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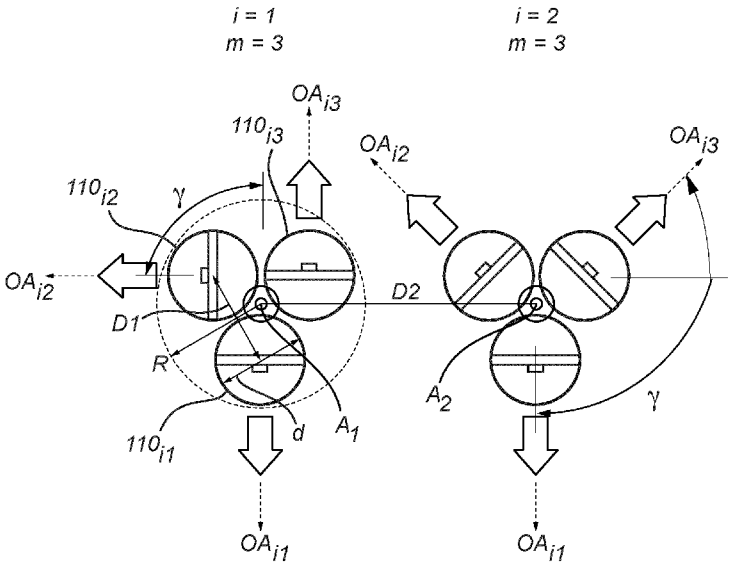


Fig. 3

(57) **Abstract:** A LED filament arrangement (100) is provided, comprising a plurality of n > 6 LED filaments (110) with an elongated carrier (120), an array (125) of a plurality of LEDs (130) arranged on a first major surface (127) of the elongated carrier (120), wherein the plurality of LEDs (130) is configured to emit LED light (135) along a main optical axis, OA_1, of the LED filament light, wherein the main optical axis, OA_1, is parallel to a normal, N, of the first major surface of the elongated carrier. The plurality of *n* LED filaments (110) comprises k > 2 clusters of LED filaments, wherein each cluster of LED filaments (110) comprises at least $m \geq 2$ LED filaments, and wherein, for each cluster i of LED filaments, i=l,..., *k*, (i) the m LED filaments are arranged in parallel with a central axis, Ai, of the cluster i of LED filaments, and congregated with respect to the central axis, Ai.

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LED FILAMENT ARRANGEMENT WITH CLUSTERED LED FILAMENTS

FIELD OF THE INVENTION

The present invention generally relates to a light emitting diode, LED, filament arrangement. More specifically, the present invention relates to a LED filament arrangement with LED filaments arranged in clusters.

BACKGROUND OF THE INVENTION

The use of light emitting diodes, LEDs, for illumination purposes continues to attract attention. Compared to incandescent lamps, fluorescent lamps, neon tube lamps, etc., LEDs provide numerous advantages such as a longer operational life, a reduced power consumption, and an increased efficiency related to the ratio between light energy and heat energy.

Many LED filament lamps or devices in the prior art comprise LED filaments for achieving the above-mentioned advantages, as well as achieving aesthetically appealing lamps. However, in case a plurality of LED filaments is used in a single lamp, there is a risk that the efficiency and/or luminous flux of the LED filament lamp becomes non-optimal and/or that the aesthetical aspect of the lamp is impaired. Hence, it is of interest to further improve the properties of the light emitted from the LED filaments and/or the visual appearance of the LED filament lamps. More specifically, it is desirable to improve the light emission from the LED filament lamps, without impairing the appearance and/or the decorative aspect of the LED filaments and/or the LED filament lamps.

Hence, it is an object of the present invention to increase the functionality of LED filament lamps by improving the properties of the light emission from the LED filaments, whilst providing a desired aesthetical appearance and/or decorative aspect of the LED filaments and/or the LED filament lamps.

WO 2019/166273 discloses an LED filament lamp, comprising a light emitting diode light source, comprising at least one first filament, arranged to emit light having a first color temperature, at least one second filament, arranged to emit light having a second color temperature, different from the first color temperature, wherein each of the first and second

filaments comprises a substrate of elongated shape, wherein at least one light emitting diode is arranged on the substrate.

SUMMARY OF THE INVENTION

It is of interest to explore the possibility of combining one or more of the numerous advantages of LED filament arrangements comprising LEDs, whilst improving the properties of the light emission from the LED filaments and improving the appearance and/or the decorative aspect of the LED filaments and/or the LED filament lamps.

This and other objects are achieved by providing a LED filament arrangement having the features in the independent claim. Preferred embodiments are defined in the dependent claims.

According to the present invention, there is provided a LED filament arrangement, configured to emit LED filament arrangement light. The LED filament arrangement comprises a plurality of $n \geq 6$ LED filaments, wherein each LED filament of the plurality of LED filaments is configured to emit LED filament light. Each LED filament comprises an elongated carrier, an array of a plurality of LEDs is arranged on a first major surface of the elongated carrier. Alternatively or additionally, the LEDs are arranged in the carrier. The plurality of LEDs is configured to emit LED light along a main optical axis, OA_1, of the LED filament light, wherein the main optical axis, OA_1, is parallel to a normal, N, of the first major surface of the elongated carrier. Each LED filament further comprises an encapsulant at least partially enclosing the elongated carrier and at least partially enclosing the at least one array of the plurality of LEDs. The plurality of n LED filaments comprises $k \geq 2$ clusters of LED filaments, wherein each cluster of LED filaments comprises at least $m \geq 2$ LED filaments, and wherein, for each cluster i of LED filaments, $i=1, \ldots, k$, (i) the m LED filaments are arranged in parallel with a central axis, A_i, of the cluster i of LED filaments, and congregated with respect to the central axis, A_i, such that the m LED filaments are confined within a radius, R_i, perpendicular to the central axis, A_i, and (ii) the main optical axis, OA_{i1}, of at least one first LED filament is different from the main optical axis, OA_{i2}, of at least one second LED filament, and (iii) the main optical axis, OA_{i1}, of any LED filament is not facing the respective main optical axis, OA_{i2}, of all other LED filaments.

Thus, the present invention is based on the idea of providing a LED filament arrangement with clustered (grouped) LED filaments emitting light in different directions for improved appearance while taking into account efficiency and light distribution. By the LED filament arrangement including these clustered LED filaments, the properties of the light

emission from the LED filaments are improved, whilst providing a desired aesthetical appearance and/or decorative aspect of the LED filaments and/or the LED filament lamps.

The present invention is advantageous by its achievement of lighting efficiency and aesthetical appearance. Albeit prior art arrangements may use LED filaments in a single lamp for trying to improve the efficiency, the LED filament appearance and a transparency of the lamp may be lost. In contrast, the clustered LED filaments of the present invention overcomes this problem by emitting light in different directions for improved appearance while taking into account efficiency and light distribution.

It should be noted that prior art arrangements may result in about 70 % of the LED filament light being emitted in a direction facing away from the LEDs, even by the use of a light-transmissive carrier. In contrast, the LED filament arrangement of the present invention, with its clustered LED filaments, provides a highly efficient light emission.

The present invention is further advantageous in that the LED filament arrangement may achieve a relatively slim line LED light emission, an improved mixing of the LED light and/or less spottiness of the LED light compared to prior art arrangements.

The present invention is further advantageous in that the numerous advantages of using LED technology may be combined with the attractiveness and the appealing properties of the LED filament arrangement as disclosed.

