

DEVICE, SYSTEM, AND METHOD FOR DISINFECTING AN AREA

TECHNICAL FIELD

5 [0001] The present disclosure relates to a device, system, and method for providing disinfection. In particular, the disclosure relates to a device, system, and method for using electromagnetic radiation for disinfection.

BACKGROUND

10 [0002] The following discussion of the background is intended to facilitate understanding of the present disclosure. However, it should be appreciated that the discussion is not an acknowledgment or admission that any of the material referred to was published, known, or a part of the common general knowledge in any jurisdiction as of the priority date of the application.

15 [0003] In view of the outbreak of infectious diseases, there exists an increased need for scheduled and routine cleaning. In particular, it has become nearly essential for routine disinfection of public or commonly accessed areas. There is also a general expectation for such disinfection to be done quickly and effectively so as to minimise disruptions to operations.

20 [0004] In particular, public toilets or lavatories are deemed as areas that require frequent cleaning as these premises are likely to pose a higher risk associated with the spread of diseases due to constant usage.

[0005] There exists a need for an improved apparatus, system, and/or method for providing disinfection, without comprising operations and productivity.

25 SUMMARY

[0006] The present disclosure provides an apparatus, system, and/or method for providing disinfection, with improved efficiency and effectiveness.

[0007] According to one aspect of the disclosure, there is a disinfection

device comprising a housing for receiving a plurality of light emitting diode (LED) units capable of emitting at least one radiation for disinfection, the housing having an internal surface coated with a light reflective material, the internal surface arranged to reflect radiation emitted from each of the LED units;
5 wherein each of the plurality of LED units comprises a corresponding lens unit arranged to focus or collimate radiation emitted by the LED unit.

[0008] In some embodiments, the light/radiation reflective material comprises polished aluminium, polished aluminium alloy, and/or Polytetrafluoroethylene. Where the light reflective material is polished aluminium alloy, the polished
10 aluminium alloy comprises at least 80% aluminium, and preferably is an aluminium alloy comprising aluminium, chromium, and magnesium.

[0009] In some embodiments, at least one of the pluralities of light emitting diode (LED) units is operable to emit an ultraviolet-A (UV-A) radiation.

[0010] In some embodiments, at least one of the plurality of light emitting
15 diode (LED) units is operable to emit ultraviolet-C (UV-C) radiation. It is appreciable that the UV-C radiation and UV-A radiation may be controlled to be emitted together or as an alternative. The at least one UV-C emitter may be configured to emit a wavelength in the range of about 270 nanometers to 280 nanometers (nm).

20 **[0011]** Parts of the device, such as the housing, may be formed from a die-cast process or an additive manufacturing process.

[0012] The device may be in the form of a downlight or a linear light and comprise at least one heat sink module.

25 **[0013]** In some embodiments, the device comprises at least one intensity sensor arranged to detect the intensity of the radiation emitted in operation.

[0014] In some embodiments, each of the corresponding lens unit is formed of or from optically transparent polymers, preferably liquid silicone rubber (LSR).

[0015] In some embodiments, the device may comprise a transparent cover, the transparent cover formed at least in part of or from quartz glass.

[0016] In some embodiments, the device of any one of the preceding claims, further comprising a driver configured to produce electrical current having less
5 than 5% fluctuations in current ripple.

[0017] In some embodiments, the device is in the form of a downlight, and wherein the downlight has a diameter of between 60 millimetres (mm) to 210 mm. Alternatively, the device may be in the form of a linear light, wherein the linear light has a length of between 600 mm to 1300 mm.

10 **[0018]** According to another aspect of the present disclosure there is a system for disinfection of an enclosed area comprising a plurality of disinfection devices, each disinfection device comprises a housing for receiving a plurality of light emitting diode (LED) units capable of emitting at least one radiation for disinfection, the housing having an internal surface coated with a light reflective
15 material, the internal surface arranged to reflect radiation emitted from each of the LED units; each of the plurality of LED units comprises a corresponding lens unit arranged to focus or collimate radiation emitted by the LED unit; and a processor configured to toggle each of the plurality of LED units between an off state and an on state.

