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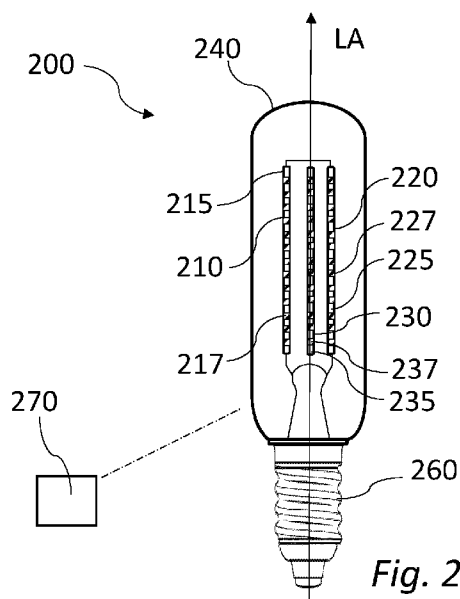


Fig. 2

(57) Abstract: There is provided a light emitting diode, LED, filament lighting device (100a) and a LED filament lamp (200). The LED filament lighting device comprises at least one first LED filament (110) comprising a plurality of first LEDs (217) arranged on a first elongated carrier (215) and configured to emit first ultraviolet, UV, light having a first centroid wavelength, λ_{c1} , in a wavelength range from 100 to 380 nm. The LED filament lighting device further comprises at least one second LED filament (120) comprising a plurality of second LEDs (427) arranged on a second elongated carrier (425) and configured to emit second UV light having a second centroid wavelength, λ_{c2} , in a wavelength range from 100 to 380 nm, wherein $\lambda_{c1} + 30\text{nm} < \lambda_{c2}$. The LED filament lighting device further comprises an envelope (140) comprising an at least partially light-transmissive material and extending along a longitudinal axis (LA). The longitudinal axis (LA) is positioned such that a cross-section of the envelope is arranged symmetrically around the longitudinal axis (LA). The envelope at least partially encloses the at least one first and second LED filaments. The at least one first and second LED filaments are asymmetrically arranged relative to the longitudinal axis (LA).

Lamp having different UV LED filaments emitting different uv light asymmetrically arranged in said lamp

FIELD OF THE INVENTION

The present invention generally relates to light emitting diode, LED, filaments. More specifically, the present invention is related to LED filaments arranged to emit ultraviolet, UV, light and arranged asymmetrically in an envelope.

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BACKGROUND OF THE INVENTION

The use of light emitting diodes (LED) 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. In particular, LED filament lamps are highly appreciated as they are very decorative.

Due to the advantageous aspects of the use of LEDs, the interest has rapidly increased to replace conventional light sources with LEDs in many lighting arrangements. It will be appreciated that this replacement, also called retrofitting, is appreciated and desired by users who wish lamps having the look of an incandescent bulb. The light source replacement (retrofitting) is often performed by removing the conventional light source(s) from the luminaire (e.g. a lamp holder) of the lighting arrangement and attaching the LEDs, LED arrangement(s) or LED device(s) into the luminaire. One of these concepts is based on LED filaments which are placed in a bulb, as the appearance of lamps of this kind are appreciated as they are highly decorative.

Furthermore, it is of interest to combine the advantageous properties of LED filaments with respect to aesthetics and light distribution purposes according to the above with the advantageous properties of disinfection (bactericidal) lighting. It will be appreciated that disinfection lighting has become a topic of renewed interest as the demand for sterilization increases. For example, UVA (315-400 nm) and/or violet light (400-420 nm) can be used for disinfection purposes, e.g. inactivating/killing bacteria.

It should also be noted that it is a wish to replace older technologies (e.g. mercury-based UV tubes) with UV LED-based solutions. Furthermore, existing arrangements

comprising LEDs arranged to emit UV light may suffer from complexity and/or operational issues regarding efficiency characteristics and/or safety.

Hence, it is an object of the present invention to combine the advantageous properties of LEDs with respect to energy efficiency and light distribution purposes with the advantageous properties of disinfection (bactericidal and/or viricidal) lighting.

SUMMARY OF THE INVENTION

It is of interest to combine the advantageous properties of LED filaments with respect to aesthetics and light distribution purposes with the advantageous properties of providing disinfection (bactericidal and/or viricidal) lighting, whilst providing a non-complex and/or conveniently operated LED filament lighting device.

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

Hence, according to a first aspect of the present invention, there is provided a light emitting diode, LED, filament lighting device comprising at least one first LED filament comprising a plurality of first LEDs arranged on a first elongated carrier and configured to emit first ultraviolet, UV, light having a first centroid wavelength, λ_{c1} , in a wavelength range from 100 to 380 nm. The LED filament lighting device further comprises at least one second LED filament comprising a plurality of second LEDs arranged on a second elongated carrier and configured to emit second UV light having a second centroid wavelength, λ_{c2} , in a wavelength range from 100 to 380 nm, where $\lambda_{c1} + 30 \text{ nm} < \lambda_{c2}$. The LED filament lighting device further comprises an envelope comprising an at least partially light-transmissive material and extending along a longitudinal axis, LA. The longitudinal axis, LA, is positioned such that a cross-section of the envelope is arranged symmetrically around the longitudinal axis, LA. The envelope at least partially encloses the at least one first and second LED filaments. The at least one first and second LED filaments are asymmetrically arranged relative to the longitudinal axis, LA.

In certain embodiments, the difference between the first centroid wavelength and the second centroid wavelength may be larger, such as for example, $\lambda_{c1} + 40 \text{ nm} < \lambda_{c2}$ or $\lambda_{c1} + 50 \text{ nm} < \lambda_{c2}$. A larger difference in centroid wavelength may improve the disinfection performance, because a larger spectral space between the first centroid wavelength and the second centroid wavelength is provided.

According to a second aspect of the present invention there is provided a LED filament lamp comprising a LED filament lighting device according to the first aspect. The LED filament lamp further comprises a base for electrically and mechanically connecting the LED filament lamp to a socket of a luminaire.

