. Thus, said fluid flow 110 is forced by rotation of the common shaft 107, either clockwise or counterclockwise. To be more specific: the very configuration of the plurality of planar discs 106 enables the air to be distributed amongst the spaces 112 in-between said planar discs 106,
15 and subsequently enables said air to be forced outward through said spaces 112 in-between said planar discs 106, which outward (spiraling) force is caused by the friction forces of the surface of each planar disc acting on the air. This is alike a Tesla turbine but in reverse modality of a compressor. Hence, the space 112 in-between two consecutive planar discs may establish a channel, which renders a flow in-between parallel plates. That is: The fluid
20 flow 110 according to the present invention is forced by (surface) friction forces caused by the very rotation of said plurality of planar discs 106 stacked apart parallelly on the common shaft 107; which may be Couette flow. Said planar discs 106 are thereby be stacked apart parallelly densely, as discussed below.

 The aperture 117 is hereby located between the rotation axis 108 and two-
25 thirds of the radius of a planar disc of the plurality of planar discs 106. This enables for example the hollow common shaft and the electromotor accommodated therein. This further allows that kinetic energy is transferred to the air particle as it moves outward through the spaces 112 in-between said planar discs 106. Alternatively, to add more kinetic energy, the aperture or at least one further aperture may be located between the rotation axis and halve
30 the radius of a planar disc of the plurality of planar discs. This may be more common when having a solid shaft instead of a hollow shaft. Hereby, the radius of the common shaft 107 is smaller than halve the radius of the plurality of planar discs 106.

Still referring to figure 1B and figure 1C, since the plurality of fins 105 is arranged at least partly around the circumference of the plurality of planar discs 106, the resulting fluid flow 110 of air convectively cools the light source via the heat sink.

As mentioned, the plurality of fins 105 comprise a blade shape. Said blade shape comprises a radial component and a tangential component in respect to the rotation axis 108, hence diverting any flow entering at the leading edge of said blade in said directions when leaving at the trailing edge. Alternatively, said plurality of fins may comprise any other fin shape, such as protruding cylinders.

Here, the plurality of fins 105 extend in axial direction along the rotation axis 108 surrounding the plurality of planar discs 105, because the heat sink base 104 is perpendicular to said rotation axis 108 and parallel to said plurality of planar discs 106, and because the plurality of fins 105 is perpendicular to this heat sink base 104.

The heat sink may be made of a heat sink material. Here, the heat sink material is copper, but may alternatively be any other metal such as iron, steel, stainless steel, aluminum; or a polymer with a thermally conductive filler (e.g. copper particles); or a ceramic, or a combination thereof.

Still referring to figure 1B and figure 1C, the physical measures and the operating parameters of the lighting device are the following: The plurality of planar discs 106 are stacked apart parallelly closely. The axial spacing in-between two consecutive discs of the plurality of planar discs 106 is 0.5 centimeter, while the thickness of each planer disc is 2 millimeter and their diameter 6 centimeters. In total of 7 planar discs are arranged onto the common shaft 107. The rotational speed may be 360 rpm. The height of the slit-shaped aperture is 1 centimeter. Thus, the cylindrical housing may comprise a diameter of 8 centimeters, which tightly leaves room for each of the plurality of fins to have a radial length of at most 1 centimeters.

Alternatively, the plurality of planar discs may be accommodated on a solid common shaft and comprise an aperture and a further aperture. The axial spacing in-between two consecutive discs of the plurality of planar discs 106 may be 0.5 centimeter, while the thickness of each planer disc may be 3 millimeter and their diameter 6 centimeters. In total of 5 planar discs may be arranged onto the common shaft 107. The rotational speed may be 360 rpm. A diameter of the circular aperture and further aperture may be 1.2 centimeters. Thus, the cylindrical housing may comprise a diameter of 8 centimeters, which tightly leaves room for each of the plurality of fins to have a radial length of at most 1 centimeters.

Alternatively, said rotational speed may be at least 360 rpm, for example 3600 rpm, or at least 3000 rpm. Said rotational speed may for example be 10000 rpm, or between 8000 and 12000 rpm.