20 **[0019]** The system may comprise one or more sensors, such as one or more motion sensors arranged to detect the presence of one or more human beings within the enclosed area, wherein upon detecting the presence of one or more human beings, the processor is configured to toggle at least one LED unit of the plurality of LED units to the off state.

25 **[0020]** The plurality of LED units comprises a first LED unit capable of emitting a UV-C radiation and a second LED unit capable of emitting a UV-A radiation, wherein when the first LED unit is toggled to the on state, the second LED unit is toggled to the off state, and vice versa. Such an arrangement may be advantageous to provide a basic level of disinfection to the area even when

one or more human beings are present. In such an arrangement, the processor of the system, upon detecting the presence of one or more human beings via the motion sensor(s), is configured to toggle the first LED unit to the off state and the second LED unit to the on state.

5 **[0021]** In some embodiments, the system further comprises an air-disinfection device. The air-disinfection device comprises a collimator mounted on a first wall surface at a height from a ceiling of the enclosed area; the collimator containing a UV-C emitter and operable to emit a narrowed beam of UV-C radiation through a nozzle opening; and a plurality of UV-C radiation
10 sensors mounted on a second wall surface for detection the UV-C radiation emitted from the collimator; wherein the plurality of UV-C radiation sensors is arranged to detect at least two levels of UV-C radiation corresponding to two different regions on the second wall.

15 **[0022]** The processor may be operable to control the collimator at a continuous on state unless UV-C radiation is detected at a predetermined region of the two regions on the second wall.

20 **[0023]** According to another aspect of the disclosure there is a method for providing disinfection to an enclosed area having walls and a ceiling, comprising the steps of: providing a disinfection device mounted on a ceiling of the enclosed area to provide surface disinfection of at least one object in the enclosed area; the disinfection device comprises a housing for receiving a plurality of light emitting diode (LED) units capable of emitting a radiation for disinfection, the housing having an internal surface coated with a light reflective material, the internal surface arranged to reflect radiation emitted from each of
25 the LED units, each of the plurality of LED units comprises a corresponding lens unit arranged to focus or collimate radiation emitted by the LED unit; and providing a processor to toggle each of the plurality of LED units between an on state and an off state the disinfection device.

30 **[0024]** The method may further comprise the step of switching one of the plurality of LED units to the on state and switching another one of the plurality

of LED units to the off state.

5 **[0025]** The method may further comprise the steps of providing an air-disinfection device, the air-disinfection device comprises a collimator containing an UV-C emitter operable to emit a narrowed beam of UV-C radiation through a nozzle opening; and providing a plurality of UV-C radiation sensors mounted on a second wall surface for detection the UV-C radiation emitted from the collimator; wherein the plurality of UV-C radiation sensors are arranged to detect at least two levels of UV-C radiation corresponding to two different regions on the second wall.

10 **[0026]** Other aspects of the disclosure will be apparent to those of ordinary skill in the art upon review of the following description of specific embodiments of the disclosure in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

15 **[0027]** Various embodiments are described, by way of example only, with reference to the accompanying drawings, in which:

[0028] Figures 1a to 1e show embodiments of a device for providing disinfection in the form of downlights.

20 **[0029]** Figures 2a to 2c show one or more embodiments of a system for providing disinfection.

[0030] Figure 3a shows a setup demonstrating the efficacy of the system for providing disinfection,

[0031] Figure 3b is a table detailing the results of various configurations associated with the setup shown in Figure 3a.

25 **[0032]** Other arrangements are possible, and it is appreciable that the accompanying drawings are not to be understood as superseding the generality of the preceding description of the disclosure.

