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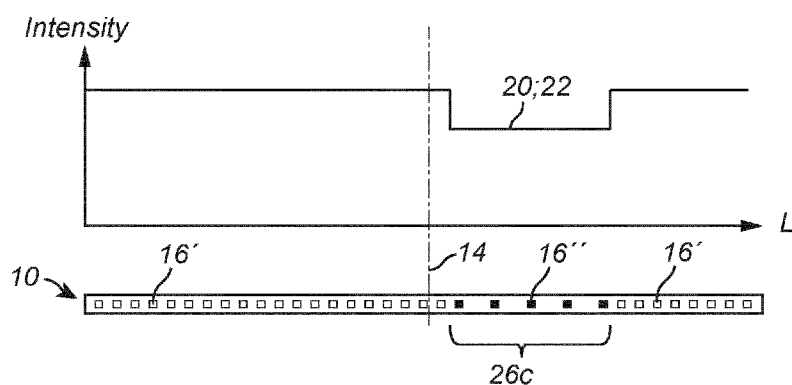


Fig. 1e

(57) Abstract: A lighting device (10) for disinfection, comprising: an elongated substrate (12) having a length (L); and a plurality of light emitting diodes, LEDs, (16) adapted to emit light (20), wherein the emitted light includes one of a) UV light and b) UV light and violet light, the plurality of LEDs being mounted on the elongated substrate along the length of the substrate in at least one row (18), wherein at least one of the intensity (22) and the spectral distribution (24) of the light emitted from the plurality of LEDs in operation varies asymmetrically along the length of the elongated substrate.



Lighting device for disinfection

FIELD OF THE INVENTION

The present invention relates to a lighting device, for example an LED strip, for disinfection. The present invention also relates to a lighting system comprising such a lighting device. The present invention also relates to a disinfection method using such a
5 lighting device.

BACKGROUND OF THE INVENTION

It is desired to protect people from the spread of bacteria and viruses such as influenza or against the outbreak of novel viruses like COVID-19. To this end, UV light from
10 UV LEDs and/or lasers can be used for disinfection.

For example, WO2019117853 (A1) discloses a flexible UV light generation sheet constructed as a ribbon or tape, such as a rectangular configuration in which a width is considerably smaller than a length, such as where the length is 5 times greater (or more) than the width.

15 GB2583881A discloses an LED based lighting system for providing mixed light for illumination and disinfection that combines ultraviolet (UV-A) light and white light with an adjustable correlated colour temperature (CCT) value. The lighting system includes a first plurality of LEDs emitting red light and a second plurality of LEDs emitting blue light and including a photo-luminescent material for shifting the output of the second plurality of
20 LEDs to produce white light. A controller controls the individual LEDs or groups of LEDs. A waveguide material is further provided, having a mixing region for mixing the produced light and an output region for outputting the white light. Tunable adjustments to the output of the non-UV-A LEDs, or to all of the LEDs, result in an overall mixed output conforming to a target CCT value.

25 US2020/254125A1 discloses a system of disinfecting an area using germicidal radiation. The system is configured to capture images of an environment, analyze the images to determine locations of a person or unprotected skin of a person in the environment, and control one or more germicidal radiation emitters to decontaminate the environment where the person or exposed skin of persons in the environment are not located. The system and

method allow for safe decontamination of an environment using hazardous levels of germicidal radiation while occupied by a person who may not be fully protected from the radiation.

5 SUMMARY OF THE INVENTION

It is an object of the present invention to improve the safety and/or effectiveness of UV disinfection.

According to a first aspect of the invention, this and other objects are achieved by a lighting device for disinfection, comprising: an elongated substrate having a length; and
10 a plurality of light emitting diodes (LEDs) adapted to emit light, wherein the emitted light includes one of a) UV light in a wavelength range from 100 to 380 nm and b) UV light in a wavelength range from 100 to 380 nm and violet light in a wavelength range from 380 to 420 nm, the plurality of LEDs being mounted on the elongated substrate along the length of the substrate in at least one row, wherein at least one of the intensity and the spectral distribution
15 of the light emitted from the plurality of LEDs in operation varies asymmetrically along the length of the elongated substrate.

The lighting device may for example be an LED strip.

LEDs should here be construed as including any diodes emitting light, such as light emitting diodes, laser diodes, superluminescent diodes, etc.

20 Intensity may be radiant flux (optical W_{opt}) per unit area (W/m²), wherein the radiant flux is the radiant energy transmitted through (e.g.) an exit window of the LEDs. The SI unit of radiant flux is Watt (W).

If the LEDs are not mounted along the complete length of the elongated substrate, the light emitted from the LEDs should vary asymmetrically along the portion of
25 the length of the elongated substrate where the LEDs are mounted. The length of the elongated substrate refers to the longest dimension of the elongated substrate.

The present invention is based on the understanding that by varying the UV/violet light asymmetrically along the length of the elongated substrate of the lighting device (LED strip), safety may be improved in that one or more portions along the lighting
30 device that may be in level with a person's skin (e.g. the person's head and/or hands) can have lower intensity and/or longer wavelength. At the same time, the effectiveness of the disinfection may be improved in that at least one other portion along the lighting device, for example near a floor and in level with the person's shoes, can have higher intensity and/or shorter wavelength to surely disinfect potentially highly contagious areas (like those shoes).

In other words, more UV LEDs and/or the most effective UV LEDs may be arranged close to surfaces which needs most disinfection (e.g. toilet opening and door handle), whereas less UV LEDs and/or the least harmful UV LEDs may be arranged at a height where the skin of a person is uncovered (e.g. hand and face).

5 The plurality of LEDs may be asymmetrically arranged along the length of the elongated substrate such that the intensity of the light emitted from the plurality of LEDs in operation varies asymmetrically along the length of the elongated substrate. An advantage of this is that varying intensity may be realized although all the LEDs may be connected in the same way and/or be driven at the same current. The lighting device may here have higher and
10 lower densities of LEDs (different pitch, gradient in pitch, various gradient in pitches) along the length of the elongated substrate.

 At least one LED of the plurality of LEDs may in operation be driven at a higher current by a controller than at least one other LED of the plurality of LEDs such that the intensity of the light emitted from the plurality of LEDs varies asymmetrically along the
15 length of the elongated substrate. An advantage of this is that varying intensity may be realized with high flexibility. The ‘at least one LED’ may here be several neighboring LEDs, for example at least five neighboring LEDs. The ‘at least one other LED’ may here be several neighboring LEDs, for example at least five neighboring LEDs. The controller could be included in the lighting device.

20 Some LEDs of the plurality of LEDs may be connected by a first circuitry part and other LEDs of the plurality of LEDs are connected by a second circuitry part different than the first circuitry part such that the intensity of the light emitted from the plurality of LEDs in operation varies asymmetrically along the length of the elongated substrate. The LEDs connected by the first circuitry part may for example be connected in series, and the
25 LEDs connected by the second circuitry part may be connected in parallel, whereby the intensity at the LEDs connected in series becomes higher than the intensity at the LEDs connected in parallel. Alternatively, the LEDs connected by the first circuitry part are connected in parallel, and the LEDs connected by the second circuitry part are connected in parallel, but the number of parallel tracks is different.

30 The intensity of the light emitted from the plurality of LEDs in operation may have a maximum at at least one end portion of the elongated substrate, wherein the intensity of the light emitted from the plurality of LEDs in operation has at least one minimum at an intermediate portion of the elongated substrate. The maximum intensity may for example be achieved by at least one of high LED density, individual control, and series-connected LEDs

at the end portion(s). The minimum intensity could be achieved by at least one of low LED density, individual control, and parallel-connected LEDs at the intermediate portion. In use, one end portion (with maximum intensity) of the elongated substrate may be close to a ceiling, and the other/opposite end portion (with maximum intensity) may be close to a floor.

- 5 The intermediate portion (with minimum intensity) of the elongated substrate could be 160-190 cm from one end of the elongated substrate, such that the intermediate portion is use (the lighting device vertically erected from the floor) gets in level with people's heads.

The plurality of LEDs may include LEDs of a first type and LEDs of a second type different than the first type, wherein the first and second types are selected from the group of: extreme UV-C LEDs adapted to emit ultraviolet radiation with a wavelength in the range of 100-190 nm, far UV LEDs adapted to emit ultraviolet radiation with a wavelength in the range of 190-230 nm, near UV-C LEDs adapted to emit ultraviolet radiation with a wavelength in the range of 230-280 nm, UV-B LEDs adapted to emit ultraviolet radiation with a wavelength in the range of 280-315 nm, UV-A LEDs adapted to emit ultraviolet radiation with a wavelength in the range of 315-380 nm, and violet LEDs adapted to emit light with a wavelength in the range of 380-420 nm. In this way, the spectral distribution of the light emitted from the plurality of LEDs in operation can vary along the length of the elongated substrate. The number of extreme UV-C/far UV/near UV-C LEDs is preferably lower than the number of UV-B/UV-A/violet LEDs. The lighting device preferably comprises at least ten LEDs of any UV type.