5 The LED filaments of the present invention comprises a plurality of LEDs arranged on an elongated carrier. The LEDs may be arranged in a linear array on the elongated carrier. By the term “carrier”, it is here meant an element, substrate, or the like, arranged to mechanically and/or electrically support LEDs. Hence, the plurality of LEDs may be arranged, mounted and/or mechanically coupled on/to the carrier (e.g. a substrate),
10 wherein the carrier is configured to mechanically and/or electrically support the LEDs. Furthermore, the carrier may be light transmissive and/or reflective.

By “centroid wavelength”, it is here meant a (dominant) peak wavelength, i.e. a wavelength at which the UV light reaches a maximum intensity. The relation between the first centroid wavelength, λ_{c1} , and the second centroid wavelength, λ_{c2} , is $\lambda_{c1} + 30 \text{ nm} < \lambda_{c2}$.

15 Hence, there is an offset between the first and second UV lights by at least 30 nm.

By the term “envelope” it is here meant an enclosing element, such as a cap, cover, bulb, or the like, comprising an at least partially translucent and/or transparent material. In certain embodiments, the envelope may be translucent. The envelope may preferably be, in other embodiments, transparent such that the LED filaments are visible from
20 the outside of the envelope and minimum light is lost due to (multiple) back reflection(s) of LED filament light by the envelope, thusly improving the efficiency. The present embodiment is advantageous in that the LED filament lighting device may be conveniently arranged in substantially any luminaire, lamp or LED lighting device, such as a LED filament lamp or a LED filament luminaire, lighting system, or the like. The luminaire may further
25 comprise a driver for supplying power to the LEDs of the LED filament.

By the term “asymmetrically” is meant that the LED filaments are arranged at least partially parallel along or under an angle with the longitudinal axis but not on the longitudinal axis of the envelope so that they are not symmetrical. In case there are more than one first filament and/or more than one second filament, the term “asymmetrically” is meant
30 that the center placement of the first LED filaments and/or the center of placement of the second LED filaments is not coinciding with the longitudinal axis. This means that the LED filaments are arranged asymmetrically (off-center) in an envelope or bulb of the lighting device.

For lamps using LEDs and LED filaments with wavelengths in the visible spectrum symmetry is often a requirement in order to avoid spottiness. However, UV light is not visible and therefore the symmetrical placing of the LED filaments is not critical from an aesthetic point of view. Further, since the performance of different UV LEDs may vary, placing them asymmetrically within the envelope can instead help in ensuring that the light from the different LED filaments is evenly distributed in for example a room.

Thus, the present invention is based on the idea of providing a LED filament lighting device comprising at least two LED filaments arranged asymmetrically in an envelope or bulb and arranged to emit ultraviolet light of different wavelengths. The LED filaments are configured to emit different types of UV light, wherein the centroid (peak dominant) wavelength differs between the emitted UV lights. Hence, there is provided a LED filament lighting device and LED filament lamp that are able to efficiently and safely provide disinfection (bactericidal and/or viricidal) lighting.

The present invention is advantageous in that the plurality of LEDs, that may for example be arranged in linear arrays, of the LED filament allow for a non-complex and convenient electric circuitry. In turn, this increases the service life of the LED filament and/or reduces the risk of malfunction thereof at operation.

The present invention is further advantageous in that substantially different UV wavelengths are used and a higher disinfection performance is therefore achieved because different bacteria and/or viruses have different absorption maxima. In addition, different wavelengths may use different mechanisms of inactivating bacterial and/or viruses e.g. destroying the proteins or DNA/RNA in a virus.

The present invention is further advantageous in that the number of LEDs may be smaller than LED filaments using LEDs arranged to emit white light. This is based on the fact that UV light is invisible, and the gap/distance between UV LEDs may be relatively large, which is not suitable for LED filaments with LEDs arranged to emit white light. As a consequence, the present UV LED filaments may be produced more cost-efficiently and/or be less prone to malfunction.

It will be further appreciated that the LED filament lighting device of the present invention furthermore comprises relatively few components. The relatively low number of components is advantageous in that the LED filament lighting device is relatively inexpensive to fabricate. Moreover, the relatively low number of components of the LED filament lighting device 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.

According to an embodiment of the present invention, the LED filament lighting device further comprises at least one third LED filament. The third LED filament comprises a plurality of third LEDs arranged on a third elongated carrier and configured to emit third UV light with a third centroid wavelength, λ_{c3} , in a wavelength range from 100 to 380 nm, wherein $\lambda_{c1} + 30\text{nm} < \lambda_{c2} < \lambda_{c3} - 30\text{nm}$. The envelope at least partially encloses the at least one third LED filament. The at least one third LED filament is asymmetrically arranged relative to the longitudinal axis, LA. In general, the more LED filaments emitting light in different UV wavelengths, the better disinfection performance the LED filament lighting device will have. Therefore, having at least three LED filaments emitting light in different UV wavelengths will be advantageous.

According to an embodiment, the LED filament lighting device further comprises at least one third LED filament. The third LED filament comprises a plurality of third LEDs arranged on a third elongated carrier and configured to emit third UV light with a third centroid wavelength, λ_{c3} , in a wavelength range from 100 to 380 nm, wherein $\lambda_{c1} + 50\text{nm} < \lambda_{c2} < \lambda_{c3} - 50\text{nm}$. The envelope at least partially encloses the at least one third LED filament. The at least one third LED filament is asymmetrically arranged relative to the longitudinal axis, LA. In general, the more LED filaments emitting light in different UV wavelengths, the better disinfection performance the LED filament lighting device will have. Therefore, having at least three LED filaments emitting light in different UV wavelengths will be advantageous.

In embodiments, the first UV light may be UVC light (i.e. in a wavelength range from 100 to 280 nm), the second UV light may be UVB light (i.e. in a wavelength range from 280 to 315 nm) and/or the third UV light may be UVA light (i.e. in a wavelength range from 315 to 380 nm).