The present invention is further advantageous in that the LED filament arrangement of the present invention comprises relatively few components. The low number of components is advantageous in that the LED filament arrangement is relatively inexpensive to fabricate. Moreover, the low number of components of the LED filament arrangement implies an easier recycling, especially compared to devices or arrangements comprising a relatively high number of components which impede an easy disassembling and/or recycling operation.

There is provided a LED filament arrangement, configured to emit LED filament arrangement light. The LED filament arrangement comprises a plurality of $n \geq 6$ LED filaments. It will be appreciated that a LED filament is providing LED filament light and comprises a plurality of LEDs arranged in a linear array. By the term “array”, it is here meant a linear arrangement or chain of LEDs, or the like. Preferably, the LED filament has a length, L, and a width, W, wherein L > 5W. The LED filament may be arranged in a straight configuration or in a non-straight configuration such as for example a curved configuration, a 2D/3D spiral or a helix. Each LED filament of the plurality of LED filaments is configured to emit LED filament light. Each LED filament comprises an elongated carrier. The elongated

carrier may, for instance, be a substrate, that may be rigid (made from e.g. a polymer, glass, quartz, metal or sapphire) or flexible (e.g. made of a polymer or metal e.g. a film or foil). The carrier may be reflective or light transmissive, such as translucent and preferably transparent. An array of a plurality of LEDs is arranged on a first major surface of the elongated carrier, wherein the plurality of LEDs is configured to emit LED light along a main optical axis, OA_1, of the LED filament light, wherein the main optical axis, OA_1, is parallel to a normal, N, of the first major surface of the elongated carrier. Each LED filament further comprises an encapsulant at least partially enclosing the elongated carrier and at least partially enclosing the at least one array of the plurality of LEDs. By the term "encapsulant", it is here meant an elongated material, element, arrangement, or the like, which in the present context is configured or arranged to at least partially surround, encapsulate and/or enclose the carrier and the array(s) of the plurality of LEDs. The encapsulant may be a polymer material which may be flexible such as for example a silicone. The encapsulant may comprise a luminescent material that is configured to at least partly convert LED light into converted light. The luminescent material may be a phosphor such as an inorganic phosphor and/or quantum dots or rods. The plurality of n LED filaments comprises $k \geq 2$ clusters of LED filaments, wherein each cluster of LED filaments comprises at least $m \geq 2$ LED filaments. Hence, the LED filament arrangement may comprise two or more clusters (groups) of LED filaments, each comprising two or more LED filaments. For each cluster i of LED filaments, $i=1, \ldots, k$, the m LED filaments are arranged in parallel with a central axis, A_i, of the cluster i of LED filaments, and congregated with respect to the central axis, A_i, such that the m LED filaments are confined within a radius, R_i, perpendicular to the central axis, A_i. Hence, the LED filaments are arranged in bundles, in close proximity to each (respective) central axis, A_i. For each cluster i of LED filaments, $i=1, \ldots, k$, the main optical axis, OA_{i1}, of at least one first LED filament is different from the main optical axis, OA_{i2}, of at least one second LED filament. Hence, at least two LED filaments (and, optionally, all LED filaments) have main optical axes which are different, i.e. pointing in different directions. For each cluster i of LED filaments, $i=1, \ldots, k$, the main optical axis, OA_{i1}, of any LED filament is not facing the respective main optical axis, OA_{i2}, of all other LED filaments. Hence, none of the LED filaments has a main optical axis which is facing the main optical axis of any other LED filament.

According to an embodiment of the present invention, each cluster of the k clusters of LED filaments may comprise $m >= 3$ LED filaments. Hence, the cluster (group) of LED filaments may comprise three or more LED filaments. The present embodiment is

advantageous in that a relatively large amount of the LED filaments may be provided in the cluster, thereby further augmenting the efficiency of the light emission.

According to an embodiment of the present invention, for each cluster *i* of LED filaments, *i=1, ..., k*, a main optical axis, OA_{i1}, of any LED filament is different from the respective main optical axis, OA_{i2}, of all other LED filaments. Hence, all LED filaments of each cluster of LED filaments have unique main optical axes, i.e. pointing in different directions. The present embodiment is advantageous in that the distribution of the light from the clusters, and also, from the LED filament arrangement, is even further improved.

According to an embodiment of the present invention, the LED filaments of each cluster of the *k* clusters of LED filaments may be aligned such that the main optical axis, OA_{i1}, of at least one first LED filament is arranged perpendicular or parallel with respect to the main optical axis, OA_{i2}, of at least one second LED filament. Hence, at least two LED filaments of each cluster are aligned in parallel or perpendicular to each other. The present embodiment is advantageous in that the properties of the light emission from the LED filaments are even further improved, whilst providing a desired aesthetical appearance and/or decorative aspect of the LED filaments.

According to an embodiment of the present invention, each cluster of the *k* clusters of LED filaments may comprise $m \geq 3$ LED filaments, and wherein for each cluster *i* of LED filaments, *i=1, ..., k*, the main optical axis, OA_{i1}, of any LED filament is perpendicular or parallel to the respective optical axis, OA_{i2}, of all other LED filament. Hence, the present embodiment implies a relatively large amount of LED filaments, of which all are parallel or perpendicular to each other. The present embodiment is advantageous in that the properties of the LED filament arrangement light and/or the visual appearance of the LED filament arrangement are even further improved.

According to an embodiment of the present invention, each cluster of the *k* clusters of LED filaments may comprise $m \geq 3$ LED filaments, whereby the LED filaments of a cross-section, perpendicular to the central axis, A_i, of the at least one cluster of LED filaments, form one of an “L”-shape, an “I”-shape, and an “V”-shape. Hence, in a top or bottom view of the bundle or cluster of LED filaments, the cross-section is formed as an “L”, “I” or “V”. The present embodiment is advantageous in that a particularly efficient light distribution is achieved, and that the shapes as embodied are particularly appealing.

According to an embodiment of the present invention, one of (i) at least one cluster of the *k* clusters of LED filaments comprises $m = 3$ LED filaments symmetrically congregated with respect to the central axis, A_i, whereby the LED filaments of a cross-

section, perpendicular to the central axis, A_i, of the at least one cluster of LED filaments, form a triangular pattern, and (ii) at least one cluster of the *k* clusters of LED filaments comprises $m = 4$ LED filaments symmetrically congregated with respect to the central axis, A_i, whereby the LED filaments of a cross-section, perpendicular to the central axis, A_i, of the at least one cluster of LED filaments, form a rhombus pattern, is fulfilled. Hence, the embodiment comprises either case (i) or case (ii), wherein case (i) implies clusters of three LED filaments arranged in a triangular shape or pattern seen from the top or bottom of the cluster or group of LED filaments, and wherein case (ii) implies clusters of four LED filaments arranged in a rhombus shape or pattern seen from the top or bottom of the cluster or group of LED filaments.

According to an embodiment of the present invention, the optical axis, OA_{i1}, of any LED filament may have an azimuthal phase shift, γ, with respect to the optical axis, OA_{i2}, of any other LED filament, wherein in case of (i), $\gamma = 120°$, and in case of (ii), $\gamma = 90°$. Hence, in case (i), comprising clusters of three LED filaments arranged in a triangular shape or pattern seen from the top or bottom of the cluster or group of LED filaments, the optical axis, OA_{i1}, of any LED filament may have an azimuthal phase shift, γ, with respect to the optical axis, OA_{i2}, of any other LED filament, wherein $\gamma = 120°$, whereas in case (ii), comprising clusters of four LED filaments arranged in a rhombus shape or pattern seen from the top or bottom of the cluster or group of LED filaments, the optical axis, OA_{i1}, of any LED filament may have an azimuthal phase shift, γ, with respect to the optical axis, OA_{i2}, of any other LED filament, wherein $\gamma = 120°$.