DETAILED DESCRIPTION

- 5 **[0033]** Embodiments are described with reference to the accompany drawings. The terminology used herein is for the purpose of describing particular embodiments only and is not intended to limit the scope of the present disclosure. Other definitions for selected terms used herein may be found within the detailed description of the disclosure and apply throughout the description.
- 10 Additionally, unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one ordinary skilled in the art to which the present disclosure belongs. Where possible, the same reference numerals are used throughout the figures for clarity and consistency.
- 15 **[0034]** Throughout the specification, unless the context requires otherwise, the word “comprise” or variations such as “comprises” or “comprising”, will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.
- 20 **[0035]** Throughout the specification, unless the context requires otherwise, the word “include” or variations such as “includes” or “including”, will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.
- 25 **[0036]** Throughout the specification, unless the context requires otherwise, the word “have” or variations such as “has” or “having”, will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.
- [0037]** As used herein, the term “disinfection”, “disinfecting”, “disinfectant” and variants refer to the use of a method to at least minimize bacteria/germs/virus of an area/premise. The terms include methods via

physical, chemical contact, and/or via exposure to radiation (e.g., exposure to the area to specific radiation such as ultra-violet radiation). The term “air disinfection” may be construed as a disinfection method to minimize bacteria/germs/viruses in the air flowing within the area/premise. The term
5 “surface disinfection” may be construed as a disinfection method to minimize bacteria/germs/viruses on a surface of an object within the area/premise. An object may include, but is not limited to, chairs, tables, wash basins, handles, flush handles, water closets, and other items in a lavatory.

[0038] As used herein, the term “associate”, “associated”, “associate”, and
10 “associating” indicate a defined relationship (or cross-reference) between at least two items. For instance, a plurality of devices (e.g., in the form of disinfection device/apparatus) may be controlled by a central server/processor and hence ‘associated’ with the central server/processor. In a group of devices (e.g., disinfection apparatus with other disinfection apparatus and/or sensors),
15 each device may interact with another device and hence be associated with one another.

[0039] As used herein, the term “network” can be any means of providing communication between one or more devices and/or content stored elsewhere. As used herein, network can be a personal area network, local area network, a
20 storage area network, a system area network, a wide area network, a virtual private network, and an enterprise private network. The network can include one or more gateways or no gateways. The network communication can be conducted via published standard protocols or proprietary protocols.

[0040] As used herein, communication of data through any network can be:
25 (i) encoded or unencoded; (ii) encrypted or unencrypted; (iii) delivered via a wired network, a wireless network, or a combination of wired and wireless. Wireless communication can be accomplished in any practical manner including via a Wi-Fi 802.11 network, a Bluetooth™ network, or mobile phone network (such as 3G, 4G, LTE, and 5G). The terms “connected”, “connected”,

and “connecting” as used herein refer to a communication link between at least two devices and can be accomplished as discussed in this paragraph.

5 **[0041]** As used herein, the term “computing device” may be a single stand-alone computer such as a desktop computer or a laptop computer, a thin client, a tablet computer, or a mobile phone. The computing device may run a local operating system and store computer files on a local storage drive. The computing device may access files and application through a gateway to one or more content repositories, the content repository can host files and/or run virtual applications and generate a virtual desktop for the computing device.

10 **[0042]** As used herein, the term “server” or “processor” may include a single stand-alone computer, a single dedicated server, multiple dedicated servers, and/or a virtual server running on a larger network of servers and/or cloud-based service. The processor may include integrated circuit (IC) chips such as application specific integrated circuit (ASIC) chips.

15 **[0043]** As used herein, the term “database” may include one or more data repositories to store data and access data from a single stand-alone computer, a data server, multiple dedicated data servers, a cloud-based service, and/or a virtual server running on a larger network of servers.

20 **[0044]** As used herein, the term “sensor” or “sensors” include hardware sensors, software sensors and combinations of hardware and software sensors.

[0045] As used herein, the terms “ultraviolet-A” and “UV-A” include, but is not limited to ultraviolet radiation at a wavelength in the range of 315 to 405 nanometers (nm).

25 **[0046]** As used herein, the terms ultraviolet-C and “UV-C” include, but is not limited to all UV-C radiation, short-wave ultraviolet, FAR-UV, deep UV etc. A UV-C radiation may be at a wavelength of 200 to 280 nanometres (nm).

[0047] As used herein, the term 'ceiling' refers to an upper interior surface of an enclosed area, such as a room, or other similar compartment. The ceiling is not limited by shape and does not necessarily has to be a flat surface.

