(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 December 2022 (15.12.2022)

WIPO | PCT

(10) International Publication Number
WO 2022/258441 A1

(51) International Patent Classification:
A61L 9/22 (2006.01) *A61L 9/20* (2006.01)

(21) International Application Number: PCT/EP2022/064791

(22) International Filing Date: 31 May 2022 (31.05.2022)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
21178035.8 07 June 2021 (07.06.2021) EP

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) Title: A LIGHTING DEVICE FOR DISINFECTION

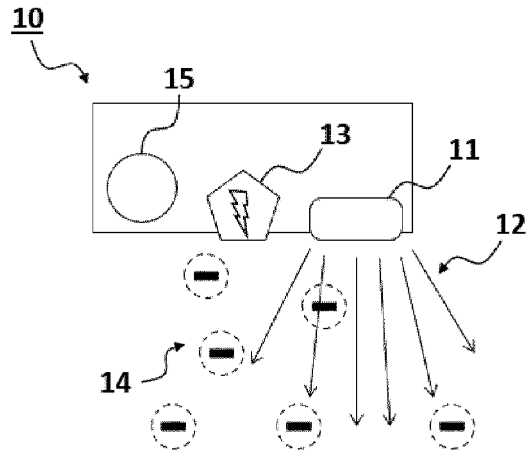

FIG.1.

(57) Abstract: The invention provides a lighting device comprising: a ultraviolet light source configured to emit ultraviolet light; an ion generation source for generating ionized air molecules; a controller configured to: (i) control the ion generation source to generate ionized air molecules during a disinfection period spanned between a first moment in time and a second moment in time, and (ii) control the ultraviolet light source to provide ultraviolet light at a first intensity level at the first moment in time and to gradually decrease the first intensity level during the disinfection period to a second intensity level at the second moment in time.

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report (Art. 21(3))*
— *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

A lighting device for disinfection

FIELD OF THE INVENTION

The invention relates to a lighting device comprising a controller, a light source and an ion generation source. The invention further relates to a lamp assembly comprising said lighting device. The invention further relates to a method of disinfection with such a lighting device, and a corresponding computer program product.

BACKGROUND OF THE INVENTION

Societal health is periodically contested by virus outbreaks, such as seasonal symptomatic influenza A/B outbreak, SARS, MERS, COVID-19. Future outbreaks, mutations, epidemics, and pandemics are not excluded. At least partly due to an increasing population, urbanization and people movement, the topic of people health & wellbeing is becoming more and more relevant.

Such developments have clearly risen the demand for various disinfection devices. For example, a clear demand exists for ionizers, which generate ionized molecules in air to purify and disinfect volumes of air from undesired pathogens and contaminants (i.e. with an ionization cloud, often negatively charged). Such a demand is not only observed in the professional domain, but also in the consumer market.

Furthermore, as a solution, such ionizers may advantageously be implemented in lighting devices, such as lamps and luminaires. The ionizer may thereby benefit from the fact that lamps and luminaires are typically positioned at a location where people and/or animals are present, and where a connection to mains power exists, so as to power the ionizer.

However, when implementing ionizers in lamps and luminaires, internal research of Signify found that the ionization effectiveness of ionizers is not instantaneous upon turn-on, but that said ionization effectiveness increases, e.g. non-linearly, mostly exponentially, over time during operation (i.e. e.g. in the first hour of operation). Therefore, the ionization effectiveness, and hence the disinfection performance of such devices may not be constant over time, and certainly not instantaneous. This may be considered a clear disadvantage.

SUMMARY OF THE INVENTION

It is an object of the invention to provide an improved system, which at least alleviates the problems and disadvantages mentioned above. Thereto, the invention provides a lighting device comprising: a ultraviolet light source configured to emit ultraviolet light; an ion generation source for generating ionized air molecules; a controller configured to: (i) control the ion generation source to generate ionized air molecules during a disinfection period spanned between a first moment in time and a second moment in time, and (ii) control the ultraviolet light source to provide ultraviolet light at a first intensity level at the first moment in time and to gradually decrease the first intensity level during the disinfection period to a second intensity level at the second moment in time.

Hence, the lighting device according to the invention comprises an ion generation source and a controller. The ion generation source is configured to generate, in operation, ionized air molecules for the purpose of disinfection and/or purification. The controller is thereby configured to control the ion generation source to generate said ionized air molecules during a disinfection period. This disinfection period is spanned between a first moment in time and a second moment in time. The first moment in time may for example be the turn-on of the ion generation source, or may for example alternatively be one moment in time within an ongoing disinfection program, such as a setpoint moment to a new setting. However, as mentioned before, the ionization effectiveness, and hence the disinfection performance of an ion generation source may not be constant over time, and certainly not instantaneous.

Therefore, the lighting device according to the invention also comprises an ultraviolet light source. The ultraviolet light source is configured to emit, in operation, ultraviolet light for the purpose of disinfection. The lighting device may be configured to emit ultraviolet light for disinfecting a volume of air. It is namely known that e.g. UV-C radiation has a strong germicidal effect. UV-A and UV-B radiation may be effective as well. The disinfection effectiveness of ultraviolet light may be considered instantaneous. However, ultraviolet light may become harmful to people at certain doses and exposure times. Therefore, exposure to UV-light should be kept to a minimum. Particularly for UV-C. Another reason for reducing the operational time of energy-demanding UV-light is to reduce power consumption.

Hence, the controller according to the invention advantageously controls the ultraviolet light source to provide the ultraviolet light at a first intensity level at the first moment in time and to gradually decrease the first intensity level during the disinfection period to a second intensity level at the second moment in time.

Consequently, the present invention advantageously leverages the instantaneous disinfection performance of ultraviolet light to compensate for the inconstant disinfection efficiency of the ion generation source (e.g. upon turn-on, or e.g. setpoint), and also reduces the exposure to unnecessary harmful ultraviolet light by gradually reducing the intensity while the disinfection performance of the ion generation source increases in time. As a result, the present invention renders a lighting device with an ultraviolet light source and an ion generation source for the purpose of disinfection, wherein said disinfection is provided at a substantially constant level during the disinfection period.

The lighting device according to the invention may alternatively be phrased as a disinfection device. Said first intensity level and said second intensity level may alternatively be phrased as respectively the first ultraviolet (UV) intensity level and second ultraviolet (UV) intensity level. In aspects, the lighting device may comprise a housing, wherein the ultraviolet light source, the ion generation source, and the controller may be arranged within the same housing.