According to an embodiment of the present invention, each LED filament of the plurality of LED filaments has a diameter, d, wherein, for each cluster *i* of LED filaments, $i=1, \ldots, k$, $1.05 \leq R_i \leq 2 \cdot d$, is fulfilled. Hence, the *m* LED filaments are confined within a radius, R_i, perpendicular to the central axis, A_i, which is relatively small, leading to a relatively narrow or tight bundle of LED filaments. The present embodiment is advantageous in that the space that the clusters take up is limited, whilst still providing the advantageous effects of light distribution and visual attractiveness.

According to an example of the present invention, d may be in a range from 1 mm to 4 mm.

According to an embodiment of the present invention, the encapsulant may comprise a luminescent material configured to at least partly convert the LED light into converted light. The obtained effect by this embodiment is high efficiency, as due to the

particular orientation and placement of the LED filaments, there is less occurrence of cross-talk.

According to an embodiment of the present invention, at least one cluster of the k clusters of LED filaments may comprise a common first electrode and a common second electrode. The present embodiment is advantageous in that an even easier assembly of the LED filament arrangement is achieved. Furthermore, it is easier to power or control clusters of LED filaments.

According to an embodiment of the present invention, for each cluster i of LED filaments, $i=1, \ldots, k$, a maximum distance, D_1, perpendicular to the central axis, A_i, between any LED filament and any other LED filament, and a distance, D_2, between any two central axes, A_i, fulfil $D_1 \leq 0.2 \cdot D_2$. The present embodiment is advantageous in that the relation between the size of the clusters of bundles of LED filaments compared to the intra distance of the LED filament clusters is optimized with respect to the light distribution and visual attractiveness of the LED filament arrangement.

According to an embodiment of the present invention, the LED filament arrangement may further comprise a controller configured to, at least one of, (i) control the luminous flux of the light emitted from the cluster of LED filaments individually, and (ii) control the luminous flux of the LED filament light of each LED filament of each cluster of LED filaments individually. By "controller", it is here meant any device, unit, or the like, which is able to control the luminous flux either by wire or via wireless technology. The present embodiment is advantageous in that the controller may conveniently and efficiently control the LED filament, thereby even further ameliorating the light emission from the LED filament and improving the appearance and/or the decorative aspect of the LED filament.

According to an embodiment of the present invention, wherein in case of (i) of the previous embodiment, at least two clusters of LED filaments emit clustered LED filament light having different correlated color temperatures, CCTs, such that the correlated color temperature, CCT, of the LED filament arrangement light is varied, and in case of (ii) of the previous embodiment, at least two LED filaments in each cluster of LED filaments emit LED filament light having different correlated color temperatures, CCTs, such that the correlated color temperature, CCT, of the LED filament arrangement light is varied. The present embodiment is advantageous in that the possibility of the controller to vary the correlated color temperature, CCT, of the LED filament light may even further augment the light emission and/or the aesthetic appearance of the LED filaments. For example, the LED filament arrangement, via the difference in color temperature between its LED filaments,

may provide a desired color temperature of the LED filament arrangement light. The present embodiment is further advantageous in that a difference in color temperature between the arrays of LEDs may even further contribute to the aesthetical attractiveness of the LED filament arrangement during operation. The LED filament arrangement may hereby achieve an effectful emission of the LED filament arrangement light and achieve a decorative LED filament arrangement during operation.

According to an embodiment of the present invention, there is provided a lamp comprising the LED filament arrangement according to any one of the preceding embodiments. The lamp further comprises a cover comprising an at least partially translucent material, wherein the cover at least partially encloses the LED filament arrangement, and a connector electrically connected to the LED filament arrangement for a supply of power to the plurality of LEDs of the plurality of LED filaments of the LED filament arrangement. The present embodiment is advantageous in that the lamp, comprising the LED filament arrangement, combines the aspects of a desired light emission and aesthetical appearance provided via the LED filament arrangement and/or via the feature(s) of the lamp.

Further objectives of, features of, and advantages with, the present invention will become apparent when studying the following detailed disclosure, the drawings and the appended claims. Those skilled in the art will realize that different features of the present invention can be combined to create embodiments other than those described in the following.

BRIEF DESCRIPTION OF THE DRAWINGS

This 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.

Figs. 1a-c show a LED filament lamp according to the prior art,

Fig. 2a schematically shows a LED filament arrangement according to an exemplifying embodiment of the present invention,

Fig. 2b schematically shows a LED filament of a LED filament arrangement according to an exemplifying embodiment of the present invention,

Figs. 3 and 4 schematically show clusters of LED filaments according to exemplifying embodiments of the present invention,

Figs. 5a-5c schematically show arrangements of clusters of LED filaments according to exemplifying embodiments of the present invention, and

Fig. 6 shows a lamp comprising a LED filament arrangement according to an exemplifying embodiment of the present invention.

DETAILED DESCRIPTION

Fig. 1a shows a LED filament lamp 10 according to the prior art, comprising a plurality of LED filaments 20, and Fig. 1b is a top view of the LED filament lamp 10 as exemplified in Fig. 1a. LED filament lamps 10 of this kind are highly appreciated as they are very decorative, as well as providing numerous advantages compared to incandescent lamps such as a longer operational life, a reduced power consumption, and an increased efficiency related to the ratio between light energy and heat energy. LED filament lamps 10 of this kind are able to produce warm white light. However, albeit prior art arrangements may use LED filaments in a single lamp for trying to improve the efficiency, the LED filament appearance and a transparency of the lamp may be lost. Furthermore, as exemplified in Fig. 1c, prior art LED filament lamps 10 may result in about 70 % of the LED filament light being emitted in a direction facing away from the LEDs, even by the use of a light-transmissive carrier. Hence, it is of interest to improve the properties of the light distribution emitted from the LED filaments 20, and to even further augment the appearance and/or the decorative aspect of the LED filaments 20 and/or the LED filament lamps 10.

Fig. 2a shows a LED filament arrangement 100 according to an exemplifying embodiment of the present invention. The LED filament arrangement 100 is configured to emit LED filament arrangement light 105. The LED filament arrangement 100 comprises a plurality of LED filaments 110, wherein each LED filament 100 is configured to emit LED filament light 115. The LED filament arrangement 100 comprises a plurality of $n \geq 6$ LED filaments 110. The plurality of n LED filaments 110 comprises $k \geq 2$ clusters of LED filaments 110, wherein each cluster of LED filaments 110 comprises at least $m \geq 2$ LED filaments 110. The LED filament arrangement 100 exemplified in Fig. 2a comprises $k = 4$ clusters of LED filaments 110, wherein each cluster comprises $m = 3$ LED filaments, such that the LED filament arrangement 100 comprises $n = k \cdot m = 4 \cdot 3 = 12$ LED filaments 110 in total. However, it will be appreciated that as long as the requirements $n \geq 6$ LED filaments 110, $k \geq 2$ clusters of LED filaments 110 and $m \geq 2$ LED filaments 110 are fulfilled, the number and/or arrangements of LED filaments 110 are arbitrary. For example, and according to one or more embodiments, one of the following may apply: (i) n=6, k=3, m=2; (ii) n=6, k=2, m=3; (iii) n=8, k=4, m=2; (iv) n=9, k=3, m=3; (v) n=10, k=5, m=2; (vi) n=12, k=6, m=2; (vii) n=12, k=4, m=3; (viii) n=15, k=5, m=3.

