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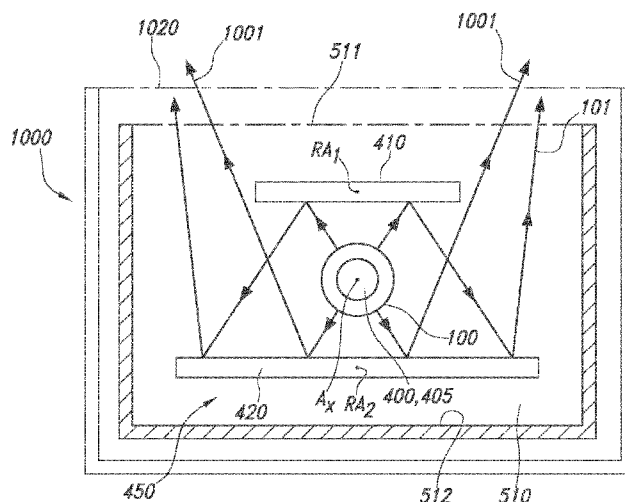


FIG. 1

(57) Abstract: The invention provides a radiation generating system (1000) comprising an excimer lamp (100), a light chamber (510), and optics (450) wherein the excimer lamp (100) comprises a discharge vessel (400), wherein the discharge vessel (400) contains a gas composition (405) comprising chlorine, neon and krypton; wherein the excimer lamp (100) is configured to generate in an operational mode radiation (101) having one or more wavelengths in the wavelength range of 200-300 nm; wherein the optics (450) comprises a first reflector (410) and a second reflector (420); wherein the discharge vessel (400) is configured between the first reflector (410) and the second reflector (420); wherein the first reflector (410) is configured to reflect at least part of the radiation (101) in a direction of the second reflector (420); wherein the excimer lamp (100), the first reflector (410), and the second reflector (420) are configured such that at least part of the radiation (101) can only escape from the radiation generating system (1000) via at least a reflection at the

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second reflector (420); wherein the second reflector (420) has a first wavelength averaged reflection R1 in a first wavelength range 210-245 nm, a second wavelength averaged reflection R2 in a second wavelength range of 250-270 nm, and a third wavelength averaged reflection R3 in a third wavelength range of 190 nm and smaller, wherein $R2/R1 \leq 0.6$ and wherein $R3/R1 \leq 0.6$; wherein the radiation generating system (1000) is configured to generate system light (1001) comprising at least part of the radiation (101) reflected at the second reflector (420).

Disinfection lamp with reflector

FIELD OF THE INVENTION

The invention relates to a radiation generating system and to a method for treating a gas, such as air, or a surface.

5 BACKGROUND OF THE INVENTION

UV emitting lamps are known in the art. US 10071262 B2, for instance, describes an apparatus and method for generating at least one bactericidal radiation, comprising an overhead surgical illumination system or a surgeon's surgical headlight system comprising; comprising an excilamp configured to generate the at least one bactericidal
10 radiation having a peak wavelength provided in a range of 190 nanometers (nm) to 230 nm, wherein the peak wavelength is 207 nm or 222 nm; comprising at least one filter arrangement which includes a band pass filter, or a combination of a low pass filter and a high pass filter, wherein the at least one filter arrangement is configured to; comprising preventing all ultraviolet wavelengths of the at least one generated bactericidal radiation that are outside of
15 the range of 190 to 230 nm from passing through the at least one filter arrangement; and comprising allowing all wavelengths in the range of 190 to 230 nm to pass through the at least one filter arrangement; and comprising fluoresce visible light in response to the at least one bactericidal radiation impinging on the at least one filter arrangement to indicate that the excilamp is operating.

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SUMMARY OF THE INVENTION

UV light has been used for disinfection for over 100 years. Wavelengths between about 190 nm and 300 nm may be strongly absorbed by nucleic acids, which may result in defects in an organism's genome. This may be desired for inactivating (killing),
25 bacteria and viruses, but may also have undesired side effects for humans. Therefore, the selection of wavelength of radiation, intensity of radiation and duration of irradiation may be limited in environments where people may reside such as offices, public transport, cinema's, restaurants, shops, etc., thus limiting the disinfection capacity. Especially in such environments, additional measures of disinfection may be advantageous to prevent the spread

of bacteria and viruses such as influenza or novel (corona) viruses like COVID-19, SARS, and MERS.

It appears desirable to produce systems, that provide alternative ways for air treatment, such as disinfection. Further, existing systems for disinfection may not easily be implemented in existing infrastructure, such as in existing buildings like offices, hospitality areas, etc. and/or may not easily be able to serve larger spaces. This may again increase the risk of contamination. Further, incorporation in HVAC systems may not lead to desirable effects and appears to be relatively complex. Further, existing systems may not be efficient, or may be relatively bulky, and may also not easily be incorporated in functional devices, such as e.g. luminaires.

Other disinfection systems may use one or more anti-microbial and/or anti-viral means to disinfect a space or an object. Examples of such means may be chemical agents which may raise concerns. For instance, the chemical agents may also be harmful for people and pets.

In embodiments, the disinfecting light, may especially comprise ultraviolet (UV) radiation (and/or optionally violet radiation), i.e., the light may comprise a wavelength selected from the ultraviolet wavelength range (and/or optionally the violet wavelength range). However, other wavelengths are herein not excluded. The ultraviolet wavelength range is defined as light in a wavelength range from 100 to 380 nm and can be divided into different types of UV light / UV wavelength ranges (Table 1). Different UV wavelengths of radiation may have different properties and thus may have different compatibility with human presence and may have different effects when used for disinfection (Table 1).

Table 1: Properties of different types of UV, violet, and NIR wavelength light

Name	Short name	Wavelength (nm)	(Relative) sterilization effectiveness		Safe Radiation	Vitamin D generation	Ozone generation
			Bacteria	Viruses			
Near Infrared (deep red)	NIR	780-950	+	+/-	+++		
Violet	V	380-420	+/-	-	+		

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

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

especially implies that ozone is produced which may be useful for disinfection applications, but may be harmful for humans / animals when they are exposed to it. Hence, in many applications this “+” may actually be undesired while in others, it may be desired. The types of light indicated in above table may in embodiments be used to sanitize air and/or surfaces.

5 The terms “inactivating” and “killing” with respect to a virus may herein especially refer to damaging the virus in such a way that the virus can no longer infect and/or reproduce in a host cell, i.e., the virus may be (essentially) harmless after inactivation or killing.

 Hence, in embodiments, the light may comprise a wavelength in the UV-A
10 range. In further embodiments, the light may comprise a wavelength in the UV-B range. In further embodiments, the light may comprise a wavelength in the Near UV-C range. In further embodiments, the light may comprise a wavelength in the Far UV-C range. In further embodiments, the light may comprise a wavelength in the extreme UV-C range. The Near UV-C, the Far UV-C and the extreme UV-C ranges may herein also collectively be referred
15 to as the UV-C range. Hence, in embodiments, the light may comprise a wavelength in the UV-C range. In other embodiments, the light may comprise violet radiation.

 Hence, light or radiation described herein may also be indicated as disinfection light.

 The present invention focusses, amongst others, on KrCl excimer discharge
20 lamps. Such lamps may especially emit at a wavelength of about 222 nm, which may, as indicated above, be relatively safe and be relatively efficient in reducing e.g. the virus load. The (about) 222 nm peak may have a relatively narrow band width. In addition to the about 222 nm emission, there may be a second (weaker) KrCl* peak at around 235 nm, which may have a broader bandwidth. Further, there may be emission at about 258 nm.

25 Prior art solutions may have as disadvantage a relatively high emission of undesired wavelengths, such as at about 258 nm (chlorine molecular radiation), and/or a relatively low efficiency. Other disadvantages of the prior art may be the removal of more radiation than necessary. Yet, prior art solutions may have less desirable beam shapes.

 Hence, it is an aspect of the invention to provide an alternative radiation
30 generating system, which preferably further at least partly obviates one or more of above-described drawbacks. The present invention may have as object to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

 According to a first aspect, the invention provides a radiation generating system comprising an excimer lamp, a and optics. The radiation generating system

may further comprise a light chamber. In embodiments, the excimer lamp may comprise a discharge vessel. Especially, the discharge vessel may contain a gas composition comprising chlorine and krypton. Further, in embodiments, the excimer lamp may be configured to generate in an operational mode radiation having one or more wavelengths in the wavelength range of 200-300 nm. The optics may in embodiments comprise a first reflector and a second reflector. In embodiments, the discharge vessel may be configured between the first reflector and the second reflector. Especially, the first reflector may be configured to reflect at least part of the radiation in a direction of the second reflector. Furthermore, the excimer lamp, the first reflector, and the second reflector may be configured such that at least part of the radiation can only escape from the radiation generating system via at least a reflection at the second reflector. Especially, the second reflector may have a first wavelength averaged reflection R1 in a first wavelength range 210-245 nm and a second wavelength averaged reflection R2 in a second wavelength range of 250-270 nm. Further, the second reflector may in embodiments have a third wavelength averaged reflection R3 in a third wavelength range of 190 nm and smaller, such as the 160-190 nm wavelength range. Especially, $R2/R1 \leq 0.6$ may apply. Further, $R3/R1 \leq 0.6$ may apply. Additionally, in embodiments, the radiation generating system may be configured to generate system light comprising at least part of the radiation reflected at the second reflector. Hence, the invention may provide a disinfection lamp with reflector. Therefore, in specific embodiments, the invention provides a radiation generating system comprising an excimer lamp, a light chamber, and optics wherein the excimer lamp comprises a discharge vessel, wherein the discharge vessel contains a gas composition comprising chlorine and krypton; wherein the excimer lamp is configured to generate in an operational mode radiation having one or more wavelengths in the wavelength range of 200-300 nm; wherein the optics comprises a first reflector and a second reflector; wherein the discharge vessel is configured between the first reflector and the second reflector; wherein the first reflector is configured to reflect at least part of the radiation in a direction of the second reflector; wherein the excimer lamp, the first reflector, and the second reflector are configured such that at least part of the radiation can only escape from the radiation generating system via at least a reflection at the second reflector; wherein the second reflector has a first wavelength averaged reflection R1 in a first wavelength range 210-245 nm and a second wavelength averaged reflection R2 in a second wavelength range of 250-270 nm, wherein $R2/R1 \leq 0.6$; wherein the radiation generating system is configured to generate system light comprising at least part of the radiation reflected at the second reflector.

With the present system, it may be possible to more efficiently disinfect bacteria and/or viruses. The system may provide more power, and may thus have more impact upon the disinfection speed and/or the versatility of the type of bacteria and/or viruses which may be treated. Further, the higher efficiency of the system may also allow a reduction of the power, would this be desirable. Further, with the present system, it may be possible to provide a desirable beam shape, such as e.g. a batwing shape beam.

Here below, first some general embodiments of the system are described, followed by some more specific embodiments.

As indicated above, the invention may provide a radiation generating system comprising an excimer lamp and optics, and optionally a light chamber.

Hence, in embodiments, the radiation generating system may comprise an excimer lamp. The excimer lamp may be a radiation source (or light source), especially an ultraviolet light source. The excimer lamp may work on the principle of a dielectric barrier discharge, which refers to the electric discharge in an insulating medium configured between two conductors (or electrodes) upon the application of electricity. The excimer lamp may apply a potential difference (for example by applying an alternating current) between two electrodes configured on either side of a vessel containing a gas composition (typically comprising halides). Hence, in embodiments the excimer lamp may comprise a discharge vessel. Especially, the discharge vessel may contain a gas composition comprising chlorine and krypton, more especially chlorine, neon and krypton i.e. gas composition may comprise Cl_2 , Ne and Kr. However, other components may also be possible, but especially at least 90 %, even more especially at least 95% of the gas composition may consist of Cl_2 , Ne and Kr. Even more especially, 98% or more of the gas composition consists of Cl_2 , and Kr. Other components that could be available may e.g. be one or more of Ne, Ar, Br_2 , N_2 , or H_2 , such as one or more of Ar and N_2 . Further below, specific embodiments of the gas composition are provided (see further below). Especially, the combination of Kr and Cl_2 may provide the radiation in the range 200-300 nm. In embodiments, the excimer lamp may be configured to generate in an operational mode radiation having one or more wavelengths in the wavelength range of 200-300 nm.

The term “operational mode” may e.g. refer to which discharge conditions the gas composition is subjected (see further also below).

Further, the discharge vessel may contain a gas composition, which may be brought to discharge and generate radiation, including UV radiation. As indicated above, this radiation can inactivate harmful viruses by destroying their DNA/RNA, and/or inactivate

other parts of the virus proteins. Further, as indicated above, this radiation (in certain desirable wavelengths) may be absorbed by skin to produce vitamin D.

As indicated above, in embodiments the radiation generating system may comprise a light chamber. Especially, the light chamber may enclose at least a part of the radiation generating system. Further, in embodiments, the walls of the light chamber may be reflective for radiation (or light), especially ultraviolet light. Especially, the reflective walls of the light chamber may be reflective for radiation in the wavelength range of 200-300 nm.

Moreover, the light chamber in embodiments of the radiation generating system, may be cuboidal in geometry. In embodiments, the light chamber may comprise two reflective walls, especially three reflective walls, especially four reflective walls, more especially five reflective walls. The light chamber may (also) have, in embodiments, a pentagonal, a hexagonal or a higher order polygonal cross-section. Further, in embodiments, the light chamber may comprise at least a part comprising a chamber exit window. In embodiments, radiation (or light) may escape from light chamber (only) via the chamber exit window. Further, the light chamber may be defined by at least the one or more walls and the chamber exit window. Yet further, in embodiments, parts of the wall may be reflective for the radiation. The term “reflective” with regards to the light of the discharge vessel may herein refer to at least 50% of incident light source light being reflected, such as at least 60%, especially at least 70%, such as at least 80%, especially at least 90%, such as at least 95%, under perpendicular irradiation. Here, the percentages may refer to percentages based on Watts. The term “wall” may also include a bottom (or bottom wall) (and optionally in embodiments a closure).

In embodiments, the radiation generating system may comprise optics. Here “optics” may especially refer to elements that may interact with light, such as by reflecting, absorbing or transmitting radiation (especially light, such as especially ultraviolet light).

Especially, the optics may comprise a first reflector and a second reflector. In embodiments, the first reflector may be especially reflective for ultraviolet light, such as light in the wavelength 200-300 nm. Further, the second reflector may (also) be reflective for light, such as especially ultraviolet light, more especially such as light in the wavelength 200-300 nm. However, the second reflector may be selective in the wavelengths of light reflected, meaning that the second reflector may preferentially reflect light in a certain range of wavelengths (see below) and have a lower reflectivity for wavelengths outside such range. Exposure to ultraviolet radiation may be harmful, especially in high doses. Hence, the second reflector may provide the advantage of selectively reflecting (only) wavelengths of ultraviolet

light not or less harmful to humans (or living organisms). Alternatively or additionally, in embodiments, the second reflector may be configured to reflect (only) the wavelengths of ultraviolet light that may be harmful to living organisms, such as for use in a disinfection device.

5 Hence whereas the second reflector may have a wavelength dependence of the reflectivity in the 200-300 nm wavelength range, or at least in those wavelength ranges where the excimer lamp provides its radiation, the first reflector may have a relatively constant reflectivity of the wavelength range, or at least in those wavelength ranges where the excimer lamp provides its radiation.

10 Hence, in embodiments the first reflector may have a substantially wavelength independent reflection, at least in the 210-245 nm wavelength range, more especially in the 210-270 nm wavelength range, yet even more especially in the 200-300 nm wavelength range. For instance, differences in reflection from an average reflection in the indicated wavelength range(s) may be less than 30%, such as less than 20%. However, in specific
15 embodiments also the first reflector may have a wavelength dependent reflection.