Moreover, the lighting device may comprise a light module. The ultraviolet light source may be part of said light module, wherein the light module may comprise at least one other light source configured to emit, in operation, a respective spectrum of light. Said spectrum of light may e.g. be white light. Hence, the light module may comprise the ultraviolet light source and a white light source.

In aspects, said gradually decrease the first intensity level during the disinfection period to a second intensity level at the second moment in time may alternatively be phrased as gradually decrease the first intensity level during at least part of the disinfection period to a second intensity level at the second moment in time.

As partly mentioned before, the ionization (or disinfection) effectiveness of an ion generation source may increase non-linearly, e.g. exponentially over time during operation. Since the light source according to the invention emits ultraviolet light to compensate for the ion generation source not having an instantaneous performance and/or effectiveness, it may be advantageous to match the gradual decrease in ultraviolet light intensity to the increase in ionization effectiveness of the ion generation source, also to reduce unnecessary exposure to ultraviolet light. Hence, in an embodiment, <2> the controller may be configured to non-linearly decrease the first intensity level to the second intensity level during the disinfection period. More specifically, in an embodiment, <x> the controller may be configured to exponentially decrease the first intensity level to the second intensity level during the disinfection period. Consequently, an ion concentration may be built up gradually, while the gradual decrease of the ultraviolet light intensity renders a substantially constant overall disinfection performance.

Some ionizers may however have a linear increase in ionization effectiveness in operation. Hence, in another embodiment, the controller may be configured to linearly decrease the first intensity level to the second intensity level during the disinfection period. In aspects, said linear decrease may comprise a constant rate of change, or slope, in ultraviolet light intensity. The controller may require less computational power to execute, or store a programmed control function of, such a linear decrease.

In another embodiment, the controller may be configured to decrease, in a step function, the first intensity level to the second intensity level during the disinfection period. Such a stepped reduction in intensity level according to a step function may be advantageous, because the control of the dimming of the light source may be more straightforward and less complicated. Moreover, a stepped decrease in intensity of the ultraviolet light may render a constant intensity for a subperiod of time during each respective step, so as to improve consistency in disinfection.

In a related embodiment, the controller may be configured to maintain the first intensity level during an initial step of the step function for at least a quarter of the disinfection period and for at most a half of the disinfection period before decreasing the first intensity level to a subsequent step of the step function. Such an embodiment may be advantageous, because such an initial step with the first intensity level maintained for at least a quarter of the disinfection period and for at most a halve of the disinfection period may improve the instantaneous disinfection performance of the lighting device according to the invention.

Alternatively, the controller may be configured to maintain the first intensity level during an initial step of the step function for at least a tenth of the disinfection period and for at most two-thirds of the disinfection period before decreasing the first intensity level to a subsequent step of the step function.

Hence, as mentioned before, said gradual decrease may comprise a linear, a non-linear, or a stepped decrease during the disinfection period from the first intensity level to the second intensity level. However, still allowing for a gradual decrease during the disinfection period of the first intensity level at the first moment in time to a second intensity level at the second moment in time, it may also be beneficial to maintain the first intensity for an initial period of time during the start of the disinfection period before decreasing the first intensity level to the second intensity level. Such a decrease is still a gradual decrease. Hence, in an embodiment, the controller may be configured to maintain the first intensity level during an initial period of time for at least a quarter of the disinfection period and for at most a half of the disinfection period before decreasing the first intensity level to the second intensity level at the second moment in time.

Alternatively, the controller may be configured to maintain the first intensity level during an initial period of time for at least a tenth of the disinfection period and for at most two-thirds of the disinfection period before decreasing the first intensity level to the second intensity level at the second moment in time.

In yet alternative aspects, a combination of linear, non-linear, and/or stepped decrease during subperiods of time within said disinfection period may be envisioned. Hence, in aspects, the controller is configured to decrease the first intensity level to the second intensity level during the disinfection period according to a decrease function, wherein the decrease function comprises at least one of: a non-linear decrease part, linear decrease pear, a stepped decrease part , and/or an exponential decrease part.

In an embodiment, the controller may obtain (or: determine) a slope of decrease or a function of decrease, wherein the controller may control the ultraviolet light source to gradually decrease the first intensity level during the disinfection period to a second intensity level at the second moment in time based on slope of decrease or said function of decrease. Said slope may e.g. be constant. Said obtaining may e.g. be retrieving or receiving, or determining by the controller itself based on stored data or obtained data.

In an embodiment, the lighting device may comprise a sensor for sensing a contextual parameter, wherein the controller may control the ultraviolet light source to gradually decrease the first intensity level during the disinfection period to a second intensity level at the second moment in time based on said contextual parameter. The sensor may be at least one sensor, or a sensor bundle. Said contextual parameter may then respectively be at least one contextual a parameter.

For example, said contextual parameter may be people count, and the sensor may be an occupancy sensor for sensing such people count. The controller may then control the gradual decrease of the first intensity level to the second intensity level during said disinfection period based on the people count. Namely, if a number of people larger than a threshold number of people may be sensed, a slope or shape of said gradual decrease may be less steep than the case in which a number of people lower than the threshold number of people may be sensed. Based on the number of people detected, the shape of the gradual decrease may similarly be adapted, such as a linear decrease for e.g. two people sensed, and an exponential decrease for ten people sensed. This is advantageous, as the lighting device may operate by taking into account contextual parameters. Other examples may be envisioned similarly.

Moreover, said sensor may e.g. be a Volatile Organic Compound (VOC) sensor, or pollution sensor, for sensing air pollution, or a level of pathogens in air. Said contextual parameter may thus be air pollution. The controller may control the control the ultraviolet light source to gradually decrease the first intensity level during the disinfection period to a second intensity level at the second moment in time based on said contextual parameter of air pollution.

In aspects, the controller may be configured to control the ultraviolet light source to gradually decrease the first intensity level during the disinfection period to a second intensity level at a third moment in time, and maintain the second intensity level constant between the third moment in time to the second moment in time, wherein the third moment in time occurs after the first moment in time and before the second moment in time. In aspects, the third moment in time occurs at a moment within the last third, or preferably last quarter, of the disinfection period.

In an embodiment, the first intensity level may be a maximum intensity level of the light source. Such an embodiment may be advantageous, as the full capabilities of the ultraviolet light source are utilized for providing said first intensity level of ultraviolet light.

In an embodiment, the first moment in time may be the turn-on of the ion generation source. Hence, the controller may be configured to turn on the ion generation source to provide said ionized air molecules, wherein the first moment in time is the moment of turning on said ion generation source by the controller.