Alternatively: The axial spacing in-between two consecutive discs of the plurality of planar discs 106 is 0.5 centimeter, while the thickness of each planar disc is 5 millimeter and their diameter 10 centimeters. In total of 10 planar discs are arranged onto the common shaft 107. The rotational speed may be 300 rpm. The diameter of the circular aperture and further aperture is 4 centimeters. Thus, the cylindrical housing may comprise a diameter of 12 centimeters, which tightly leaves room for each of the plurality of fins to have a radial length of at most 1 centimeters.

Furthermore, the housing 101 of the lighting device 100 at least partly encloses the plurality of planar discs 106. The housing comprises an entrance window (not depicted) for enabling air to enter said housing 101 and at least one exit window 113 for enabling the air to exit said housing. Moreover, a front-plate 111 may be mounted onto the common shaft 107 and/or blades of the heat sink 103 in front of the plurality of planar discs, which may hold/fixate/accommodate the electromotor or provide other mechanical/structural functions. In alternative embodiments, the heat sink may be part of the housing.

The advantage of the lighting device according to the invention is that said occurring fluid flow 110 convectively cools the light source 100 via the heat sink 103, of which the plurality of fins 105 is arranged at least partly around the plurality of planar discs 106, from in-between the fluid flow 110 is forced out; while at the same time said occurring fluid flow 110 may not be turbulent, hence providing noise-reduction.

Experimental results with a prototype lighting device according to the present application have resulted that the thermal resistance of the prototype lighting device decreases from 3.3 K/W to 0.9 K/W when the electromotor rotates the plurality of planar discs in operation. Initial sound tests with focus groups in a room with the lighting device according to the present invention indicated a noticeable noise decrease in comparison to a similar lighting device for entertainment lighting.

Figure 2 depicts schematically, by non-limiting example, a cross-sectional-view of a second embodiment of a lighting device 200 according to the invention, which is partly similar to the embodiment depicted in figure 1A, figure 1B and figure 1C.

Said lighting device 200 is a TLED-luminaire comprising a TLED 202 as a light source. By its very nature, the TLED and the TLED-luminaire are elongated in one direction. Again, similarly, the lighting device 200 comprises a plurality of planar discs 206

stacked apart parallelly on a common shaft 207 extending over a rotation axis 208, wherein each disc comprises an aperture 217 for enabling a fluid flow (not depicted) along the common shaft 207 and at least partly outward in-between the plurality of planar discs 206.

The fluid flow (not depicted) then leaves the lighting system again in axial direction. The

5 aperture 217 comprises four circular openings (or holes). In other words, there may be provided said aperture and three further apertures, which are similar in shape. The elongated TLED 202 is arranged here in axial direction along the common shaft 207. Consequently, the elongated TLED luminaire 200 may be integrated effectively with the plurality of planar discs 206 stacked apart parallelly on the common shaft 207 extending over the rotation axis
10 208, wherein the rotation axis 208 is in the elongated direction of the TLED 202.

Furthermore, again, similarly, the lighting device 200 comprises an electromotor (not depicted) for rotating, during operation via the common shaft 207, the plurality of planar discs 206 with a rotational speed to induce said fluid flow (not depicted). The electromotor may be provided in an end-cap of the TLED-luminaire. The lighting device
15 200 also comprises a heat sink 203 with a heat sink base 204 in thermal contact with the TLED 202 and comprising a plurality of fins 205; wherein the plurality of fins 205 is arranged at least partly (namely not fully surrounding) around the circumference of the plurality of planar discs 206 for enabling the fluid flow (not depicted) to convectively cool the TLED 202 via the heat sink 203.

20 Referring to figure 2, here, a heat sink base 204 of the heat sink 203 extends in axial (elongated) direction along the rotation axis 208 at least partly surrounding the plurality of planar discs 206 with its plurality of fins 205. Here, the heat sink is part of the TLED-luminaire housing and is made of metal. Alternatively, the TLED-luminaire may have a separate housing, the heat sink of the TLED-luminaire may be made of e.g. a polymer with
25 thermally conductive filler.