The LEDs of the first type may be distributed asymmetrically along the length of the elongated substrate, wherein the LEDs of the second type are distributed asymmetrically along the length of the elongated substrate. In this way, a highly adapted spectral distribution along the length of the elongated substrate may be provided, which (further) may provide safety and/or effectiveness of the UV disinfection.

Alternatively, the LEDs of the first type may be arranged asymmetrically along the length of the substrate, wherein the LEDs of the second type are arranged symmetrically along the length of the substrate. The LEDs of the second type arranged symmetrically along the length of the substrate are preferably violet LEDs (adapted to emit light with a wavelength in the range of 380-420 nm), because they are safe, kill bacteria, and provide a purple glow. The violet LEDs preferably provide 405 nm light.

The plurality of LEDs may further include LEDs of a third type different than the first type and the second type, the third type being selected from the aforementioned group. The LEDs of the third type may be arranged asymmetrically along the length of the

substrate. Preferably, the LEDs of the first type are extreme UV-C LEDs or far-UV LEDs, the LEDs of the second type are UV-B LEDs or violet LEDs, and the LEDs of the third type are near UV-C LEDs. The difference in max peak between the types of LEDs is preferably at least 30 nm.

5 The plurality of LEDs includes at least one extreme UV-C LED adapted to emit ultraviolet radiation with a wavelength in the range of 100-190 nm and/or at least one far-UV LED adapted to emit ultraviolet radiation with a wavelength less than 230 nm and/or at least one near UV-C LED adapted to emit ultraviolet radiation with a wavelength in the range of 230-280 nm, the at least one extreme UV-C LED and/or the at least one far-UV
10 LED and/or the at least one near UV-C LED being mounted on at least one end portion of the elongated substrate. In use, one end portion (with extreme UV-C/far-UV/near UV-C LEDs) of the elongated substrate may be close to a ceiling, and the other/opposite end portion (also with extreme UV-C/ far-UV/UV-C LEDs) may be close to a floor. An intermediate portion of the elongated substrate between the end portions could be devoid of extreme UV-C/far-
15 UV/near UV-C LEDs.

The length of the elongated substrate may be in the range of 1-3 m (preferably 2-3 m). The elongated substrate may have a length-to-width ratio (L/W) of at least 20. As mentioned above, the present lighting device may for example be an LED strip for disinfection.

20 According to a second aspect of the invention, there is provided a lighting system, comprising: a lighting device for disinfection according to the first aspect; and a controller adapted to individually or in groups (e.g. typewise or in subsets of say 2-10 LEDs) control the plurality of LEDs of the lighting device. The controller may in operation drive at least one LED of the plurality of LEDs at a higher current than at least one other LED of the
25 plurality of LEDs, such that the intensity of the light emitted from the plurality of LEDs may vary asymmetrically along the length of the elongated substrate. This controller may be external of the lighting device/LED strip.

The lighting system may further comprise a sensor adapted to detect at least one property of a person adjacent the lighting device, wherein the controller is configured to
30 individually or in groups dynamically (i.e. over time) control the plurality of LEDs of the lighting device based on the at least one property detected by the sensor. Specifically, the at least one property of a person may be one or more of: a height of the person, a position of the person's head, a position of the person's eyes, and a position of the person's hand(s), wherein the controller is configured to individually or in groups dynamically control the plurality of

LEDs of the lighting device such that the intensity of the light emitted from the plurality of LEDs is locally reduced in level with the person's head, eyes, and/or hand(s) as detected by the sensor and/or such that the wavelength of the light emitted from the plurality of LEDs is locally increased in level with the person's head, eyes, and/or hand(s) as detected by the sensor. In this way, the light emitted from the plurality of LEDs may be dynamically adapted for different persons (e.g. a shorter child vs. a longer adult), which (further) may provide safety and/or effectiveness of the UV disinfection. The sensor could for example be a radar for height detection and/or a camera with face/eye/hand detection functionality.

According to a third aspect of the invention, there is provided a disinfection method, comprising: providing a lighting device according to the first aspect or a lighting device of the system according to the second aspect at a disinfection location, for example a lavatory or a door frame or a corridor; and operating the lighting device such that at least one of the intensity and the spectral distribution of the light emitted from the plurality of LEDs of the lighting device varies asymmetrically along the length of the elongated substrate of the lighting device. This aspect may exhibit the same or similar features and technical effects as the previous aspect(s), and vice versa.

At least a portion of the lighting device may be substantially vertically arranged at the disinfection location. 'Substantially' may here be construed as +/- 10 deg or +/- 5 deg. The (complete) lighting device may for example be vertically arranged on a wall of the lavatory/restroom/corridor (e.g. from the floor to the ceiling preventing shadowing effect) or on a jamb of the door frame. The lighting device may alternatively be arranged in an upside down U-shape, e.g. along both jambs and the head of a door frame. Two lighting devices of the type disclosed herein could also be (substantially vertically) arranged facing each other, for example one on each jambs of a door frame or one on either side of a corridor. A third lighting device of the type disclosed herein could be substantially horizontally arranged along the head of the door frame.

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

BRIEF DESCRIPTION OF THE DRAWINGS

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

Figs. 1a-1l are top views of lighting devices according to embodiments of the present invention.

Fig. 2 shows a lighting system according to an embodiment of the present invention.

Figs. 3a-g show various applications of the lighting device(s) according to the present invention.

5 Like reference numerals refer to like elements throughout.

DETAILED DESCRIPTION

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

Figures 1a-1l each discloses a lighting device 10 for disinfection according to an embodiment of the present invention. The lighting device 10 is specifically an elongated (disinfection) lighting device. The lighting device 10 may for example be an LED strip.
15

The lighting device 10 comprises an elongated substrate 12 having a length L. The length L may for example be in the range of 1-3 m, preferably 2-3 m. The elongated substrate 12 may have a length-to-width ratio (L/W) of at least 20. In other words, the length
20 L may be at least 20 times greater than the width W of the elongated substrate 12. Imaginary line 14 indicates half the length L of the elongated substrate 12. The elongated substrate 12 may be flexible. Alternatively, the elongated substrate 12 may be rigid. The elongated substrate 12 may for example be a (flexible) printed circuit board (PCB).

The lighting device 12 further comprises a plurality of LEDs 16. The LEDs 16
25 are mounted on an LED mounting surface 17 of the elongated substrate 12 along the length L of the elongated substrate 12 in at least one row. In Figures 1a-g and 1k-1l, the LEDs 16 of the lighting device 10 are mounted in a single (straight) row 18. In Figures 1h-i, the LEDs 16 of the lighting device 10 are mounted in two (straight and parallel) rows 18a-b. In Figure 1j, the LEDs 16 of the lighting device 10 are mounted in three (straight and parallel) rows 18a-c.
30 The LEDs 16 are preferably mounted along (substantially) the complete length of the elongated substrate 12.

The plurality of LEDs 16 are adapted to emit light 20, wherein the emitted light includes one of a) UV light and b) UV light and violet light. To this end, the plurality of LEDs 14 may include LEDs of at least one of the types in Table 1 presented hereinbelow.

The ultraviolet wavelength range is defined as light in a wavelength range from 100 to 380 nm and can be divided into different types of UV light / UV wavelength ranges (Table 1). Different UV wavelengths of radiation may have different properties and thus may have different compatibility with human presence and may have different effects

5 when used for disinfection (Table 1).