According to an embodiment, at least one of the first, second and optionally third elongated carrier is light transmissive and configured to transmit at least part of the first, second and third UV light, respectively. The present embodiment is advantageous in that the elongated carriers may improve the spatial UV light distribution in case they are at least partially light transmissive. Compared to LEDs emitting visible light, UV LEDs have a lower performance. Further, there are differences in performance between different UV LEDs and UV LEDs emitting different wavelengths. The UV LEDs may further have differences in efficiency and thus different UV LEDs may need different cooling. The present embodiment

may mitigate some of these effects by providing a light transmissive elongated carrier. The light transmissive elongated carrier can ensure that the light is distributed 360 degrees, e.g., via scattering. Further, some UV LEDs need a more reliable and thus more expensive carrier, especially since lower UV wavelengths will cause more degradation to insulating layers, electrical contacts and other possible components of a printed circuit board (PCB). Thus, different UV LEDs may need different PCB requirements.

According to an embodiment, the first centroid wavelength, λ_{c1} , is in a wavelength range from 200 to 280 nm and the second centroid wavelength, λ_{c2} , is in a wavelength range from 280 to 380 nm. In the present embodiment, the first centroid wavelength is in the UVC wavelength range and the second centroid wavelength is in the UVB or UVA wavelength range. The present embodiment is advantageous in that the UVC light in the range of 100-280 nm may penetrate the skin less than UV light of a longer wavelength, such as UVB light. Consequently, the UVC light may be less harmful than other types of UV light, for example to the skin of a person. The present embodiment is further advantageous in that the UVA (and UVB) wavelength range has an improved disinfection performance, i.e. an improved operation of inactivating/killing bacteria, while the UVC wavelength range has an improved disinfection performance, i.e. an improved operation of inactivating/killing viruses.

According to an embodiment, the first LED filament is arranged at a first distance from the longitudinal axis LA, the second LED filament is arranged at a second distance from the longitudinal axis LA, and optionally the third LED filament is arranged at a third distance from the longitudinal axis LA. Each one of the first, second and third distances may be equal or larger than 5 mm. Further, the first, second and third distances may be equal to one another.

According to an embodiment, the LED filament lighting device further comprises at least one fourth LED filament comprising a plurality of fourth LEDs arranged on a fourth elongated carrier and configured to emit Violet light having a fourth centroid wavelength, λ_{c4} , in a wavelength range from 380 to 420 nm. The present embodiment is advantageous in that the fourth LED filament emits light in the visual spectrum which can visualize that the UV light is turned on. Further, the present embodiment is advantageous since the violet light also assists (helps) in disinfection.

According to an embodiment, the at least one fourth LED filament is arranged along, and on, the longitudinal axis, LA. Since the fourth LED filament emits light in the visual spectrum, it is advantageous to have it placed symmetrically in the LED filament

lighting device. By placing the fourth LED filament along the longitudinal axis LA, the fourth LED filament will shine equally in all directions and spottiness can be avoided.

According to an embodiment, the at least one fourth LED filament includes at least two fourth LED filaments arranged at a fourth distance from and symmetrically around the longitudinal axis LA. The present embodiment is advantageous since two LED filaments may provide more visual violet light that can both indicate that the UV light is turned on as well as assist in disinfection of surfaces and the like. Further, the present embodiment provides a symmetrical light since the at least two (fourth) LED filaments are placed symmetrically with regards to the longitudinal axis LA.

According to an embodiment, the at least one first LED filament includes a first number, N1, of first LED filaments. The at least one second LED filament includes a second number, N2, of second LED filaments. The at least one optional third LED filament includes a third number, N3, of third LED filaments, and $N1 < N2$ and/or $N2 < N3$. In general, the shorter the wavelength, the more harmful the UV radiation. Therefore, LED filaments emitting shorter wavelengths, such as UVC, are relatively less safe. It may therefore be advantageous to have more of the LED filaments with the longer wavelengths.

According to an embodiment, the at least one fourth LED includes a fourth number, N4, of fourth LED filaments, and $N4 < N1$, $N4 < N2$ and/or $N4 < N3$. The fourth LED filaments may be arranged symmetrically in the LED filament lighting device in order to provide an aesthetically pleasing lighting.

According to an embodiment, each first LED filament comprises M1 first LEDs. Each second LED filament comprises M2 second LEDs, wherein $M1 < M2$. Further, optionally each third LED filament comprises M3 third LEDs, wherein $M2 < M3$. Depending on the application or intended use, different UV light may be needed. However, it may be advantageous to have the maximum amount of LEDs emitting light in the wavelengths that certain bacteria are most susceptible to. This may for example be provided by the LEDs of the second LED filament. In certain embodiments, it may be preferable for LED filaments emitting shorter wavelengths to include fewer LEDs. Further, having a large number of LEDs emitting UV light of shorter wavelengths may not be allowed due to safety reasons. Further, LEDs emitting shorter wavelengths may also need more space and cooling, why it may be advantageous to have fewer of these.

According to an embodiment, the first LEDs are arranged on the first LED filament at a first pitch, P1. The second LEDs are arranged on the LED filament at a second pitch, P2, wherein $P1 > P2$. Further, optionally the third LEDs are arranged on the third LED

filament at a third pitch, P_3 , wherein $P_2 > P_3$. By “pitch” is here meant the number of LEDs per unit length of the LED filaments. Since LEDs emitting shorter wavelengths are less efficient and need more cooling, a larger pitch may be advantageous. Therefore, in some embodiments, the LED filaments comprising LEDs emitting light in lower wavelengths may have a larger pitch.

According to an embodiment, a first elongated light transmissive encapsulant covers at least part of the plurality of first LEDs and at least part of a major surface of the first elongated carrier. A second elongated light transmissive encapsulant covers at least part of the plurality of second LEDs and at least part of a major surface of the second elongated carrier, and/or optionally a third elongated light transmissive encapsulant covers at least part of the plurality of third LEDs and at least part of a major surface of the third elongated carrier. The present embodiment is advantageous in that the light outcoupling may be improved, and thus the efficiency of the LED filaments may be improved. By the term “encapsulant”, it is here meant a material, element, arrangement, or the like, which is configured or arranged to at least partially surround, encapsulate and/or enclose the set of linear arrays and the carrier. The encapsulant may be translucent, i.e., it may comprise a translucent material. By the term “translucent material”, it is here meant a material, composition and/or substance which is translucent and/or transparent. The encapsulant may further comprise a luminescent material configured to scatter light emitted from the LEDs.