In an embodiment, the controller may be configured to control the ion generation source to generate the ionized air molecules at a first ionization rate during said disinfection period, wherein the controller may determine the first intensity level based on said first ionization rate. Said first ionization rate may be a constant first ionization rate. Such an embodiment may be advantageous, because the controller may tailor the first intensity level to the actual operational performance of the ion generation source, i.e. the ionization rate of the ion generation source.

In an embodiment, the controller may be configured to control the ultraviolet light source to turn off at the second moment in time, wherein the second intensity level is zero. Hence, the intensity of the ultraviolet light may advantageously be reduced to zero, because no ultraviolet light may be needed when the ion generation source may have provided sufficient ionized molecules for disinfection at the second moment in time (i.e. the end of said disinfection period). For example, the second intensity level may be reduced to zero Watt per square centimeter at the second moment in time.

In an embodiment, the second intensity level may be in the range of 0.05 to 0.2 times the first intensity level. Hence, the decrease, or reduction, of the intensity level of the emitted ultraviolet light may up to twenty times. Maintaining a second intensity level at a minimum allows for an improved disinfection performance, while the level of risk of exposure to ultraviolet light is reduced as well.

In an embodiment, the disinfection period may be at least one hour. Said disinfection period may alternatively be at least twenty minutes, at least thirty minutes, at least forty minutes, at least two hours, at least four hours.

Such a duration may at least be required to fill a respective room with ions in a homogeneous manner. For example, the lighting device may be mounted in a space, wherein the space comprises a predefined volume, wherein the controller is configured to determine the disinfection period based on said predefined volume. The controller may obtain said predefined volume from a user input, or retrieve or receive said predefined volume from an external device, such as a backed server or user input device.

In an embodiment, said ion generation source may be a bi-polar ionizer. Hence, the ion generation source may be configured to generate both positively charged ionized air molecules as well as negatively charged ionized air molecules. The ionizer may alternate the generation of the negative and positive ionized air molecules.

In aspects, the ultraviolet light source or light module according to the invention may be configured to illuminate an illumination region in a space, wherein the ion generation source may be arranged to generate the ionized air molecules in said space and/or said illumination region in said space. Thereby, the ion generation source may generates the ionized air molecules that are conveyed into said space and/or into said illumination region within said space. Said ionized air molecules may disperse and diffuse by natural convection of the air in said space, but alternatively may be forced by e.g. a fan.

In an embodiment, the ultraviolet light comprises at least one of: UV-C light, UV-B light, UV-A light, Ultra Deep UV-C light in the range of 100 -190 nm, Far UV-C light in the range of 190-230 nm, near UV-C light in the range of 230-280 nm, UV-B light in the range of 280-315 nm, UV-A light in the range of 315-380 nm, UV light at 254 nm. Such spectra may provide a germicidal effect. Said ultraviolet light may additionally comprise at least one of: UV light at 207 nm, UV light at 222 nm. Such UV light may e.g. be provided by an excimer lamp.

In an embodiment, the lighting device may be a light bulb. In an embodiment, the light source is a LED light source or a laser light source. In aspects, the lighting device may be an elongated lighting device, such as a luminaire, TLED, or a LED strip. In aspects, the light source may be a solid state light source.

In an embodiment, the lighting device may be a upper-air disinfection luminaire. Such an upper-air disinfection luminaire may comprise a first light source for illuminating into a first direction and illuminate a first surface (typically illuminate upwards relative to gravity to illuminate a ceiling surface). The first light source being the ultraviolet light source according to the invention. Said upper-air disinfection luminaire may further comprise a second light source for illuminating into a second direction, opposite to the first direction, and illuminate a second surface and/or a space (beneath the upper-air disinfection luminaire).

In an embodiment, the lighting device may be a light-based disinfection chamber. Such a light-based disinfection chamber may comprise the ultraviolet light source to disinfect an object within said disinfection chamber.

In an embodiment, the lighting device may comprise a cap arranged for retrofitting the lighting device to a fixture or a luminaire. Said cap may alternatively be a connector for connecting the lighting device to a fixture or a luminaire.

It is further an object of the invention to provide a lamp assembly. Thereto, the invention provides a lamp assembly comprising luminaire and the lighting device according to the invention, wherein the lighting device according to the invention comprises a connector for connecting the lighting device to the luminaire. Said connector may e.g. provide a mechanical connection, but also an electrical connection and/or a data connection. The luminaire may comprise a driver for powering the lighting device, and associated ultraviolet light source and/or ion generation source.

It is further an object of the invention to provide a method of disinfection. Thereto, the invention provides a method of disinfection, performed by a ultraviolet light source comprising a light source, an ion generation source and a controller, wherein the method comprises: controlling the ion generation source to generate ionized air molecules during a disinfection period spanned between a first moment in time and a second moment in time; controlling the ultraviolet light source to provide ultraviolet light at a first intensity level at the first moment in time and gradually decreasing the first intensity level during the disinfection period to a second intensity level at the second moment in time. Thereby, advantages and/or embodiments applying to the lighting device according to the invention may mutatis mutandis apply to said method according to the invention.

For example, in an embodiment, the step of gradually decreasing the first intensity level during the disinfection period to a second intensity level at the second moment in time comprises non-linearly decreasing the first intensity level to the second intensity level during the disinfection period.

For example, in an embodiment, the step of gradually decreasing the first intensity level during the disinfection period to a second intensity level at the second moment in time comprises exponentially decreasing the first intensity level to the second intensity level during the disinfection period.

For example, in an embodiment, the step of gradually decreasing the first intensity level during the disinfection period to a second intensity level at the second moment in time comprises linearly decreasing the first intensity level to the second intensity level during the disinfection period.

For example, in an embodiment, the step of gradually decreasing the first intensity level during the disinfection period to a second intensity level at the second moment in time comprises decreasing, in a step function, the first intensity level to the second intensity level during the disinfection period. And optionally in further embodiments: maintaining the first intensity level during an initial step of the step function for at least a tenth, preferably a quarter, of the disinfection period and for at most two-thirds, preferably a half, of the disinfection period before decreasing the first intensity level to a subsequent step of the step function.

For example, in aspects, the method may comprise: controlling the ultraviolet light source to gradually decrease the first intensity level during the disinfection period to a second intensity level at a third moment in time, and maintaining the second intensity level constant between the third moment in time to the second moment in time, wherein the third moment in time occurs after the first moment in time and before the second moment in time. In aspects, the third moment in time occurs at a moment within the last third, or preferably last quarter, of the disinfection period.