[0048] Disclosed herein is a surface disinfection solution and method for automatically disinfecting the contact surfaces of objects using suitable electromagnetic radiation, such as, but not limited to, ultraviolet (UV) radiation. UV radiation may be provided in the form of emitters as a means for providing disinfection that is intelligently controlled and enabling protection of cleaners by disinfecting before cleaning tasks begins.

[0049] It was realized that although the use of UV radiation for disinfection is known, many known UV emitters do not provide effective disinfection. This is in part due to the lack of mechanisms to focus or collimate the UV radiation. In addition, the efficacy of present UV emitters is not properly measured. The inventor is motivated by the need to develop a device for disinfection that can achieve high log reduction, a measurement that is used to express the relative number of living microbes that are eliminated by disinfection. Based on this, a log 2 reduction will see a 99 percent reduction, or microbe reduction by a factor of 100, and so on.

[0050] Figures 1a to 1e show various embodiments of a disinfection device 100 in the form of a downlight. A downlight is typically installed on a ceiling of an enclosed area, such as a lavatory to project radiation including visible light or ultraviolet light in a downward direction. The ceiling may be recessed, surface mounted, or otherwise.

[0051] Figure 1a is a perspective view of the disinfection device 100, Figure 1b is a side view showing a heat sink assembly 150 of the device 100. Figure 1c shows an embodiment of the disinfection device 100 in the form of a downlight, with particular emphasis on a plurality of LED units without lens or other collimating elements. Figure 1d shows an embodiment of the disinfection device 100 in the form of a downlight, with particular emphasis on a plurality of LED units, each LED unit with lens for collimating the emitted radiation to within

17 degrees of beam angle. Figure 1e shows an embodiment of the disinfection device 100 in the form of a downlight, with particular emphasis on a plurality of LED units, each LED unit with lens for collimating the emitted radiation to within 60 degrees of beam angle.

5 **[0052]** In each of the embodiments shown in Figures 1a to 1e, the disinfection device 100 comprises a housing 102 for receiving a plurality of light emitting diode (LED) units 104 capable of emitting a radiation for disinfection, the housing 102 having an internal/inner surface 106 coated with a light reflective material 107, the inner surface 106 arranged to reflect radiation emitted from
10 each of the LED units 104. The heat sink assembly 150 may suitably be attached to a base of the housing 102 and is arranged in thermal connectivity with the LED units 104 to dissipate heat away from the LED units 104. Electrical circuits (not shown) may be contained within the housing 102 to provide control signals to switch each of the LED units 104 between at least an on state and
15 an off state. The heat sink assembly 150 may contain a number of fins arranged to maximize the surface area for heat dissipation.

[0053] In addition to the heat sink assembly 150, the device may include a metal core printed Circuit board (MCPCB) to further enhance heat dissipation, which include the creation of one or more protrusions on printed circuit boards
20 to increase heat dissipation.

[0054] In the embodiments shown in Figures 1d and 1e, each of the plurality of LED units 104 is arranged with a corresponding lens unit 108 to focus or collimate radiation emitted by the LED unit 104. It is appreciable that each lens unit 108 may collimate radiation emitted by the LED unit 104 to different extent.
25 In the embodiments shown in Figures 1d and 1e, there may comprise a reflective base plate 110 to further reflect radiation emitted from the LED units 104. The reflective base plate 110 is shaped and dimensioned with multiple hollow portions adapted aligned with the positioning of LED units 104 on the device 100.

[0055] The light reflective material 107 may be formed of or from polished aluminium, polished aluminium alloy and/or Polytetrafluoroethylene. In general, the radiation reflective material 107 is capable of reflecting radiation emitted by each of the LED units 104 with minimal degradation/adverse effect associated with exposure to the radiation. Where the radiation reflective material comprises aluminium alloy, the polished aluminium alloy comprises at least 80% aluminium, and preferably is an aluminium alloy comprising aluminium, chromium, and magnesium.

[0056] The lens unit 108 may be formed of or from optically transparent polymers, preferably liquid silicone rubber (LSR). In some embodiments, each lens unit may be removably attached to the LED unit 104, which may allow the lens to be exchanged to achieve different amounts of light attenuation.