According to an embodiment, at least one of the first, second and/or optional third elongated encapsulant comprises a light scattering material to scatter the first, second and/or optional third UV light, respectively. The light scattering material may improve the spatial UV light distribution. The light scattering material may be any light scattering material. It may for example comprise a silicone matrix with at least one of Al_2O_3 , BaSO_4 , SiO_2 , TiO_2 , CaF_2 , CaCO_3 , and BaTiO_3 particles.

According to an embodiment, the LED filament lighting device further comprises a controller for individually controlling the first UV light emitted by the at least one first LED filament, the second UV light emitted by the at least one second LED filament, and optionally the third UV light emitted by the at least one third LED filament. The LED filament lighting device may further comprise an antenna in order to receive signals, for example from an external controller.

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

5 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-b schematically show LED filament lighting devices according to exemplifying embodiments of the present invention.

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

Figs. 3a-b schematically show LED filament lighting devices according to exemplifying embodiments of the present invention.

Fig. 4 schematically shows LED filaments for use in LED filaments lighting devices according to exemplifying embodiments of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

Figs. 1a-b schematically shows LED filament lighting devices 100a, 100b according to exemplifying embodiment of the present invention.

Figure 1a discloses a LED filament lighting device 100a according to an
20 exemplifying embodiment of the present invention. The LED filament lighting device comprises a first LED filament 110 and a second LED filament 120. The first LED filament 110 comprises a plurality of first LEDs (not shown) arranged on a first elongated carrier (not shown) and configured to emit first ultraviolet, UV, light having a first centroid wavelength, λ_{c1} , in a wavelength range from 100 to 380 nm. The second LED filament 120 comprises a
25 plurality of second LEDs (not shown) arranged on a second elongated carrier (not shown) and configured to emit second UV light having a second centroid wavelength, λ_{c2} , in a wavelength range from 100 to 380 nm. Even though the wavelengths λ_{c1} , λ_{c2} are in the same range, they are different from each other. The relation between the wavelengths is $\lambda_{c1} + 30\text{nm} < \lambda_{c2}$. The LED filament lighting device 100a further comprises an envelope 140 comprising
30 an at least partially light-transmissive material and extending along a longitudinal axis LA. In Figure 1a, the longitudinal axis extends out from the figure. The longitudinal axis LA is positioned such that a cross-section of the envelope 140 is arranged symmetrically around the longitudinal axis LA. The envelope 140 at least partially encloses the first and second LED filaments 110, 120. Further, the first and second LED filaments 110, 120 are asymmetrically

arranged relative to the longitudinal axis LA. In other words, the positioning of the LED filaments 110, 120 is made so that they are not symmetrical with regards to the longitudinal axis LA. Compared to lighting devices using visible light, there is no immediate need for symmetry when using UV light since it is invisible to the human eye. Instead, other features and properties may be more relevant to manufacture the LED filament lighting device 100a. For example, depending on the UV light emitted from the LED filaments 110, 120, different placements of the LED filaments may be selected. This may be based on a difference between the different types of UV LEDs and further on the fact that some UV light may be more needed than others.

In certain embodiments, the difference between the first centroid wavelength λ_{c1} and the second centroid wavelength λ_{c2} may be larger, such as, for example, $\lambda_{c1} + 40 \text{ nm} < \lambda_{c2}$ or $\lambda_{c1} + 50 \text{ nm} < \lambda_{c2}$. A larger difference in centroid wavelength may improve the disinfection performance, because a larger spectral space of the UV wavelength range is covered. The enhancement is based on the insight that different bacteria and/or different viruses have different absorption maxima at different wavelengths.

The LED filament lighting device 100b in Figure 1b, as compared to the embodiment of Figure 1a, further comprises a third LED filament 130 comprising a plurality of third LEDs (not shown) arranged on a third elongated carrier (not shown) and configured to emit third UV light with a third centroid wavelength, λ_{c3} , in a wavelength range from 100 to 380 nm, where $\lambda_{c1} + 30 \text{ nm} < \lambda_{c2} < \lambda_{c3} - 30 \text{ nm}$. The envelope 140 at least partially encloses the at least one third LED filament 130. The third LED filament 130 is asymmetrically arranged relative to the longitudinal axis, LA. By adding multiple different LEDs emitting UV light at different wavelengths, the disinfective properties of the lighting device is increased. In certain embodiment, it is instead envisioned that $\lambda_{c1} + 50 \text{ nm} < \lambda_{c2} < \lambda_{c3} - 50 \text{ nm}$. As an example, the first UV light may be UVC light (i.e., in a wavelength range from 100 to 280 nm), the second UV light may be UVB light (i.e., in a wavelength range from 280 to 315 nm) and/or the third UV light may be UVA light (i.e., in a wavelength range from 315 to 380 nm).

The elongated carriers (not shown in Figures 1a and 1b) may further be light transmissive and configured to transmit at least part of the first, second and third UV light. The elongated carriers may improve the spatial UV light distribution in case they are at least partially light transmissive. Compared to LEDs emitting visible light, UV LEDs have a lower performance. Further, there are differences in performance between different UV LEDs and UV LEDs emitting different wavelengths. The UV LEDs may further have differences in

efficiency and thus different UV LEDs may need different cooling. Having light transmissive elongated carriers may mitigate some of these effects. The light transmissive elongated carriers can ensure that the light is distributed 360 degrees, e.g., via scattering.

Further, the number of LED filaments 110, 120, 130 may vary depending on the application. For example, the at least one first LED filament 110 may include a first number, N_1 , of first LED filaments. The second LED filament 120 may include a second number, N_2 , of second LED filaments, and the third LED filament 130 may include a third number, N_3 , of third LED filaments. Further, in certain embodiments, the relation between the number of filaments may be $N_1 < N_2$ and/or $N_2 < N_3$.

Further, the pitch of the LEDs of the LED filaments 110, 120, 130 may vary. For example, the first LEDs may be arranged on the first LED filament 110 at a first pitch, P_1 . The second LEDs may be arranged on the second LED filament 120 at a second pitch, P_2 , where $P_1 > P_2$. Further, the third LEDs may be arranged on the third LED filament at a third pitch, P_3 , where $P_2 > P_3$.