The invention further relates to a computer program product. Hence, the invention provides a computer program product for a computing device, the computer program product comprising computer program code to perform a method according to the invention when the computer program product is run on a processing unit of the computing device. The computing device may be the controller according to the invention.

Thus, aspects of the invention may be implemented in a computer program product, which may be a collection of computer program instructions stored on a computer readable storage device which may be executed by a computer. The instructions of the present invention may be in any interpretable or executable code mechanism, including but not limited to scripts, interpretable programs, dynamic link libraries (DLLs) or Java classes. The instructions can be provided as complete executable programs, partial executable programs, as modifications to existing programs (e.g. updates) or extensions for existing programs (e.g. plugins). Moreover, parts of the processing of the present invention may be distributed over multiple computers or processors.

BRIEF DESCRIPTION OF THE DRAWINGS

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

Fig. 1 depicts schematically an embodiment of a lighting device according to the invention;

Figs. 2A-D depict schematically a schematic overview of the operation of the lighting device according to the invention in time;

Fig. 3 depicts schematically an alternative embodiment of a lighting device according to the invention;

Fig. 4 depicts schematically a method according to the invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

As mentioned, ionizers may advantageously be implemented in lighting devices, such as lamps and luminaires. The ionizer may thereby benefit from the fact that lamps and luminaires are typically positioned at a location where people and/or animals are present, and where a connection to mains power exists, so as to power the ionizer. However, when implementing ionizers in lamps and luminaires, it is found that the ionization effectiveness of ionizers is not instantaneous upon turn-on, but that said ionization effectiveness increases, e.g. non-linearly, mostly exponentially, over time during operation (i.e. e.g. in the first hour of operation). Therefore, the ionization effectiveness, and hence the disinfection performance of such devices may not be constant over time, and certainly not instantaneous. This may be considered a clear disadvantage. The present invention resolves this disadvantage.

Figure 1 depicts schematically, by non-limiting example, a lighting device 10 comprising an ultraviolet light source 11, an ion generation source 13, and a controller 15. The ultraviolet light source 11 emits, in operation, ultraviolet light 12. The ion generation source 13 generates, in operation, ionized air molecules 14. The lighting device may alternatively be phrased as a disinfection device, lighting system or disinfection system.

The lighting device 10 may optionally comprises a housing, in which the controller 15, the ultraviolet light source 11, and the ion generation source 13 are housed together. However, in alternative examples, the controller may be embodied separate, or at least partly separate, from the ultraviolet light source and the ion generation source. For example, the ultraviolet light source and the ion generation source may be embodied in the same housing of the lighting device, but the controller may be an external controller for controlling the ultraviolet light source and the ion generation source.

The lighting device 10 is arranged in a space to be disinfected, namely with the ionized air molecules 14, as well as with the ultraviolet light 12. The ultraviolet light 12 illuminates an illumination region within said space. The ionized air molecules 14 are conveyed into said illumination region and/or said space.

Here, the ion generation source 13 generates negatively charged ionized air molecules 14. Alternatively, said ion generation source may generate positively charged ionized air molecules, or a combination of negatively and positively charged ionized air molecules. The latter may be achieved with the ion generation source being a bi-polar ionizer. Said ionized air molecules may alternatively be phrased as an ionization cloud.

Here, the ultraviolet light source 11 is a LED light source, and the ultraviolet light 12 comprises UV-C light. Thus, the ultraviolet light 12 provides a substantially instantaneous germicidal effect, and thereby disinfects the illumination region. Alternatively, said ultraviolet light may comprise at least one of: Ultra Deep UV-C light in the range of 100 -190 nm, Far UV-C light in the range of 190-230 nm, near UV-C light in the range of 230-280 nm, UV-B light in the range of 280-315 nm, UV-A light in the range of 315-380 nm, UV light at 207 nm, UV light at 222 nm. Such spectra may also provide a germicidal effect.

The ultraviolet light source 11 may alternatively be a laser light source. The ultraviolet light source may alternatively be a plurality of ultraviolet light sources, e.g. an array of LED lights. In related embodiments, not depicted, the lighting device may comprise a light module comprising the ultraviolet light source. The light module may further comprise at least one other light source configured to emit, in operation, a respective spectrum of light other than the spectrum of light emitted by the ultraviolet light source. For example, the light module may comprise the ultraviolet light source and a white light source configured to emit white light.

Still referring to figure 1, the ion generation source 13 is configured to generate, in operation, ionized air molecules 14 for the purpose of disinfection and/or purification. The controller 15 is thereby configured to control the ion generation source 13 to generate said ionized air molecules 14 during a disinfection period 20. The disinfection period 20 is thereby determined and set by the controller 15.

The disinfection period 20 may for example be one hour, but alternatively any other time duration mentioned in the present application, for example at least five minutes, at least 20 minutes, at least one hour, at most two hours, at least a day. Said disinfection period may depend on a disinfection routine, or disinfection program performed by the controller in association with the ion generation source. Moreover, in aspects, a data entry indicative of said disinfection period, or indicative of a duration of said disinfection period, may be obtained by the controller, such that said disinfection period may be determined based on said data entry. The data entry may for example be sent by a user interaction device, such as e.g. a control device or smartphone. Said duration may also depend on a volume of the space to be disinfected. The controller may retrieve said disinfection period, or a duration of said disinfection period, from e.g. an external device, such as a building management device or server.

Referring to figure 2A-D as well, said disinfection period 20 is spanned between a first moment in time 21 and a second moment in time 22. Here, the first moment in time 21 corresponds to the turn-on moment of the ion generation source 13. Here, the second moment in time 22 corresponds to a turn-off moment of the ion generation source 13. The first moment in time may alternative correspond to a first moment within an ongoing disinfection program of the ion generation source, and second moment in time may be a subsequent moment within said ongoing disinfection program of the ion generation source.

Since the ion generation source 13 continues generating ionized air molecules 14 in the space during the disinfection period 20, the concentration 25 of ionized air molecules 14 in the space increases gradually. Here, in figures 2A, 2B & 2D, the concentration 25 is depicted to increase exponentially, until it reaches a saturation point in time, after which the concentration 25 of ionized air molecules 14 in the space remains substantially constant. Said saturation point in time may characterize the second moment in time 22, at which also the ion generation source 13 is turned-off. In an alternative and optional example, referring to figure 2C, the concentration 25 is depicted to increase linearly in the space during the disinfection period. The concentration of the ionized air molecules may for example depend on a type of ion generation source, or e.g. an operational mode.