In embodiments, one or more or all LED filaments 110 in a cluster may emit white LED filament light. The white LED filament light may have a correlated color temperature, CCT, in a range from 1700K to 6500K and/or have a color rendering index, CRI, of at least 80. In embodiments, one or more or all LED filaments 110 may be phosphor-converted LED filaments, i.e. wherein the encapsulant comprises a luminescent material, e.g. a green-yellow and/or a red phosphor.

Fig. 2b schematically shows a cross section of a LED filament 110 of a LED filament arrangement according to an exemplifying embodiment of the present invention. The LED filament 110 comprises an elongated carrier 120, and an array 125 of a plurality of LEDs 130 arranged on a first major surface 127 of the elongated carrier 120 or the plurality of LEDs is arranged in the carrier. It should be noted that the LED filament 110 may comprise substantially any number of array(s) 125. The plurality of LEDs 130 preferably comprises more than 5 LEDs, more preferably more than 8 LEDs, and even more preferred more than 10 LEDs. The plurality of LEDs 130 may be direct emitting LEDs which provide a color. The plurality of LEDs 130 is configured to emit LED light 135 along a main optical axis, OA_1, of the LED filament light 115, wherein the main optical axis, OA_1, is parallel to a normal, N, of the first major surface 127 of the elongated carrier 120. The LED filament 110 further comprises an encapsulant 140 at least partially enclosing the elongated carrier 120 and at least partially enclosing the array(s) 125 of the plurality of LEDs 130. The encapsulant 140 may comprise at a light-scattering material configured to scatter at least part of the LED light 135 into scattered light and/or a luminescent material configured to convert at least part of the LED light into converted light. The luminescent material of the encapsulant 140 may be a light-scattering material, e.g. a polymer matrix comprising $BaSO_4$, Al_2O_3 and/or TiO_2 particles. The luminescent material may be a phosphor such as an inorganic phosphor (e.g. YAG, LuAG, ECAS, KSiF, etc.) and/or quantum dots or rods. The phosphor may further be e.g. a (blue) green/yellow and/or red phosphor. Although not shown, the thickness of the encapsulant 140 and/or a concentration of the luminescent material in the encapsulant 140 may vary over the length of the LED filament 110.

From the exemplifying disclosures of the LED filament arrangement 100 according to Fig. 2a and the LED filament 110 according to Fig. 2b, the LED filament arrangement 100 of the present invention fulfills requirements or criterions that are exemplified in Fig. 3. According to a first requirement or criterion (i), for each cluster *i* of LED filaments 110, *i=1, ..., k*, the *m* LED filaments 110 are arranged in parallel with a central axis, A_i, of the cluster *i* of LED filaments 110, and congregated with respect to the

central axis, A_i, such that the *m* LED filaments 110 are confined within a radius, R_i, perpendicular to the central axis, A_i. As exemplified in the leftmost cluster *i=1* of LED filaments 110 in Fig. 3, the *m*=3 LED filaments 110 are arranged in parallel with a central axis, A_1, of the cluster *i*=1 of LED filaments 110, and congregated with respect to the central axis, A_1, such that the *m*= 3 of LED filaments 110 are confined within a radius, R_1, which is perpendicular to the central axis, A_1. According to a second requirement or criterion (ii), for each cluster *i* of LED filaments 110, *i=1, ..., k*, the main optical axis, OA_{i1}, of at least one first LED filament 110_{i1} is different from the main optical axis, OA_{i2}, of at least one second LED filament 110_{i2}. As exemplified in the leftmost cluster *i=1* of LED filaments 110 in Fig. 3, all main optical axes are different from each other, i.e. $OA_{i1} \neq OA_{i2} \neq OA_{i3}$. In this example, all main optical axes OA_{i1}, OA_{i2}, OA_{i3} are parallel or perpendicular to each other. Furthermore, a cross-section of the LED filaments perpendicular to the central axis, $A_i = A_1$, of the cluster *i=1* of LED filaments 110, forms a "V"-shape. Furthermore, the LED filaments are symmetrically congregated with respect to the central axis, A_i, whereby the LED filaments of a cross-section, perpendicular to the central axis, A_i, of the cluster *i=1* of LED filaments, form a triangular pattern. Furthermore, all main optical axes OA_{i1}, OA_{i2}, OA_{i3} have an azimuthal phase shift, γ, with respect to each other, wherein $\gamma = 90°$ (perpendicular) or $\gamma = 180°$ (parallel). According to a third requirement or criterion (iii), for each cluster *i* of LED filaments 110, *i=1, ..., k*, the main optical axis, OA_{i1}, of any LED filament 110_{i1} is not facing the respective main optical axis, OA_{i2}, of all other LED filaments 110_{i2}. As exemplified in the leftmost cluster *i=1* of LED filaments 110 in Fig. 3, none of the LED filaments 110 has a main optical axis which is facing the main optical axis of any other LED filament 110.

Analogously, as exemplified in the rightmost cluster *i=2* of LED filaments 110 in Fig. 3, all main optical axes are different from each other, i.e. $OA_{i1} \neq OA_{i2} \neq OA_{i3}$. A cross-section of the LED filaments perpendicular to the central axis, $A_i = A_2$, of the cluster *i=2* of LED filaments 110, forms a "V"-shape. Furthermore, the LED filaments are symmetrically congregated with respect to the central axis, A_i, whereby the LED filaments of a cross-section, perpendicular to the central axis, A_i, of the cluster *i=2* of LED filaments, form a triangular pattern. Furthermore, all main optical axes OA_{i1}, OA_{i2}, OA_{i3} have an azimuthal phase shift, γ, with respect to each other, wherein $\gamma = 120°$. According to a third requirement or criterion (iii), for each cluster *i* of LED filaments 110, *i=1, ..., k*, the main optical axis, OA_{i1}, of any LED filament 110_{i1} is not facing the respective main optical axis, OA_{i2}, of all other LED filaments 110_{i2}. As exemplified in the rightmost cluster *i=2* of LED

filaments 110 in Fig. 3, none of the LED filaments 110 has a main optical axis which is facing the main optical axis of any other LED filament 110.

Fig. 3 further exemplifies the embodiment that each LED filament of the plurality of LED filaments 110 has a diameter, d, wherein, for each cluster *i* of LED filaments, $i=1, \ldots, k$, $1.05 \leq R_i \leq 2 \cdot d$ is fulfilled. For example, d may be in a range from 1 mm to 4 mm. Furthermore, Fig. 3 exemplifies the embodiment that a maximum distance, D_1, perpendicular to the central axis, A_i, between any two LED filaments, and a distance, D_2, between any two central axes, A_i, as indicated between the leftmost cluster $i=1$ and the rightmost cluster $i=2$, i.e. the distance between axes A_1 and A_2, fulfil $D_1 \leq 0.2 \cdot D_2$.