Further, in some embodiments a first elongated light transmissive encapsulant may be covering at least part of the plurality of first LEDs and at least part of a major surface of the first elongated carrier of the first LED filament 110. Also, a second elongated light transmissive encapsulant may be covering at least part of the plurality of second LEDs and at least part of a major surface of the second elongated carrier of the second LED filament 120.

Further, a third elongated light transmissive encapsulant may cover at least part of the plurality of third LEDs and at least part of a major surface of the third elongated carrier of the third LED filament 130. In the present embodiment, the light outcoupling may be improved, and thus the efficiency of the LED filaments may also be improved. In this embodiment, at least one of the first, second and third elongated encapsulants may comprise light scattering material to scatter the first, second and third UV light respectively. The light scattering material may comprise a silicone matrix with at least one of Al_2O_3 , $BaSO_4$, SiO_2 , TiO_2 , CaF_2 , $CaCO_3$, and $BaTiO_3$ particles. Further, as an example, the first encapsulant may be configured to reflect UV light emitted from the plurality of second LEDs. For example, the first encapsulant may comprise a material which reflects UV light in the wavelength range of 100-380 nm, which would help in spreading the emitted UV light.

The LED filament lighting devices 100a, 100b of Figures 1a and 1b may further have at least one fourth LED filament comprising LEDs arranged to emit violet light. This may be used to let the user know when the LED filament lighting device 100a, 100b is turned on and this aspect will be discussed in more detail with reference to Figures 3a and 3b.

In the embodiment shown in Figures 1a and in 1b, the first LED filament 110 is arranged at a first distance D1 from the longitudinal axis LA. Further, the second LED filament is arranged at a second distance D2 from the longitudinal axis LA. Both D1 and D2 may be larger or equal to 5 mm, they may also be equal to each other. Further, as seen in Figure 1b, in case the LED filament lighting device 100b comprises a third LED filament 130, the third LED filament 130 may be arranged at a third distance D3 from the longitudinal axis LA. D3 may also be larger or equal to 5 mm. Further, in some embodiments, the three distances may be equal such that $D1=D2=D3$.

Fig. 2 schematically shows a LED filament lamp 200 according to an exemplifying embodiment of the present invention.

The LED filament lamp 200 comprises a LED filament lighting device in accordance to any embodiments described in relation to any of the other figures of the present disclosure. Furthermore, the LED filament lamp 200 comprises a base 260 for electrically and mechanically connecting the LED filament lamp 200 to a socket of a luminaire. The LED filament lamp 200 comprises an envelope or cover 240, which is exemplified as being bulb-shaped. The envelope 240 may comprise an at least partially light transmissive (e.g. transparent) material, and the envelope 240 at least partially encloses the LED filaments.

LED filament lamps 200 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.

The LED filament lamp 200 in figure 2 comprises a first LED filament 210, a second LED filament 220 and a third LED filament 230. The LED filaments are arranged asymmetrically relative to the longitudinal axis LA. In Figure 2, the plurality of LEDs 217, 227, 237 are arranged along the respective elongated carriers 215, 225, 235 of the LED filaments 210, 220, 230. The first LEDs 217 are configured to emit first UV light with a first centroid wavelength, λ_{c1} , in a wavelength range from 100 to 380 nm. The second LEDs 227 are configured to emit second UV light with a second centroid wavelength, λ_{c2} , in a wavelength range from 100 to 380 nm. The third LEDs 237 are configured to emit third UV light with a third centroid wavelength, λ_{c3} , in a wavelength range from 100 to 380 nm. The wavelengths are different such that $\lambda_{c1}+30\text{nm} < \lambda_{c2} < \lambda_{c3}-30\text{nm}$. In some preferred embodiments, λ_{c1} is in a wavelength range from 200 to 280 nm and λ_{c2} is in a wavelength range from 280 to 380 nm.

The LED filament lamp 200 further comprises a controller 270 for individually controlling the first UV light emitted by the first LED filament 210, the second UV light emitted by the second LED filament 220 and the third UV light emitted by the third LED filament 230. Further, the LED filament lamp 200 or the LED filament lighting device of the LED filament lamp 200 may comprise an antenna. The antenna may receive or transmit signals to the controller 270.

Fig. 3a schematically illustrates an embodiment of the LED filament lighting device 300a according to an embodiment of the present invention.

The LED filament lighting device 300a may have any features of the embodiments described above with reference to the previous Figures, such as for example Figure 1b. The LED filament light device 300a further comprises a fourth LED filament 350a comprising a plurality of fourth LEDs (not shown) arranged on a fourth elongated carrier (not shown) and configured to emit violet light having a fourth centroid wavelength, λ_{c4} , in a wavelength range from 380 to 420 nm. The fourth LED filament 350a may assist in visualizing/showing for a user that the LED filament lighting device 300a is turned on. Further, the violet light may also contribute to of surfaces.

In Figure 3a, the fourth LED filament 350 is arranged along, and on, the longitudinal axis LA (not shown) and is thusly arranged symmetrically in the envelope 340. This ensures that the visible light is both letting the user know that the LED lighting device 300a is turned on as well as providing an aesthetically pleasing lighting without spottiness (or at least with reduced spottiness).

Fig. 3b schematically illustrates an embodiment of the LED filament lighting device 300b according to an embodiment of the present invention.

The LED filament lighting device 300b may have any features of the embodiments described above with reference to the previous Figures, such as for example Figure 1b. The LED filament lighting device 300b further comprises two fourth LED filaments 350 arranged at a fourth distance D4 and arranged symmetrically around the longitudinal axis LA. The LED filament lighting device 300b may comprise any number of fourth LEDs 350 arranged in the envelope 340 and arranged symmetrically around the longitudinal axis LA in order to provide a violet light both being aesthetical and having disinfective properties.

Fig. 4 schematically illustrates LED filaments 410, 420, 430, 440 for use in LED filament lighting devices according to exemplifying embodiments of the present invention.