 In embodiments, the discharge vessel may be configured between the first reflector and the second reflector. The excimer lamp may provide radiation, such as ultraviolet light of wavelengths in the range 200-300 nm in a radial direction.

 The radiation may be provided over an angle θ , wherein θ is the angle over
20 which radiation is provided i.e. the extremities of the cone of light (in a cross-sectional view) extend by an angle $\theta/2$ in the clockwise and anti-clockwise direction measured from a line perpendicular to a system exit window and passing through the center of the excimer lamp. Especially, the discharge vessel may have a cylindrical shape. Hence, in embodiments over 360° radiation may be provided by the discharge vessel during operation. Hence, in a plane
25 perpendicular to an axis of elongation of the discharge vessel, in the entire 360° radiation may be provided.

 Hence, by configuring the excimer lamp between the first reflector and the second reflector, a majority of the radiation provided by the excimer lamp over at least about 120° (especially when assuming an essentially cylindrical cross-section), such as at least
30 about 150°, may be reflected (at least once, by at least one of the reflectors). In specific embodiments, radiation provided by the excimer lamp over at least about 270°, such as even up to about 360° may be reflected (at least once, by at least one of the reflectors). Hence, in embodiments the light or radiation may be reflected by the first reflector and/or the second reflector.

Further, at least part of the radiation incident on the first reflector may be reflected in the direction of the second reflector. Hence, in embodiments, the first reflector may be configured to reflect at least part of the radiation (from the discharge vessel) in a direction of the second reflector. This may provide the advantage of protecting the user from direct exposure to radiation provided by the excimer lamp. In embodiments, at least 30% of the radiation generated by the excimer lamp may be reflected by the first reflector (at least once), such as at least about 40%, even more especially at least about 50%. A substantial part of the light reflected at the first reflector may reach the second reflector.

Especially, at least 70%, more especially at least 80% of the radiation generated by the excimer lamp may reach the second reflector. The radiation of the excimer lamp may reach the second reflector directly or after reflection at the first reflector. A (minor) part may reach the second reflector after at least a reflection at a reflective wall of the light chamber.

Hence, the excimer lamp may provide radiation which may be reflected by the first reflector and/or the second reflector.

As indicated above, at least a part of the radiation reflected by the first reflector may be reflected (subsequently) by the second reflector. Hence, in embodiments, the excimer lamp, the first reflector, and the second reflector may be configured such that at least part of the radiation can (only) escape from the radiation generating system via at least a reflection at the second reflector.

Rather, the majority of the system light provided by the radiation generating system may comprise radiation reflected at the second reflector, such as 60% of the system light, such as especially 70% of the system light, more especially 80% of the system light. Hence, at least as 60% of the system light escaping from the system may have been reflected at the second reflector at least once.

Here, the percentages may refer to percentage of the total spectral power (of the radiation or system light).

Further, in embodiments, the second reflector may have a first wavelength averaged reflection R1 in a first wavelength range 210-245 nm, a second wavelength averaged reflection R2 in a second wavelength range of 250-270 nm, and optionally a third wavelength averaged reflection R3 in a third wavelength range of 190 nm and smaller. Hence, the second reflector may be selective of the wavelength of the reflected wavelength.

Wavelength of ultraviolet light in about the range 250-270 nm may especially be harmful to living organisms. The desirable averaged wavelength safe for exposure (for

living organisms or people) may especially be in the range 210-245 nm; for this reason a wavelength averaged reflection R1 may be relatively high. Further, the third wavelength averaged reflection R3 in a wavelength range of 190 nm or smaller may (not-necessarily) be harmful but may yet be an undesirable wavelength of reflection. Typically, KrCl excimer lamps do not have an emission at a wavelength equal to or lower than 190 nm. Hence, in embodiments, the second reflector may be reflective for desirable wavelengths such as wavelength averaged reflection R1 and absorptive and/or transmissive for undesirable wavelength averaged reflection such as R2 and optionally R3. For example, the first and/or second reflector may have an absorption of at least 65%, such as 80% or 90% or more, for the second wavelength range, and an absorption of at the most 35%, such as 20% or 10% or less for the first wavelength range.

Especially, $R2/R1 \leq 0.6$, meaning the (undesirable) wavelength averaged reflection R2 may be at least 60% lower than the (desirable) averaged reflection R1, such as especially 40% lower or ($R2/R1 \leq 0.4$), more especially 20% lower (or $R2/R1 \leq 0.2$), most especially 10% (or $R2/R1 \leq 0.1$).

Yet further, in specific embodiments, the averaged reflection R3 may especially be lower than the (desirable) averaged reflection R1, such as 60% lower than the (desirable) averaged reflection R1, such as especially 40% lower or ($R3/R1 \leq 0.4$), more especially 20% lower (or $R3/R1 \leq 0.2$), most especially 10% (or $R3/R1 \leq 0.1$).

Especially, in embodiments, $R1 \geq 50\%$ and $R2 \leq 20\%$, and optionally $R3 \leq 20\%$. More especially, in embodiments $R1 \geq 60\%$ and/or $R2 \leq 15\%$, and optionally $R3 \leq 15\%$.

The second reflector may reflect desirable radiation in another direction than less desirable radiation; and/or the second reflector may absorb, or transmit less desirable (or undesirable) radiation (more than desirable radiation). Desirable radiation may especially be radiation in the wavelength range of 210-245 nm. Less desirable radiation may especially be in the wavelength range of 250-270 nm. For instance, safety issues may be more relevant in this range (of 250-270 nm) than in the range of 210-245 nm. Less desirable radiation may also be radiation with wavelengths equal to or smaller than about 190 nm, such as selected from the wavelength range of 160-190 nm. Note that percentages of transmission and/or reflection herein may especially be based upon perpendicular irradiation. Hence, the radiation generating system may provide system light, which comprises a majority of desirable wavelength radiation, while the undesirable wavelength may be minimized to improve safety.

As indicated above, in embodiments the radiation generating system may be configured to generate system light comprising at least part of the radiation reflected at the

second reflector. Hence, the radiation generating system may provide (desirable) reflected radiation. Especially, the first reflector reflects radiation generated by the excimer lamp, thus, protecting humans (or living organisms) from direct exposure to radiation. Further, the first reflector may increase the output of the radiation generating system by reflecting (at least a part of) the radiation towards the second reflector. Hence, in embodiments, the second reflector may reflect the radiation incident on its surface, wherein the source of the radiation may be radiation generated by the excimer lamp, directly or reflected via the first reflector (especially a combination of both). Therefore, the radiation provided by the excimer lamp may be a primary source of radiation and the radiation reflected from the first reflector (onto the second reflector) may be a secondary source of radiation. Especially, the ratio of light incident on the second reflector (from the primary source or the secondary source) may be in dependence of the spatial configuration of the optics and the excimer lamp within the light chamber. Further, the second reflector may absorb, transmit, or deflect undesirable (or harmful) wavelengths in the radiation provided. Therefore, in embodiments, the system light may comprise (desirable) and safe wavelengths reflected by the second reflector.

Additionally, specific embodiments of the radiation generating system may be configured to provide (some) radiation (or light) of the harmful wavelengths (such as wavelengths in the range 250-270 nm). This may be important to provide a device for (enhanced) disinfection. Hence, in embodiments, the system light may comprise radiation, or radiation reflected from the first reflector, or radiation reflected by the second reflector. Therefore, in specific embodiments $R2/R1 \geq 0.01$, such as more especially $R2/R1 \geq 0.1$. In specific embodiments $0.01 \leq R2/R1 \leq 0.8$, such $R2/R1 \leq 0.4$ or $0.01 \leq R2/R1 \leq 0.6$, like especially $R2/R1 \leq 0.2$ or $0.11 \leq R2/R1 \leq 0.4$.

Useful combinations of configuring the radiation generating system to provide system light comprising radiation of different wavelengths will be described further in specific embodiments.

In embodiments, the system may comprise a chamber exit window (or “light exit”, like an end window or an (other) optical element, or an opening, from which the system light may escape to the external of the system. The system may comprise a housing, comprising such light exit. The housing may at least partly enclose one or more light generating devices and one or more (other) optical elements.

In embodiments, the system may comprise a light chamber, wherein the light chamber may at least partially host the first reflector and/or the second reflector, and may at least partly host the discharge vessel. As indicated above the light chamber may have

reflective walls. Further, the housing may comprise an exit window or “chamber exit window”. The light chamber may be comprised by a housing of the system. In embodiments, the light chamber may be at least part of the housing of the system.

Note that in embodiments, the chamber exit window may be different from the system exit window. However, in other embodiments, the chamber exit window may be the same as the system exit window.

The system exit window may be the opening via which system light may be outcoupled from the radiation generating system. The chamber exit window may be a part of the light chamber via which radiation may be outcoupled from the light chamber. In some embodiments, the system exit window may comprise the chamber exit window. Window (i.e. the chamber exit window or the system exit window or both) may essentially be an opening via which radiation may escape.

In specific embodiments, the chamber exit window or the system exit window or both may (also) comprise an optical filter (or layer) via which radiation may escape. In yet further embodiments, the optical filter may be wavelength selective for the radiation generated by the discharge vessel during operation (of the system). Hence, an optical filter for a window may have a wavelength dependent transmission. In embodiments, the optical filter may have a first wavelength averaged transmission T_1 in a first wavelength range 210-245 nm, and a second wavelength averaged transmission T_2 in a second wavelength range of 250-270 nm, wherein $T_2/T_1 \leq 0.6$. In embodiments, $T_1 \geq 50\%$, wherein $T_2 \leq 20\%$. In specific embodiments, the optical filter may have a third wavelength averaged transmission T_3 in a third wavelength range of 190 nm and smaller; wherein $T_3/T_1 \leq 0.6$; and wherein $T_3 \leq 20\%$.

In embodiments, the first reflector (or the second reflector or both) may be made of one or more of polytetrafluoroethylene (PTFE) and polyvinylidene fluoride (PVDF). However, other materials may also be possible. In other embodiments, the first reflector may be metallic.

The first reflector may be diffusively reflective or specular reflective for the radiation. In embodiments, part of the radiation impinging on the first reflector (or the second reflector or both) may be diffusively reflected and part of the radiation may be specularly reflected. For instance, in embodiments a region of the first reflector close to a plane through an axis of elongation of the first reflector and an axis of elongation of the discharge vessel, may be specular reflective. However, regions of the first reflector further away from such plane may be diffusively reflective. Therefore, in embodiments the first reflector may be configured to reflect at least part of the radiation diffusively.

In embodiments, the first reflector may be curved. Especially, the first reflector may be curved in one direction, such as to have a semi-cylinder-like shape. The term “semi-cylinder-like” or “semi-cylindrical” may refer to a shape substantially identical to a semi-cylinder. However, it may also refer to a distortion thereof, like a semi-oval cross-sectional shape. The first reflector may have a curved reflector surface, but the first reflector may also have a faceted reflector surface. Further, referring to e.g. a circle. An arc (for example a semi-circle) has an angle of curvature, wherein the angle of curvature is the angle between two lines each connecting the center of the circle (of which the arc is a part) and the extremities of the arc. Hence, a semi-circle would imply a curvature of 180° . However, the semi-circle may also be smaller, like ranging a range selected from 45° - 180° , such as selected from the range of 45° - 135° . Further, semi-cylinder-like cross-sectional shape may also refer to a circle segment (also having an angle relative to the circle of which it is a segment smaller than 180° , such as selected from the range of 45° - 135°).

Further, in embodiments, the first reflector may (also) be curved in two directions, such as to have a concave (or convex) shape. Yet further, in embodiments, the first reflector may be curved in at least one direction, defining a first reflector cavity. Here “cavity” may refer to the formation of a surface which may enclose the discharge vessel over at least about 120° (especially when assuming an essentially cylindrical cross-section), such as at least about 150° , such as at least 270° . For example, cavities may be formed from a monolithic first reflector by hollowing or removing material (for example a metal or PTFE) from an object and polishing the inner surface. Alternatively, cavities may also be formed by covering an object (or the discharge vessel) using a plurality of first reflectors, or a curved first reflector, or a segmented first reflector.

In embodiments, the first reflector may be curved in at least one direction, defining a first reflector cavity and the discharge vessel may be at least partly configured within the first reflector cavity. This may provide the advantage of reflecting radiation (or light) from the first reflector towards the second reflector. Hence, preventing the outcoupling of harmful or undesirable radiation. For instance, in embodiments the first reflector may be partially curved about an axis of elongation.

In embodiments, the excimer lamp may be configured between the vertex and the center of curvature of the (curved) first reflector. The first reflector may reflect the light from the excimer lamp incident on its surface in the direction of the second reflector. Especially, the first reflector reflects a majority of the light (from the excimer lamp) over at least about 120° (especially when assuming an essentially cylindrical cross-section), such as

at least about 150° , such as at least 270° incident on its surface towards the second reflector. Thus, the first reflector may prevent the direct outcoupling of light from the excimer lamp. Hence, in embodiments, by configuring the excimer lamp between the vertex and the center of curvature of the first reflector, the first reflector may reduce (or completely prevent) outcoupling of harmful radiation.

Alternatively in embodiments, the first reflector may comprise a planar first cross-sectional shape. This may especially be a flat shape with no curvature in any direction.

In embodiments, the first reflector may comprise n_1 segments. Especially, where n_1 is 2, wherein n_1 is 3, such as especially 4, such as especially 5 or more. Further, the n_1 segments may form a first reflector cavity. In further embodiments, the two segments may be connected along an edge such that they form an angle between them. Yet further, a multitude of different shapes for the first reflector may be formed by combining one or more segments. Note that (in embodiments) the segments may be connected along one or two edges, such that the surface normal of all segments lie in the same plane i.e. the segmented first reflector may be configured to reflect light analogous to a (curved) first reflector, curved in one direction. In other embodiments, the segments may be connected along all edges to form a three-dimensional configuration, wherein the first reflector may reflect radiation analogous to a (curved) first reflector curved in two directions.

Yet further, in embodiments each segment may have a flat cross-sectional shape, or the segment may be curved in one or two directions. Especially, in embodiments, the first reflector may comprise a combination of segments having flat cross-sectional shapes as well as curved segments (curved in one or more directions). For example, the combination of two segments comprising a flat cross-sectional shape and two reflectors having a semi-cylinder cross-section, a W-shaped first reflector may be formed.

Further, the first reflector may comprise four segments. Especially, the two segments may have a semi-cylinder cross-sectional shape and two segments may have a flat cross-sectional shape. Especially, two of the semi-cylindrical cross-sectional shaped segments may be joined along an edge. Further, the segments having the semi-cylindrical cross-sectional shape may be joined such that a center line defining a middle intersects the edge along where these two segments are joined. Yet further, the two segments having a flat cross-sectional shape may be configured on either side of the middle. Especially, the two segments having a flat cross-sectional shape may be joined to the free edge of the semi-cylindrical cross-sectional shaped first reflectors. This in embodiments, essentially forms a W-shaped first reflector (wherein the semi-cylindrical shaped first reflectors form the base of

the W-shape and the flat first reflectors form the arms of the W-shape). In further alternative embodiments, the first reflector may comprise a single monolithic body that may be W-shaped i.e. not necessarily comprising a plurality of segments. A W-shaped first reflector may provide the advantage of focusing the radiation provided by the excimer lamp i.e. (i) the curved segments (or sections) of the first reflector may focus the radiation (provided by the excimer lamp) onto specific regions on the second reflector (before they are reflected further by the second reflector), and (ii) the flat segments (or sections) may be useful in reflecting the radiation that is not reflected by the curved segments (or sections) of the first reflector.