Table 1: Properties of different types of UV wavelength light

Name	Short name	Wavelength (nm)	(Relative) sterilization/inactivation effectiveness		Safe Radiation	Vitamin D generation	Ozone generation
			Bacteria	Viruses			
Violet	V	380-420	+/-	-	+		
Ultra-violet A	UV-A	315-380	+	-	+		
Ultra--violet B	UV-B	280-315	+	+/-	+/-	+	
Near ultra-violet C	Near UV-C	230-280	+	+	-		
Far ultra-violet	Far UV	190-230	+	+	+		+/-
Extreme ultra-violet C	Extreme UV-C	100-190	+	+	-		+

Each UV type / wavelength range may have different benefits and/or drawbacks. Relevant aspects may be (relative) sterilization effectiveness, safety (regarding radiation), vitamin D production (in a skin of a human being or animal), and ozone production (as result of its radiation). Depending on an application a specific type of UV light or a specific combination of UV light types may be selected and provides superior performance over other types of UV light. UV-A may be (relatively) safe and may kill bacteria, but may be less effective in killing viruses. UV-B may be (relatively) safe when a low dose (i.e. low exposure time and/or low intensity) is used, may kill bacteria, and may be moderately effective in killing viruses. UV-B may also have the additional benefit that it can be used effectively in the production of vitamin D in a skin of a person or animal. Near UV-C may be relatively unsafe, but may effectively kill bacteria and viruses. Far UV may also be effective in killing bacteria and viruses, but may be (relatively to other UV-C wavelength ranges) (rather) safe. Far-UV light may generate some ozone which may be harmful for human beings and animals. Extreme UV-C may also be effective in killing bacteria and viruses, but may be relatively unsafe. Extreme UV-C may generate ozone which may be undesired when exposed to human beings or animals. In some application ozone may be

desired and may contribute to disinfection, but then its shielding from humans and animals may be desired. Hence, in the table “+” for ozone production especially implies that ozone is produced which may be useful for disinfection applications, but may be harmful for humans / animals when they are exposed to it. Hence, in many applications this “+” may actually be
 5 undesired while in others, it may be desired.

According to the present invention, at least one of the intensity 22 and the spectral distribution 24 of the light 20 emitted from the plurality of LEDs 16 in operation varies asymmetrically along the length L of the elongated substrate 12. This may improve the safety and/or effectiveness of UV disinfection.

10 In Figure 1a, the plurality of LEDs 16 are asymmetrically arranged along the length L of the elongated substrate 12, such that the intensity 22 of the light 20 emitted from the plurality of LEDs 16 in operation varies asymmetrically along the length L of the elongated substrate 12. The varying intensity 22 (in “side view”) is schematically indicated in Figure 1a above the lighting device 10. Specifically, there is in Figure 1a a higher density
 15 (lower pitch p1) of LEDs at two end portions 26a-b of the elongated substrate 12, wherein end portion 26a is longer than end portion 26b, and a lower density (higher pitch p2) of LEDs at an intermediate portion 26c of the elongated substrate 12 between the end portions 26a-b. All the LEDs 16 could here be UV LEDs of the same type. Or the LEDs could include LEDs of at least two of the types in Table 1, such that also the spectral distribution of the light 20
 20 could vary (asymmetrically) along the length L of the elongated substrate 12.

In Figure 1b, at least one LED of the plurality of LEDs 16 is in operation driven at a higher current by a controller 28 than at least one other LED of the plurality of LEDs 16, such that the intensity 22 of the light 20 emitted from the plurality of LEDs 16 varies asymmetrically along the length L of the elongated substrate 12. Specifically in Figure
 25 1b, the LEDs at end portion 26a are driven at a higher current than the remaining LEDs, resulting in a higher intensity at this portion. The controller 28 is generally adapted to individually or in groups control the plurality of LEDs 16. The controller 28 could be provided on the elongated substrate 12 or be separate/remote (see Figure 2).

In Figure 1c, some LEDs 16a of the plurality of LEDs 16 are connected by a
 30 first circuitry part and other LEDs 16c of the plurality of LEDs are connected by a second different circuitry part, such that a current level applied to the LEDs 16a is different from the current level applied to the other LEDs 16c, whereby the intensity 22 of the light 20 emitted from the plurality of LEDs 16 in operation varies asymmetrically along the length L of the elongated substrate 12. The LEDs 16a are in Figure 1c connected in series ($I_{\text{tot}}=I_1=I_2=I_3$ etc.),

LEDs 16b are also connected in series, and the LEDs 16c are connected in parallel ($I_{\text{tot}}=I_1+I_2+I_3$ etc.), whereby the intensity at the LEDs 16a and LEDs 16b connected in series becomes higher than the intensity at the LEDs 16c connected in parallel, even if the total input current and the pitch are the same.

5 From Figures 1a-c, it is appreciated that the intensity 22 of the light 20 may have a maximum at one or both of the end portion 26a-b of the elongated substrate 12, and at least one minimum at an intermediate portion of the elongated substrate 12, like intermediate portion 26c. The maximum intensity may for example be at least 1.5 times, or preferably at least 2 times, the minimum intensity.

10 In Figure 1d, the plurality of LEDs 16 consists of LEDs 16' of a first type at end portions 26a-b and LEDs 16'' of a second type different than the first type at intermediate portion 26c. The LEDs of the first type may for example be extreme UV-C/far UV/near UV-C LEDs, and the LEDs of the second type may UV-B/UV-A. In this way, the spectral distribution 24 of the light 20 emitted from the plurality of LEDs 16 in operation can
15 vary along the length L of the elongated substrate. The varying spectral distribution 24 (in "side view") is schematically indicated in Figure 1d above the lighting device 10, wherein the wavelength at the end portions 26a-b is shorter than at the intermediate portion 26c. The difference in wavelength ($\Delta\lambda$) here and in other embodiments/variants could for example be >30nm or >60 nm.

20 The lighting device 10 in Figure 1e is similar to that of Figure 1d, apart from a lower density of LEDs 16'' at the intermediate portion 26c. In this way, not only the spectral distribution/wavelength is different, but also the intensity at the intermediate position 26c is lower.

In Figure 1f, the plurality of LEDs 16 consists of LEDs of three different
25 types. The LEDs 16' of the first type may for example be extreme UV-C/far UV/near UV-C LEDs at the end portions 26a-b, the LEDs 16'' of the second type may UV-B/UV-A at portion 26c, and the LEDs 16''' of the third type may be violet LEDs between portions 26a and 26c and between portions 26b and 26c. In this way, the spectral distribution 24 may be more carefully varied. Furthermore, since the violet LEDs 16''' emits visible light, they can
30 indicate for a user where the safer portion 26c is located.

The lighting device in Figure 1g is similar to that of Figure 1f, apart from a lower density of LEDs at portion 26c, whereby the intensity at portion 26c is lower (like in Figure 1e). Also, the LEDs at portion 26c could be of the first type.

The lighting device in Figure 1h is similar to that of Figure 1d, but further comprises a second row 18b of LEDs of a third type, namely violet LEDs.

The lighting device in Figure 1i is similar to that of Figure 1h, apart from that the LEDs of the second row 18b are white LEDs 30 adapted to emit (visible) white light.

5 In Figure 1j, the plurality of LEDs 16 includes LEDs 16' of a first type at (end portions 26a-b) and LEDs of a second, different type (at the intermediate portion 26c) in a first row 18a. The LEDs 16 further includes LEDs 16''' of a third type, namely violet LEDs, in a second row 18b. The lighting device 10 in Figure 1j further includes white LEDs 30 mounted on the elongated substrate 12 along the length of the substrate in a third row 18c.

10 The lighting device 10 in Figure 1k is similar to that of Figure 1d, apart from that a white LEDs 30 is arranged between each two adjacent UV LEDs 16.

Finally in Figure 1l, LEDs of different types may partially overlap. For example, UV-A LEDs 16' may overlap or intermingle with UV-B LEDs 16'', and the UV-B LEDs 16'' may further overlap or intermingle with UV-C LEDs 16'''.

15 Figure 2 schematically illustrates a lighting system 32 according to an embodiment of the present invention. The lighting system 32 generally comprises at least one (vertically arranged) lighting device 10/LED strip for disinfection, like any of the lighting devices 10 of Figures 1a-k, and a controller 28. The controller 28 is generally adapted to individually or in groups (e.g. typewise) control the plurality of LEDs 16 of the lighting device 10. The controller 28 may be electrically connected to the lighting device 10. The controller 28 may in operation for example drive at least one LED of the plurality of LEDs 16 at a higher current than at least one other LED of the plurality of LEDs 16, such that the intensity 22 of the light 20 emitted from the plurality of LEDs 16 may vary asymmetrically along the length L of the elongated substrate 12, like in Figure 1b.

25 In Figure 2, the lighting system 32 further comprises a sensor 34. The sensor 34 may be connected to the controller 28. The sensor 34 adapted to detect at least one property of a person 36 adjacent the lighting device 10, wherein the controller 28 is configured to individually or in groups dynamically (i.e. over time) control the plurality of LEDs 16 of the lighting device 10 based on the at least one property detected by the sensor 34. Specifically, the at least one property of a person 36 may be one or more of: a height H of the person 36, a position of the person's head 38, a position of the person's eyes 40, and a position of the person's hand(s) 42. To this end, sensor 34 could for example be a radar for height detection and/or a camera with face/eye/hand detection functionality.