Figure 3 depicts schematically, by non-limiting example, within a flowchart, a method 300 of cooling a lighting device comprising a light source, e.g. as depicted in the embodiments depicted in figure 1A-1B-1C-2. The method 300 comprises the steps of: 301 rotating, with an electromotor via a common shaft extending over a rotation axis, a plurality
30 of planar discs stacked apart parallelly on said common shaft with a rotational speed, wherein each disc comprises an aperture; and 302 inducing, by said rotating, a fluid flow along the common shaft and at least partly outward in-between the plurality of planar discs; and 303 convectively cool, with said fluid flow, the light source via a heat sink, wherein the heat sink

is in thermal contact with the light source and comprises a plurality of fins arranged at least partly around the circumference of the plurality of planar discs.

CLAIMS:

1. A lighting device (100,200) comprising:
 - a light source (102);
 - a plurality of planar discs (106) stacked apart parallelly on a common shaft (107) extending over a rotation axis (108), wherein each disc comprises an aperture (117) for enabling a fluid flow (110) along the common shaft (107) and at least partly outward in-between the plurality of planar discs (106);
 - an electromotor (109) for rotating, during operation via the common shaft (107), the plurality of planar discs (106) with a rotational speed to induce said fluid flow (110);
 - a heat sink (103) in thermal contact with the light source (102) and comprising a plurality of fins (105);wherein the plurality of fins (105) is arranged at least partly around the circumference of the plurality of planar discs (106) for enabling the fluid flow (110) to convectively cool the light source (102) via the heat sink (103);
- wherein the common shaft is hollow and accommodates the electromotor.
2. The lighting device according to claim 1, wherein each planar disc comprises at least one further aperture for enabling a fluid flow along the common shaft and at least partly outward in-between the plurality of planar discs.
3. The lighting device according to any one of the preceding claims, wherein said aperture and/or said at least one further aperture is located between the rotation axis and halve the radius of the planar disc.
4. The lighting device according to any one of the preceding claims, wherein an axial spacing between two consecutive discs of the plurality of planar discs is at most 0.5 centimeter.

5. The lighting device according to any one of the preceding claims, wherein the rotational speed is at least 10 rad/sec.

6. The lighting device according to any one of the preceding claims, wherein the plurality of planar discs comprises a disc material being at least one of: a metal, a ceramic, or a polymer; and wherein the heat sink comprises a heat sink material being at least one of: a metal, a thermally conductive polymer, or a ceramic.

7. The lighting device according to any one of the preceding claims, wherein a radius of the common shaft may be smaller than halve the radius of the planar disc.

8. The lighting device according to any one of the preceding claims, wherein the light source is a semiconductor light source.

9. The lighting device according to any one of the preceding claims, wherein the lighting device is a spot light, preferably a pixilated spot light.

10. The lighting device according to any one of the preceding claims, wherein the lighting device is a TLED-luminaire and the light source comprises a TLED.

11. The lighting device according to claim 10, wherein said TLED is arranged in axial direction along the common shaft.

12. The lighting device according to any one of the preceding claims 1-11, wherein the heat sink extends in axial direction along the rotation axis at least partly surrounding the plurality of planar discs.

13. The lighting device according to any one of the preceding claims 1-11, wherein the plurality of fins extends in axial direction along the rotation axis at least partly surrounding the plurality of planar discs.

14. The lighting device according to any one of the preceding claims, wherein the lighting device further comprises a housing at least partly enclosing the plurality of planar

discs, wherein the housing comprises at least one entrance window for enabling a fluid to enter said housing and at least one exit window for enabling the fluid to exit said housing.

15: A method of cooling a lighting device comprising a light source, the method
5 comprising:

- rotating (301), with an electromotor via a common shaft extending over a rotation axis, a plurality of planar discs stacked apart parallelly on said common shaft with a rotational speed, wherein each disc comprises an aperture; and wherein the common shaft is hollow and accommodates the electromotor;

10 - inducing (302), by said rotating, a fluid flow along the common shaft and at least partly outward in-between the plurality of planar discs;

- convectively cool (303), with said fluid flow, the light source via a heat sink, wherein the heat sink is in thermal contact with the light source and comprises a plurality of fins arranged at least partly around the circumference of the plurality of planar discs.