[0057] In some embodiments, at least one of the plurality of light emitting diode (LED) units is operable to emit an ultraviolet-A (UV-A) radiation.

[0058] In some embodiments, at least one of the plurality of light emitting diode (LED) units is operable to emit an ultraviolet-C (UV-C) radiation. The UV-C radiation can be at a wavelength having a range of about 270 nanometers to 280 nanometers.

[0059] It is contemplated that in some embodiments, one of the plurality of LED units 104, for example a first LED unit, may be configured to emit a UV-C radiation, while another LED unit, for example a second LED unit, may be configured to emit a UV-A radiation. In another embodiment, all the LED units 104 may be configured to emit a UV-A radiation. In yet another embodiment, all the LED units may be configured to emit a UV-C radiation.

[0060] In some embodiments, the housing 102 may be formed from a die-cast process or an additive manufacturing process. The housing 102 may be shaped and dimensioned as a downlight having flanges to be attached to a ceiling.

[0061] The device 100 may comprise at least one intensity sensor arranged to detect the intensity of the radiation emission. The intensity sensor(s) may be integrated within the device 100 or may be positioned at other locations within an enclosed area where the device 100 is deployed in.

- 5 **[0062]** In some embodiments, the device 100 comprises a transparent cover, the transparent cover formed at least in part of quartz glass. Other transparent covers formed of or from other suitable materials are contemplated.

- [0063]** In some embodiments, a driver configured to produce relatively “ripple free” electrical current is used. Examples of such a driver are disclosed in the
10 PCT patent publications WO/2011/152795, WO/2015/122848 to Oplent Electronics International Pte. Ltd. The “ripple free” current is defined to be less than 5% from the specified rated current.

[0064] In the embodiments where the device 100 is a downlight, the downlight may have a diameter of between 60 millimeters (mm) to 210 mm.

- 15 **[0065]** It is contemplated that the entire housing may be formed from an aluminum alloy, such as, but not limited to, a 5052-aluminium alloy.

- [0066]** Although the various embodiments show the device 100 in the form of downlights, it is contemplated that the device 100 may have a linear light structure, or other form of light structure comprising one or more LED units 104
20 within the device 100 mounted in a manner so as to achieve an optimal beam angle.

- [0067]** Another aspect of the present disclosure relates to a system 200 for disinfection of an enclosed area 202. The system 200 may include usage of one or more disinfection devices 100 as previously described. In addition, the
25 system 200 includes a processor 204 configured to toggle each of the plurality of LED units between an off state and an on state. The processor 204 may be part of a remote server and is arranged in data or signal communication with each of the disinfection device so as to transmit control signals to the disinfection devices and/or receive data signals from the disinfection devices.

Examples of control signals include turn on signals, switch off signals, and dimming signals. Examples of data signals include radiation intensity measurements, electrical voltage, electrical current, operating temperature associated with each disinfection device 100. In this regard, it is appreciable
5 that each disinfection device 100 can include one or more of the following sensors: voltage sensor, current sensor, temperature sensor, pressure sensor, radiation intensity sensor, etc.

[0068] As shown in Figure 2a, the system 200 may be deployed in an enclosed area, such as a lavatory. The lavatory may include one or more motion
10 sensors to detect the presence of one or more human beings. Upon detecting the presence of one or more human beings within the lavatory, the processor is configured to toggle at least one LED unit of the disinfection device to the off state. Depending on the configuration of the LED unit, radiation emitted by a LED unit deemed harmful to human beings, such as UV-C, will be turned off,
15 while radiation emitted by another LED unit deemed less harmful, or harmless, for example, UV-A, will be allowed to continue emitting even if a human being is detected to be present in the lavatory.

[0069] As another example, the plurality of LED units comprises a first LED unit capable of emitting a UV-C radiation and a second LED unit capable of
20 emitting a UV-A radiation, wherein when the first LED unit is toggled to the on state, the second LED unit is toggled to the off state, and vice versa.