The controller 28 may specifically be configured to individually or in groups dynamically control the plurality of LEDs 16 of the lighting device(s) 10 such that the intensity 22 of the light 20 emitted from the plurality of LEDs 16 is locally reduced in level with the person's head 38, eyes 40, and/or hand(s) 42 as detected by the sensor 34 and/or
5 such that the wavelength 24 of the light 20 emitted from the plurality of LEDs 16 is locally increased in level with the person's head 38, eyes 40, and/or hand(s) 42 as detected by the sensor 34. This is in Figure 2 illustrated for a shorter child 36' at a time t1 (left) and a longer adult at a different time t2 (right), wherein the intensity 22 is locally reduced and the wavelength 24 is locally increased in level with the head 38 as detected by the sensor 34.
10 Locally and dynamically increasing the wavelength 24 may be realized by having different types of LEDs equally distributed along the length L and by (individually) turning the LEDs with longer wavelength on in level with e.g. the head 38 and/or hand(s) 42 whereas the LEDs with shorter wavelength at that level are dimmed or off.

Turning to Figures 3a-g, the lighting device 10 may be provided at a
15 disinfection location, for example a lavatory 44 (Figure 3a) or a door frame 46 (Figures 3b-e) or a corridor 48 (Figures 3f-g).

At least a portion of the lighting device 10 may be substantially vertically arranged at the disinfection location 44, 46, 48. The (complete) lighting device 10 may for example be vertically arranged on a wall 50 of the lavatory 44 or corridor 48, e.g. from the
20 floor 52 to the ceiling 54 (Figures 3a and 3f), or on a jamb 56 of the door frame 46 (Figure 3b).

The lighting device 10 may alternatively be arranged in an upside down U-shape, e.g. along both jambs 56 and the head 58 of a door frame 46 (Figure 3c).

Two lighting devices 10 of the type disclosed herein could also be
25 (substantially vertically) arranged facing each other, for example one on each jamb 56 of a door frame 46 (Figure 3d) or one on either side of a corridor 48 (Figure 3g).

A third lighting device 10 of the type disclosed herein could be substantially horizontally arranged along the head 58 of the door frame 46 (Figure 3e).

The person skilled in the art realizes that the present invention by no means is
30 limited to the preferred embodiments described above. On the contrary, many modifications and variations are possible within the scope of the appended claims.

Additionally, variations to the disclosed embodiments can be understood and effected by the skilled person in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does

not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS:

1. A lighting device (10) for disinfection, comprising:
an elongated substrate (12) having a length (L); and
a plurality of light emitting diodes (LEDs) (16) adapted to emit light (20),
wherein the emitted light includes one of a) UV light in a wavelength range from 100 to 380
5 nm and b) UV light in a wavelength range from 100 to 380 nm and violet light in a
wavelength range from 380 to 420 nm, the plurality of LEDs being mounted on the elongated
substrate along the length of the substrate in at least one row (18),
wherein the plurality of LEDs includes at least one extreme UV-C LED
adapted to emit ultraviolet radiation with a wavelength in the range of 100-190 nm and/or at
10 least one far-UV LED adapted to emit ultraviolet radiation with a wavelength less than 230
nm and/or at least one UV-C LED adapted to emit ultraviolet radiation with a wavelength in
the range of 230-280 nm, the at least one extreme UV-C LED and/or the at least one far-UV
LED and/or the at least one UV-C LED being mounted on at least one end portion (26a; 26b)
of the elongated substrate, and,
15 wherein at least one of the intensity (22) and the spectral distribution (24) of
the light emitted from the plurality of LEDs in operation varies asymmetrically along the
length of the elongated substrate.
2. A lighting device according to claim 1, wherein the plurality of LEDs are
20 asymmetrically arranged along the length of the elongated substrate such that the intensity of
the light emitted from the plurality of LEDs in operation varies asymmetrically along the
length of the elongated substrate.
3. A lighting device according to claim 1 or 2, wherein at least one LED of the
25 plurality of LEDs in operation is driven at a higher current by a controller (28) than at least
one other LED of the plurality of LEDs such that the intensity of the light emitted from the
plurality of LEDs varies asymmetrically along the length of the elongated substrate.

4. A lighting device according to any one of the preceding claims, wherein some LEDs (16a; 16b) of the plurality of LEDs are connected by a first circuitry part and other LEDs (16c) of the plurality of LEDs are connected by a second circuitry part different than the first circuitry part such that the intensity of the light emitted from the plurality of LEDs in
5 operation varies asymmetrically along the length of the elongated substrate.

5. A lighting device according to any one of the preceding claims, wherein the intensity of the light emitted from the plurality of LEDs in operation has a maximum at at least one end portion (26a; 26b) of the elongated substrate, and wherein the intensity of the
10 light emitted from the plurality of LEDs in operation has at least one minimum at an intermediate portion (26c) of the elongated substrate.

6. A lighting device according to any one of the preceding claims, wherein the plurality of LEDs includes LEDs (16') of a first type and LEDs (16'') of a second type
15 different than the first type, and wherein the first and second types are selected from the group of: extreme UV-C LEDs adapted to emit ultraviolet radiation with a wavelength in the range of 100-190 nm, far UV LEDs adapted to emit ultraviolet radiation with a wavelength in the range of 190-230 nm, near UV-C LEDs adapted to emit ultraviolet radiation with a wavelength in the range of 230-280 nm, UV-B LEDs adapted to emit ultraviolet radiation
20 with a wavelength in the range of 280-315 nm, UV-A LEDs adapted to emit ultraviolet radiation with a wavelength in the range of 315-380 nm, and violet LEDs adapted to emit light with a wavelength in the range of 380-420 nm.

7. A lighting device according to claim 6, wherein the LEDs of the first type are
25 distributed asymmetrically along the length of the elongated substrate, and wherein the LEDs of the second type are distributed asymmetrically along the length of the elongated substrate.

8. A lighting device according to claim 6 or 7, wherein the plurality of LEDs further includes LEDs (16''') of a third type different than the first type and the second type,
30 the third type being selected from said group of: extreme UV-C LEDs adapted to emit ultraviolet radiation with a wavelength in the range of 100-190 nm, far UV LEDs adapted to emit ultraviolet radiation with a wavelength in the range of 190-230 nm, near UV-C LEDs adapted to emit ultraviolet radiation with a wavelength in the range of 230-280 nm, UV-B LEDs adapted to emit ultraviolet radiation with a wavelength in the range of 280-315 nm,

UV-A LEDs adapted to emit ultraviolet radiation with a wavelength in the range of 315-380 nm, and violet LEDs adapted to emit light with a wavelength in the range of 380-420 nm.

9. A lighting device according to any one of the preceding claims, wherein a
5 further extreme UV-C LED and/or a further far-UV LED and/or a further UV-C LED is being mounted on the other end portion (26a; 26b) of the elongated substrate.
10. A lighting device according to any one of the preceding claims, wherein the
length of the elongated substrate is in the range of 1-3 m, and/or wherein the elongated
10 substrate has a length-to-width ratio (L/W) of at least 20.
11. A lighting system (32), comprising:
a lighting device (10) for disinfection according to any one of the preceding
claims; and
15 a controller (28) adapted to individually or in groups control the plurality of LEDs (16) of the lighting system.
12. A lighting system according to claim 11, further comprising:
a sensor (34) adapted to detect at least one property (H; 38; 40; 42) of a person
20 (36) adjacent the lighting device, wherein the controller is configured to individually or in groups dynamically control the plurality of LEDs of the lighting device based on the at least one property detected by the sensor.
13. A lighting system according to claim 12, wherein the at least one property of a
25 person is one or more of: a height (H) of the person, a position of the person's head (38), a position of the person's eyes (40), and a position of the person's hand or hands (42), and wherein the controller is configured to individually or in groups dynamically control the plurality of LEDs of lighting device such that the intensity (22) of the light emitted from the plurality of LEDs is locally reduced in level with the person's head, eyes, and/or hand(s) as
30 detected by the sensor and/or such that the wavelength (24) of the light emitted from the plurality of LEDs is locally increased in level with the person's head, eyes, and/or hand(s) as detected by the sensor.
14. A disinfection method, comprising:

providing a lighting device (10) according to any one of the claims 1-10 or a lighting device (10) of the system (32) according to any one of the claims 11-13 at a disinfection location, for example a lavatory (44) or a door frame (46) or a corridor (48); and operating the lighting device such that at least one of the intensity (22) and the spectral distribution (24) of the light (20) emitted from the plurality of LEDs (16) of the lighting device varies asymmetrically along the length (L) of the elongated substrate (12) of the lighting device.