However, as mentioned before, the overall ionization effectiveness, and hence the disinfection performance of an ion generation source 13, may not be constant over time, and certainly not instantaneous. Namely, upon the start of generating ionized air molecules, the ionized air molecules still need to be generated and still need to fill the space first, so as to reach desired concentrations for disinfection. On the other hand, the disinfection effectiveness of ultraviolet light may be considered substantially instantaneous. However, ultraviolet light may become harmful to people at certain doses and exposure times. Therefore, exposure to UV-light should be kept to a minimum. Particularly for UV-C.

Still referring to figure 1 and figure 2A-D, the present invention is characterized by the controller 15 controlling the ultraviolet light source 11 to provide ultraviolet light 12 at a first intensity level 23 at the first moment in time 21. The controller 15 is also configured to gradually decrease said first intensity level 23 during the disinfection period 20 to a second intensity level 24 at the second moment in time 22.

As a result, the present invention advantageously leverages the instantaneous disinfection performance of ultraviolet light 12 to compensate for the inconstant disinfection efficiency of the ion generation source 13; and also reduces the exposure to unnecessary and possibly harmful ultraviolet light by gradually reducing the intensity 26, 27, 28, 29 of the ultraviolet light 12 while the disinfection performance of the ion generation source 13 increases in time. As a result, the present invention renders a lighting device 10 with an ultraviolet light source 11 and an ion generation source 13 for the purpose of disinfection, wherein said disinfection is provided at a substantially constant level during the disinfection period 20 of the ion generation source 13.

Hence, the controller 15 of the lighting device 10 controls the ultraviolet light source 11 to gradually decrease the intensity 26, 27, 28, 29 of the ultraviolet light 12 during the disinfection period 20, while the ion generation source 13 is controlled to generate the ionized air molecules 14. Said decrease in intensity 26, 27, 28, 29 may for example be at least one of: a linear decrease, a non-linear decrease, an exponential decrease, and/or a stepped decrease. Figures 2A-D depict, by non-limiting example, various embodiments of such a decrease of the intensity 26 of the ultraviolet light 12.

Namely, figure 2A depicts, by non-limiting example, an exemplar case in which the first intensity level 23 at the first moment in time 21 is a maximum intensity level of the ultraviolet light source 11; and in which the controller 15 controls the ultraviolet light source 11 to linearly decrease the first intensity level 23 during the disinfection period 20 to the second intensity level 24 at the second moment in time 22. The decrease is thus characterized by a linear decrease function 27. The second intensity level 24 is thereby zero. Hence, the ultraviolet light source 11 is off. Alternatively, a non-linear decrease may be provided.

Namely, figure 2B depicts, by non-limiting example, an exemplar case in which the first intensity level 23 at the first moment in time 21 is a maximum intensity level of the ultraviolet light source 11; and in which the controller 15 controls the ultraviolet light source 11 to exponentially decrease the first intensity level 23 during the disinfection period 20 to the second intensity level 24 at the second moment in time 22. The decrease is thus characterized by an exponential decrease function 27. The second intensity level 24 is thereby 10% of the maximum intensity level of the ultraviolet light source 11. Hence, the ultraviolet light source 11 is dimmed to 10% at the second moment in time 22. Hence, in figure 2B, the second light intensity level 24 is 0.1 times the maximum intensity level of the ultraviolet light source 11.

Figure 2C depicts, by non-limiting example, an exemplar case in which the first intensity level 23 at the first moment in time 21 is at 70% of the maximum intensity level of the ultraviolet light source 11; and in which the controller 15 controls the ultraviolet light source 11 to decrease, in a step function 28, the first intensity level 23 during the disinfection period 20 to the second intensity level 24 at the second moment in time 22. The second intensity level 24 is thereby 20% of the maximum intensity level of the ultraviolet light source 11. Hence, the ultraviolet light source 11 is dimmed to 20% at the second moment in time 22. Hence, in figure 2C, the second light intensity level 24 is 0.2 times the maximum intensity level of the ultraviolet light source 11.

Moreover, referring to figure 2C, the controller maintains the first intensity level 23 during an initial period of time 281 before decreasing the first intensity level 23 to the second intensity level 24 at the second moment in time 22. Here, the initial period of time 281 is a quarter of the disinfection period 20. Alternatively, the controller is configured to maintain the first intensity level during the initial step of the step function for at least a tenth, preferably at least a quarter, of the disinfection period and for at most two-thirds, preferably at most a half, of the disinfection period before decreasing the first intensity level to a subsequent step of the step function.

Such an initial period of time in which the first intensity level is maintained (constant) before decreasing the first intensity level to the second intensity level at the second moment in time may also, and alternatively, be envisioned for the other examples depicted in figure 2A-D. Hence, in aspects, the controller may be configured to maintain the first intensity level during an initial period of time for at least a tenth, preferably at least a quarter, of the disinfection period and for at most two-thirds, preferably at most a half, of the disinfection period before decreasing the first intensity level to the second intensity level at the second moment in time.

Yet alternatively, the controller may control the ultraviolet light source to gradually decrease the first intensity level during the disinfection period to a second intensity level at a third moment in time, and maintain the second intensity level constant between the third moment in time to the second moment in time, wherein the third moment in time occurs after the first moment in time and before the second moment in time. In aspects, the third moment in time occurs at a moment within the last third, or preferably last quarter, of the disinfection period. For example, Figure 2C depicts that the second intensity level is maintained for the last quarter of the disinfection period.

Figure 2D depicts, by non-limiting example, an exemplar case in which the first intensity level 23 at the first moment in time 21 is the maximum intensity level of the ultraviolet light source 11; and in which the controller 15 controls the ultraviolet light source 11 to gradually decrease said first intensity 23 to said second intensity 24 during the disinfection period 20 according to a (hybrid) decrease function 29 by (i) maintaining said first intensity level 23 for an initial period 291 of time corresponding to a quarter of the disinfection period 20, and then (ii) further decreasing the first intensity level 23 firstly exponentially and secondly linearly during the disinfection period 20 to the second intensity level 24 at the second moment in time 22. The second intensity level 24 is thereby zero. Hence, the ultraviolet light source 11 is off at the second moment in time 22.