Fig. 4 schematically shows clusters of LED filaments 110 according to an exemplifying embodiment of the present invention. It should be noted that the clusters of Fig. 4 have many features in common with the clusters of Fig. 3, and it is also referred to Fig. 3 and the associated text for an increased understanding of Fig. 4. In Fig. 4, the LED filaments 110 of each cluster of the $k=2$ clusters of LED filaments 110 are aligned such that the main optical axis, OA_{i1}, of at least one first LED filament 110_{i1} is arranged perpendicular or parallel with respect to the main optical axis, OA_{i2}, of at least one second LED filament 110_{i2}. More specifically, of the $m = 3$ LED filaments 110 for each cluster $i = 1$ and $i = 2$, the main optical axis, OA_{i1}, of any LED filament 110_{i1} is perpendicular or parallel to the respective optical axis, OA_{i2}, of all other LED filaments 110_{i2}. Furthermore, the LED filaments 110 of each cluster $i = 1$ and $i = 2$ form an "I"-shape of a cross-section, perpendicular to the central axis, A_i. Fig. 4 further discloses, schematically, that the leftmost cluster of LED filaments comprises a common first electrode 250 and a common second electrode 260.

Figs. 5a-5c schematically show arrangements, assemblies or units of clusters of LED filaments according to exemplifying embodiments of the present invention. It is referred to Fig. 3 and/or Fig. 4 and the associated text(s) for an increased understanding of Figs. 5a-5c. It should be noted that there are numerous possible combinations of clusters according to the present invention, and that the examples shown in Figs. 5a-5c merely disclose a few of these combinations. Fig. 5a shows four clusters of the cluster (type) $i = 1$ in the leftmost part of Fig. 4, whereas Fig. 5b shows four clusters, wherein two clusters are of the cluster (type) $i = 1$ in the leftmost part of Fig. 4, and wherein two clusters are of the cluster (type) $i = 2$ in the rightmost part of Fig. 4. Fig. 5c shows four clusters of the cluster (type) $i = 2$ in the rightmost part of Fig. 4.

Fig. 6 schematically shows a lamp 500 according to an embodiment of the present invention. The lamp 500, which may constitute a lamp or a luminaire, comprises a

LED filament arrangement 100 according to any one of the previously described embodiments. The lamp 500 further comprises a cover 505, which is exemplified as being bulb-shaped. The cover 505 may comprise an at least partially light transmissive (e.g. transparent) material and at least partially encloses the LED filament arrangement 100. The lamp 500 further comprises an electrical connection 510 connected to the LED filament arrangement 100 for a supply of power to the plurality of LED filaments of the LED filament arrangement 100.

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, one or more of the LED filaments, the clusters of LED filaments, etc., may have different shapes, dimensions and/or sizes than those depicted/described.

CLAIMS

1. A light emitting diode, LED, filament arrangement (100), configured to emit LED filament arrangement light (105), comprising

a plurality of $n \geq 6$ LED filaments (110), wherein each LED filament of the plurality of LED filaments is configured to emit LED filament light (115) and comprises

an elongated carrier (120),

an array (125) of a plurality of LEDs (130) arranged on a first major surface (127) of the elongated carrier or in the carrier, wherein the plurality of LEDs is configured to emit LED light (135) along a main optical axis, OA_1, of the LED filament light, wherein the main optical axis, OA_1, is parallel to a normal, N, of the first major surface of the elongated carrier, and

an encapsulant (140) at least partially enclosing the elongated carrier and at least partially enclosing the at least one array of the plurality of LEDs,

wherein the plurality of n LED filaments comprises $k \geq 2$ clusters of LED filaments, wherein each cluster of LED filaments comprises at least $m \geq 3$ LED filaments, and

wherein, for each cluster i of LED filaments, $i=1, \ldots, k$,

(i) the m LED filaments are arranged in parallel with a central axis, A_i, of the cluster i of LED filaments, and congregated with respect to the central axis, A_i, such that the m LED filaments are confined within a radius, R_i, perpendicular to the central axis, A_i, and

(ii) the main optical axis, OA_{i1}, of at least one first LED filament (110_{i1}) is different from the main optical axis, OA_{i2}, of at least one second LED filament (110_{i2}), and

(iii) the main optical axis, OA_{i1}, of any LED filament (110_{i1}) is not facing and is different from the respective main optical axis, OA_{i2}, of all other LED filaments (110_{i2}) and

(iv) the main optical axis, OA_{i1}, of any LED filament (110_{i1}) is perpendicular or parallel to the respective optical axis, OA_{i2}, of all other LED filament (110_{i2}).

2. The LED filament arrangement according to claim 1, wherein the LED filaments of each cluster of the k clusters of LED filaments are aligned such that the main optical axis, OA_{i1}, of at least one first LED filament (110_{i1}) is arranged perpendicular or

parallel with respect to the main optical axis, OA_{i2}, of at least one second LED filament (110_{i2}).

3. The LED filament arrangement according to any one of the preceding claims, wherein each cluster of the *k* clusters of LED filaments comprises $m \geq 3$ LED filaments, whereby the LED filaments of a cross-section, perpendicular to the central axis, A_i, of the at least one cluster of LED filaments, form one of

an "L"-shape,

an "I"-shape, and

an "V"-shape.

4. The LED filament arrangement according to any one of the preceding claims, wherein one of

(i) at least one cluster of the *k* clusters of LED filaments comprises $m = 3$ LED filaments symmetrically congregated with respect to the central axis, A_i, whereby the LED filaments of a cross-section, perpendicular to the central axis, A_i, of the at least one cluster of LED filaments, form a triangular pattern, and

(ii) at least one cluster of the *k* clusters of LED filaments comprises $m = 4$ LED filaments symmetrically congregated with respect to the central axis, A_i, whereby the LED filaments of a cross-section, perpendicular to the central axis, A_i, of the at least one cluster of LED filaments, form a rhombus pattern,

is fulfilled.

5. The LED filament arrangement according to claim 4, wherein the optical axis, OA_{i1}, of any LED filament (110_{i1}) has an azimuthal phase shift, γ, with respect to the optical axis, OA_{i2}, of any other LED filament (110_{i2}), wherein

in case of (i), $\gamma = 120°$, and

in case of (ii), $\gamma = 90°$.

6. The LED filament arrangement according to any one of the preceding claims, wherein each LED filament of the plurality of LED filaments has a diameter, d, wherein, for each cluster *i* of LED filaments, $i=1, \ldots, k$,

$$1.05 \leq R_i \leq 2 \cdot d$$

is fulfilled.

7. The LED filament arrangement according to any one of the preceding claims, wherein the encapsulant comprises a luminescent material configured to at least partly convert the LED light into converted light.

8. The LED filament arrangement according to any one of the preceding claims, wherein at least one cluster of the *k* clusters of LED filaments comprises a common first electrode (250) and a common second electrode (260).

9. The LED filament arrangement according to any one of the preceding claims, wherein, for each cluster *i* of LED filaments, $i=1, \ldots, k$,

a maximum distance, D_1, perpendicular to the central axis, A_i, between any LED filament (110_{i1}) and any other LED filament (110_{i2}), and

a distance, D_2, between any two central axes, A_i,

fulfil $D_1 \leq 0.2 \cdot D_2$.

10. The LED filament arrangement according to any one of the preceding claims, further comprising a controller configured to, at least one of,

(i) control the luminous flux of the light emitted from the cluster of LED filaments individually, and

(ii) control the luminous flux of the LED filament light of each LED filament of each cluster of LED filaments individually.

11. The LED filament arrangement according to claim 10, wherein

in case of (i), at least two clusters of LED filaments emit clustered LED filament light having different correlated color temperatures, CCTs, such that the correlated color temperature, CCT, of the LED filament arrangement light is varied, and

in case of (ii), at least two LED filaments in each cluster of LED filaments emit LED filament light having different correlated color temperatures, CCTs, such that the correlated color temperature, CCT, of the LED filament arrangement light is varied.