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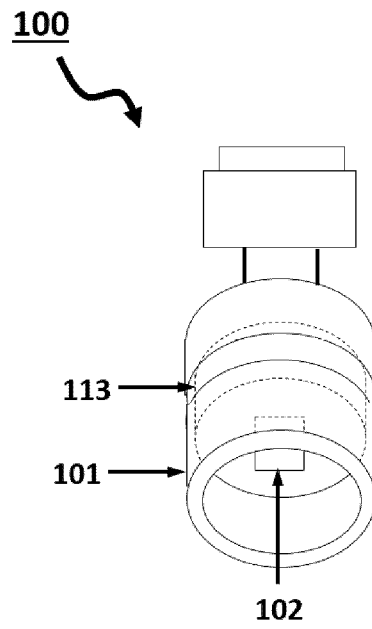


FIG.1A

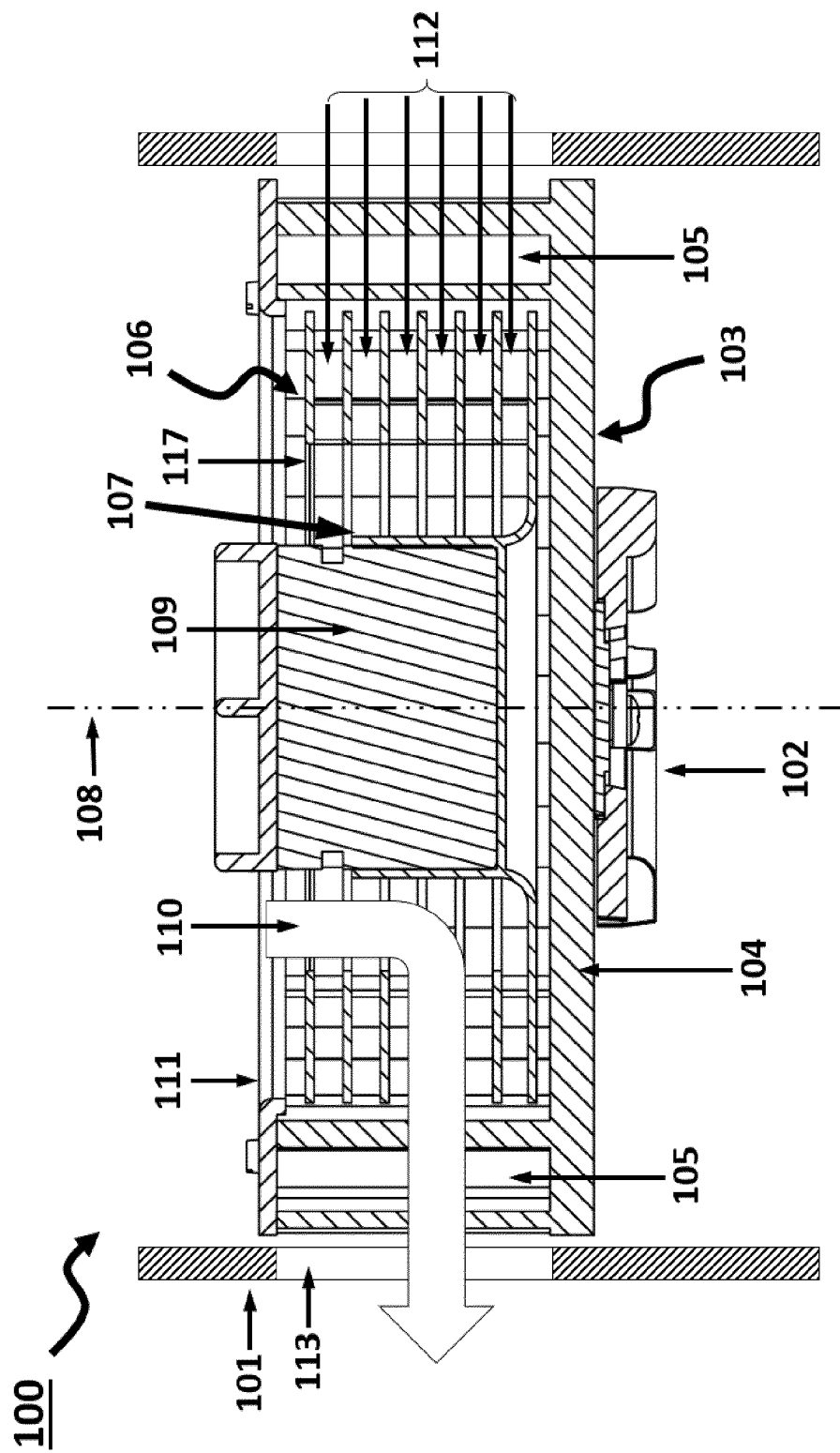