For example, in embodiments, a W-shaped first reflector may be used in combination with a plurality k_3 of second reflectors segments, wherein k_3 may be 2, such as especially 3, such as especially 4 or more. Especially, the adjacent second reflector segments may be configured to provide an opening between them by positioning the segments at a distance dr_2 apart. Hence, in such an embodiment the W-shaped first reflector may provide the advantage of focusing the radiation (provided by the excimer lamp), such that the radiation is reflected off the second reflector segment before being escaped from the radiation generating system. Hence, in such an embodiment, along the optical path (via which the radiation may escape), the first reflector may be configured upstream of the excimer lamp, the excimer lamp may be configured upstream of the second reflector, the second reflector may be configured upstream of the system exit window.

The use of the (segmented) first reflector may provide the advantage of higher degree of control in directing the reflected radiation towards the second reflector. Further, the first reflector comprising segments may be easier to manufacture as compared to curved reflectors.

The discharge vessel may be elongated (along a discharge vessel axis). The first reflector may also be elongated. In embodiments, the axes of elongation of the discharge vessel and the first reflector may be configured essentially parallel.

In embodiments, the radiation generating system may comprise a plurality n_2 of first reflectors. Especially, n_2 may be at least 2, such as at least 3, such as at least 4. Further, at least two of the n_2 plurality of first reflectors may be arranged such that they form an opening between them i.e. a first reflector opening. Especially, a set of two adjacent first reflectors may have a mutual distance (dr_1) providing the first reflector opening. Note that in embodiments, dr_1 is not necessarily constant and hence may be varied. Meaning, the distance dr_1 between two adjacent first reflectors may be different from the distance dr_1 between two (other) first reflectors. Yet further, the adjacent first reflectors may (also) be configured at an

angle with respect to one another. Hence, the set of two adjacent first reflectors may be configured such that part of the radiation may be propagated through the first reflector opening. In embodiments, at least two closest first reflectors may be connected such that they form a V-shaped configuration. Hence, between two neighboring first reflectors, the mutual distance ($dr1$) may vary along a direction.

In embodiments, the first reflectors may be arranged such that at least a part of the radiation of the excimer lamp may escape via the openings between the $n2$ plurality of first reflectors. Especially, the radiation of the excimer lamp may escape with at least one reflection at one of the two adjacent first reflectors. In embodiments, relative to a system exit window (via which system light escapes from the radiation generating system), along an optical path of the system light, the $n2$ first reflectors may be configured closer to the system exit window than the second reflector. Hence, in embodiments along the optical path via which system light escapes, the second reflector may be configured upstream of the excimer lamp, the excimer lamp may be configured upstream of the plurality $n2$ of first reflectors, and the plurality $n2$ of first reflectors may be configured upstream of the system exit window. Therefore, in embodiments the radiation generating system may comprise a plurality $n2$ of first reflectors, wherein $n2$ is at least 2, wherein a set of two adjacent first reflectors may have a mutual distance ($dr1$) providing a first reflector opening, wherein the set of two adjacent first reflectors may be configured such that part of the radiation propagates through the first reflector opening, with at least one reflection at one of the two adjacent first reflectors; wherein relative to a system exit window via which system light escapes from the radiation generating system, along an optical path of the system light, the $n2$ first reflectors are configured closer to the system exit window than the second reflector.

As indicated above, the system may comprise a second reflector. Also the second reflector may have different shapes.

In embodiments, the second reflector may comprise a double semi-cylinder-like cross-sectional shape. Especially, comprising two reflector regions, each comprising a semi-cylinder-like cross-sectional shape, where (i) a center line defining a middle between the two reflector regions, and (ii) a discharge vessel axis (A) of the discharge vessel may be configured in a single place.

With such a second reflector, the outcoupling of the radiation from the light chamber may be increased. Good outcoupling may also be obtained with the second reflector which has a kind of W-shape. Hence, instead of a single semi-cylinder-like cross-sectional shape, two of such shapes, especially configured parallel, may be comprised by the second

reflector. Hence, essentially any embodiment described above in relation to the semi-cylinder-like cross-sectional shape may also apply to the double semi-cylinder-like cross-sectional shaped reflector.

Therefore, in embodiments the second reflector may have a double semi-cylinder-like cross-sectional shape, comprising two reflector regions, each having a semi-cylinder-like cross-sectional shape. Especially, in embodiments (i) a center line defining a middle between the two reflector regions (i.e. the two semi-cylinder-like reflector regions comprised by the second reflector) and (ii) a discharge vessel axis (A) of the discharge vessel may be configured in a single plane. Further, the second reflector may be monolithic, even when comprising a semi-cylinder-like cross-sectional shape.

Hence, in embodiments, the first reflector (or the second reflector or both) may comprise a plurality of segments to achieve one or more geometric configurations. Especially, in alternative embodiments, these geometric configurations may (also) be achieved using a monolithic first reflector (or second reflector or both).

Here below some further embodiments in relation to the second reflector are described.

In embodiments, the second reflector may comprise one or more dichroic filters. Dichroic reflectors or filters are known in the art, and it will be apparent to the person skilled in the art that such reflectors may be used to selectively reflect specific wavelengths of light. Hence, dichroic mirrors may be used to reflect light of desirable wavelengths such as to provide the first wavelength averaged reflection R1 as opposed to the less desired wavelengths, such as to provide the second wavelength averaged reflection R2 (and optionally the third wavelength average reflection R3).

Particularly, the use of certain optical filters, such as dichroic filters with a cutoff at about 245 nm instead of 230 nm, may improve the output provided by the radiation generating system by 6%, such as 7%, especially up to about 8%.

Dichroic mirrors work on the principle of thin-film interference. Dichroic mirrors may comprise a series of thin films or membranes, where light incident on the top layer of a membrane may be reflected from its surface. Further, a part of the light transmitted through the membrane may be reflected again at the bottom layer. Hence, the delay in the two reflections may cause the light to constructively interfere reinforcing certain wavelengths while negating other wavelengths. Hence, by a series of carefully selected layers of differing refractive indices, the dichroic reflectors may be configured to reflect (e.g. by constructive interference) the wavelength averaged reflection R1 and negate (for instance by destructive

interference) wavelength averaged reflection R2 (and R3). Hence, as known in the art, by choosing the right interference reflector or interference reflectors, the spectral transmission characteristics and/or reflection characteristics may be created.

In embodiments, the dichroic mirror may essentially be flat and hence may be provided on the second reflector in a flat configuration.

However, alternatively in embodiments, the second reflector may comprise a plurality of segments. Hence, a multitude of different shapes, such as a curved shape may be achieved by series of connected segments. Hence, a curved (segmented) second reflector may comprise dichroic filters i.e. each individual connected segment may comprise a dichroic filter (or mirror).

Therefore, in embodiments the second reflector may comprise one or more dichroic mirrors. Further, in embodiments, the first reflector may also comprise one or more dichroic filters.

In embodiments, the second reflector may comprise a planar second cross-sectional shape. Hence, in embodiments, the second reflector may have a flat shape without a curvature in any direction.

In embodiments the second reflector may comprises n_3 segments. Especially, n_3 may be at least 2, such as at least 3, such as at least 4. A segmented second reflector provides the advantage of configuring the second reflector in a curved shape. This may be useful in directing radiation incident on the second reflector in a particular direction. For example, the second reflector may be used to reflect wavelength averaged reflection R2 in the direction of the chamber exit window. Especially, the second reflector may comprise segments comprising a flat cross-sectional shape, wherein at least one edge of each segment is connected to another segment. Further, the angle between the reflective surface of two segments may be selected from the range 90° - 180° . Hence, in embodiments, two segments may help form a V-shaped second reflector. Further, the segments may have a flat cross-sectional profile or a curved cross-sectional profile. Hence, the second reflector may (also) be configured in a U-shaped configuration. Further, the second reflector comprising 4 or more segments may be configured in a W-shaped configuration. Hence, the segmented second reflector may be configured in a plurality of different configurations.

Especially, the second reflector (for example in a U-shaped) configuration may form (or enclose) a second reflector cavity. Hence, in embodiments, the discharge vessel may be at least partly configured within the second reflector cavity. Configuring the discharge vessel within the cavity formed by the second reflector, may provide the advantage

of reflecting a majority of the radiation from the discharge vessel over at least about 120° (especially when assuming an essentially cylindrical cross-section), such as at least about 150°, such as at least 270°.

The discharge vessel may be elongated (along a discharge vessel axis). The second reflector may also be elongated. In embodiments, the axes of elongation of the discharge vessel and the second reflector may be configured essentially parallel. Yet, in embodiments, the axes of elongation of the discharge vessel, the first reflector and the second reflector may be configured essentially parallel.

In embodiments, the second reflector may be curved. Especially, the second reflector may be curved in one direction, such as to have a semi-cylinder-like shape. The term “semi-cylinder-like” or “semi-cylindrical” may refer to a shape substantially identical to a semi-cylinder. However, it may also refer to a distortion thereof, like a semi-oval cross-sectional shape. The second reflector may have a curved reflector surface, but the second reflector may also have a faceted reflector surface. Further, referring to e.g. a circle. An arc (for example a semi-circle) has an angle of curvature, wherein the angle of curvature is the angle between two lines each connecting the center of the circle (of which the arc is a part) and the extremities of the arc. Hence, a semi-circle would imply a curvature of 180°. However, the semi-circle may also be smaller, like ranging a range selected from 45-180°, such as selected from the range of 45-135°. Further, semi-cylinder-like cross-sectional shape may also refer to a circle segment (also having an angle relative to the circle of which it is a segment smaller than 180°, such as selected from the range of 45-135°.

Further, in embodiments, the second reflector may (also) be curved in two directions, such as to have a concave (or convex) shape. Yet further, in embodiments, the second reflector may be curved in at least one direction, defining a second reflector cavity. Here “cavity” may refer to the formation of a surface which may enclose the discharge vessel over at least about 120° (especially when assuming an essentially cylindrical cross-section), such as at least about 150°, such as at least 270°. For example, cavities may be formed from a monolithic second reflector by hollowing or removing material (for example a metal or PTFE) from an object and polishing the inner surface. Alternatively, cavities may also be formed by covering an object (or the discharge vessel) using a plurality of second reflectors, or a curved second reflector, or a segmented second reflector.

In embodiments, the second reflector may be curved in at least one direction, defining a second reflector cavity and the discharge vessel may be at least partly configured within the second reflector cavity. This may provide the advantage of reflecting radiation (or

light) from the second reflector towards the second reflector. Hence, preventing the outcoupling of harmful or undesirable radiation. For instance, in embodiments the second reflector may be partially curved about an axis of elongation.

In embodiments, the excimer lamp may be configured between the vertex and the center of curvature of the (curved) second reflector. The second reflector may reflect the light from the excimer lamp incident on its surface in the direction of the first reflector. Especially, the second reflector reflects a majority of the light (from the excimer lamp) over at least about 120° (especially when assuming an essentially cylindrical cross-section), such as at least about 150° , such as at least 270° incident on its surface towards the second reflector.

Alternatively in embodiments, the second reflector may comprise a planar second cross-sectional shape. This may especially be a flat shape with no curvature in any direction.

In embodiments, the second reflector may comprise n_3 segments. Especially, where n_3 is 2, wherein n_3 is 3, such as especially 4, such as especially 5 or more. Further, the n_3 segments may form a second reflector cavity. In further embodiments, the two segments may be connected along an edge such that they form an angle between them. Yet further, a multitude of different shapes for the second reflector may be formed by combining one or more segments. Note that (in embodiments) the segments may be connected along one or two edges, such that the surface normal of all segments lie in the same plane i.e. the segmented second reflector may be configured to reflect light analogous to a (curved) second reflector, curved in one direction. In other embodiments, the segments may be connected along all edges to form a three-dimensional configuration, wherein the second reflector may reflect radiation analogous to a (curved) second reflector curved in two directions.

Yet further, in embodiments each segment may have a flat cross-sectional shape, or the segment may be curved in one or two directions. Especially, in embodiments, the second reflector may comprise a combination of segments having flat cross-sectional shapes as well as curved segments (curved in one or more directions). For example, the combination of two segments comprising a flat cross-sectional shape and two reflectors having a semi-cylinder cross-section, a W-shaped second reflector may be formed.

Further, the second reflector may comprise four segments. Especially, the two segments may have a semi-cylinder cross-sectional shape and two segments may have a flat cross-sectional shape. Especially, two of the semi-cylindrical cross-sectional shaped segments may be joined along an edge. Further, the segments having the semi-cylindrical

cross-sectional shape may be joined such that a center line defining a middle intersects the edge along where these two segments are joined. Yet further, the two segments having a flat cross-sectional shape may be configured on either side of the middle. Especially, the two segments having a flat cross-sectional shape may be joined to the free edge of the semi-cylindrical cross-sectional shaped second reflectors. This in embodiments, essentially forms a W-shaped second reflector (wherein the semi-cylindrical shaped second reflectors form the base of the W-shape and the flat second reflectors form the arms of the W-shape). In further alternative embodiments, the second reflector may comprise a single monolithic body that may be W-shaped i.e. not necessarily comprising a plurality of segments.

In embodiments, the radiation generating system may comprise a plurality n_4 of second reflectors. Especially, n_4 may be at least 2, such as especially at least 3, such as especially at least 4. Further, a set of two adjacent second reflectors may have a mutual distance (dr_2) providing a second reflector opening. The distance dr_2 is not necessarily fixed. In embodiments, the distance dr_2 between two adjacent second reflectors may be different from the distance dr_2 between two (other) adjacent second reflectors. In further embodiments, two pairs of second reflectors (i.e. 4 second reflectors) may be configured such that each pair of second reflectors are at a distance dr_2 apart and one second reflector from each pair may be joined. In embodiments, at least two closest second reflectors may be connected such that they form a V-shaped configuration. Hence, between two neighboring second reflectors, the mutual distance (dr_2) may vary along a direction. Hence, the (at least 4) second reflectors may form two or more openings via which radiation may escape. Especially, the set of two adjacent second reflectors may be configured such that part of the radiation propagates through the second reflector opening. Especially, with at least one reflection at one of the two adjacent second reflectors. Further, relative to a system exit window (via which system light escapes from the radiation generating system) along an optical path of the system light, the n_4 second reflectors may be configured closer to the system exit window than the first reflector. Meaning, that along the optical path, the first reflector may be configured upstream of the discharge vessel, the discharge vessel may be configured upstream of the second reflector, and the second reflector may be configured upstream of the system exit window.

In embodiments, the first reflector and the second reflector may be configured parallel to each other. Especially, in embodiments the first reflector may comprise a planar first cross-sectional shape and the second reflector may comprise a planar second cross-sectional shape. In further embodiments, the first reflector, the second reflector and a

chamber exit window may be configured parallel. Especially, the planar first cross-sectional shape may have a smaller area than the planar second cross-sectional shape. Therefore, in embodiments, the first reflector and the second reflector may be configured parallel, such that the planar first cross-sectional shape has a smaller area than the planar second cross-sectional shape.

The radiation provided by the excimer lamp may be reflected at the first reflector. Hence, the first reflector may essentially block a part of the radiation from being escaped from the light chamber. Further, the radiation reflected from the second reflector (either directly or following a reflection from the first reflector) may also be blocked by the first reflector. Further, the larger cross-sectional area of the second reflector may increase the surface area from which light may be reflected. Hence, selecting a first reflector with a smaller cross-sectional area as compared to the second reflector, less radiation may be blocked by the first reflector and more radiation may be reflected from the second reflector. Hence, this choice of having a first reflector with a smaller cross-sectional area than the second reflector may increase the amount of radiation outcoupled from the system.

In alternative embodiments, the first reflector may have a cross-sectional area larger than the cross-sectional area of the second reflector. Here, it may be of interest to outcouple light towards the sides of the light chamber (as opposed to directly in front of the light chamber). Hence, selecting the first reflector to have a cross-sectional area larger than the second reflector may be useful in facilitating such an embodiment.