Still referring to figure 1, and figures 2A-D, the controller 15 is configured to control the ion generation source 13 to generate ionized air molecules 14 at a first ionization rate during said disinfection period 20. The first ionization rate may render the concentration 25 of ionized air molecules 14 in said space, as said ionized air molecules 14 may be accumulated over time. In embodiments, the first intensity level may be based on the ionization rate. For example, referring to figure 2C, wherein the first intensity level is 70% of the maximum intensity level of the ultraviolet light source 11, the controller may determine the first intensity level to be 70% based on the first ionization rate of the ion generation source it controls. For example, if the ion generation source is operated at 70% power of the maximum power of the ion generation source, and the thereby corresponding ionization rate, the first intensity level of the ultraviolet light 12 emitted by the ultraviolet light source 11 may scale similarly, whereby the controller determines the first intensity to be mutatis mutandis 70% intensity of the maximum intensity level of the ultraviolet light source 11. Such embodiments may be advantageous, because the controller 15 may tailor the first intensity level 23 to the actual operational performance of the ion generation source 13, i.e. the ionization rate of the ion generation source 13.

Figure 3 depicts schematically, by non-limiting example, a lighting device 30 according to the invention. The lighting device 30 is arranged within a space to be disinfected. The lighting device 30 may also be defined as a lighting system.

The lighting device 30 comprises a controller 35, a housing 37, an ultraviolet light source 31, a sensor 38, an ion generation source 33, and optionally a cap 39. Here, the controller 35 is separate from the housing 37. Here, the housing 37 comprises (or: houses) the ultraviolet light source 31, the sensor 38, and the ion generation source 33. The sensor may alternatively also be separate from the housing.

The controller 35 is configured to communicate, in operation, with the sensor 38, the ultraviolet light source 31 and/or the ion generation source 33. Here, said communication is via wireless communication. Alternatively, said communication may be via a wired connection. Known communication means may be envisioned for such a communication. Here, the controller 35 comprises a wireless transceiver (not depicted) that communicates with a wireless transceiver (not depicted) comprised by the housing 37. Said wireless transceiver operates via ZigBee, but may alternatively operate via one of: Bluetooth, Wi-Fi, Lo-Ra, RF, IR, VLC, Li-Fi, UWB, 5G, 4G.

The cap 39 is configured to (retro-)fit the housing 37 of the lighting device 30 to a lighting assembly or complementary socket. Said fit may be mechanical, but also electrical. The cap 39 is configured to convey power and/or data to the components of the lighting device 30, such as the sensor 38, the ion generation source 33, and/or the ultraviolet light source 31. Hence, in aspects, the lighting device depicted in figure 3 may be a smart light bulb operated by an external controller, such as a smartphone.

Referring to figure 3, the ultraviolet light source 31 emits, in operation, ultraviolet light 32. Here, the ultraviolet light 32 is UV-B, but may alternatively be any other ultraviolet light (spectrum) as mentioned in the present application, such as e.g. UV-A, UV-C.

The ion generation source 33 generates, in operation, ionized air molecules 34. The ion generation source 33 may be bi-polar ionizer. The sensor 38 is configured to sense a contextual parameter. Namely, the sensor 38 according to the present embodiment is a presence sensor configured to count the amount of people present in said space, and output a sensor signal indicative of the amount of people present in said space. The presence sensor may e.g. be one of: a camera, a thermopile array, a Single Pixel Thermopile, a PIR sensor, a microphone, a pressure sensor. Alternatively, other contextual parameters may be envisioned, such as air quality measured by an air quality sensor, or sounds indicative of a contamination by a microphone, etc. The sensor may alternatively be a sensor bundle, or at least one sensor, for sensing respectively at least one contextual parameter.

Still referring to figure 3, the controller 35 is configured to control the ion generation source 33 to generated ionized air molecules 34 during a disinfection period. The disinfection period is thereby spanned between a first moment in time and a second moment in time. The controller 35 is more specifically configured to control the ion generation source 33 to generate the ionized air molecules at a first ionization rate during said disinfection period, and at least at the first moment in time. The first ionization rate may be constant, but alternatively dynamic according to an ionization program or ionization function, which is run to disinfect said space.

The controller 35 is further configured to control the ultraviolet light source 31 to provide (or: emit) ultraviolet light at a first (ultraviolet light) intensity level at the first moment in time. Here, the controller 35 is further configured to determine the first light intensity level based on the first ionization rate. Alternatively, or additionally, the controller is configured to obtain (e.g. receive or retrieve) the sensor signal from the sensor, and determine the first light intensity level based on the sensor signal. Hence, the controller may determine the first light intensity level based on the sensor signal and/or the first ionization rate.

Still referring to figure 3, the controller 35 is configured to gradually decrease, by controlling the ultraviolet light source 31, the first (ultraviolet light) intensity level during the disinfection period to a second (ultraviolet light) intensity level at the second moment in time.

Said decrease in intensity may for example be at least one of: a linear decrease, a non-linear decrease, an exponential decrease, and/or a stepped decrease. Hence, according to the invention, said decrease may be characterized as a decrease function. The controller 35 controls the ultraviolet light source 31 to gradually decrease the first intensity level during the disinfection period to the second intensity level at the second moment in time according to a decrease function.

Figures 2A-D depict, by non-limiting example, various embodiments of such a decrease of the intensity of the ultraviolet light, or decrease function, which may mutatis mutandis apply to the embodiment depicted in figure 3. Hence, the subject-matter describing figures 2A-D may mutatis mutandis apply to the embodiment of the lighting device depicted in figure 3.

Still referring to figure 3, the controller is configured to determine the second intensity level and/or said decrease function based on said sensor signal. Said determining may alternatively be phrased as selecting. Hence, in alternative phrasing, the controller controls the ultraviolet light source 31 to gradually decrease the first intensity level during the disinfection period to a second intensity level at the second moment in time based on said contextual parameter as sensed by the sensor.

For example, based on the amount of people present within said space, the decrease function may be selected. More people being detected during the disinfection period, may for example result in a higher second intensity level to tailor the overall disinfection performance to the more people being present, and for example in an exponential decrease of the decrease function to ensure that the amount of people will not be exposed to high doses of ultraviolet light during the disinfection period since an exponential decrease reduces its value quicker. Other examples may be envisioned similarly.

For example, in alternative embodiments, wherein the sensor may be a Volatile Organic Compound (VOC) sensor, the sensor may output a sensor signal indicative of air pollution. The controller may receive or retrieve said sensor signal, and based thereon, determine a gradual decrease of the ultraviolet light intensity levels, or determine a decrease function according to the invention. For example, when the sensed air pollution exceeds a predetermined pollution level, the controller may determine the first intensity level and/or the second intensity level to be higher, and the decrease function to be e.g. less steep.

Alternatively, said sensor may be at least one sensor, for example a sensor bundle comprising the presence sensor and the VOC sensor. The controller may then receive a sensor signal indicative of the contextual parameter of the VOC sensor and the presence sensor, so as to determine the decrease in intensity of the ultraviolet light and/or the second intensity level as mentioned.