The first LED filament 410 comprises a plurality of first LEDs 417 arranged on a first elongated carrier 415. The first LEDs are configured to emit first UV light having a first centroid wavelength, λ_{c1} , in a wavelength range from 100 to 380 nm. The second LED filament 420 comprises a plurality of second LEDs 427 arranged on a second elongated carrier 425. The second LEDs are configured to emit second UV light having a second centroid wavelength, λ_{c2} , in a wavelength range from 100 to 380 nm. The third LED filament 430 comprises a plurality of third LEDs 437 arranged on a third elongated carrier 435. The third LEDs are configured to emit third UV light having a third centroid wavelength, λ_{c3} , in a wavelength range from 100 to 380 nm. The fourth LED filament 440 comprises a plurality of fourth LEDs 447 arranged on a fourth elongated carrier 445. The fourth LEDs 447 are configured to emit violet light having a fourth centroid wavelength, λ_{c4} , in a wavelength range from 380 to 420 nm.

In Figure 4, the number of LEDs 417, 427, 437, 447 are the same in every LED filament 410, 420, 430, 440. However, this may not always be the case. In some embodiments, the first LED filament 410 comprises M1 first LEDs, the second LED filament 420 comprises M2 second LEDs, where $M1 < M2$. Further, the third LED filament may comprise M3 third LEDs, where $M2 < M3$. The number M4 of fourth LEDs 447 may also vary and may for example be larger than the numbers M1, M2, M3. For example, to provide a pleasant visible light, there may be a need for more LEDs of the fourth LED filament 440.

Further, the pitch, i.e. the number of LEDs per unit length, of the LED filaments 410, 420, 430, 440 may also vary. For example, the first LEDs 417 may be arranged on the first LED filament 410 at a first pitch, P1, the second LEDs may be arranged on the second LED filament at a second pitch, P2, where $P1 > P2$. Further, the third LEDs may be arranged on the third LED filament at a third pitch, P3, where $P2 > P3$. In order to achieve an aesthetically pleasing lighting, the fourth LEDs 440 may be arranged so that the distance between adjacent LEDs is less than a certain distance, for example 4 mm. This may ensure that the fourth LEDs 440 provides a pleasing line pattern.

In a LED filament lighting device or LED filament lamp as discussed in relation to the previous figures, any number of first, second, third and fourth LED filaments 410, 420, 430, 440 may be used. For example, for a LED filament lighting device, there may be a first number, N1, of first LED filaments 410, a second number, N2, of second LED filaments 420, and a third number, N3, of third LED filaments 430. As an example, in embodiments including both first, second and third LED filaments 410, 420, 430 the relation between the number of filaments may be $N1 < N2$ and/or $N2 < N3$. In case the embodiment also

includes a number of fourth LED filaments 440, the LED filament lighting device may comprise a fourth number, N_4 , of fourth LED filaments 440, where $N_4 < N_1$, $N_4 < N_2$ and/or $N_4 < N_3$. The first, second and third LED filaments 410, 420, 430 may then be arranged asymmetrically around a longitudinal axis of the LED filament lighting device while the

5 fourth LED filaments 440 are arranged symmetrically with regards to the longitudinal axis.

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 carrier, the LEDs, etc., may have different shapes,

10 dimensions and/or sizes than those depicted/described.

CLAIMS:

1. A light emitting diode, LED, filament lighting device (100a) comprising:
at least one first LED filament (110) comprising a plurality of first LEDs (217) arranged on a first elongated carrier (215) and configured to emit first ultraviolet, UV, light having a first centroid wavelength, λ_{c1} , in a wavelength range from 100 to 380 nm;

5 at least one second LED filament (120) comprising a plurality of second LEDs (227) arranged on a second elongated carrier (225) and configured to emit second UV light having a second centroid wavelength, λ_{c2} , in a wavelength range from 100 to 380 nm, wherein $\lambda_{c1}+30\text{nm} < \lambda_{c2}$; and

an envelope (140) comprising an at least partially light-transmissive material and extending along a longitudinal axis LA, wherein the longitudinal axis LA is positioned
10 such that a cross-section of the envelope is arranged symmetrically around the longitudinal axis LA, wherein the envelope at least partially encloses the at least one first and second LED filaments, and wherein the at least one first and second LED filaments are asymmetrically arranged relative to the longitudinal axis LA,

15 wherein at least one of the first and second elongated carrier is light transmissive for transmitting at least part of the first and second UV light, and

wherein the first LED filament is arranged at a first distance (D1) from the longitudinal axis LA, the second LED filament is arranged at a second distance (D2) from the longitudinal axis LA, wherein each one of the first and second distance is equal or larger than
20 5 mm, and/or wherein the first and second distance is equal to one another.

2. The LED filament lighting device according to claim 1, further comprising at least one third LED filament (130) comprising a plurality of third LEDs (237) arranged on a third elongated carrier (235) and configured to emit third UV light with a third centroid
25 wavelength, λ_{c3} , in a wavelength range from 100 to 380 nm, wherein $\lambda_{c1}+30\text{nm} < \lambda_{c2} < \lambda_{c3}-30\text{nm}$, and wherein the envelope at least partially encloses the at least one third LED filament, and wherein the at least one third LED filament is asymmetrically arranged relative to the longitudinal axis LA.

3. The LED filament lighting device according to claim 2, wherein at least one of the third elongated carrier is light transmissive for transmitting at least part of the third UV light.

5 4. The LED filament lighting device according to any one of the preceding claims, wherein λ_{c1} is in a wavelength range from 200 to 280 nm and λ_{c2} is in a wavelength range from 280 to 380 nm.

5. The LED filament lighting device according to claims 2 or 3, wherein the third
10 LED filament is arranged at a third distance (D3) from the longitudinal axis LA, wherein each one of the third distance is equal or larger than 5 mm, and/or wherein the first, second and third distances is equal to one another.

6. The LED filament lighting device according to any one of the preceding
15 claims, further comprising at least one fourth LED filament (350) comprising a plurality of fourth LEDs (457) arranged on a fourth elongated carrier (455) and configured to emit Violet light having a fourth centroid wavelength, λ_{c4} , in a wavelength range from 380 to 420 nm.

7. The LED filament lighting device according to claim 6, wherein the at least
20 one fourth LED filament is arranged along, and on, the longitudinal axis LA, or wherein the at least one fourth LED filament includes at least two LED filaments arranged at a fourth distance (D4) from and symmetrically around the longitudinal axis LA.