The discharge vessel may have a vessel length LD and the first reflector may have a first reflector length $L1$. In embodiments, they may be about the same. However, one may (thus) be larger than the other or the other may be larger than the one. Hence, in embodiments the discharge vessel has a vessel length (LD) and the first reflector has a first reflector length ($L1$), wherein $0.75*LD \leq L1 \leq 1.1*LD$. In embodiments, the second reflector may have a second reflector length $L2$. In embodiments, the vessel length LD and the second reflector length $L2$ may be about the same. However, one may (thus) be larger than the other or the other may be larger than the one. Hence, in embodiments the discharge vessel has a vessel length (LD) and the second reflector has a second reflector length ($L2$), wherein $0.75*LD \leq L2 \leq 1.1*LD$. Further, in embodiments $0.9 \leq L1/L2 \leq 1.1$.

In specific embodiments, the second reflector may comprise a luminescent material. A luminescent material may convert light incident on it, such as radiation incident on the surface of the luminescent material, into luminescent material light. Especially, the luminescent material herein may be selected from a luminescent material that is reflective or

transmissive for radiation with a wavelength selected from the first wavelength range and is less reflective, more especially higher absorbing for radiation with a wavelength selected from the second wavelength range, for example, the luminescent material may have an absorption of at least 65%, such as 80% or 90% or more, for the second wavelength range, and an absorption of at the most 35%, such as 20% or 10% or less for the first wavelength range. Hence, in embodiments the luminescent material may have a higher reflectivity for radiation with a wavelength selected from the first wavelength range than for radiation with a wavelength selected from the second wavelength range. More especially, in embodiments the luminescent material may have a higher wavelength averaged reflectivity in the first wavelength range (i.e. first wavelength averaged reflection) than in the second wavelength range (i.e. second wavelength averaged reflection). As indicated above, in embodiments $R_2/R_1 \leq 0.6$.

The luminescent material may comprise $\text{Ca}_{(1-x-y)}\text{SO}_4:\text{Pr}_x^{3+}, \text{M}_y^+$ where M^+ is an alkaline metal ion like Li^+ or Na^+ . The luminescent material may comprise $\text{Sr}_{(1-x-y)}\text{SO}_4:\text{Pr}_x^{3+}, \text{M}_y^+$ where M^+ is an alkaline metal ion like Li^+ or Na^+ . The luminescent material may comprise $\text{LiLu}_{(1-x)}\text{F}_4:\text{Pr}_x^{3+}$. The luminescent material may comprise $\text{LiY}_{(1-x)}\text{F}_4:\text{Pr}_x^{3+}$. The luminescent material may comprise $\text{La}_{(1-x)}\text{PO}_4:\text{Pr}_x^{3+}$. The luminescent material may comprise $(\text{Lu}_{(1-y)}\text{Gd}_y)_3\text{Al}_5\text{O}_{12}:\text{Ce}_x^{3+}$. The luminescent material may comprise $\text{Sc}_{(1-x)}\text{PO}_4:\text{Ce}_x^{3+}$. The luminescent material may comprise $\text{Lu}_{(1-x)}\text{PO}_4:\text{Ce}_x^{3+}$. The luminescent material may comprise $\text{Y}_{(1-x)}\text{PO}_4:\text{Ce}_x^{3+}$. The luminescent material may comprise $\text{Gd}_{(1-x)}\text{PO}_4:\text{Ce}_x^{3+}$. In embodiments, the luminescent material may comprise a cerium doped aluminate. For instance, in embodiments the luminescent material may comprise $(\text{M})(\text{A})_{12}\text{O}_{19}:\text{Ce}^{3+}$, wherein M comprises one or more of Sr, Ba, and Ca, especially at least, or exclusively, Sr, and wherein A comprises one or more of Al and Ga, especially at least, or exclusively, Al. The aluminate, such as e.g. indicated, may for instance comprise 0.1-5 mol% Ce. The luminescent material may comprise $\text{Sr}_{(1-x)}\text{SiO}_3:\text{Pb}_x^{2+}$. In general, $0.01 \leq x \leq 0.2$, though other values may also be possible. Combinations of two or more luminescent materials may also be selected. Suitable luminescent material are amongst others described in WO2022043167A2, which is herein incorporated by reference. In specific embodiments, the luminescent material may be based on praseodymium (Pr).

Here below, some further embodiments in relation to the discharge lamp are described.

Especially, in embodiments the discharge lamp (more especially the discharge vessel) may have an (essentially) cylindrical design. The electrodes may be configured external of the cylinder (see further also below).

Further, in embodiments the discharge vessel may at least partly be defined by a discharge vessel wall. Such discharge vessel wall may especially comprise quartz. Alternatively, the discharge vessel wall may comprise e.g. CaF_2 , MgF_2 , or Al_2O_3 (sapphire or PCA).

The electrodes may enclose the discharge vessel over at least about 120° (especially when assuming an essentially cylindrical cross-section), such as at least about 150° . Especially, the electrodes may enclose the discharge vessel over at least 180° , even more especially at least 270° , like in embodiments 360° . In embodiment, the electrodes (at least partly enclosing the discharge vessel) may be thin plate-like electrodes (e.g. in embodiments up to about a few μm s thickness) (especially when assuming an essentially cylindrical cross-section). In other embodiments, the electrodes (at least partly enclosing the discharge vessel) may be mesh-like electrodes (especially when assuming an essentially cylindrical cross-section). The distance between the electrodes may be selected from the range of about 4-10 mm, such as about 5-10 mm. Hence, especially in embodiments the discharge vessel may have an inner diameter (D1) selected from the range of 4-10 mm, the discharge vessel may have a vessel wall having a wall thickness (d1) selected from the range of 0.4-2.0 mm, wherein the electrodes may be configured external of the discharge vessel, and wherein the electrodes have an inter electrode distance l1 selected from the range of 4-10 mm.

The (cylindrical) discharge vessel may in embodiments have a length (L1) selected from the range of at least about 10 mm, such as especially at least about 15 mm, like in embodiments 15-80 mm, like e.g. in the range of about 15-50 mm. However, larger than about 80 mm may also be possible. Further, the discharge vessel may have a wall thickness d1 selected from the range of 0.4-2.0 mm, like at least about 0.7 mm, such as up to about 1.5 mm, like 0.5-1.5 mm, such as 0.7-1.2 mm. Especially, in embodiments the discharge vessel may have an outer diameter selected from the range of about 4.5-12 mm, such as e.g. selected from the range of about 4-8 mm.

The electrodes may have a width (W2), defined parallel to a length axis of the discharge vessel, which is individually selected for the two electrodes from the range of 2-45% of the length of the discharge vessel. Even more especially, each electrode may have a width selected from the range of 10-30% of the electrode length. The dimensions of the

electrodes may especially be selected such that the electrodes have an inter electrode distance 11 selected from the range of 4-10 mm. One of the electrodes may be earthed. As indicated above, in embodiments the electrodes may comprise mesh electrodes. With mesh electrodes, less light may be blocked.

5 Further, it appears that some operation conditions may especially provide a desirable performance. For instance, in embodiments the radiation generating system may be configured to provide in an operational mode pulsed potential differences to the electrodes, wherein the potential difference may be selected from the range of 3.5-7.5 kV, especially selected from the range of 4-6.5 kV, such as in embodiments selected from the range of 4.5-5
10 kV. Further, in embodiments in an operational mode the pulse frequency selected from the range 0.5-200 kHz, like at least 1 kHz, such as especially at least 2 kHz, such as selected from the range of 7.5-150 KHz, like especially selected from the range of about 10-100 kHz. Especially, in this way during at least part of the time the operational mode is executed, the discharge vessel emits radiation (“discharge vessel radiation”) having a desirable spectral
15 power distribution.

Therefore, in embodiments the radiation generating system may further comprise electrodes functionally coupled to the discharge vessel, wherein in an operational mode, the radiation generating system is configured to provide pulsed potential differences to the electrodes, wherein the potential difference may be selected from the range of 4.5-5 kV,
20 with a pulse frequency selected from the range of 0.5-200 kHz, like 10-100 kHz. As indicated above, the functional coupling of the electrodes may include an at least partial enclose of the discharge vessel. Further, the electrodes may be in physical contact with the discharge vessel. In specific embodiments, the pulsed potential differences have a pulse width selected from the range of 0.25-5 μ s, such as selected from the range of 0.7-1.5 μ s.

25 In embodiments, the excimer lamp may be a dielectric barrier discharge (DBD) lamp. Dielectric barrier discharges are a mercury free source of UV radiation. The use of halogens like bromine and chlorine may enable the generation of UV in the range of about 200-230 nm. As indicated above, this radiation can inactivate harmful viruses by destroying their DNA/RNA, and/or inactivate other parts of the virus proteins. Their wavelength is
30 substantially long enough to prevent the generation of substantial amounts of ozone and substantially short enough not to reach the living skin cells or the cornea of humans possibly present when the UV source is operational.

Dielectric barrier based radiation lamps are known in the art, and are for instance described in US2010/0164410; U. Kogelschatz, *Dielectric-Barrier Discharges*:

Their History, Discharge Physics, and Industrial Applications. Plasma Chemistry and Plasma Processing 23, 1-46, <https://doi.org/10.1023/A:1022470901385>; WO 2006/006139; and R. Brandenburg, *Dielectric barrier discharges: progress on plasma sources and on the understanding of regimes and single filaments*, Plasma Sources Science and Technology, Vol. 26, No. 5, 1-29, including corrigendum, which four disclosures are herein incorporated by reference.

Especially, dielectric-barrier discharge (DBD) is the electrical discharge between two electrodes separated by an insulating dielectric barrier. DBD devices can be made in many configurations, typically planar, using parallel plates separated by a dielectric or cylindrical, using coaxial plates with a dielectric tube between them. Other shapes may also be possible, such as tubular or coaxial tubular.

The basic principle of these lamps may be the generation and emission of radiation by means of a dielectric barrier discharge. Usually, at least one of the two electrodes of such a lamp is located outside the discharge volume. In embodiments, both electrodes of the lamp are located outside the discharge volume. The discharge volume comprises a discharge gas, wherein the energy supply may be accomplished by capacitive coupling through the wall(s) of the discharge vessel (discharge envelope) into the discharge volume, in order to initiate within this volume the gas discharge and the excitation and emission of radiation. Generally, such dielectric barrier discharge lamps may be used as an alternative to conventional mercury based discharge lamps in a wide area of applications, where a radiation of a certain wavelength has to be generated for a variety of purposes. Some applications are for example the generation of ultraviolet (UV) radiation with wavelengths of between about 170 nm and about 380 nm for industrial purposes such as wastewater treatment, disinfection of gases and fluids, especially of drinking water, dichlorination or production of ultra-pure water, activation and cleaning of surfaces, curing of lacquers, inks or paints, ozone generation, or for liquid crystal display (LCD) backlighting or photocopiers and others. Furthermore, dielectric barrier discharge lamps are of increasing importance especially as a source for generating and/or emitting high intensity and high power ultraviolet (UV) radiation in a narrow and well defined spectral range with high efficiency and high radiation intensity. WO 2006/006139 (incorporated herein by reference), for instance, describes a dielectric barrier discharge lamp comprising a discharge gap being at least partly formed and/or surrounded by at least an inner wall and an outer wall, wherein at least one of the walls is a dielectric wall and at least one of the walls has an at least partly transparent part, a filling located inside the discharge gap, at least a first electrical contacting means for

contacting the outer wall and a second electrical contacting means for contacting the inner wall, and at least one multifunctional means which is arranged adjacent to the discharge gap and which on the one hand serves as an improved and optimized ignition aid, especially for initial ignition or ignition after a long pause, and on the other hand serves at least as guiding means for easily arranging two walls towards each other, thereby forming an optimized discharge gap especially for coaxial dielectric barrier discharge lamps. In embodiments, the dielectric barrier discharge lamp may comprise a discharge volume which is delimited by a first and a second wall, wherein (during operation) both walls are exposed to different electrical potentials by means of a power supply for exciting a gas discharge within the discharge volume. In other embodiments, the dielectric barrier discharge lamp may comprise a discharge volume which is delimited by essentially a single wall, wherein (during operation) different parts of the wall are exposed to different electrical potentials by means of a power supply for exciting a gas discharge within the discharge volume. Hence, especially the (excimer) lamp is of the dielectric barrier discharge lamp type.

As indicated above, the excimer lamp may comprise a discharge vessel. In embodiments, the discharge vessel may be tubular or coaxial tubular. In alternative embodiments, the discharge vessel may have a disc shape or an oval shape. Especially, the shape may refer to a cross-sectional shape. Especially, in embodiments the discharge vessel may be coaxially shaped. Embodiments of coaxially shaped discharge vessels are described in US8174191, which is herein incorporated by reference.

Further, in embodiments, the excimer lamp may comprise a geometry selected from the group comprising tube shape, tube shape with tubular electrodes, coaxial, disk shaped, and oval shaped. In further embodiments, at least a part of the excimer lamp may be covered by a mesh. In embodiments, the excimer lamp may comprise multiple burners.

Further, in embodiments, the system light may have a spectral power distribution in the 200-300 nm wavelength range with 95-100% of the spectral power within the 210-245 nm wavelength range and 0-5% of the spectral power within the 250-270 nm wavelength range

The combination of the excimer lamp and the second reflector (and the first reflector) may provide system light have a substantial part of the spectral intensity in the 200-230 nm wavelength range and a relatively small, but not necessarily zero, part in the 230-300 nm wavelength range. Intensities at other wavelengths are herein not excluded, but it is especially referred herein to the 200-300 nm wavelength range. In embodiments, the system light may have a spectral power distribution in the 200-300 nm wavelength range with 95-

100% of the spectral power within the 200-230 nm wavelength range and 0-5% of the spectral power within the 230-300 nm wavelength range. Especially, in specific embodiments the system light has 0.5-3% of the spectral power within the 230-300 nm wavelength range (relative to the total spectral power in the 200-300 nm wavelength range), with less than
5 0.5% of the spectral power in the (second) wavelength range of 250-270 nm (relative to the total spectral power in the 200-300 nm wavelength range). Hence, of the total the spectral intensity in the 200-300 nm wavelength range, in embodiments less than 0.5% may be in the 250-270 nm wavelength range (relative to the total spectral power in the 200-300 nm wavelength range). In the wavelength range of 230-250 nm, in the order of 0.5-5% of the
10 total spectral power may be provided (relative to the total spectral power in the 200-300 nm wavelength range). Hence, in embodiments, at least 80% of the spectral power of the system light comprises radiation reflected at the second reflector.

Would the radiation generated by the excimer lamp escape from the system, then the spectral power distribution may also include intensity which may be less desirable.
15 Hence, herein optics are applied which may be used to optimize the generation and outcoupling of a desired spectral power distribution and/or intensity of radiation from the system.

In embodiments, the radiation generating system may also comprise (or may be functionally coupled to) a control system to control the excimer lamp, especially its
20 operation. Further embodiments in relation to controlling the excimer lamp are described below.

In embodiments, the gas composition may comply with the following conditions: a total gas pressure P is selected from the range of 50-500 mbar, a Cl_2 gas partial pressure p_{Cl_2} is selected from the range of 0.5-4 mbar, a Ne/Kr partial pressure ratio $R_{\text{Ne,Kr}}$ is
25 selected from the range of 0.5-10, a Kr partial pressure p_{Kr} selected from the range of over 15 mbar. Especially, the gas composition may comprise at least 33% Ne. Further, the Ne/Kr partial pressure ratio $R_{\text{Ne,Kr}}$ may comply with the formula $R_{\text{Ne,Kr}} \leq (0.03 * P / \text{mbar}) - 4$. Yet further, for total gas pressures P below 150 mbar applies that $R_{\text{Ne,Kr}}$ is at least 0.5.