FIG.1B

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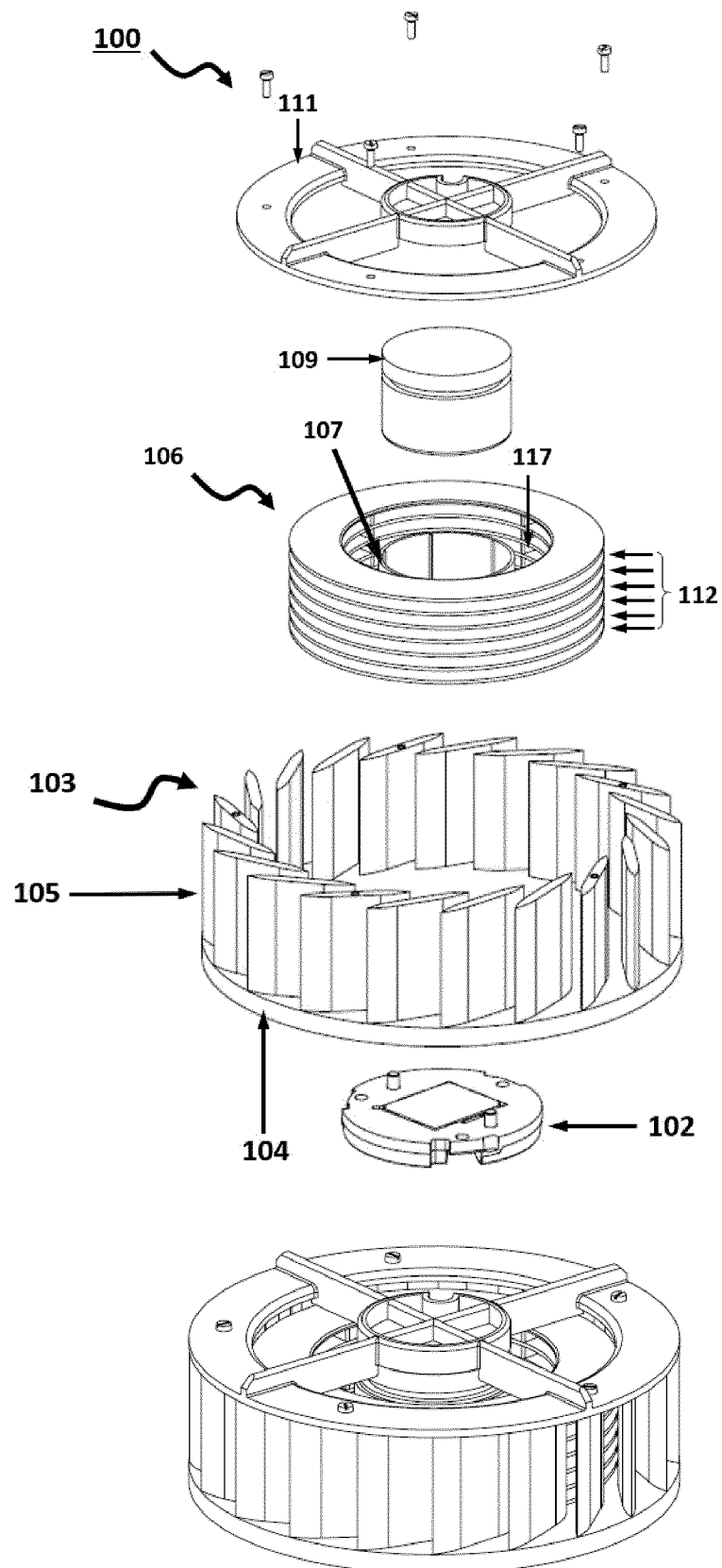