15. A method according to claim 14, wherein the at least a portion of the lighting device is substantially vertically arranged at the disinfection location.

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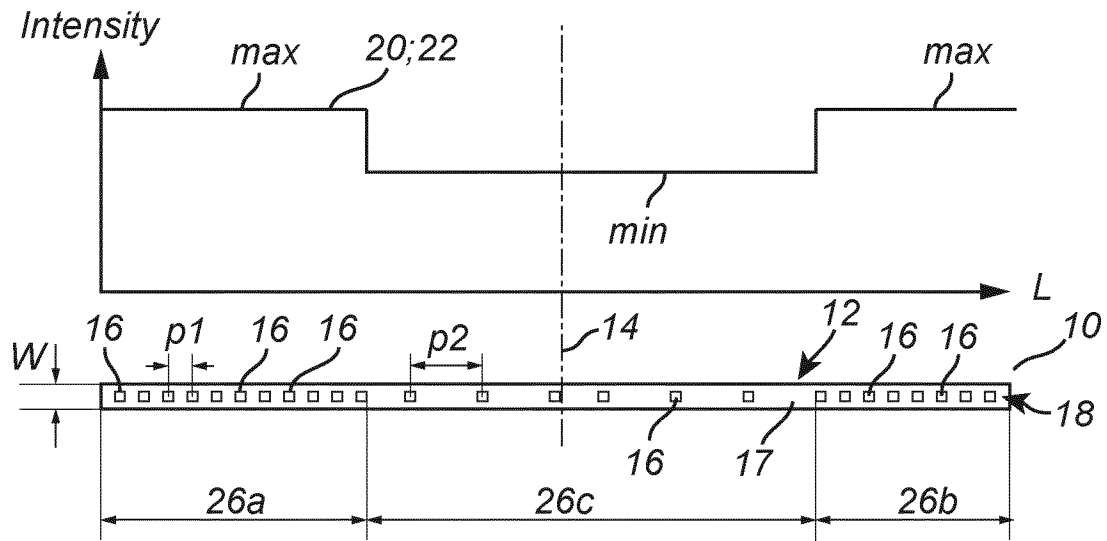


Fig. 1a

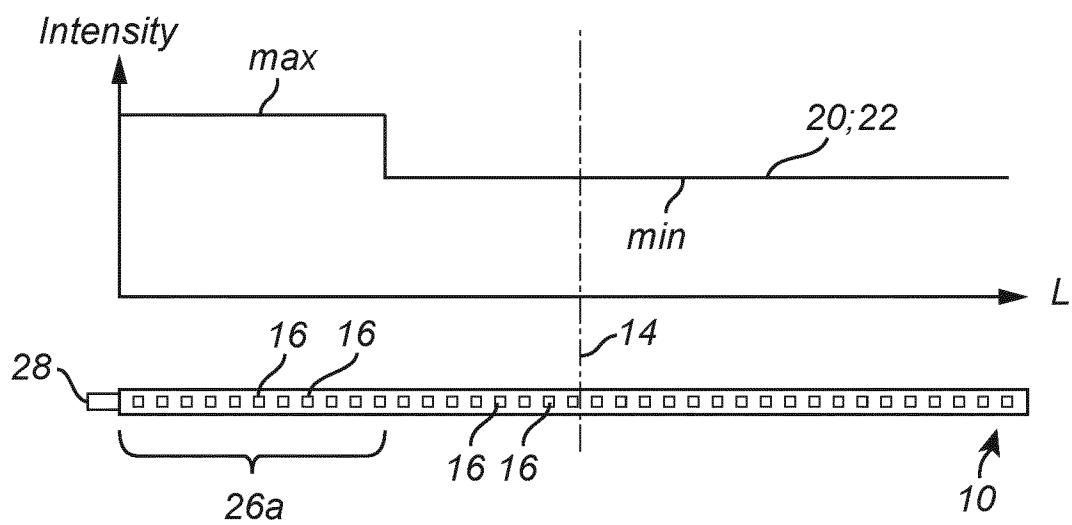


Fig. 1b

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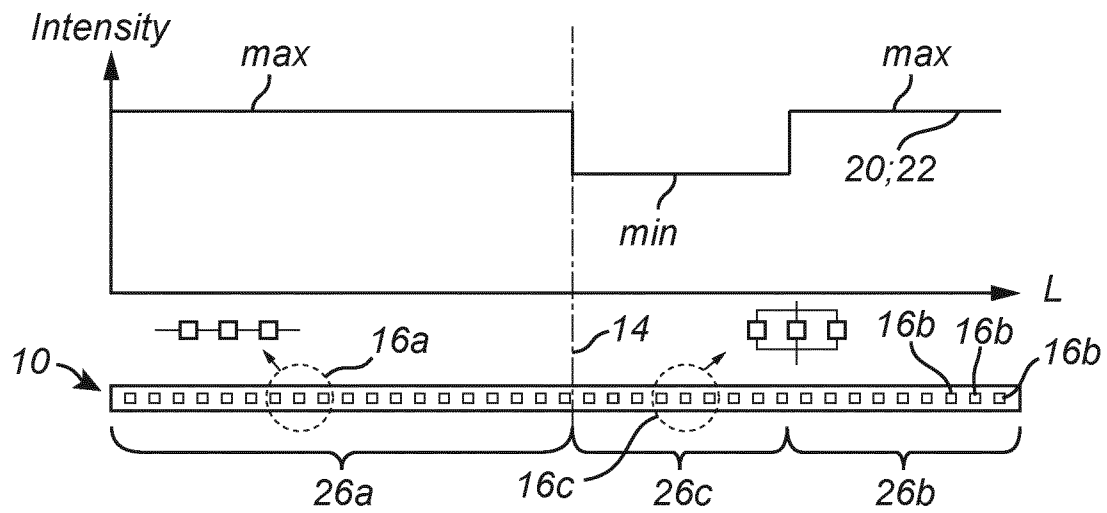