The gas composition may comprise Cl_2 , Ne and Kr. Other components may
30 also be possible, but especially at least 90 %, even more especially at least 95% of the gas composition consists of Cl_2 , Ne and Kr. Even more especially, 98% or more of the gas composition consists of Cl_2 , Ne and Kr. Other components that could be available may e.g. be one or more of Ar, Br_2 , N_2 , or H_2 , such as one or more of Ar and N_2 . A composition consisting of essentially Cl_2 , Ne and Kr appeared to provide the best results in terms of

efficiency and desired emission. The combination of Kr and Cl₂ may especially provide the desired radiation of about 222 nm.

The total gas pressure (herein also indicated with “P”) in the discharge vessel may be about 40-1000 mbar, such as about 50-650 mbar. Amongst others based on simulations, the total gas pressure may especially be selected from the range of at least about 50 mbar and/or at maximum about 500 mbar. Hence, especially the total gas pressure may be selected from the range of 50-500 mbar, such as at least 100 mbar. Here, the total gas pressure especially refers to the gas pressure in the discharge vessel at ambient temperature (and (thus) not in an operational mode), especially at about 24°C.

It appears desirable that with a total gas pressure in the range of about 40-1000 mbar, especially in the range of about 50-650 mbar, even more especially in the range of about 50-500 mbar, the gas composition may comprise at least about 0.5 mbar Cl₂ (partial pressure). At higher total pressures (within the afore-mentioned ranges of the total pressure) the amount of chlorine (here referring to Cl₂) may be larger than at lower total pressures, and at lower total pressures the amount of chlorine may be lower than at higher total pressures. In general, the chlorine partial pressure is not higher than about 4 mbar, even more especially not higher than 3.5 mbar. Especially, the chlorine partial pressure may be at maximum about 3 mbar. Hence, especially in embodiments the Cl₂ gas partial pressure pCl₂ may be selected from the range of 0.5-3 mbar. Cl₂ gas partial pressures pCl₂ outside these ranges may lead to a reduction in output and efficiency. Especially, this partial pressure refers to ambient temperature (and (thus) not in an operational mode), especially at about 24°C. Partial pressures are herein also indicated with “p”.

Further, it appears desirable that with a total gas pressure in the range of about 40-1000 mbar, especially in the range of about 50-650 mbar, even more especially in the range of about 50-500 mbar, the Kr partial pressure pKr may be selected from the range of over 10 mbar, even more especially at least about 15 mbar, such as at least about 16.5 mbar. A too low or too high Kr partial pressure may lead to performance issues. Hence, Kr gas partial pressures pKr outside these indicated ranges may lead to a reduction in output and/or efficiency. At higher total pressures within the herein indicated total pressure ranges, the amount (i.e. partial pressure) of Kr may be larger than at lower total pressures, and at lower total pressures within the herein indicated total pressure ranges the amount of Kr may be lower than at higher total pressures. In general, the Kr partial pressure is not higher than about 67% of the total pressure, such as not higher than about 64% of the total pressure. Especially, the Kr partial pressure may be at maximum about 50% of the total pressure.

Especially, these partial pressure refer to ambient temperature (and (thus) not in an operational mode), especially at about 20°C.

Further, it may be useful to have a lower chlorine partial pressure at higher Kr partial pressures and a higher chlorine partial pressure at lower Kr partial pressure.

5 Further, it appears useful when there is a substantial presence of neon in the gas composition. Especially, the gas composition comprises at least 25, such as at least 30% neon. Even more especially, the gas composition comprises at least 33% neon in the composition.

Further, it appears that within specific Ne/Kr partial pressure ratios $R_{Ne,Kr}$ the relatively high performance and/or relatively low 258 nm intensity may be obtained, or that operation may be easier than outside the ratio range, such as in terms of voltage, frequency, startup, etc. A relatively high Ne/Kr partial pressure ratio $R_{Ne,Kr}$ may provide a relatively low about 258 nm contribution. However, at a too high partial pressure ratio $R_{Ne,Kr}$ performance (especially efficiency) may start to decrease. Hence, especially the partial pressure ratio $R_{Ne,Kr}$ is not larger than about 20, such as not larger than 10, like not larger than about 6, especially not larger than about 5. At too small partial pressure ratio $R_{Ne,Kr}$, however, also the performance may start to decrease. Hence, especially the partial pressure ratio $R_{Ne,Kr}$ may not be smaller than about 0.5. In specific embodiments for every total pressure selected in the herein indicated total pressure ranges, such as in the total pressure range of 50-500, $R_{Ne,Kr}$ is at least 0.5.

In specific embodiments the Ne/Kr partial pressure ratio $R_{Ne,Kr}$ may be selected from the range of 1-10, especially not larger than 6, like selected from the range of 1-5. Even more especially, the Ne/Kr partial pressure ratio $R_{Ne,Kr}$ may be selected from the range of 1.5-4.5, such as 1.5-4. With these Ne/Kr partial pressure ratios, simulations and tests were executed which gave relatively high efficiencies.

In yet other embodiments, however, the Ne/Kr partial pressure ratio may be over 5, such as in the range of 5-20, like up to about, such as selected from the range of 5-10.

Hence, in specific embodiments the discharge vessel may contain a gas composition, which gas composition may comply with the following conditions, especially at about 20 °C: (a) a total gas pressure P may be selected from the range of 50-500 mbar; (b) a Cl_2 gas partial pressure p_{Cl_2} may be selected from the range of 0.5-3 mbar; (c) a Ne/Kr partial pressure ratio $R_{Ne,Kr}$ may be selected from the range of 0.5-20; (d) a Kr partial pressure p_{Kr} may be selected from the range of over 15 mbar; and (e) at least 33% Ne.

In embodiments, the light chamber may comprise (a) reflective walls and (b) a chamber exit window. As described above, the internal walls of the light chamber may be reflective. Especially, the inner walls of the light chamber may be specularly reflective or diffusive reflective. Yet further, some of the walls of the light chamber may be specularly reflective, while the remaining walls may be diffusively reflective. In some embodiments, the inner walls of the light chamber may comprise the first reflector. In other embodiments, the inner walls of the light chamber may comprise the second reflector. Hence, in embodiments, the light chamber may comprise the first reflector or the second reflector, such as the inner walls of the light chamber may be the first reflector or the second reflector.

Further, as described above, the chamber exit window may be an opening via which radiation may escape. Especially, the radiation from the excimer lamp, or radiation reflected from the first reflector, or radiation reflected from the second reflector, or a combination thereof. In embodiments, the chamber exit window may be an opening via which radiation may escape. In other embodiments, the chamber exit window may (also) comprise an optical filter. Especially, the filter may be selective for specific wavelength of radiation (or light), (see also above). Yet further, the system may comprise the system exit window via which system light may escape.

Especially, the light chamber may enclose the discharge vessel, the first reflector and the second reflector. Hence, in embodiments, the discharge vessel, the first reflector and the second reflector may be configured within the light chamber.

Further, in embodiments, the radiation generating system may be configured to generate a beam of system light. It will be apparent to the skilled person that a beam of light refers to directional projection of light (or radiation). Especially, the beam of light may have a solid angle of illumination such as a beam angle. Hence, the radiation generating system in an operational mode may be configured to generate a beam of system light. Especially, the beam of system light may have an optical axis (O). The optical axis may be an imaginary line along the direction of propagation of light. Especially, the optical axis (O) may be along the center of the beam of light, such that the beam of light may be aligned radially symmetric about the optical axis (O).

Especially, in at least one cross-section of the beam parallel to the optical axis (O) at least 50% of the spectral power (in Watt) may be at a beam angle $2*\theta$ larger than 100° . The beam angle is angle over which light may be spread. In a cross-sectional view, the angle θ may be measured from the farthest ray of light to the optical axis. Hence, the beam angle may essentially be $2*\theta$. Especially, the beam angle may be at least 100° , such as at least

120°, such as at least 140°, such as at least 160°. The beam angle may be defined by the full width half maximum.

In embodiments, the system light may be provided as batwing beam.

The first reflector, the second reflector, and the discharge vessel may be configured such that the beam of system light escaping from the system may have a wavelegnth dependendent angular distribution. For instance, in embodiments optically filtered light may have a more narrow beam shape and optically unfiltered light may have a broader beam shape. For instance, the former may have a relatively more lambertian shape than the latter, and the latter may have a relatively more batwing shape than the former.

Hence, in specific embodiments under larger angles some light of the discharge vessel may escape from the system without being reflected at the second reflector. As can be derived from the above, in other embodiments, essentially no light escapes from the system without having been reflected at least once at the second reflector.

In another aspect, the invention may provide a method for treating a gas or a surface external of the radiation generating system. Especially, the method may comprise providing the radiation to the gas or the surface with the radiation generating system.

In embodiments, the method may comprise exposing air (external from the system) to the radiation from the system. Hence, in specific embodiments, the method for treating air may comprise: exposing air to the radiation from the system. In this way, the method may provide one or more of disinfection of pathogens, removal of particles and dust, and removal of odors. Especially, the treatment of the air may comprise disinfection of (the) air. In embodiments, the method may comprise exposing a surface to the radiation from the system. The surface may be selected from a desk, a floor, a wall, a kitchen counter, a door handle, a tap, a handrail, a control panel, etc. The embodiments described above in relation to the system of the present invention, may also apply for the method of the invention. The radiation may be provided in a space, e.g. in the method for treating a gas or a surface (available in the space).

The system may comprise a control system or may be functionally coupled to a control system. The control system may especially be configured to control the (excimer) lamp. For instance, the control system may control the excimer lamp in dependence of a sensor signal, a time scheme (or timer), or a user input (signal).

The term “controlling” and similar terms especially refer at least to determining the behavior or supervising the running of an element. Hence, herein “controlling” and similar terms may e.g. refer to imposing behavior to the element

(determining the behavior or supervising the running of an element), etc., such as e.g. measuring, displaying, actuating, opening, shifting, changing temperature, etc.. Beyond that, the term “controlling” and similar terms may additionally include monitoring. Hence, the term “controlling” and similar terms may include imposing behavior on an element and also imposing behavior on an element and monitoring the element. The controlling of the element can be done with a control system, which may also be indicated as “controller”. The control system and the element may thus at least temporarily, or permanently, functionally be coupled. The element may comprise the control system. In embodiments, the control system and element may not be physically coupled. Control can be done via wired and/or wireless control. The term “control system” may also refer to a plurality of different control systems, which especially are functionally coupled, and of which e.g. one control system may be a master control system and one or more others may be slave control systems. A control system may comprise or may be functionally coupled to a user interface.

The control system may also be configured to receive and execute instructions form a remote control. In embodiments, the control system may be controlled via an App on a device, such as a portable device, like a Smartphone or I-phone, a tablet, etc.. The device is thus not necessarily coupled to the lighting system, but may be (temporarily) functionally coupled to the lighting system.

Hence, in embodiments the control system may (also) be configured to be controlled by an App on a remote device. In such embodiments the control system of the lighting system may be a slave control system or control in a slave mode. For instance, the lighting system may be identifiable with a code, especially a unique code for the respective lighting system. The control system of the lighting system may be configured to be controlled by an external control system which has access to the lighting system on the basis of knowledge (input by a user interface of with an optical sensor (e.g. QR code reader) of the (unique) code. The lighting system may also comprise means for communicating with other systems or devices, such as on the basis of Bluetooth, WIFI, LiFi, ZigBee, BLE or WiMAX, or another wireless technology.

The system, or apparatus, or device may execute an action in a “mode” or “operation mode” or “mode of operation” or “operational mode”. Likewise, in a method an action or stage, or step may be executed in a “mode” or “operation mode” or “mode of operation” or “operational mode”. This does not exclude that the system, or apparatus, or device may also be adapted for providing another controlling mode, or a plurality of other

controlling modes. Likewise, this may not exclude that before executing the mode and/or after executing the mode one or more other modes may be executed.

However, in embodiments a control system may be available, that is adapted to provide at least the controlling mode. Would other modes be available, the choice of such modes may especially be executed via a user interface, though other options, like executing a mode in dependence of a sensor signal or a (time) scheme, may also be possible. The operation mode may in embodiments also refer to a system, or apparatus, or device, that can only operate in a single operation mode (i.e. “on”, without further tunability).

Hence, in embodiments, the control system may control in dependence of one or more of an input signal of a user interface, a sensor signal (of a sensor), and a timer. The term “timer” may refer to a clock and/or a predetermined time scheme.

The control system may e.g. control the intensity of the radiation of the excimer lamp via e.g. pulse-width modulation. For instance, in embodiments by reducing or increasing the pulse frequency, the intensity of the discharge vessel radiation may be reduced or increased, respectively.

As can be derived from the above, the (radiation generating) system may comprise a sensor or may be functionally coupled to a sensor. Especially, the sensor may be functionally coupled to a control system. Hence, the system, more especially the excimer lamp, may be operated in dependence of a sensor signal of a sensor.

In embodiments, the sensor may be selected from the group comprising a movement sensor, a presence sensor, a distance sensor, an ion sensor, a gas sensor, a volatile organic compound sensor, a pathogen sensor, an airflow sensor, a sound sensor, a temperature sensor, and a humidity sensor.

A movement sensor may be used to sense people. A movement sensor may also be used to sense the number of people. A movement sensor may also be used to sense an activity level of the people (e.g. occupied or non-occupied working cubicle or fitness room). A presence sensor may be used to sense people. A presence sensor may also be used to sense the number of people. A presence sensor may also be used to sense an activity level of the people (e.g. occupied or non-occupied working cubicle or fitness room). A distance sensor may be used to sense one or more dimensions of a space for which the ionizer device is used. A distance sensor may also be used to sense distances between people. The ion sensor may comprise a positive ion sensor. Additionally or alternatively, the ion sensor may comprise a negative ion sensor. The ion sensor may be used to sense the effect of the ionizer device (the more ions, the better the air treatment may be). A gas sensor may be used to sense gas one or

more gas components. The gas sensor may be used to sense whether ventilation is sufficient or insufficient. The gas sensor may e.g. (thus) also be used to sense the number of people and/or an activity level of the people. A volatile organic compound (VOG) sensor may be used to sense one or more volatile organic compounds. The VOG sensor may be used to sense whether ventilation is sufficient or insufficient. The VOG sensor may e.g. (thus) also be used to sense the number of people and/or an activity level of the people. The pathogen sensor may comprise a sensor for one or more of bacteria, viruses, and spores. The pathogen sensor may be used to sense whether ventilation is sufficient or insufficient. The pathogen sensor may e.g. (thus) also be used to sense the number of people and/or an activity level of the people. An airflow sensor may be used to sense an airflow. The airflow sensor may be used to sense whether ventilation is sufficient or insufficient. The airflow sensor may e.g. (thus) also be used to sense the number of people and/or an activity level of the people. A sound sensor may be used to sense sound. The sound sensor may be used to sense whether ventilation is sufficient or insufficient. The sound sensor may e.g. (thus) also be used to sense the number of people and/or an activity level of the people. The temperature sensor may be used to sense temperature. On the basis thereon, it may be determined whether pathogens may be more detrimental or less detrimental. The humidity sensor may be used to sense (air) humidity. On the basis thereon, it may be determined whether pathogens may be more detrimental or less detrimental (as there seems to be a relation between humidity and transferability of e.g. airborne pathogens).