Figure 4 depicts schematically, by non-limiting example, a method 40 of disinfection according to the invention. The method 40 may be performed by a lighting device as depicted in the embodiments of figures 1-3. Such a lighting device comprises at least an ultraviolet lighting source, an ion generation source, and a controller. The controller may e.g. be an external, or remote controller.

The method 40 comprises a step 41 of controlling the ion generation source to generate ionized air molecules during a disinfection period spanned between a first moment in time and a second moment in time. The method comprises a step 42 of controlling the ultraviolet light source to provide ultraviolet light at a first intensity level at the first moment in time and gradually decreasing the first intensity level during the disinfection period to a second intensity level at the second moment in time.

Thereby, the step 41 of gradually decreasing the first intensity level during the disinfection period to a second intensity level at the second moment in time comprises decreasing the first intensity level to the second intensity level during the disinfection period by at least one of a non-linear decrease function, a linear decrease function, an exponential decrease function and/or a stepped decrease function.

In an optional step 43, the method may comprise maintaining the first intensity level during an initial step of the step function for at least a tenth, preferably a quarter, of the disinfection period and for at most two-thirds, preferably a half, of the disinfection period before decreasing the first intensity level to a subsequent step of the step function.

In alternative embodiments, not depicted, the method may comprise controlling the ultraviolet light source to gradually decrease the first intensity level during the disinfection period to a second intensity level at a third moment in time, and maintaining the second intensity level constant between the third moment in time to the second moment in time, wherein the third moment in time occurs after the first moment in time and before the second moment in time. In aspects, the third moment in time occurs at a moment within the last third, or preferably last quarter, of the disinfection period.

CLAIMS:

1. A lighting device comprising:

- a ultraviolet light source configured to emit ultraviolet light;
- an ion generation source for generating ionized air molecules;
- a controller configured to:

(i) control the ion generation source to generate ionized air molecules during a disinfection period spanned between a first moment in time and a second moment in time, and

(ii) control the ultraviolet light source to provide ultraviolet light at a first intensity level at the first moment in time and to gradually decrease the first intensity level during the disinfection period to a second intensity level at the second moment in time.

2. The lighting device according to claim 1, wherein the controller is configured to non-linearly decrease the first intensity level to the second intensity level during the disinfection period.

3. The lighting device according to claim 1, wherein the controller is configured to linearly decrease the first intensity level to the second intensity level during the disinfection period.

4. The lighting device according to any one of the preceding claims, wherein the controller is configured to decrease, in a step function, the first intensity level to the second intensity level during the disinfection period.

5. The lighting device according to any one of the preceding claims, wherein the controller is configured to maintain the first intensity level during an initial period of time for at least a quarter of the disinfection period and for at most a half of the disinfection period before decreasing the first intensity level to the second intensity level at the second moment in time.

6. The lighting device according to any one of the preceding claims, wherein the first intensity level is a maximum intensity level of the light source.

7. The lighting device according to any one of the preceding claims, wherein the controller is configured to control the ultraviolet light source to turn off at the second moment in time, wherein the second intensity level is zero.

8. The lighting device according to any one of the preceding claims, wherein the disinfection period is at least one hour.

9. The lighting device according to any one of the preceding claims, wherein the ultraviolet light comprises at least one of: Ultra Deep UV-C light in the range of 100 -190 nm, Far UV-C light in the range of 190-230 nm, near UV-C light in the range of 230-280 nm, UV-B light in the range of 280-315 nm, UV-A light in the range of 315-380 nm.

10. The lighting device according to any one of the preceding claims, wherein the controller is configured to control the ion generation source to generate the ionized air molecules at a first ionization rate during said disinfection period;

wherein the controller is configured to determine the first intensity level based on said first ionization rate.

11. The lighting device according to any one of the preceding claims, wherein the lighting device is a light bulb.

12. The lighting device according to any one of the preceding claims, wherein the ultraviolet light source is a LED light source or a laser light source.

13. The lighting device according to any one of the preceding claims, wherein the lighting device comprises a cap arranged for retrofitting the lighting device to a fixture or a luminaire.

14. A method of disinfection, performed by a lighting device comprising a ultraviolet light source, an ion generation source and a controller, wherein the method comprises:

- controlling the ion generation source to generate ionized air molecules during a disinfection period spanned between a first moment in time and a second moment in time;
- controlling the ultraviolet light source to provide ultraviolet light at a first intensity level at the first moment in time and gradually decreasing the first intensity level during the disinfection period to a second intensity level at the second moment in time.

15. A computer program product for a computing device, the computer program product comprising computer program code to perform the steps of the method of claim 14 when the computer program product is run on a processing unit of the computing device.

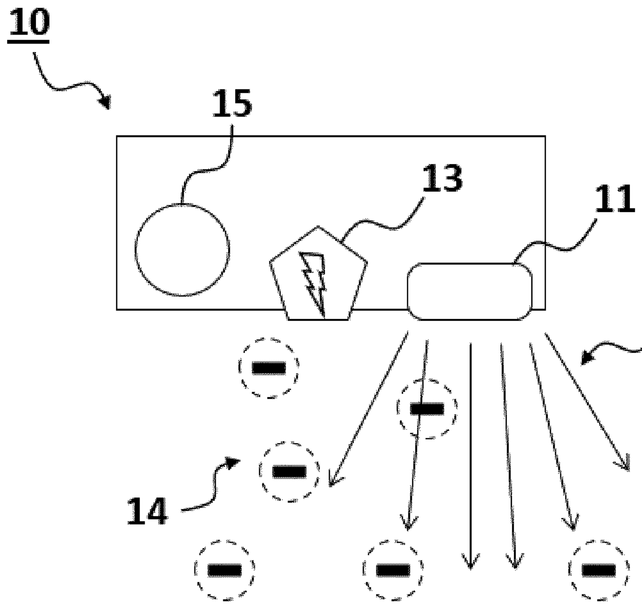

FIG.1.