Fig. 1c

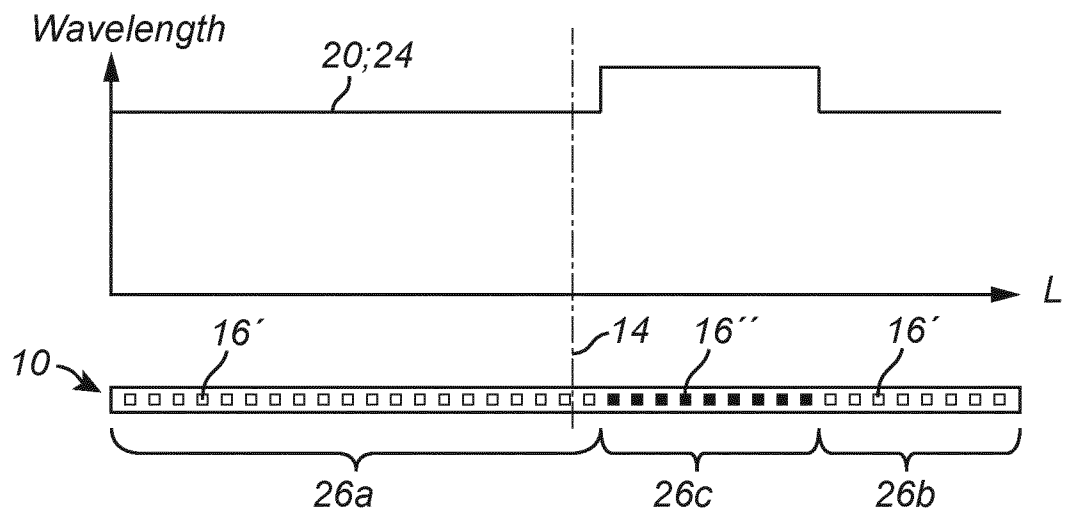


Fig. 1d

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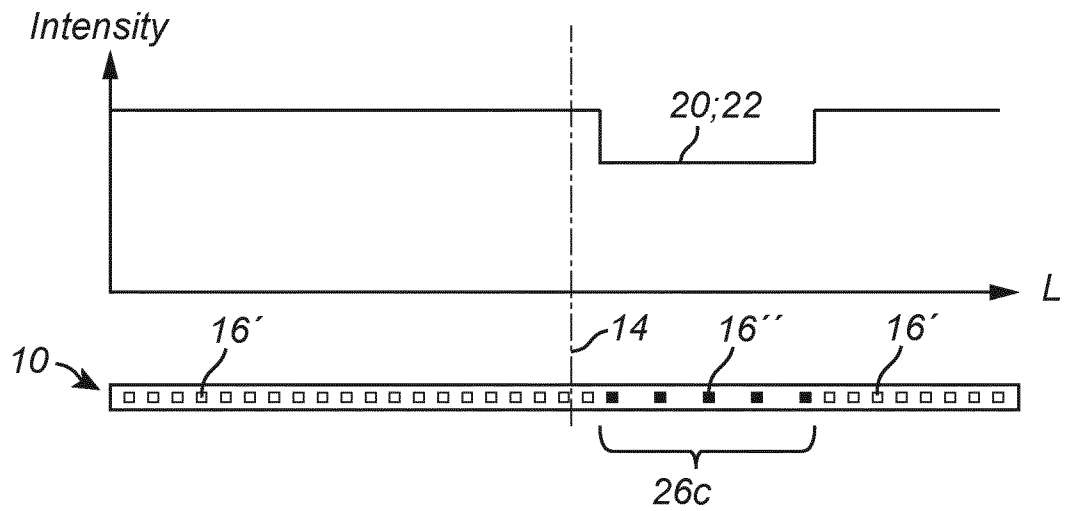


Fig. 1e

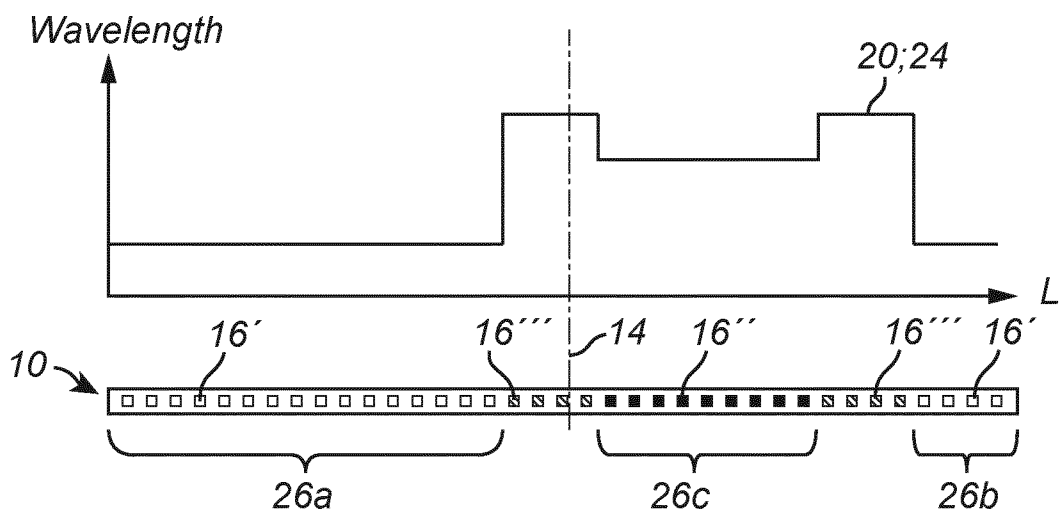
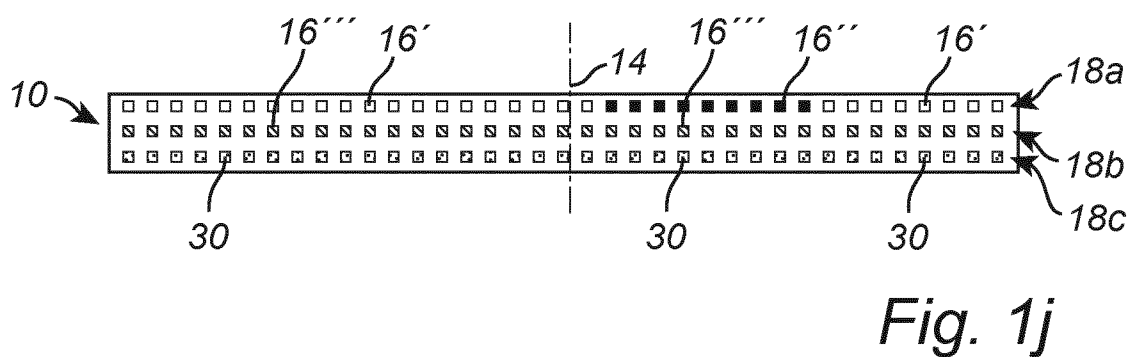
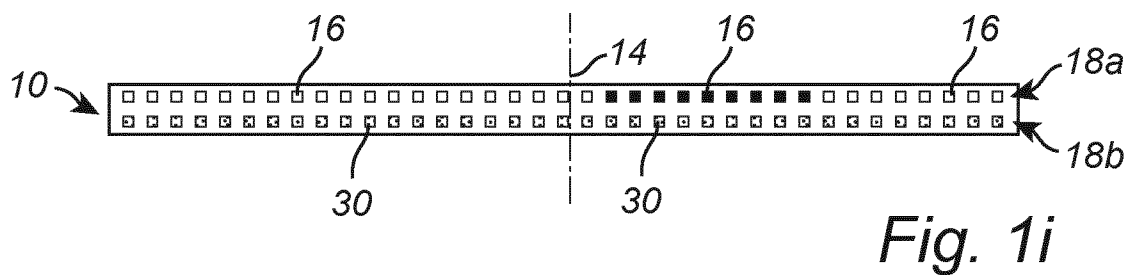
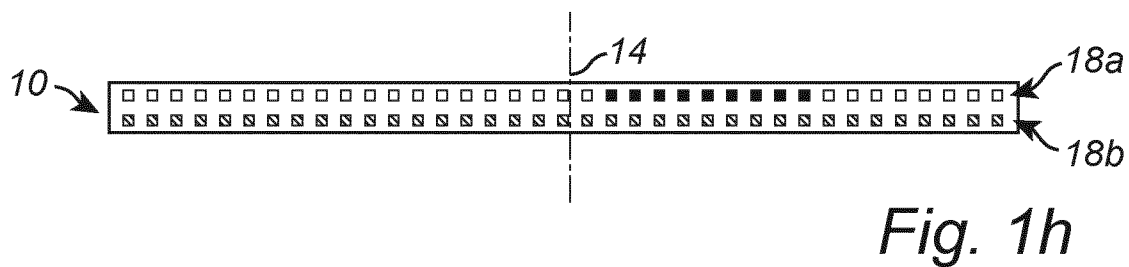
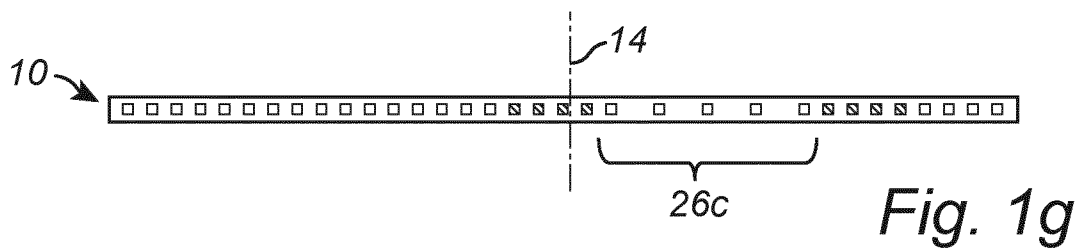


Fig. 1f

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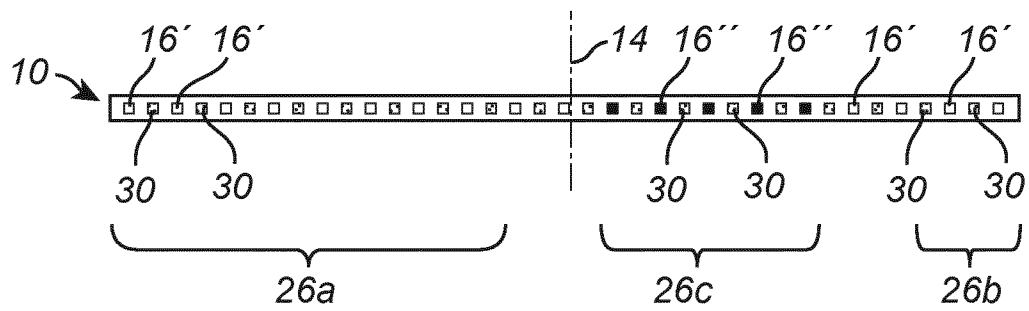