8. The LED filament lighting device according to any one of the preceding
25 claims, wherein the at least one first LED filament includes a first number, N1, of first LED filaments, wherein the at least one second LED filament includes a second number, N2, of second LED filaments, wherein the at least one optional third LED filament includes a third number, N3, of third LED filaments, and wherein $N1 < N2$ and/or $N2 < N3$.

30 9. The LED filament lighting device according to claim 6, wherein the at least one fourth LED filament includes a fourth number, N4, of fourth LED filaments, and wherein $N4 < N1$, $N4 < N2$ and/or $N4 < N3$.

10. The LED filament lighting device according to any one of the preceding claims, wherein each first LED filament comprises M1 first LEDs, wherein each second LED filament comprises M2 second LEDs, wherein $M1 < M2$, and optionally, wherein each third LED filament comprises M3 third LEDs, wherein $M2 < M3$.

5

11. The LED filament lighting device according to any one of the preceding claims, wherein the first LEDs are arranged on the first LED filament at a first pitch, P1, the second LEDs are arranged on the second LED filament at a second pitch, P2, wherein $P1 > P2$, and optionally the third LEDs are arranged on the third LED filament at a third pitch, P3, wherein $P2 > P3$.

10

12. The LED filament lighting device according to any one of the preceding claims, wherein a first elongated light transmissive encapsulant covers at least part of the plurality of first LEDs and at least part of a major surface of the first elongated carrier, wherein a second elongated light transmissive encapsulant covers at least part of the plurality of second LEDs and at least part of a major surface of the second elongated carrier, and/or optionally wherein a third elongated light transmissive encapsulant covers at least part of the plurality of third LEDs and at least part of a major surface of the third elongated carrier.

15

13. The LED filament lighting device according to claim 12, wherein at least one of the first, second and/or optional third elongated encapsulant comprises a light scattering material to scatter the first, second and/or optional third UV light.

20

14. The LED filament lighting device according to any one of the preceding claims, further comprising a controller for individually controlling the first UV light emitted by the at least one first LED filament, the second UV light emitted by the at least one second LED filament, and optionally the third UV light emitted by the at least one third LED filament.

25

15. A LED filament lamp (200) comprising the LED filament lighting device according to any one of the preceding claims and a base (260) for electrically and mechanically connecting the LED filament lamp to a socket of a luminaire.

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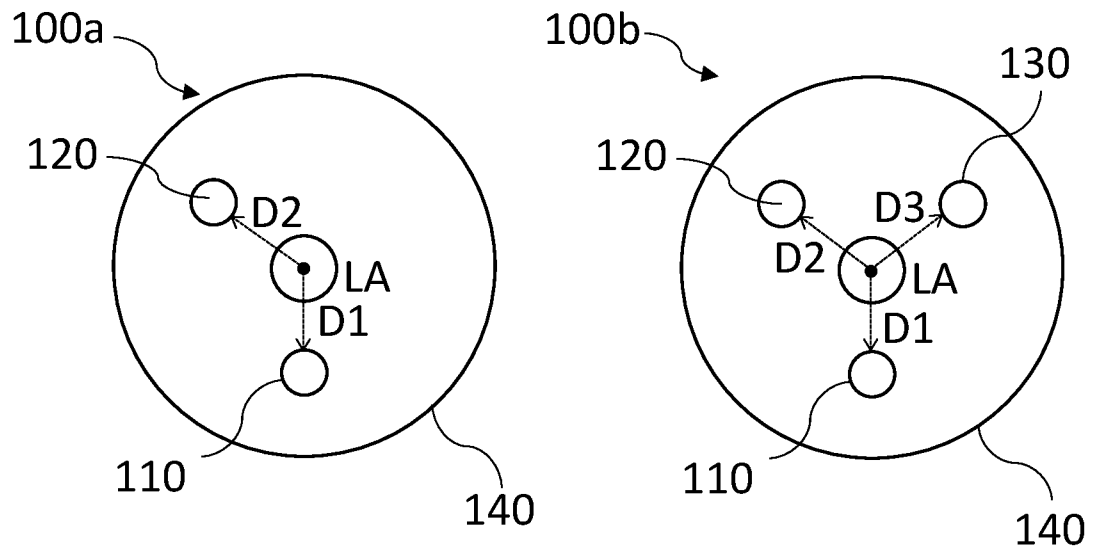