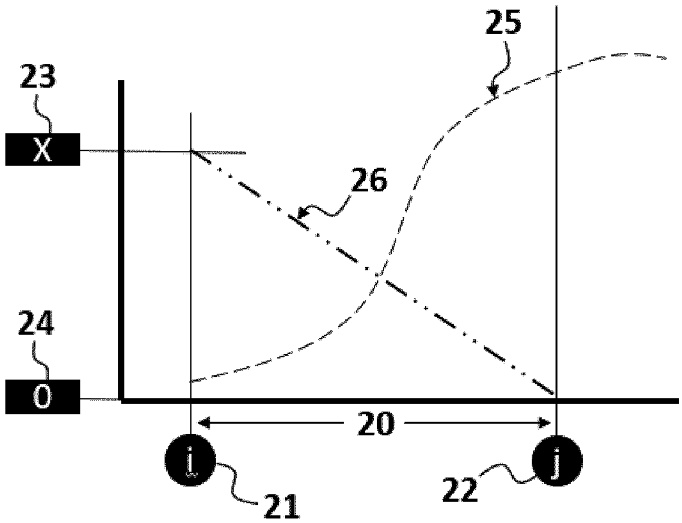

FIG.2A.

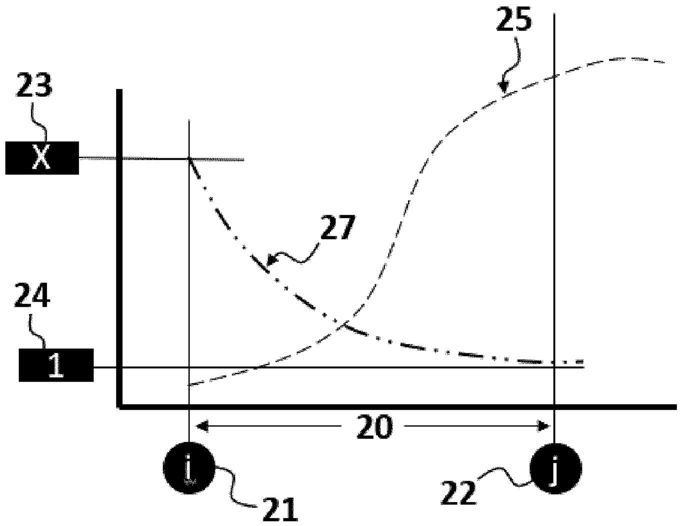

FIG.2B.

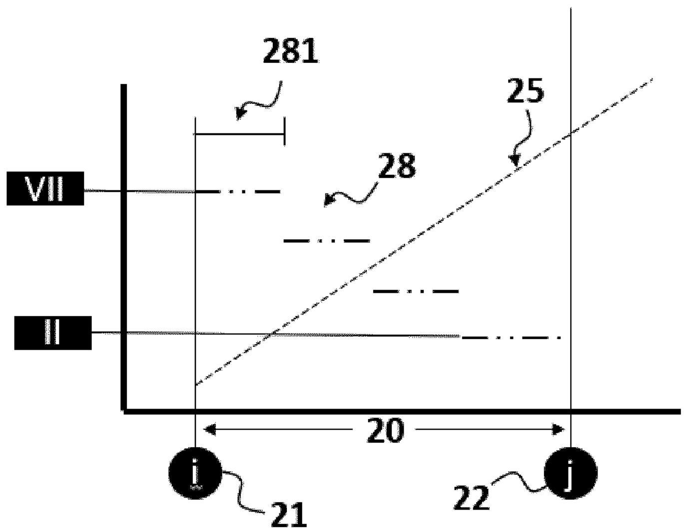

FIG.2C.

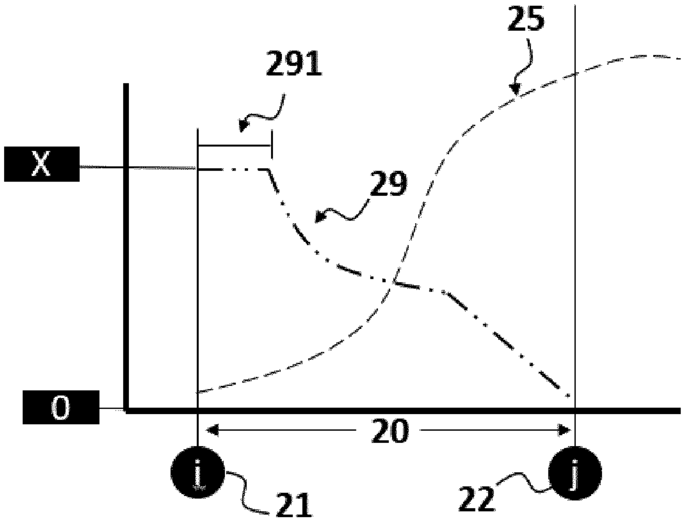

FIG.2D.

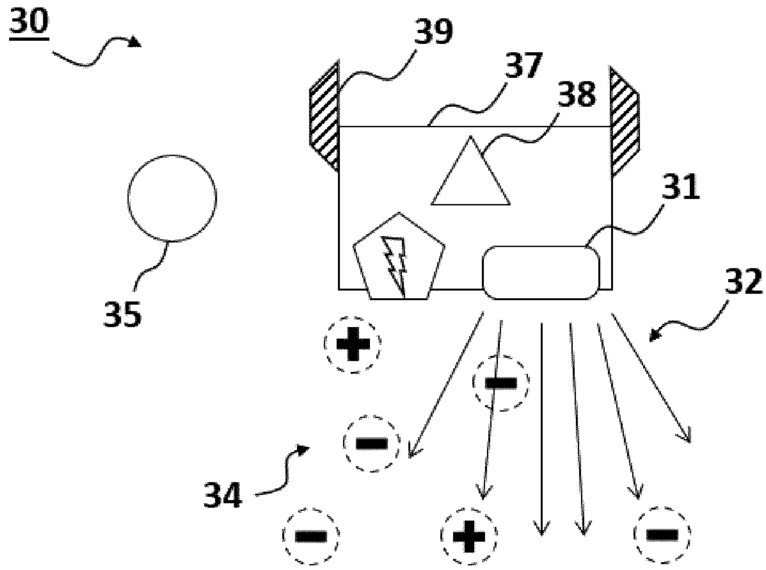

FIG.3.

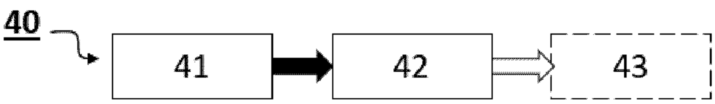

FIG.4.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/064791

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61L9/22 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

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2005/016378 A1 (YUEN SE KIT [CN]) 27 January 2005 (2005-01-27) paragraph [0034] - paragraph [0038]; figures	1-15
A	US 2003/003028 A1 (TOMASELLI GIANCARLO [IT]) 2 January 2003 (2003-01-02) the whole document	1-15

☐ 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
6 July 2022	26/07/2022

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Jazbec, Simon

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2022/064791

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