FIG.1C

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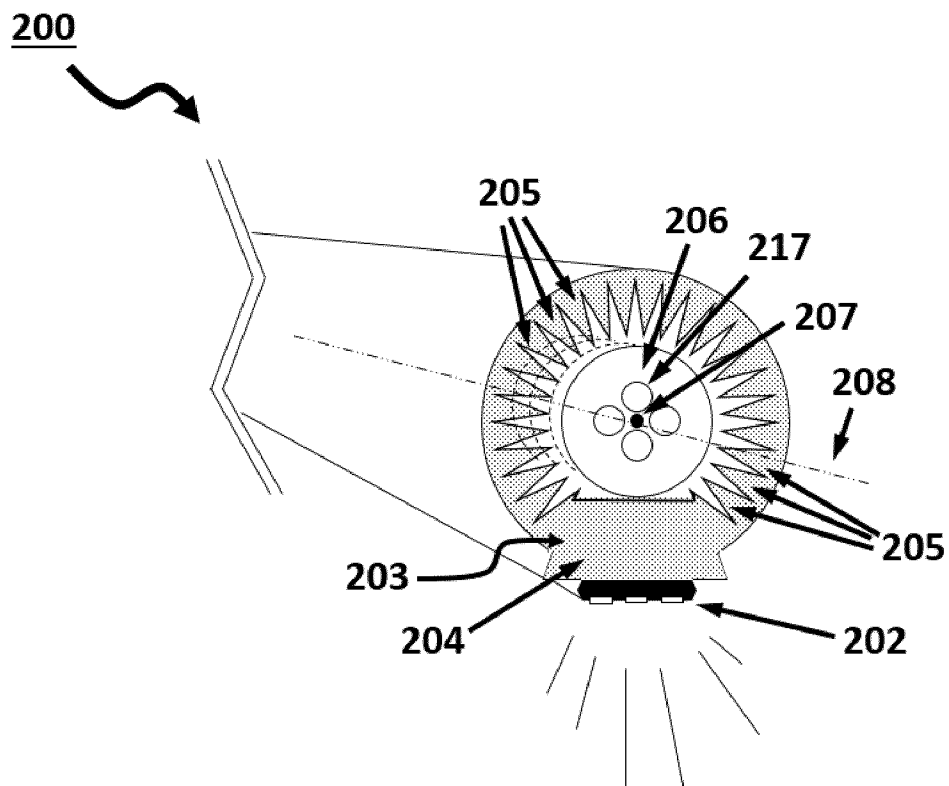


FIG. 2

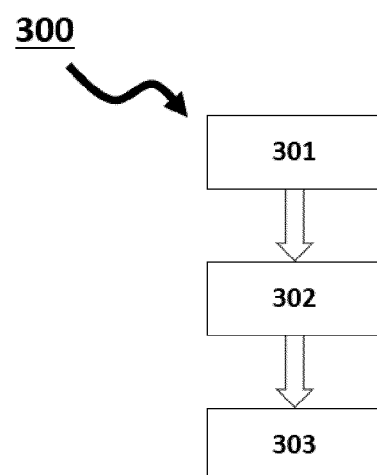


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/068097

A. CLASSIFICATION OF SUBJECT MATTER

INV. F21V29/60 F21V29/74 F04D17/16
ADD. F21Y115/10 F21Y103/00 F21S8/04

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)

F21V F21Y F21S H01L F04D F28D

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.
A	US 2011/114296 A1 (HORNG ALEX [TW] ET AL) 19 May 2011 (2011-05-19) paragraph [0004] - paragraph [0006] paragraph [0031] figures 1,2 -----	1-15
A	US 6 659 169 B1 (LOPATINSKY EDWARD [US] ET AL) 9 December 2003 (2003-12-09) column 1, line 5 - column 2, line 36 column 9, line 1 - column 10, line 16 figures 10,11 -----	1-15
A	US 2017/051757 A1 (SARMIENTO PEDRO ARNULFO [US]) 23 February 2017 (2017-02-23) the whole document ----- -/-	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

19 August 2019

Date of mailing of the international search report

06/09/2019

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/068097

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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Information on patent family members

International application No

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