12. A lamp (500), comprising

the LED filament arrangement according to any one of the preceding claims,

a cover (505) comprising an at least partially translucent material, wherein the cover at least partially encloses the LED filament arrangement, and

a connector (510) electrically connected to the LED filament arrangement for a supply of power to the plurality of LEDs of the plurality of LED filaments of the LED filament arrangement.

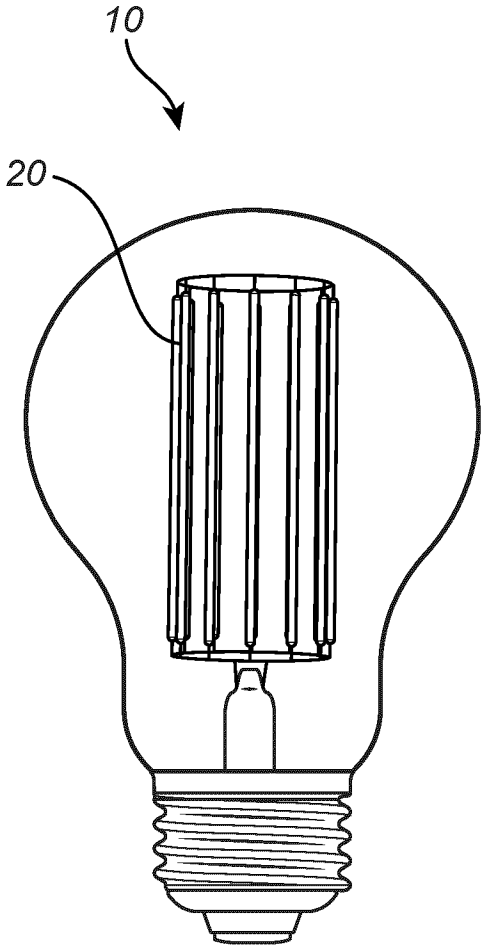


Fig. 1a

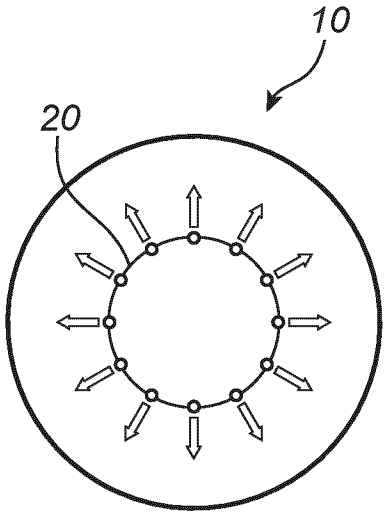


Fig. 1b

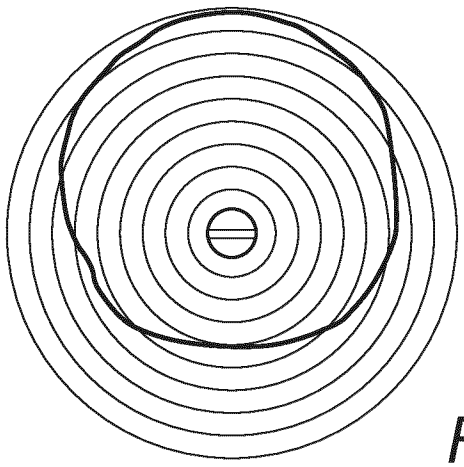


Fig. 1c

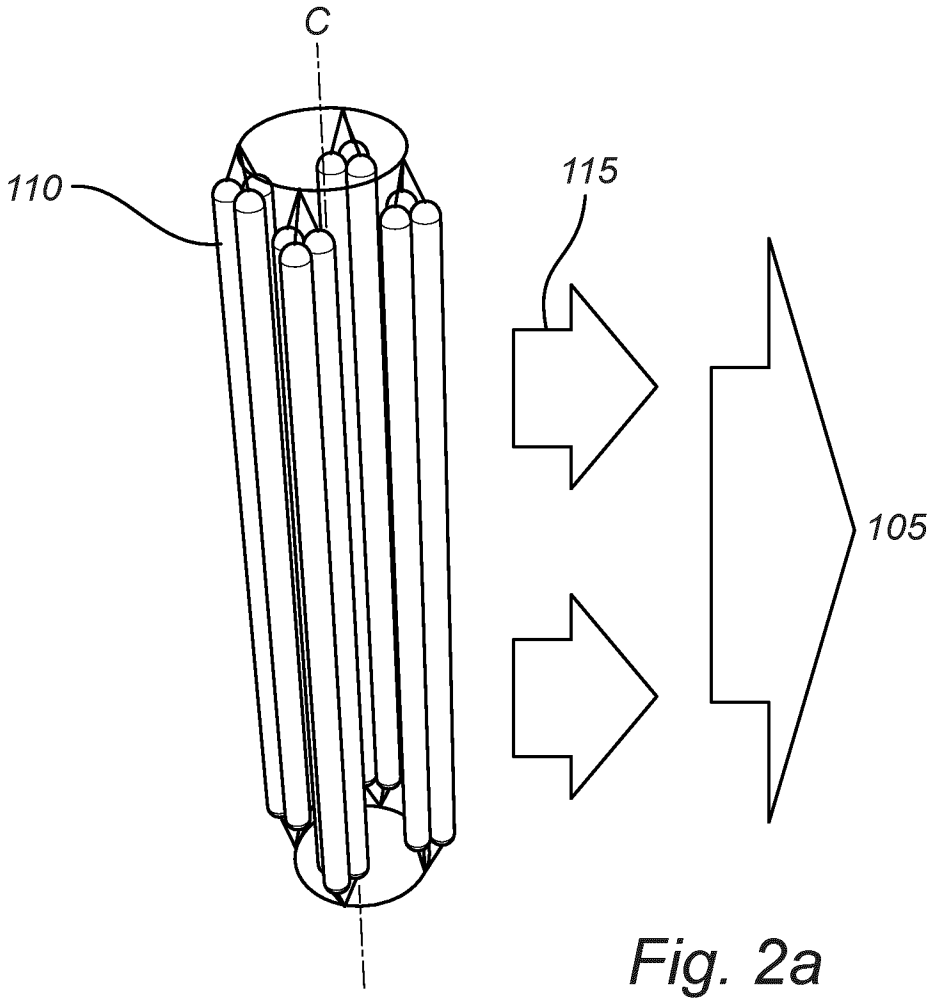


Fig. 2a

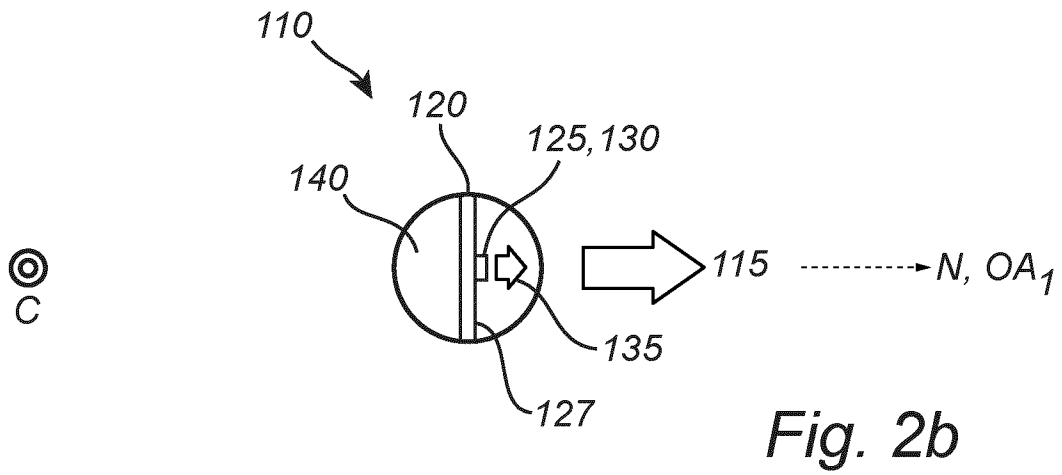


Fig. 2b

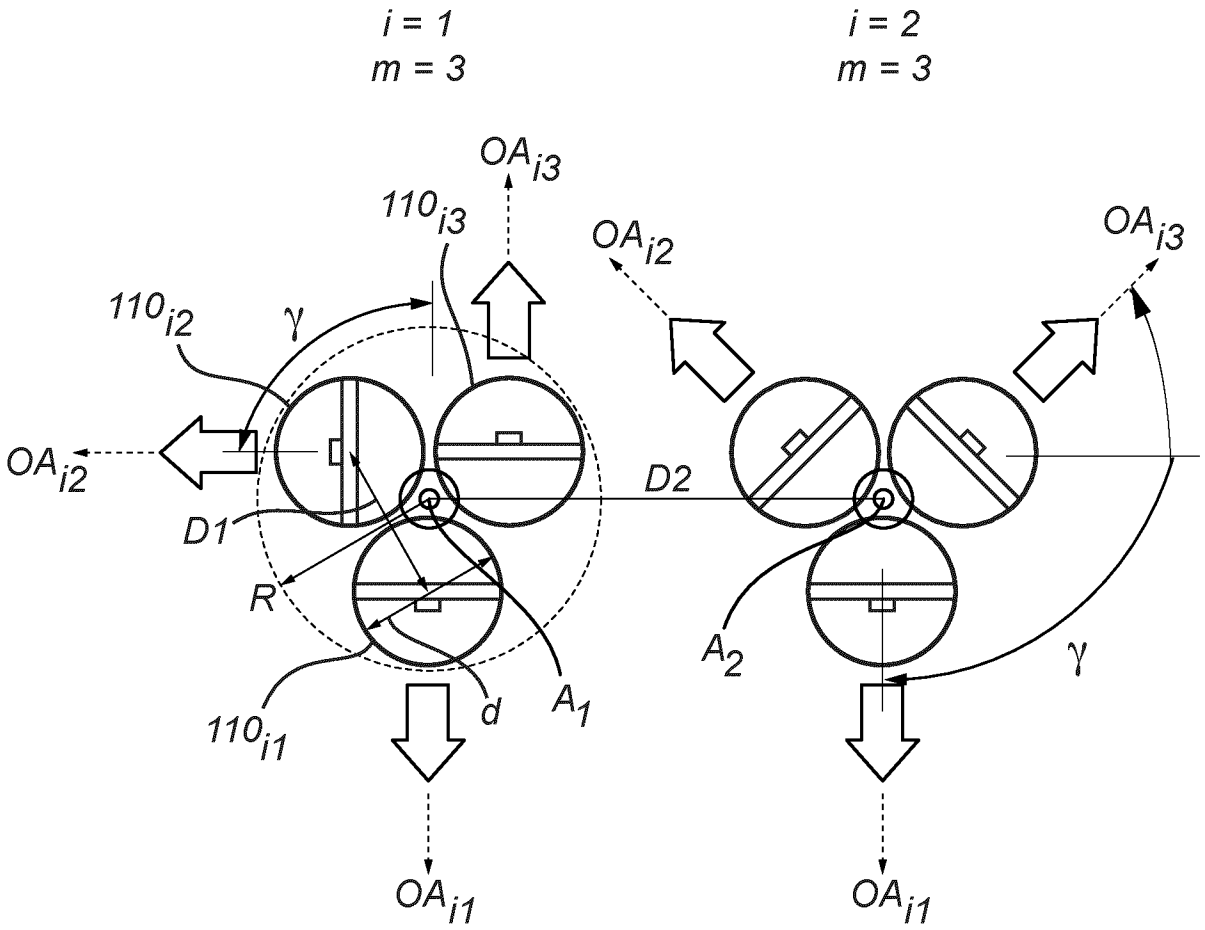
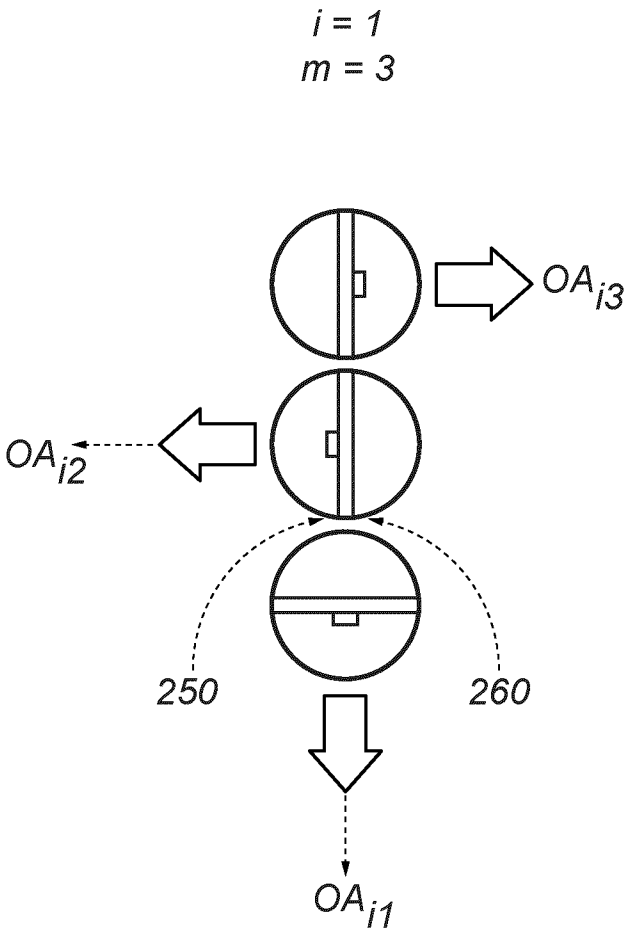

i = 1
m = 3
i = 2
m = 3
OA_i3
110_i3
OA_i2
OA_i3
110_i2
γ
OA_i2
D2
D1
R
A_2
γ
d
A_1
110_i1
OA_i1
OA_i1