In embodiments, the (radiation generating) system may comprise a grid of a plurality of lamps or luminaires. Such grid may be installed in a roof or ceiling. In embodiments, the individual DBD lamps or luminaires may be functionally connected to the control system. In embodiments, the individual DBD lamps or luminaires in the grid may comprise a sensor, especially one or more of a radiation sensor and an air flow sensor. In embodiments, a first DBD lamp or luminaire may adjust its settings based on the one or more sensor signals of one or more second DBD lamps or luminaires. In embodiments, the individual DBD lamps or luminaires, especially the control systems thereof, may communicate with one another. The individual DBD lamps or luminaires may comprise means for communicating with other units, systems or devices, such as on the basis of Bluetooth, WIFI, LiFi, ZigBee, BLE or WiMAX, or another wireless technology. In specific embodiments, settings of a first DBD lamp or luminaire of the grid may depend on the settings of a second DBD lamp or luminaire of the grid., wherein the settings may comprise one or more of device radiation intensity, location, etc.

In embodiments, the system may be comprised in a single DBD lamp or luminaire.

In yet a further aspect, the invention also provides a (DBD) lamp or a luminaire comprising the light generating system as defined herein. The luminaire may further comprise a light chamber, optical elements, louvres, etc. The lamp or luminaire may further comprise a light chamber enclosing the light generating system. The lamp or luminaire may comprise a light window (or a chamber exit window) in the light chamber or a light chamber opening, through which the system light may escape from the light chamber.

The term “space” may for instance relate to a (part of) hospitality area, such as a restaurant, a hotel, a clinic, or a hospital, etc.. The term “space” may also relate to (a part of) an office, a department store, a warehouse, a cinema, a church, a theatre, a library, etc. However, the term “space” may also relate to (a part of) a working space in a vehicle, such as a cabin of a truck, a cabin of an air plane, a cabin of a vessel (ship), a cabin of a car, a cabin of a crane, a cabin of an engineering vehicle like a tractor, etc.. The term “space” may also relate to (a part of) a working space, such as an office, a (production) plant, a power plant (like a nuclear power plant, a gas power plant, a coal power plant, etc.), etc. For instance, the term “space” may also relate to a control room, a security room, etc. Especially, the term “space” may herein refer to an indoor space. In yet other embodiments, the term “space” may also relate to a toilet room or bathroom. In yet other embodiments, the term “space” may also relate to an elevator. In embodiments, the term “space” may also refer to a conference room, a school room, an indoor hallway, an indoor corridor, an indoor space in an elderly home, an indoor space in a nursing home, etc. In embodiments, the term “space” may refer to an indoor sport space, like a gym, a gymnastics hall, in indoor ball sport space, a ballet room, a swimming pool, a changing room, etc. In embodiments, the term “space” may refer to an (indoor) bar, an (indoor) disco, etc. The method may be executed in dependence of a sensor signal of a sensor (see further also above).

The terms “light” and “radiation” are herein interchangeably used, unless clear from the context that the term “light” only refers to visible light. The terms “light” and “radiation” may thus refer to UV radiation, visible light, and IR radiation.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which:

Fig. 1 schematically depict an embodiment of the invention;

Figs. 2a-2c and Figs. 3a-3c schematically depict some aspects and
embodiments; and

Fig. 4 schematically depicts an embodiment of an application.

5 The schematic drawings are not necessarily to scale.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Fig. 1 schematically depicts an embodiment of a radiation generating system
1000, which may comprise an excimer lamp 100, a light chamber 510, and optics 450.

10 Especially, the excimer lamp 100 may comprise a discharge vessel 400. The discharge vessel
400 may contain a gas composition 405 comprising chlorine, neon, and krypton. Especially,
the excimer lamp 100 may be configured to generate in an operational mode radiation 101
having one or more wavelengths in the wavelength range of 200-300 nm. Further, the optics
450 may comprise a first reflector 410 and a second reflector 420. In embodiments, the
15 discharge vessel 400 may be configured between the first reflector 410 and the second
reflector 420. Moreover, the first reflector 410 may be configured to reflect at least part of the
radiation 101 in a direction of the second reflector 420. Especially, the excimer lamp 100, the
first reflector 410, and the second reflector 420 may be configured such that at least part of
the radiation 101 can only escape from the radiation generating system 1000 via at least a
20 reflection at the second reflector 420. Further, the second reflector 420 may have a first
wavelength averaged reflection R1 in a first wavelength range 210-245 nm and a second
wavelength averaged reflection R2 in a second wavelength range of 250-270 nm. Yet further,
the second reflector 420 may have a third wavelength averaged reflection R3 in a third
wavelength range of 190 nm and smaller.

25 Especially, $R2/R1 \leq 0.6$ may apply. Further, in specific embodiments
 $R3/R1 \leq 0.6$ may apply. Hence, in embodiments, the radiation generating system 1000 may be
configured to generate system light 1001 comprising at least part of the radiation 101
reflected at the second reflector 420. Furthermore, $R1 \geq 50\%$, $R2 \leq 20\%$, and $R3 \leq 20\%$ may
apply. Especially, $R1 \geq 60\%$, optionally $R2 \leq 15\%$, and optionally $R3 \leq 15\%$. Especially, at least
30 80% of the spectral power of the system light 1001 may comprise radiation 101 reflected at
the second reflector 420.

In embodiments, the first reflector 410 may comprise a planar first cross-
sectional shape. Also, in embodiments, the second reflector 420 may comprise a planar
second cross-sectional shape. Further, the first reflector 410 and the second reflector 420 may

be configured parallel. In embodiments, the planar first cross-sectional shape may have a smaller area than the planar second cross-sectional shape. Many other possible shapes are schematically depicted in Figs. 2a.

In embodiments, the system exit window 1020 may comprise a luminescent material 200. Especially, the luminescent material may comprise phosphor material.

Further, in embodiments, the excimer lamp 100 may be of the dielectric barrier discharge lamp type. In embodiments, the discharge vessel 400 may be coaxially shaped. In alternative embodiments, the discharge vessel 400 may be a tubular discharge vessel 400.

In embodiments, the system light 1001 may have a spectral power distribution in the 200-300 nm wavelength range with 95-100% of the spectral power within the 210-245 nm wavelength range and 0-5% of the spectral power within the 250-270 nm wavelength range. Further, the gas composition 405 may comply with the following conditions: a total gas pressure P is selected from the range of 50-500 mbar, a Cl_2 gas partial pressure p_{Cl_2} is selected from the range of 0.5-4 mbar, a Ne/Kr partial pressure ratio $R_{\text{Ne,Kr}}$ is selected from the range of 0.5-10, a Kr partial pressure p_{Kr} selected from the range of over 15 mbar, at least 33% Ne, and the Ne/Kr partial pressure ratio $R_{\text{Ne,Kr}}$ complies with the formula $R_{\text{Ne,Kr}} \leq (0.03 * P / \text{mbar}) - 4$. Especially, for total gas pressures P below 150 mbar applies that $R_{\text{Ne,Kr}}$ is at least 0.5.

In embodiments, the light chamber 510 may comprise (a) reflective walls 512 and (b) a chamber exit window 511. Especially, the light chamber 510 may enclose the discharge vessel 400, the first reflector 410 and the second reflector 420. Further, the radiation generating system 1000 may be configured to generate a beam 1011 of system light 1001 (see also Fig. 4). Especially, the beam 1011 of system light 1001 may have an optical axis (O). In embodiments, in at least one cross-section of the beam 1011 parallel to the optical axis (O), at least 50% of the spectral power in Watt may be at a beam angle $2 * \theta$ larger than 100° .

Reference Ax indicates an axis of the discharge vessel 400. In embodiments, the discharge vessel 400 may be elongated (perpendicular to the plane of drawing). Reference RA1 indicates an axis of elongation of the first reflector 410. In embodiments, the first reflector 410 may be elongated (perpendicular to the plane of drawing). Reference RA2 indicates an axis of elongation of the second reflector 420. In embodiments, the second reflector 410 may be elongated (perpendicular to the plane of drawing). In specific embodiments, the axes Ax, RA1, and RA2 may be configured parallel.

Referring to e.g. Fig. 1, as can be seen, by configuring the excimer lamp, more especially the discharge vessel 400, between the first reflector 410 and the second reflector 420, a majority of the radiation 101 provided by the excimer lamp over at least about 120° (especially when assuming an essentially cylindrical cross-section), such as at least about 150°, may be reflected (at least once, by at least one of the reflectors).

In another aspect, the invention may provide a method for treating a gas or a surface external of the radiation generating system 1000. Especially, the method may comprise providing the radiation 101 to the gas or the surface with the radiation generating system 1000.

Fig. 2A schematically depicts several embodiments of the radiation generating system, particularly demonstrating the configuration of the first reflector and the second reflector in embodiments. Hence, specific embodiments of the invention are described herein.

In embodiment (I), the first reflector 410 may have a planar cross-sectional shape and the second reflector 420 may (also) have a planar cross-sectional shape.

Especially, the first reflector 410 may be configured closer to the chamber exit window 511 than the second reflector 420. Further, the second reflector 420 may have a larger cross-sectional area than the first reflector 410.

In embodiment (II), the first reflector 410 may be curved in at least one direction defining a first reflector cavity 415. Further, the discharge vessel 400 may be at least partly configured within the first reflector cavity 415. Especially, the second reflector may have a planar cross-sectional shape. Yet further, the first reflector may be configured closer to the chamber exit window 511 than the second reflector 420.

In embodiment (III), the first reflector 410 may be curved in at least one direction defining a first reflector cavity 415. Further, the discharge vessel 400 may be at least partly configured within the first reflector cavity 415. Especially, the second reflector 420 may comprise n_3 segments 441, wherein n_3 is 3. Further, the second reflector 420 comprising 3 segments may be joined along an edge (or opposite edges), such that the segments form an angle of 90° between two segments. Yet further, the first reflector may be configured closer to the chamber exit window 511 than the second reflector 420.

In embodiment (IV), the first reflector 410 may have a planar cross-sectional shape, and the second reflector 420 may comprise n_3 segments 441, wherein n_3 is 3. Further, the n_3 segments 441 may form a second reflector cavity 425, wherein the discharge vessel 400 is at least partly configured within the second reflector cavity 425. Further, the second

reflector 420 comprising 3 segments may be joined along an edge (or opposite edges), such that the segments form an angle larger than 90° between two segments.

In embodiment (V), the first reflector 410 may be curved in at least one direction defining a first reflector cavity 415, and the second reflector 420 may be curved in at least one direction defining a second reflector cavity 425. The discharge vessel 400 may be configured either in the first reflector cavity 415, or the second reflector cavity 425.

In embodiment (VI), the first reflector 410 may have a planar configuration, and the second reflector 420 may be curved at least in one direction, such that the second reflector defines a second reflector cavity 425. Hence, the discharge vessel 400 may be configured within the second reflector cavity 425.

In embodiment (VII), the first reflector 410 may have a planar configuration, and the second reflector 420 may be curved in at least one direction. However, the second reflector 420 may be reflective on the concave side of the second reflector 420. For example, the second reflector may essentially be reflective in a manner similar to a concave mirror. Further, the cross-sectional area of the first reflector 410 may be larger than the cross-sectional area of the second reflector 420.

In embodiment (VIII), the first reflector 410 may be curved in at least one direction defining a first reflector cavity 415. Further, the discharge vessel 400 may be at least partly configured within the first reflector cavity 415. Especially, the second reflector 420 may comprise a double semi-cylinder-like cross-sectional shape, comprising two reflector regions 421, each comprising a semi-cylinder-like cross-sectional shape. Hence, the second reflector 420 may have a W-shape. Wherein (i) a center line 422 defining a middle between the two reflector regions 421, (ii) a discharge vessel axis (A) of the discharge vessel 400, and a center line 412 of the first reflector 410 may be configured in single a plane.

In embodiment (IX), the first reflector 410 may have a planar cross-sectional shape, and the second reflector 420 may comprise a double semi-cylinder-like cross-sectional shape, comprising two reflector regions 421, each comprising a semi-cylinder-like cross-sectional shape. Hence, the second reflector 420 may have a W-shape.

In embodiment (X), the first reflector 410 may have a planar cross-sectional shape. Especially, the light chamber 510 may comprise the second reflector 420, i.e. the inner walls of the light chamber 510 may be the second reflector 420.

In embodiment (XI), the first reflector may have a planar cross-sectional shape. Further, the radiation generating system 1000 may comprise a plurality n_4 of second reflectors 420, wherein n_4 is at least 2, wherein a set of two adjacent second reflectors 420

have a mutual distance (dr_2) providing a second reflector opening 427. Especially, the set of two adjacent second reflectors 420 may be configured such that part of the radiation from the discharge vessel 400 propagates through the second reflector opening 427. Specifically, with at least one reflection at one of the two adjacent second reflectors 420. Especially, relative to a system exit window 1020 via which system light escapes from the radiation generating system 1000 (see also Fig. 1), along an optical path of the system light 1001, the n_4 second reflectors 420 are configured closer to the system exit window 1020 than the first reflector 410.

In embodiments (XII), the radiation generating system 1000 may comprise a plurality n_2 of first reflectors 410, wherein n_2 is at least 2, wherein a set of two adjacent first reflectors 410 have a mutual distance (dr_1) providing a first reflector opening 417. Especially, the set of two adjacent first reflectors 410 may be configured such that part of the radiation from the discharge vessel 400 propagates through the first reflector opening 417, with at least one reflection at one of the two adjacent first reflectors 410. Furthermore, relative to a system exit window 1020 via which system light escapes from the radiation generating system 1000 (see also Fig. 1), along an optical path of the system light 1001, the n_2 first reflectors 410 may be configured closer to the system exit window 1020 than the second reflector 420.

In embodiment (XII), the first reflector 410 may comprises n_1 segments 431, wherein n_1 is at least 2, such as 3. Especially, the n_1 segments 431 form a first reflector cavity 415. Further, the discharge vessel 400 may be at least partly configured within the first reflector cavity 415. Yet further, the second reflector may have a planar cross-section.

Some of the schematically depicted embodiments of Fig. 2a may allow that under larger angles some light of the discharge vessel may escape from the system 1000 without being reflected at the second reflector.

Fig. 2B schematically depicts an embodiment (I) of the second reflector 420. Especially, the second reflector 420 may comprise one or more dichroic filters 470, wherein the dichroic filter 470 may be provided on a support 429. The figure also further depicts an embodiment (II) of the second reflector 420, which may comprise a luminescent material 200. The figure (also) depicts an embodiment (III), wherein the second reflector may comprise a plurality of segments (joined to form the second reflector). Especially, the segments may be joined such that the second reflector 420 is curved in one direction. Further, each segment may comprise either the dichroic filter or the luminescent material.

Luminescent materials are described above. An example is e.g. $(M)(A)_{12}O_{19}:Ce^{3+}$, wherein M comprises one or more of Sr, Ba, and Ca, and wherein A comprises one or more of Al and Ga, such as $SrAl_{12}O_{19}:Ce^{3+}$. The aluminate may for instance comprise 0.1-5 mol% Ce.

Fig. 2c schematically depicts in perspective view an embodiment analogous to embodiment V of Fig. 2a. Aspects described in relation to this drawing, may also apply to other embodiments schematically depicted in Fig. 2a. Reference Ax refers to the discharge vessel axis and references RA1 and RA2 refers to the reflector axes of the first reflector 410 and second reflector 420, respectively. In these embodiments, the axes are axes of elongation. LD refers to the length of the discharge vessel 400. L1 refers to the length of the first reflector 410; L2 refers to the length of the second reflector 420. In embodiments, $0.75*LD \leq L1 \leq 1.1*LD$ and/or $0.75*LD \leq L2 \leq 1.1*LD$.

Figs. 3A-3B depict some selective reflective properties of the second reflector. On the y-axis, the reflectiveness is indicated, and on the x-axis the wavelength in nanometers. Curve a in Fig. 3A schematically depicts a kind of binary optical (second) reflector 420, having high reflectivity in the 170-245 nm range and above about 275 nm, but essentially zero in between 245-275 nm. Curves b and c schematically show other embodiments, wherein the reflectivity dependence over the wavelength is more gradual, and may also not necessarily drop to about 0% reflectivity, but e.g. on average about a few % reflectivity in the less desired wavelength ranges. Note that the choice of about 170 nm, about 245 nm, and about 275 may also be different in other embodiments.