Fig. 1a

Fig. 1b

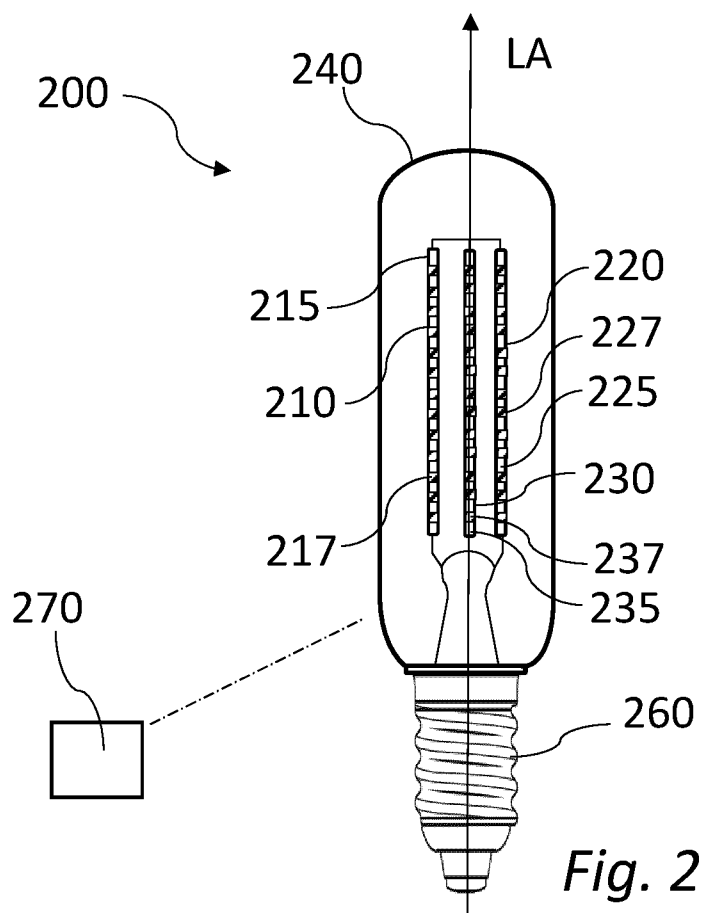
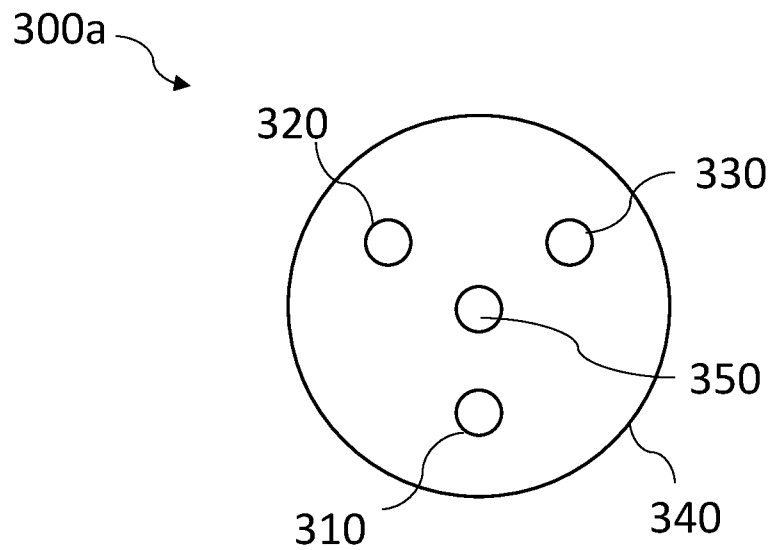
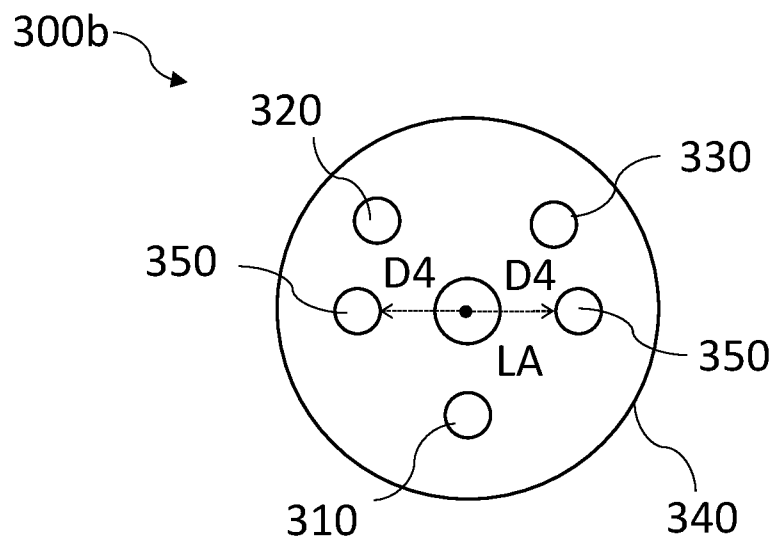


Fig. 2

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*Fig. 3a**Fig. 3b*

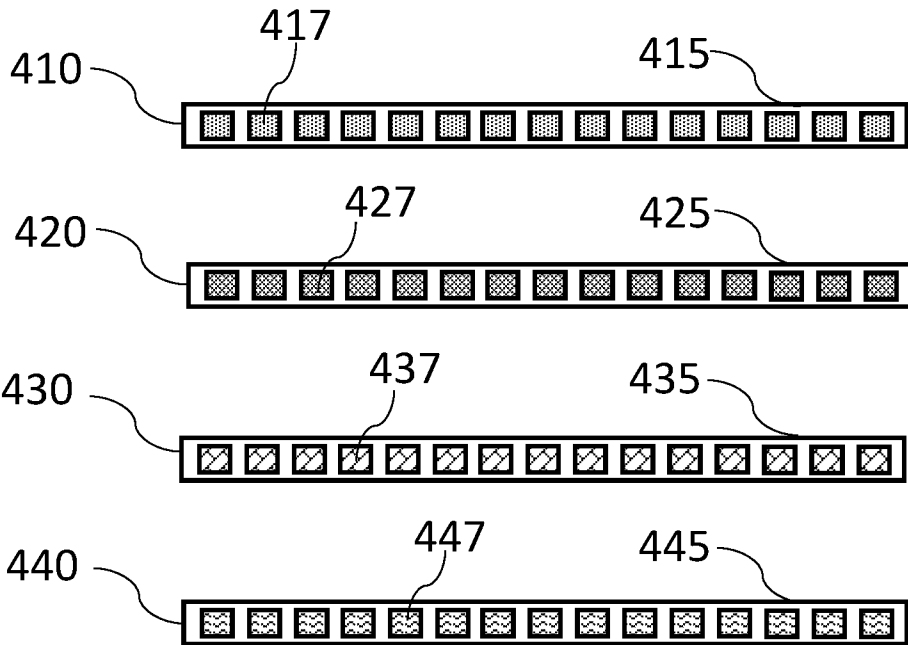


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2023/070948

A. CLASSIFICATION OF SUBJECT MATTER**INV. A61L9/20****ADD.**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61L F21K

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**

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X	WO 2017/181751 A1 (HEALTH UV TECH CO LTD [CN]) 26 October 2017 (2017-10-26) paragraph [0029] - paragraph [0033] paragraph [0037] paragraph [0046] - paragraph [0047] figures 1, 7, 8 -----	1-5, 8-11, 14, 15
X	WO 2022/011229 A1 (UNIV CALIFORNIA [US]) 13 January 2022 (2022-01-13) page 4, line 26 - line 28 page 6, line 19 - line 21 page 10, line 12 - line 15 page 14, line 13 - line 16 page 16, line 17 - page 17, line 23 figure 5 ----- -/--	1, 3, 4, 8-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"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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"&" document member of the same patent family

Date of the actual completion of the international search

9 October 2023

Date of mailing of the international search report

17/10/2023

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2023/070948

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