[0070] In some embodiments, the system 200 further comprises another disinfection device 220 that is different from the device 100. The other disinfection device may be referred to as an air disinfectant device 220, which
25 comprises a collimator mounted on a first wall surface at a height from a ceiling of the enclosed area; the collimator containing an UV-C emitter and operable to emit a narrowed beam of UV-C radiation through a nozzle opening. The collimator may include network communication elements so as to be arranged in data or signal communication with the processor. The collimator is configured
30 to emit the narrowed beam from the first wall surface toward a second wall

surface (which may be a wall opposite to the first wall) and is mounted at a height well above the height of a human being so that the beam of UV-C radiation does not contact the human being. A plurality of UV-C radiation sensors may be mounted on the second wall surface for detecting the UV-C radiation emitted from the collimator such that the plurality of UV-C radiation sensors is arranged to detect at least two levels of the UV-C radiation corresponding to two different regions on the second wall. In this regard, if UV-C radiation is detected on a region on the second wall corresponding to a lower height (measured with reference to the floor or ground), therefore implying the possibility of stray UV-C radiation that can be exposed to a human being, the processor 204 is operable to switch the air disinfection device off (i.e., off state). Otherwise, the air disinfection device is maintained at the on state.

[0071] In some embodiments, the motion sensors may include microwave powered motion sensors, embedded at specific locations of the lavatory, to protect users from being harmed by the UV-C radiation emitted by the downlight 100. The microwave motion sensor can be ceiling or wall-mounted, the detection range is up to 10 meters.

[0072] The disinfection system 200 can operate without personnel. From another perspective, the system enables safe disinfection can carry out without adverse effects to human beings.

[0073] Figure 2b and 2c shows the system 200 for disinfection of an enclosed area having walls, a ceiling, toilet bowl, toilet paper compartment, flush button, and doorknob/handle. The illustration in Figure 2b and 2c shows the enclosed area in the form of washroom or lavatory area, but it is understood that the enclosed area may be other premise such as, but not limited to, a residential room, an office or meeting room.

[0074] The system 200 comprises the device 100 mounted on a ceiling at a height of, for example, in the range of 2800 mm to 3000 mm above the floor/ground.

[0075] In some embodiments, where the enclosed area is a lavatory, the objects within the enclosed area may be arranged as follows: (a) device 100 mounted on the ceiling; (b) toilet bowl positioned at a height of 2600 mm from the ceiling; (c) flush handle positioned at a height of 2100 mm from the ceiling; 5 (d) toilet roll compartment positioned at a height of 2200 mm from the ceiling; (e) door handle positioned at a height of 2000 mm from the ceiling. The device 100, which comprise an UV-C emitter and operable to emit a uniformity beam of UV-C radiation through an optics; provides a surface disinfection with the fluence of 25 millijoule per square centimeters (mJ/cm^2) (based on log 4 10 reduction, 99.99%) on targeted and specific locations at a specific exposure time 20mins.

[0076] To increase the log reduction, surface disinfection with the fluence of $50\text{mJ}/\text{cm}^2$ (based on log 5, 99.999%) on targeted and specific locations at a specific exposure time of about 30 mins or shorter may be configured.

15 **[0077]** To further increase the log reduction, surface disinfection with the fluence of $75\text{mJ}/\text{cm}^2$ (based on log 6, 99.9999%) on targeted and specific locations at a specific exposure time of 60 mins or shorter may be configured.

[0078] It is contemplated that one or more computing devices may be used by a user to remotely control the device and/or receive data from the UV-C 20 radiation sensors.

[0079] Described is a device, system, and method for reducing the risk of bacteria or virus transmission on contact surfaces and/or transmission in the air. The device described herein may be capable of automatically cleaning the contact surfaces using irradiation, such as UV irradiation.

25 **[0080]** The system may comprise a controller system, which may be configured to drive the device according to the disinfection methods. The devices may be connected via a network into a disinfection system. The system to perform a wide variety of functions. The system may allow automatic operations of the disinfection system, manually adjust operational parameters

via user interface, enable the system to analyze the transmitted data. The system may allow centralized monitoring, storage, or analysis of data that are connected to the network.

5 **[0081]** In some embodiments, a scheduler is integrated with the system 200 to manage the disinfection duration.