Fig. 3C schematically depicts the light distribution curve (or candlepower distribution curve), herein the form of a batwing distribution. This figure depicts an embodiment of the angular distribution of system light 1001 provided by the light generating system or lighting device. The numbers on the axes can be ignored. The optical axis may be the vertical axis from the value of 0 in the middle at the top to the value of -2.5 in the middle at the bottom of the graph.

Fig. 4 schematically depicts an embodiment of a lighting device 1200. In embodiments, a lighting device 1200 may be selected from the group of a lamp 1, a luminaire 2, a projector device 3, a disinfection device, a photochemical reactor, and an optical wireless communication device, comprising the light generating system 1000 as described herein. Reference 301 indicates a user interface which may be functionally coupled with the control system 300 comprised by or functionally coupled to the light generating system 1000. The figure also schematically depicts an embodiment of lamp 1 comprising the light generating

system 1000. Reference 3 indicates a projector device or projector system, which may be used to project images, such as at a wall, which may also comprise the light generating system 1000. In embodiments, such lighting device may be a lamp 1, a luminaire 2, a projector device 3, a disinfection device, or an optical wireless communication device.

5 Lighting device light escaping from the lighting device 1200 is indicated with reference 1201. Lighting device light 1201 may essentially consist of system light 1001, and may in specific embodiments thus be system light 1001. Reference 310 indicates a sensor element which may be configured to provide a sensor signal to the control system 300. Reference 1300 indicates a space, such as an office or a living room.

10 With the increasing threat of aggressive viruses like Covid-19, there is a renewed interest in UV-based disinfection. From various studies it has been shown that UV-C (200-280 nm) radiation can effectively render viruses ineffective even at relatively low doses. This makes UV treatment of surfaces an interesting candidate to fight the spread of these kind of viruses through contact with contaminated surfaces. At the same time, however,
15 it is also known that short wavelength UV radiation can give rise to DNA mutations if the radiation hits the unprotected skin. For lamps using Hg 254 nm radiation which are commonly used disinfection lamps this limits the allowable exposure in areas where humans are present or may be present. It is known also that far-UV wavelengths (<230 nm) show a higher absorption and hence have limited penetration into the living skin. At sufficiently low
20 wavelengths this radiation does not penetrate further than the upper skin layers which consist of dead skin cells. As a result, usage of these very short wavelengths has less detrimental side-effects than the 254 nm radiation that emanates from state-of-the-art UV-C lamps using mercury as the active radiator. Since radiation between 230 and 245 nm is still effective for disinfections and still limited harmful for humans, herein a filter combination is proposed that
25 allows UV-C radiation up to 245 and increase the efficiency of the disinfection system.

Amongst others, the invention proposes a Far UV radiation system comprises a: far UV radiation source, a reflector with a combination with high reflectiveness from 210 to 245 nm and a low reflectiveness between 250 and 270 nm. Especially, the UV radiation source is based on a KrCl excimer discharge.

30 In embodiments, multiple UV sources may be applied in the UV system.

In embodiments, the UV source may be based on a tubular geometry, e.g. single tube, coaxial, etc. In embodiments, the UV source may be based on a disc shape or oval geometry.

The terms “upstream” and “downstream” relate to an arrangement of items or features relative to the propagation of the light from a light generating means (here the especially the light source), wherein relative to a first position within a beam of light from the light generating means, a second position in the beam of light closer to the light generating means is “upstream”, and a third position within the beam of light further away from the light generating means is “downstream”.

The term “plurality” refers to two or more.

The terms “substantially” or “essentially” herein, and similar terms, will be understood by the person skilled in the art. The terms “substantially” or “essentially” may also include embodiments with “entirely”, “completely”, “all”, etc. Hence, in embodiments the adjective substantially or essentially may also be removed. Where applicable, the term “substantially” or the term “essentially” may also relate to 90% or higher, such as 95% or higher, especially 99% or higher, even more especially 99.5% or higher, including 100%. The term “comprise” also includes embodiments wherein the term “comprises” means “consists of”.

The term “and/or” especially relates to one or more of the items mentioned before and after “and/or”. For instance, a phrase “item 1 and/or item 2” and similar phrases may relate to one or more of item 1 and item 2. The term “comprising” may in an embodiment refer to “consisting of” but may in another embodiment also refer to “containing at least the defined species and optionally one or more other species”.

Furthermore, the terms first, second, third and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

The devices, apparatus, or systems may herein amongst others be described during operation. As will be clear to the person skilled in the art, the invention is not limited to methods of operation, or devices, apparatus, or systems in operation.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims.

In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim.

Use of the verb "to comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise", "comprising", and the like are to be construed in an inclusive sense as opposed to an
5 exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to".

The article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements.

The invention may be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed computer. In a device claim, or an
10 apparatus claim, or a system claim, enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. In yet a further aspect, the invention (thus) provides a software product, which, when running on a computer is capable of bringing about (one or
15 more embodiments of) the method as described herein.

The invention also provides a control system that may control the device, apparatus, or system, or that may execute the herein described method or process. Yet further, the invention also provides a computer program product, when running on a computer which is functionally coupled to or comprised by the device, apparatus, or system,
20 controls one or more controllable elements of such device, apparatus, or system.

The invention further applies to a device, apparatus, or system comprising one or more of the characterizing features described in the description and/or shown in the attached drawings. The invention further pertains to a method or process comprising one or more of the characterizing features described in the description and/or shown in the attached
25 drawings.

The various aspects discussed in this patent can be combined in order to provide additional advantages. Further, the person skilled in the art will understand that embodiments can be combined, and that also more than two embodiments can be combined. Furthermore, some of the features can form the basis for one or more divisional applications.

CLAIMS:

1. A radiation generating system (1000) comprising an excimer lamp (100), a light chamber (510), and optics (450) wherein:

- the excimer lamp (100) comprises a discharge vessel (400), wherein the discharge vessel (400) contains a gas composition (405) comprising chlorine, and krypton;

5 wherein the excimer lamp (100) is configured to generate in an operational mode radiation (101) having one or more wavelengths in the wavelength range of 200-300 nm;

- the optics (450) comprises a first reflector (410) and a second reflector (420);

- the discharge vessel (400) is configured between the first reflector (410) and the second reflector (420);

10 - the first reflector (410) is configured to reflect at least part of the radiation (101) in a direction of the second reflector (420);

- the excimer lamp (100), the first reflector (410), and the second reflector (420) are configured such that at least part of the radiation (101) can only escape from the radiation generating system (1000) via at least a reflection at the second reflector (420);

15 - the second reflector (420) has a first wavelength averaged reflection R1 in a first wavelength range 210-245 nm, and a second wavelength averaged reflection R2 in a second wavelength range of 250-270 nm, wherein $R2/R1 \leq 0.6$;

- the radiation generating system (1000) is configured to generate system light (1001) comprising at least part of the radiation (101) reflected at the second reflector (420).

20 2. The radiation generating system (1000) according to claim 1, wherein $R1 \geq 50\%$, wherein $R2 \leq 20\%$, wherein the second reflector (420) has a third wavelength averaged reflection R3 in a third wavelength range of 190 nm and smaller; wherein $R3/R1 \leq 0.6$; and wherein $R3 \leq 20\%$.

25 3. The radiation generating system (1000) according to any one of the preceding claims 1-2, wherein the first reflector (410) is curved in at least one direction defining a first reflector cavity (415), and wherein the discharge vessel (400) is at least partly configured within the first reflector cavity (415).

4. The radiation generating system (1000) according to any one of the preceding claims 1-2, wherein the first reflector (410) comprises a planar first cross-sectional shape.

5. The radiation generating system (1000) according to any one of the preceding claims 1-2, comprising a plurality n_2 of first reflectors (410), wherein n_2 is at least 2, wherein a set of two adjacent first reflectors (410) have a mutual distance (dr_1) providing a first reflector opening (417), wherein the set of two adjacent first reflectors (410) is configured such that part of the radiation (101) propagates through the first reflector opening (417), with at least one reflection at one of the two adjacent first reflectors (410); wherein relative to a system exit window (1020) via which system light (1001) escapes from the radiation generating system (1000), along an optical path of the system light (1001), the n_2 first reflectors (410) are configured closer to the system exit window (1020) than the second reflector (420).

6. The radiation generating system (1000) according to any one of the preceding claims 1-3, wherein the second reflector (420) comprises a double semi-cylinder-like cross-sectional shape, comprising two reflector regions (421), each comprising a semi-cylinder-like cross-sectional shape, wherein (i) a center line (422) defining a middle between the two reflector regions (421), (ii) a discharge vessel axis (A) of the discharge vessel (400), and a center line (412) of the first reflector (410) are configured in single a plane.

7. The radiation generating system (1000) according to any one of the preceding claims, wherein the second reflector (420) comprises one or more dichroic filters (470).

8. The radiation generating system (1000) according to any one of the preceding claims, wherein the second reflector (420) comprises a planar second cross-sectional shape.

9. The radiation generating system (1000) according to claims 4 and 8, wherein the first reflector (410) and the second reflector (420) are configured parallel, and wherein the planar first cross-sectional shape has a smaller area than the planar second cross-sectional shape.

10. The radiation generating system (1000) according to claims 1-5, wherein the second reflector (420) comprises n_3 segments (441), wherein n_3 is at least 2, wherein the n_3 segments (441) form a second reflector cavity (425), wherein the discharge vessel (400) is at least partly configured within the second reflector cavity (425).

5

11. The radiation generating system (1000) according to claims 1-5, comprising a plurality n_4 of second reflectors (420), wherein n_4 is at least 2, wherein a set of two adjacent second reflectors (420) have a mutual distance (dr_2) providing a second reflector opening (427), wherein the set of two adjacent second reflectors (420) is configured such that part of the radiation (101) propagates through the second reflector opening (427), with at least one reflection at one of the two adjacent second reflectors (420); wherein relative to a system exit window (1020) via which system light (1001) escapes from the radiation generating system (1000), along an optical path of the system light (1001), the n_4 second reflectors (420) are configured closer to the system exit window (1020) than the first reflector (410).

10

15

12. The radiation generating system (1000) according to any one of the preceding claims, wherein the system exit window (1020) comprises a luminescent material (200), having a higher reflectivity for radiation with a wavelength selected from the first wavelength range than for radiation with a wavelength selected from the second wavelength range.

20

13. The radiation generating system (1000) according to any one of the preceding claims, wherein the excimer lamp (100) is of the dielectric barrier discharge lamp; wherein the system light (1001) has a spectral power distribution in the 200-300 nm wavelength range with 95-100% of the spectral power within the 210-245 nm wavelength range and 0-5% of the spectral power within the 250-270 nm wavelength range; wherein the gas composition (405) complies with the following conditions:

25

- a total gas pressure P is selected from the range of 50-500 mbar;
- a Cl_2 gas partial pressure p_{Cl_2} is selected from the range of 0.5-4 mbar;
- a Ne/Kr partial pressure ratio $R_{Ne,Kr}$ is selected from the range of 0.5-10;
- 30 - a Kr partial pressure p_{Kr} selected from the range of over 15 mbar;
- at least 33% Ne; and

wherein the Ne/Kr partial pressure ratio $R_{Ne,Kr}$ complies with the formula

$R_{Ne,Kr} \leq (0.03 * P / \text{mbar})^{-4}$, and wherein for total gas pressures P below 150 mbar applies that $R_{Ne,Kr}$ is at least 0.5.

14. The radiation generating system (1000) according to any one of the preceding claims, wherein the light chamber (510) comprises (a) reflective walls (512) and (b) a radiation exit window (511), wherein the light chamber (510) encloses the discharge vessel (400), the first reflector (410) and the second reflector (420); wherein the radiation generating system (1000) is configured to generate a beam (1011) of system light (1001), wherein the beam (1011) of system light (1001) has an optical axis (O), wherein in at least one cross-section of the beam (1011) parallel to the optical axis (O) at least 50% of the spectral power is at a beam angle $2*\theta$ larger than 100° .

15. A method for treating a gas or a surface external of the radiation generating system (1000), the method comprising providing the radiation (101) as defined in any one of the preceding claims to the gas or the surface with the radiation generating system (1000) according to any one of the preceding claims.

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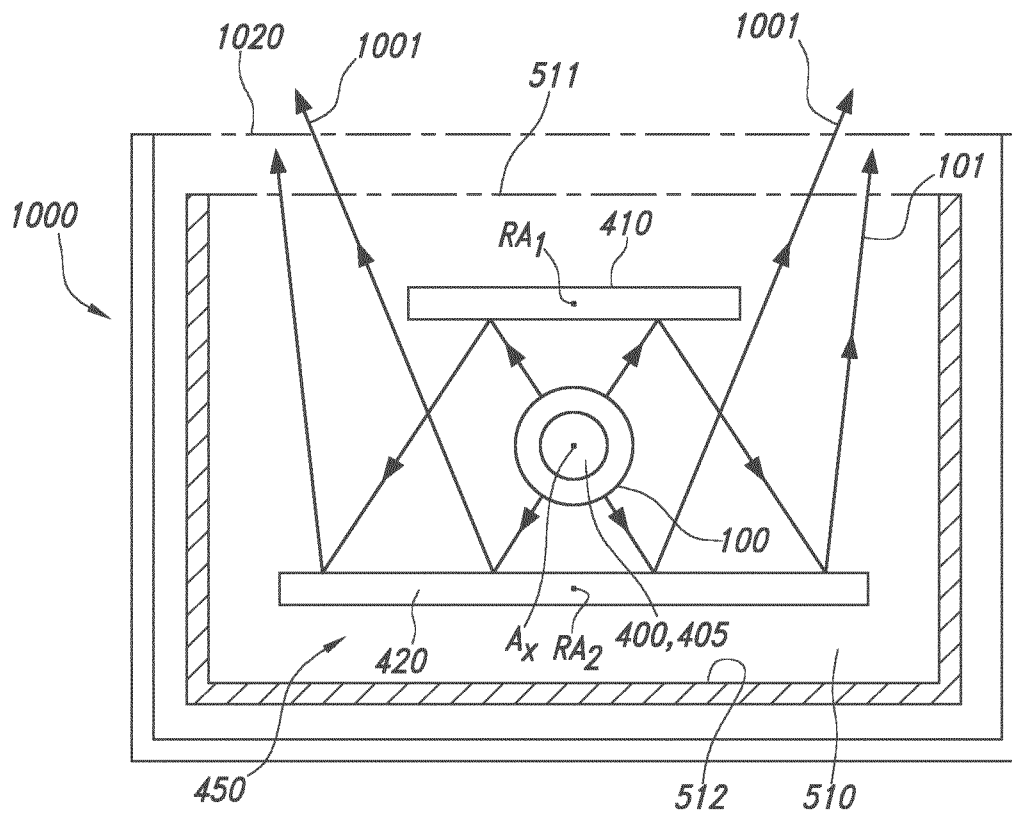