Fig. 1k

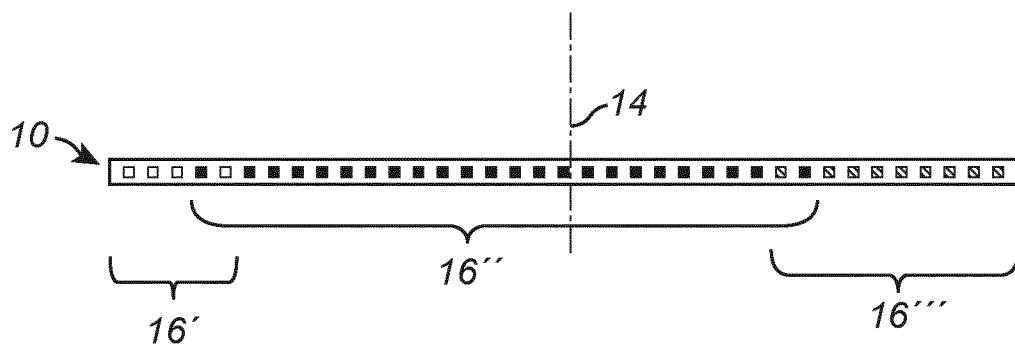


Fig. 1l

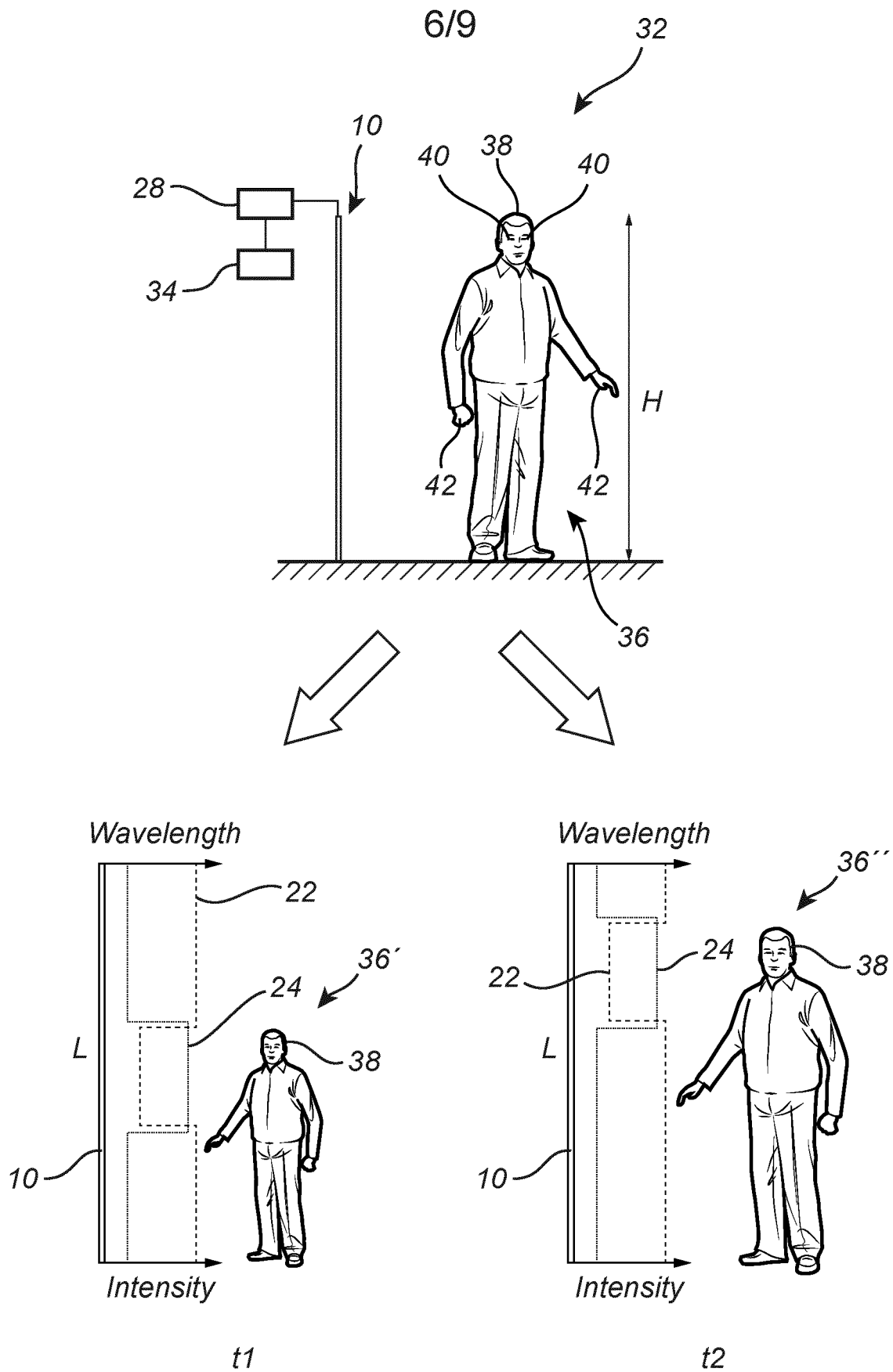


Fig. 2

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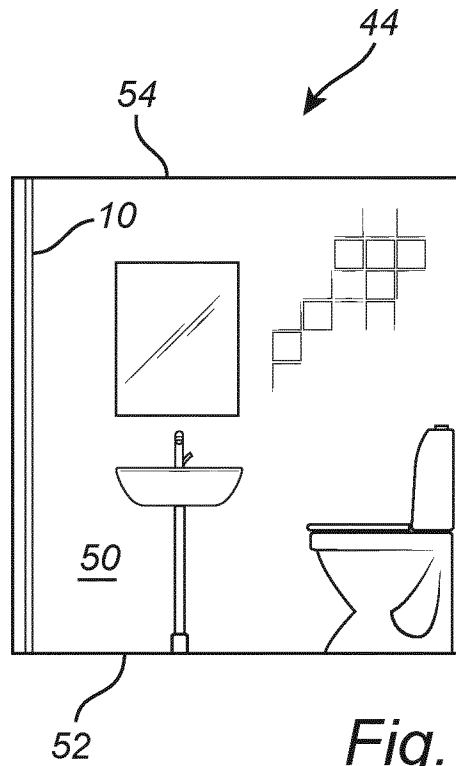