Fig. 3



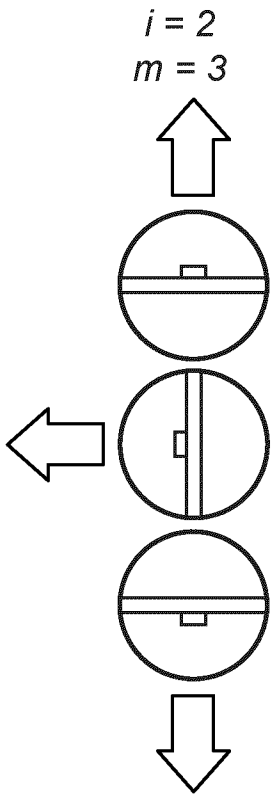


Fig. 4

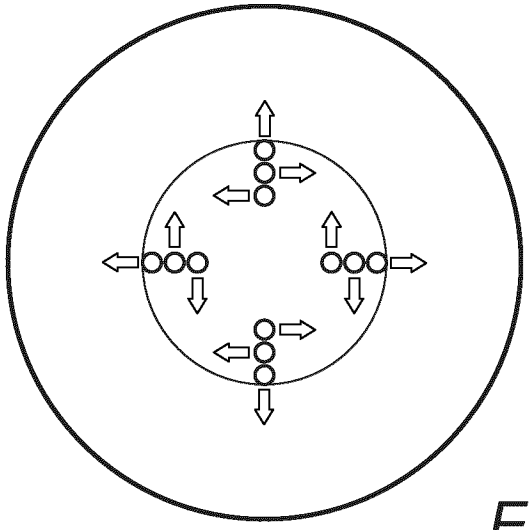


Fig. 5a

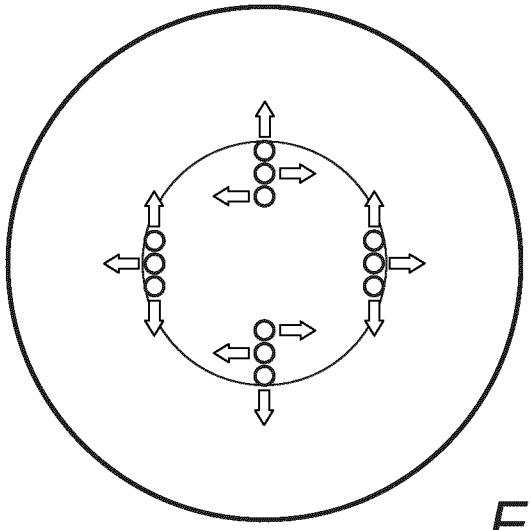


Fig. 5b

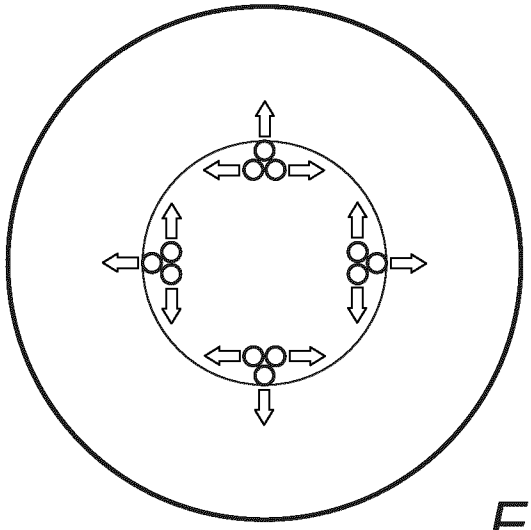


Fig. 5c

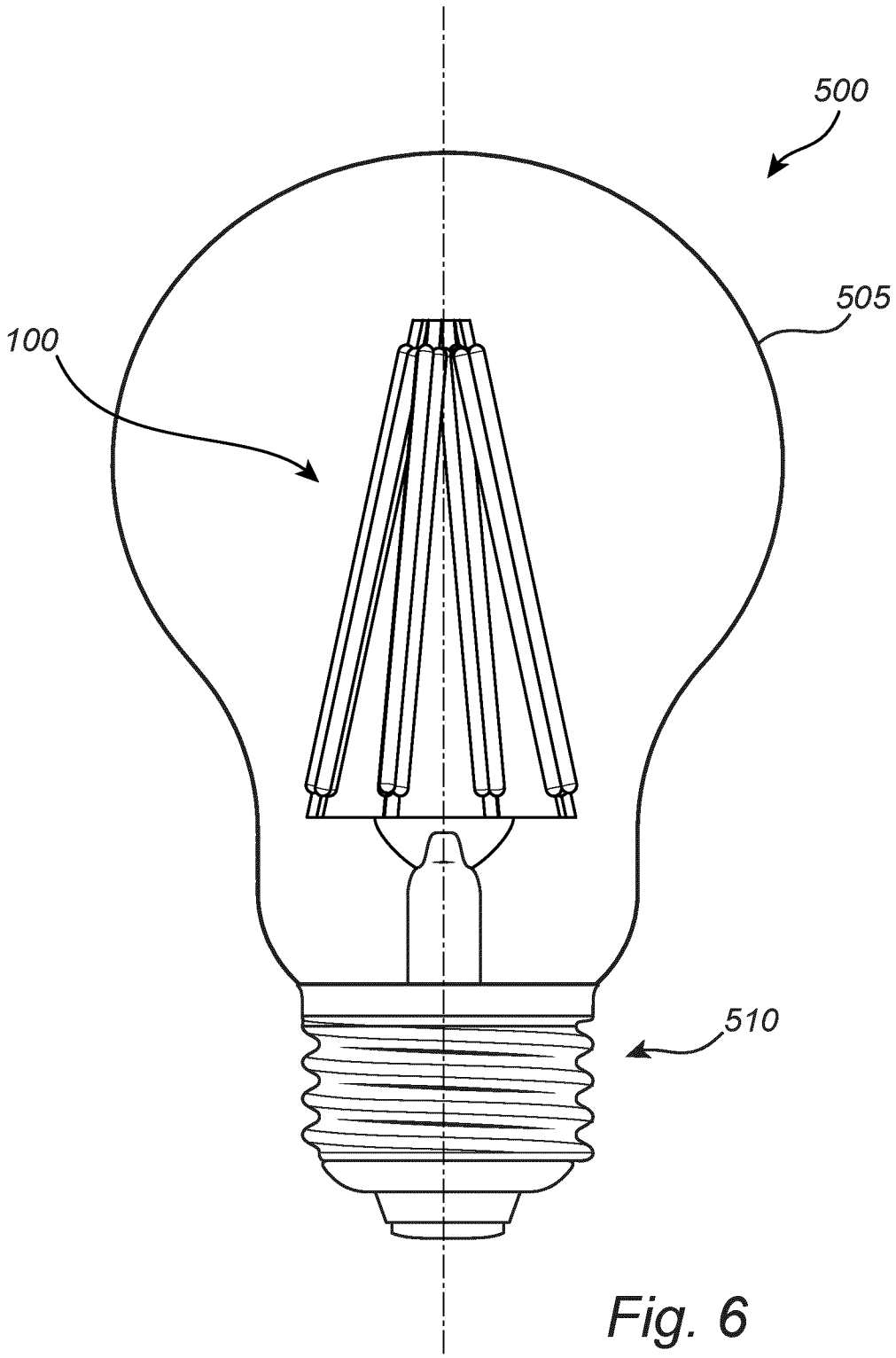


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/072070

A. CLASSIFICATION OF SUBJECT MATTER

INV. F21K9/232
ADD. F21Y115/10 H01L25/075 F21Y107/00

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)
F21K H01L F21Y

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	WO 2019/166273 A1 (SIGNIFY HOLDING BV [NL]) 6 September 2019 (2019-09-06) page 13, paragraph 1-3 figures 2a, 2b, 3b	1-12
A	EP 2 827 046 A1 (ZHEJIANG LEDISON OPTOELECTRONICS CO LTD [CN]) 21 January 2015 (2015-01-21) figures 2, 9	1-12
A	CN 205 424 484 U (ZHEJIANG LEDISON OPTOELECTRONICS CO LTD) 3 August 2016 (2016-08-03) figures 2, 3	1-12

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[x] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

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"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
8 October 2024	24/10/2024

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	Allen, Katie

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/072070

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 2017/122498 A1 (ZALKA PETER [HU] ET AL) 4 May 2017 (2017-05-04) figures 5, 6	1

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