10 **[0082]** In some embodiments, the system 200 comprises a wireless network using a Wi-Fi network protocol as the primary control and feedback interface. Such a network enables monitoring of disinfection status and generates a report after every completed disinfection. Authorized personnel, such as a facility personnel, may be deployed to determine a next action based on the success or failure of the disinfection solution to complete the disinfection cycle. Any faults or failures associated with the device, driver or system may be sent via alert via notification or email to the facility department personnel. This greatly reduce the downtime of the disinfection system which is crucial in the current situation / for daily disinfection activity. A management platform or interface may be provided flexibility to facility personnel to schedule disinfection time for non-autonomous setup.

20 **[0083]** It is contemplated that the present disclosure may be applied to systems and methods for calibrating and detecting UV-C radiation to demonstrate effective disinfection and/or mitigating safety hazards. For example, the system 200 may comprise UV-C radiation sensors capable of transmitting data to one or more servers through a network. If any safety requirement is breached, e.g., then the UV-C radiation level detected by the UV-C radiation sensors exceeds certain predetermined settings, the device 25 100/220 can be switched off.

[0084] It is contemplated that one or more computing devices may be used by a user to remotely control the device 100/220 and/or receive data from the UV-C radiation sensors.

[0085] Figure 3a shows an experimental setup to demonstrate the efficacy of four different configurations of the device 100 with lens units 108 (at varying beam angles), or without lens unit 108 in an enclosed area. A total of eight LED units 104 were used in each of the configuration of device 100. The device 100 is mounted on a ceiling at about 117 cm (1.17 meters) measured from the floor/ground of the enclosed area. Three detectors were placed at point A, point B and point C on the floor to detect the irradiance power in micro-watts per square centimeters ($\mu\text{W}/\text{cm}^2$). Detector A is placed directly below the device 100, while detectors B and C are offset or positioned at each side of detector A to measure or detect UV-C radiation associated with the beam angle emitted in the LED lens units of the device 100.

[0086] The four configuration comprises the following:

Configuration 1 (without LED lens unit): this corresponds to the arrangement shown in Figure 1c;

Configuration 2 (with LED lens unit with 17° beam angle): this corresponds to the arrangement shown in Figure 1d;

Configuration 3 (with LED lens unit with 60° beam angle): this corresponds to the arrangement shown in Figure 1e;

Configuration 4 (with both LED lens unit with 17° beam angle and 60° beam angle): this corresponds to four LED units with 17° beam angle and four LED units with 60° beam angle;

[0087] Figure 3b show the various results in the form of a table detailing irradiance power in micro-watts per square centimeters ($\mu\text{W}/\text{cm}^2$) for each of the configuration 1 to 4 as described. The results may be used as part of the data for configuring one or more operation modes of the device 100 and system 200. For example, if an object placed directly below the device 100 (e.g., a toilet bowl or water closet) requires strong disinfection power, perhaps due to immediate usage, operation modes corresponding to configuration 2 or 4 may

be used, whereas if it is general disinfection of water closet and other objects including wash basins etc., configuration 3 may be used.

[0088] It is to be appreciated by the person skilled in the art that variations and combinations of features described above, not being alternatives or substitutes, may be combined to form yet further embodiments falling within the
5 intended scope of the present disclosure.

CLAIMS

1. A system for disinfection of an enclosed area comprising

a plurality of disinfection devices, each disinfection device comprises a housing for receiving a plurality of light emitting diode (LED) units capable of emitting a radiation for disinfection, the housing having an internal surface coated with a light reflective material, the internal surface arranged to reflect radiation emitted from each of the LED units; each of the plurality of LED units comprises a corresponding lens unit arranged to focus or collimate radiation emitted by the LED unit;

a processor configured to toggle each of the plurality of LED units between an off state and an on state; and

an air disinfection device in the form of a collimator mounted on a first wall surface at a height from a ceiling of the enclosed area; the collimator containing an ultraviolet-C (UV-C) emitter and operable to emit a narrowed beam of UV-C radiation through a nozzle opening; and

a plurality of UV-C radiation sensors mounted on a second wall surface for detection of the UV-C radiation emitted from the collimator;

wherein the plurality of UV-C radiation sensors is arranged to detect at least two levels of the UV-C radiation, corresponding to two different regions on the second wall.