FIG. 1

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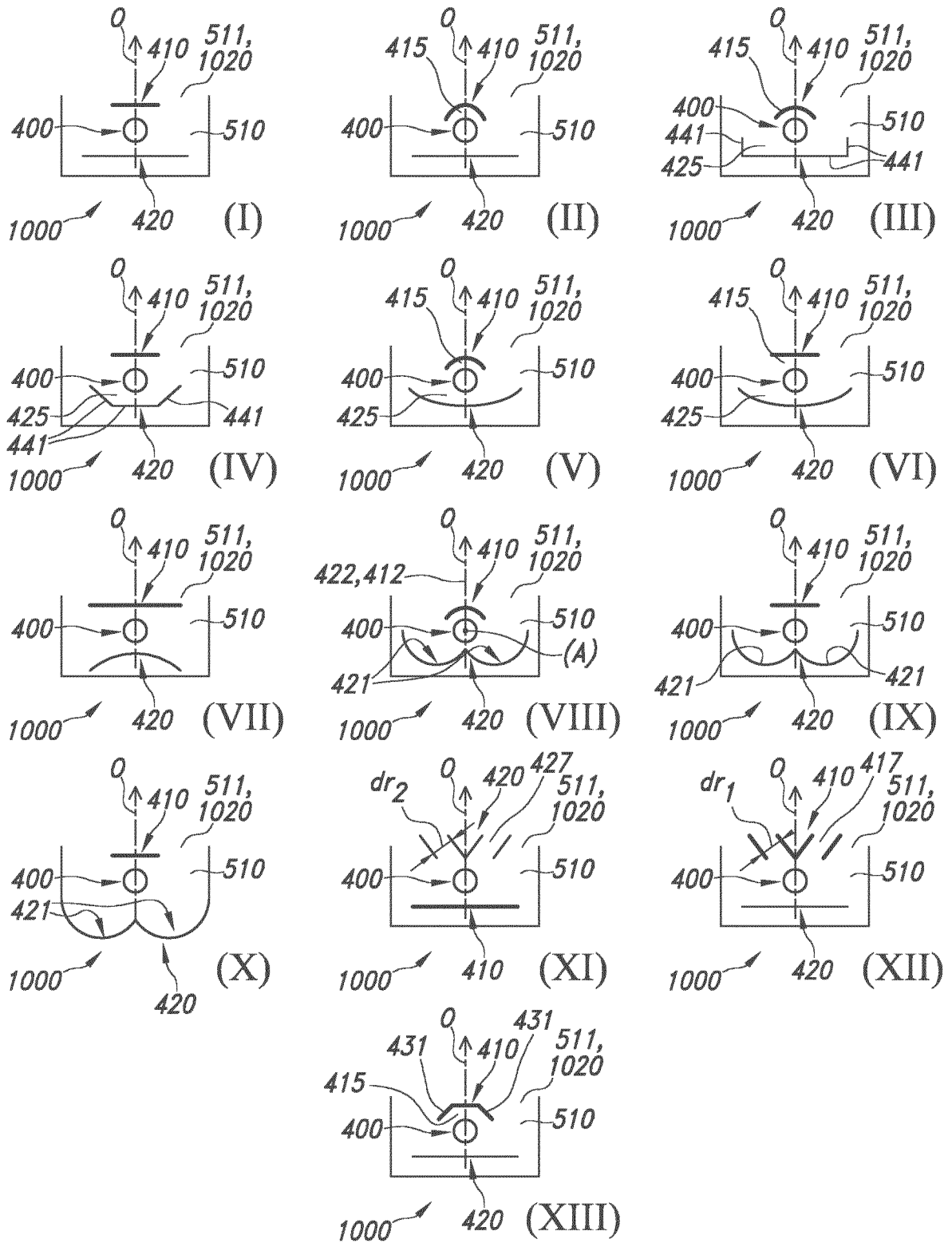


FIG. 2A

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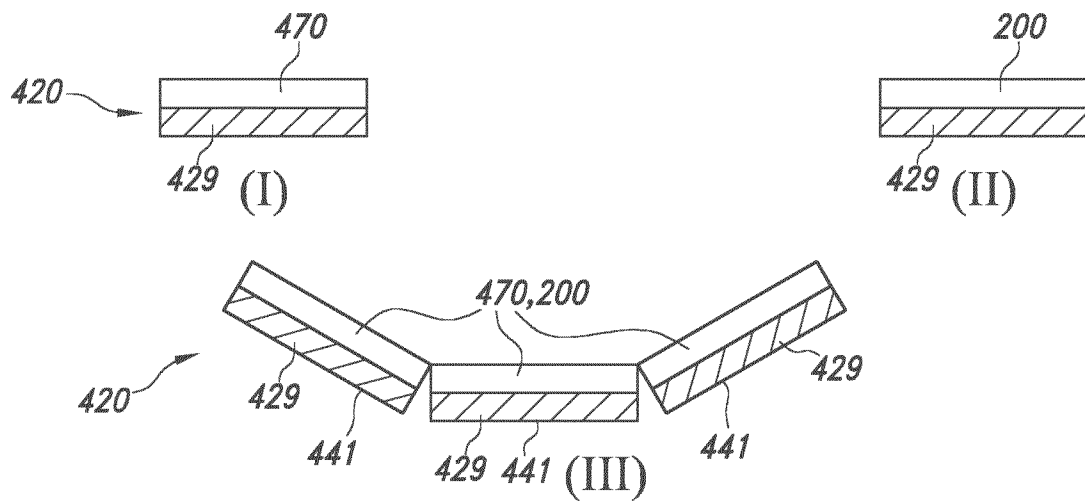


FIG. 2B

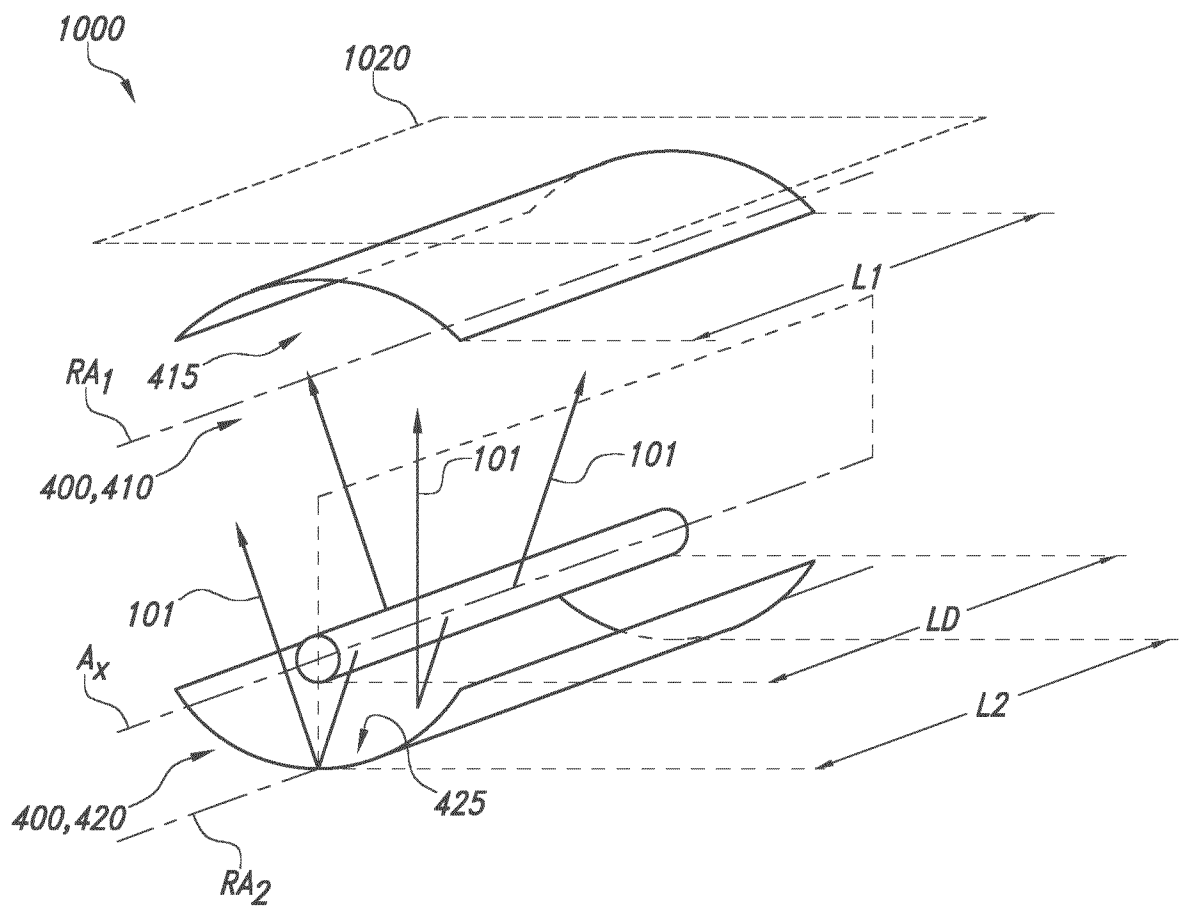


FIG. 2C

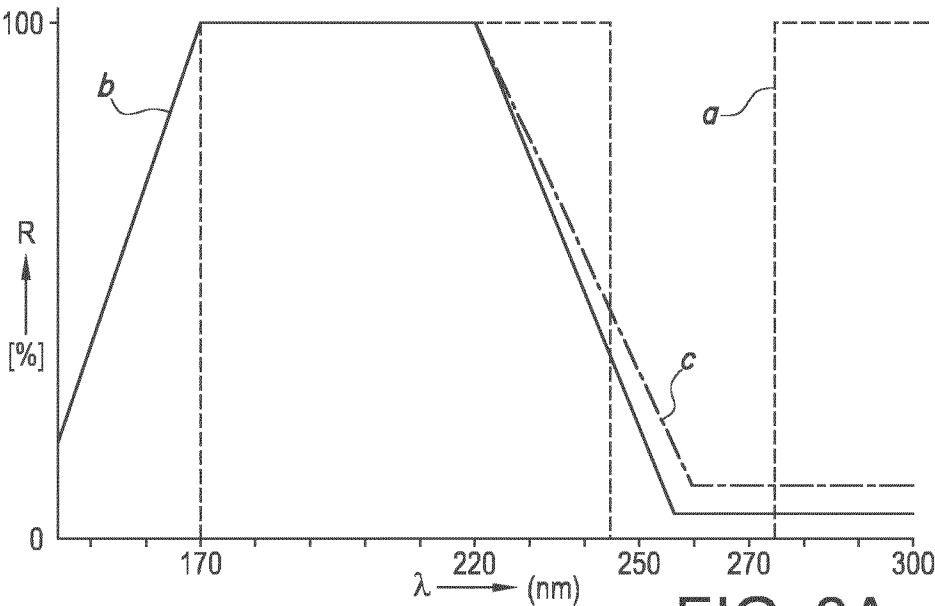


FIG. 3A

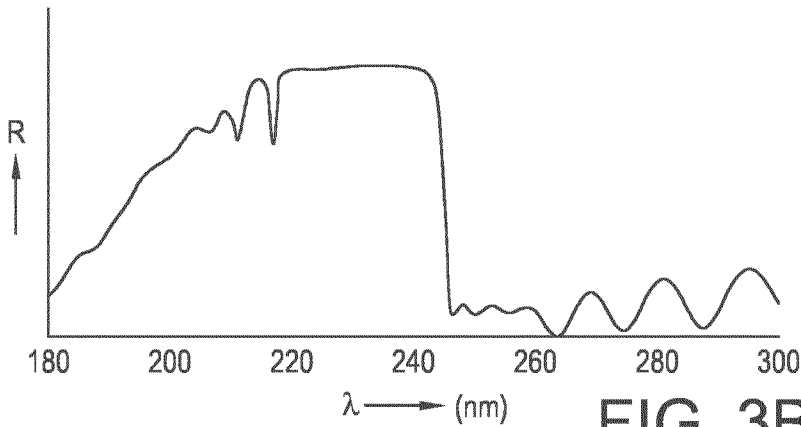


FIG. 3B

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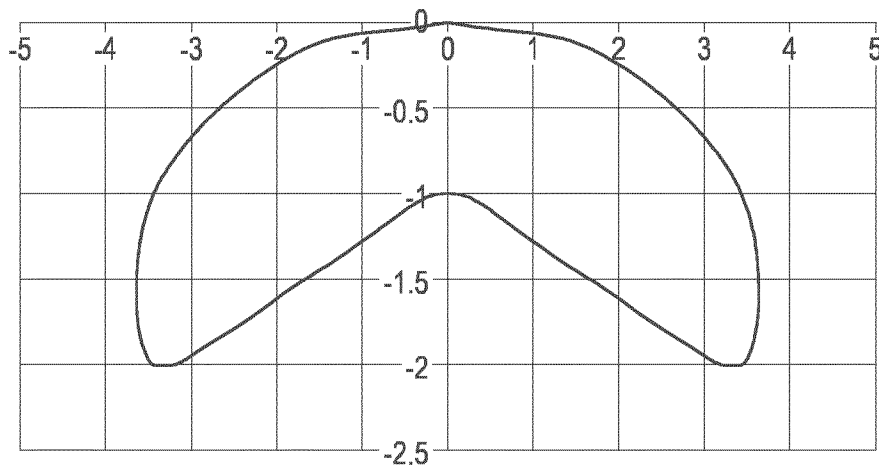


FIG. 3C

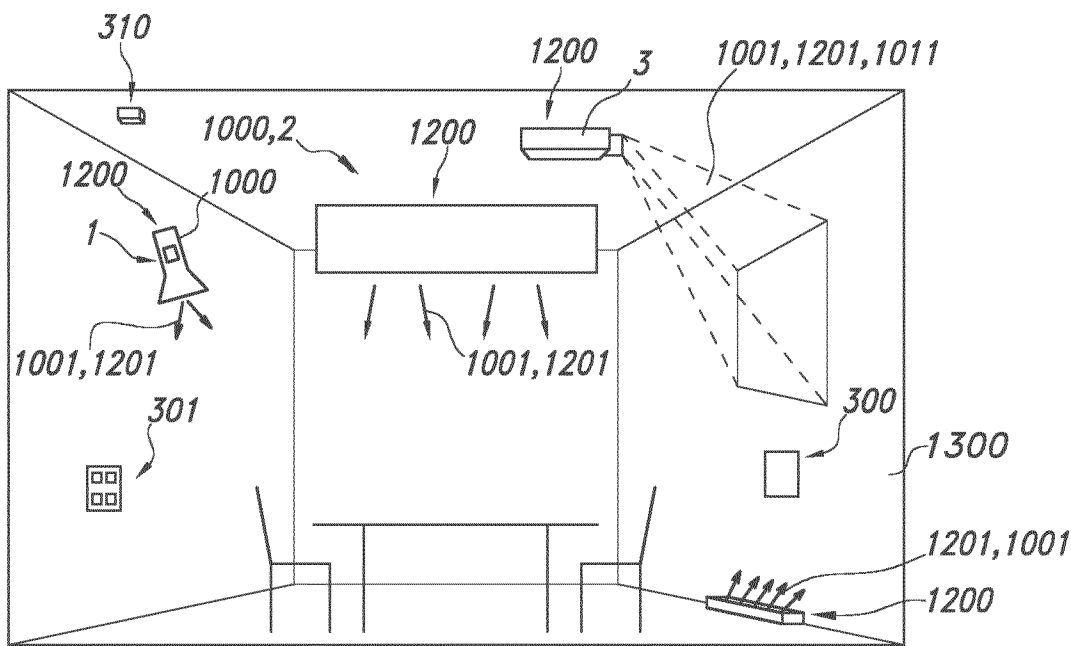


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2023/062354

A. CLASSIFICATION OF SUBJECT MATTER INV. A61L2/00 A61L2/10 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	CN 109 630 981 A (BOEING CO) 16 April 2019 (2019-04-16) paragraph [0030]; figures paragraph [0036] - paragraph [0056] -----	1-15
A	US 10 071 262 B2 (UNIV COLUMBIA [US]) 11 September 2018 (2018-09-11) cited in the application 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 3 August 2023		Date of mailing of the international search report 21/08/2023
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Jazbec, Simon

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2023/062354

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 109630981 A	16-04-2019	BR 102018069794 A2	24-04-2019
		CN 109630981 A	16-04-2019
		EP 3466451 A1	10-04-2019
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