Fig. 3a

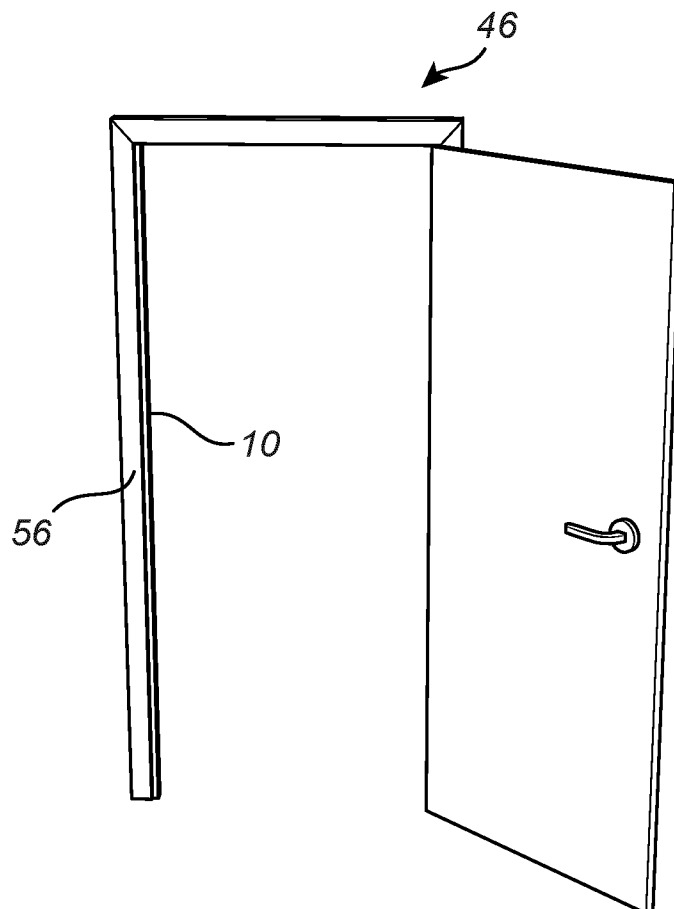


Fig. 3b

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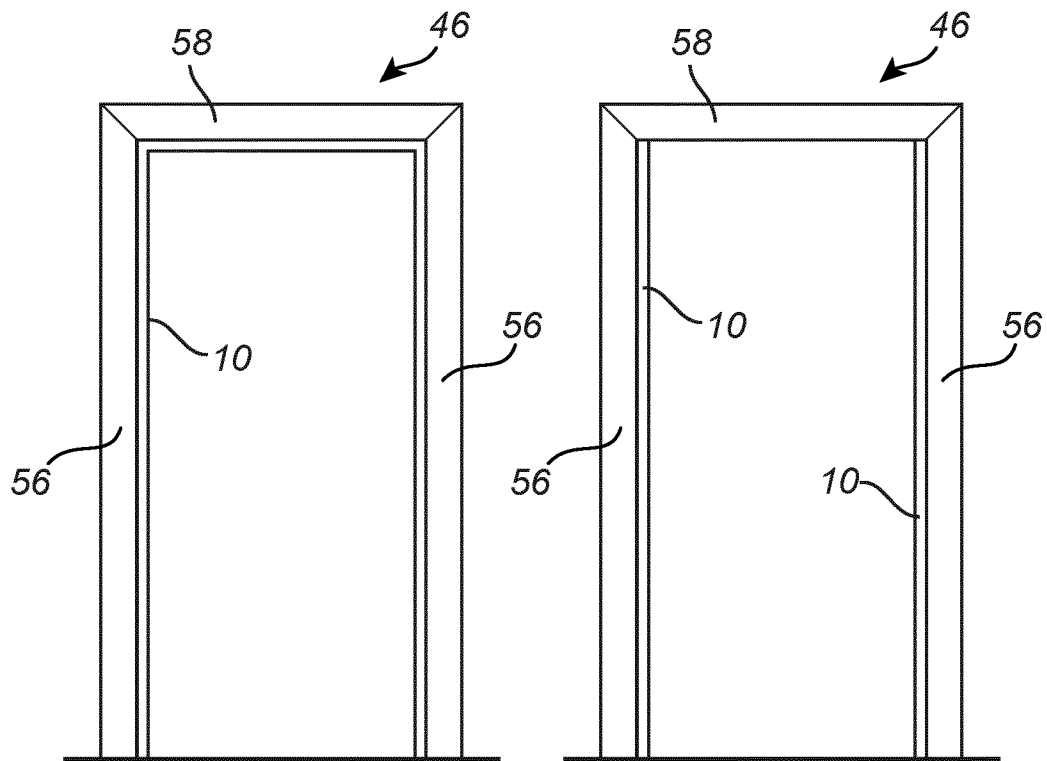


Fig. 3c

Fig. 3d

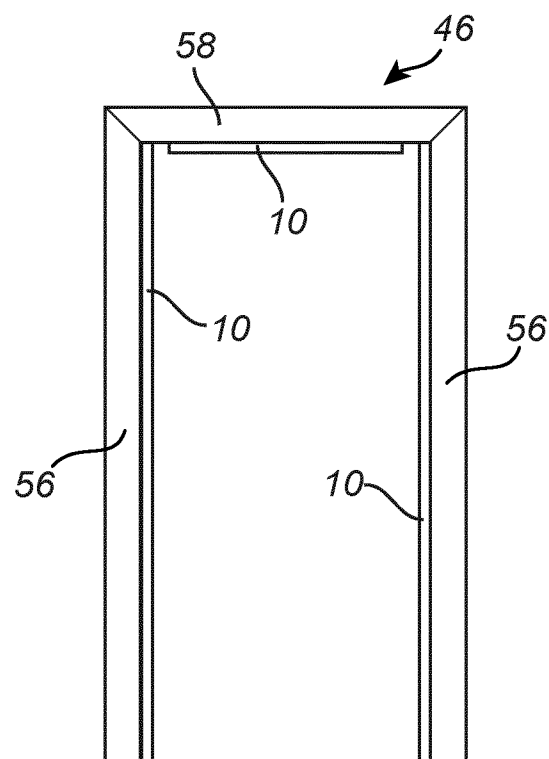


Fig. 3e

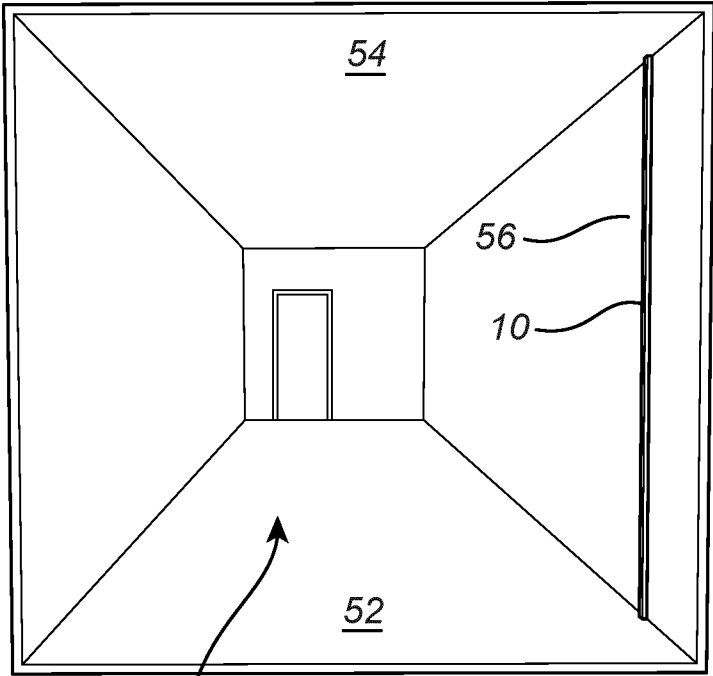


Fig. 3f

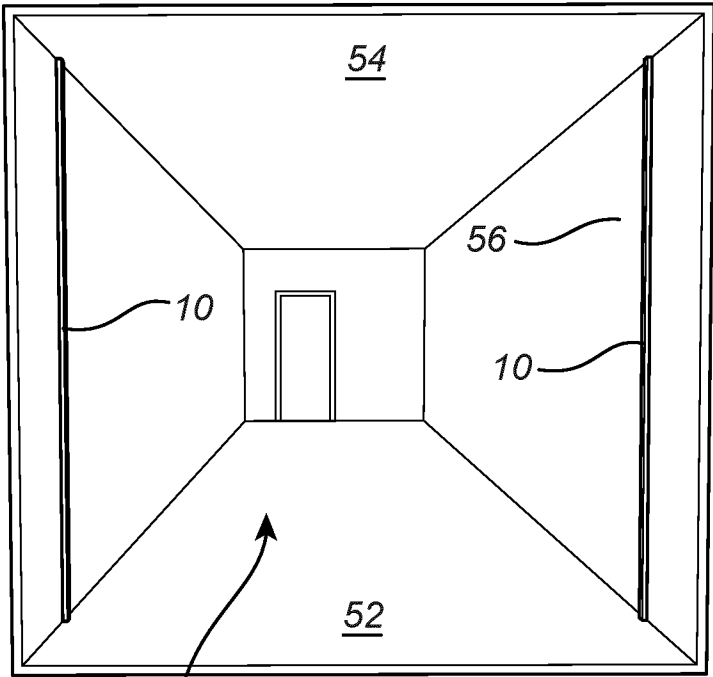


Fig. 3g

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2021/087637

A. CLASSIFICATION OF SUBJECT MATTER INV. H05B47/105 A61L9/20 F21S4/20 H05B47/125 ADD. F21Y103/10 F21Y105/12 F21Y113/13 F21Y115/10		
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) H05B A61L F21V F21S		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	11 November 2020 (2020-11-11)	15
Y	paragraphs [0001], [0023]-[0025],	13
Y	[0049]-[0050], [0052], [0066], [0071],	
Y	[0073], [0079] and [0085];	
Y	claim 16; figures 1A, 4A, 8	
Y	-----	
Y	US 2020/254125 A1 (LLOYD RALPH BIRCHARD	13
Y	[US]) 13 August 2020 (2020-08-13)	
Y	paragraph [0122]; figure 12	
Y	-----	
A	US 9 724 442 B1 (MUNN MAX [US])	1-15
A	8 August 2017 (2017-08-08)	
A	column 3, lines 61-64; column 4, lines	
A	45-48	
A	-----	
A	-/--	
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "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 "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search	Date of mailing of the international search report	
3 March 2022	14/03/2022	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Erskine, Andrew	

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2021/087637

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 2007/053188 A1 (NEW RICHARD D [US] ET AL) 8 March 2007 (2007-03-08) paragraph [0033]; figure 3 -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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