2. The system of claim 1, further comprises a motion sensor arranged to detect presence of one or more human being within the enclosed area, wherein upon detecting of the presence of the one or more human beings, the processor is configured to toggle at least one LED unit of the plurality of LED units to the off state.

3. The system of claim 2, wherein the plurality of LED units comprise a first LED unit capable of emitting a UV-C radiation and a second LED unit capable of emitting a ultraviolet-A (UV-A) radiation, wherein when the first LED unit is toggled to the on state, the second LED unit is toggled to the off state, and vice versa.

4. The system of claim 3, wherein the upon detecting the presence of the one or more human beings, the processor is configured to toggle the first LED unit to the off state and the second LED unit to the on state.
5. The system of claim 1, wherein the processor is operable to control the collimator at a continuous on state unless the UV-C radiation emitted from the collimator is detected at one of the two regions on the second wall.
6. The system of any one of claims 1 to 5, wherein the light reflective material comprises polished aluminium, polished aluminium alloy and/or Polytetrafluoroethylene.
- 10 7. The system of claim 1 or claim 2, wherein at least one of the plurality of LED units is operable to emit an UV-A radiation.
8. The system of claim 1 or claim 2, wherein at least one of the plurality of LED units is operable to emit an UV-C radiation.
9. The system of claim 8, wherein the at least one of the plurality of LED units is operable to emit the UV-C radiation having a wavelength of 270 nanometers to 280 nanometers.
- 15 10. The system of claim 6, wherein the polished aluminium alloy comprises at least 80% aluminium, and preferably is an aluminium alloy comprising aluminium, chromium, and magnesium.
- 20 11. The system of any one of claims 1 to 10, wherein the housing is formed from a die-cast process or an additive manufacturing process.
12. The system of any one of claims 1 to 11, further comprising at least one heat sink module.
13. The system of any one of claims 1 to 12, wherein the plurality of disinfection devices comprises at least one intensity sensor arranged to detect an intensity of the radiation emission.
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14. The system of any one of claims 1 to 13, wherein each of the lens unit is formed of or from optically transparent polymers, preferably liquid silicone rubber (LSR).
15. The system of any one of claims 1 to 14, wherein each of the disinfection device comprises a transparent cover, the transparent cover formed at least in part of quartz glass.
16. The system of any one of claims 1 to 15, further comprising a driver configured to produce electrical current having less than 5% fluctuations.
17. The system of any one claims 1 to 16, wherein each disinfection device is in the form of a downlight, and wherein each downlight has a diameter of between 60 millimeters (mm) to 210 mm.
18. A method for providing disinfection to an enclosed area having walls and a ceiling, comprising the steps of:
- providing a disinfection device mounted on a ceiling of the enclosed area to provide surface disinfection of at least one object in the enclosed area; the disinfection device comprises a housing for receiving a plurality of light emitting diode (LED) units capable of emitting a radiation for disinfection, the housing having an internal surface coated with a light reflective material, the internal surface arranged to reflect radiation emitted from each of the LED units, each of the plurality of LED units comprises a corresponding lens unit arranged to focus or collimate radiation emitted by the LED unit;
 - providing a processor to toggle each of the plurality of LED units between an on state and an off state; and
 - providing an air disinfection device comprising an UV-C emitter operable to emit a narrowed beam of UV-C radiation through a nozzle opening; and providing a plurality of UV-C radiation sensors mounted on a second wall surface for detecting the UV-C radiation emitted from the UV-C emitter; wherein the plurality of UV-C radiation sensors are arranged to detect at least two levels of the UV-C radiation corresponding to two different regions on the second wall.

19. The method of claim 18, further comprises the step of switching one of the plurality of LED units to the on state and switching another one of the plurality of LED units to the off state.

20. The method of claim 18, wherein the step of arranging the plurality of
5 UV-C radiation sensors corresponds to detecting three levels of the UV-C radiation corresponding to three different regions on the second wall.

21. The method of claim 20, wherein the three different regions correspond to a germicidal zone, a stray zone, and a no-radiation zone.