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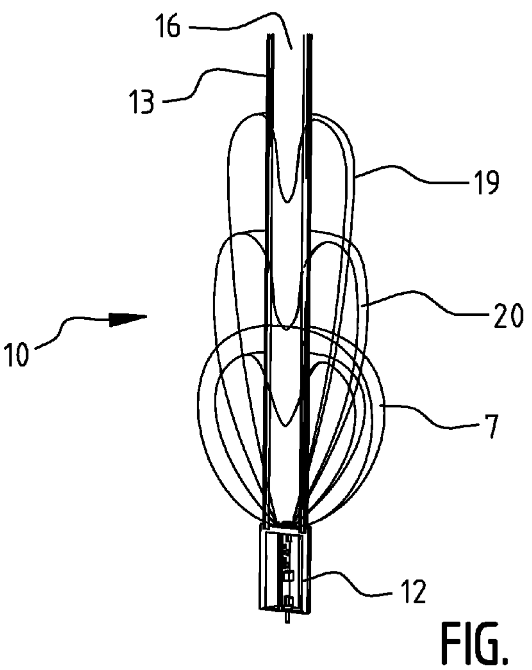

FIG. 3

(57) **Abstract**: The disclosure relates to a light device (10), comprising an elongate, preferably tubular body (13) having at least one open end and a diffusion, scattering or phosphoric layer (16) to emit light out of the body (13) after being impinged by light propagating in and through the body (13), an end cap (12) arranged on the end of the body (13) and carrying at least one light source to emit light into the body (13) and optics near the open end of the body (13), and arranged in or on the end cap (12) or in or on the at least one light source, wherein the optics is designed to direct light from the light source into the body to directly impinge in a substantially evenly distributed manner on the diffusion, scattering or phosphoric layer (16). The optics generate augmenting, complementary and potentially overlapping illumination intensity profiles (19, 20), illuminating different and/or potentially overlapping regions of the body (13) along its length.

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LIGHT DEVICE

The present application relates to light devices. In particular embodiments, a light device, comprises:

- an elongate and preferably tubular body having at least one open end and a diffusion, scattering or phosphoric layer to emit light out of the body after being impinged by light propagating in and through the body; and
- an end cap arranged on the end of the body and carrying at least one light source to emit light into the body.

Such preferably tubular light devices are generally known. Embodiments of the present disclosure have for an object to provide improved light devices, which improvements may relate to one or more than one aspect thereof. For instance, more easy assembly is desired, in particular but not exclusively of end caps in or on the at least one end of the elongate body, as this is cumbersome in many prior art light devices. Moreover, optimum light emission in all directions is desired, where many prior art light devices fail to sufficiently provide all round light emission, as well as homogenous light emission along the length of tubular or otherwise shaped elongate bodies of such prior art light devices.

Many prior art light devices exhibit considerable heat development at extremities of bodies or tubes, in particular at the end caps. To handle the generated heat, many prior art end caps comprise a heat sink or the like, contributing to complexity of assembly, and preproduction of such end caps. Even though such heat development can be addressed through such measures, requirements with respect to heat discharge and transfer also apply to materials used for the bodies or tubes in terms of the thickness thereof or the like, where thicker bodies or tubes have a detrimental effect on cost prices.

A further prior art configuration can exhibit - to address these issues - the following additional features:

- optics near the open end of the body, and arranged in or on the end cap or in or on the at least one light source,

- wherein the optics is designed to direct light, emitted by the at least one light source, into the body to directly impinge in a substantially evenly distributed manner on the diffusion, scattering or phosphoric layer.

Therein, the optics may be designed to direct light from the at least one light source to impinge on the body or tube, while avoiding higher concentrations of light output near the ends of the body or the endcaps at the ends of the body. In combination, such prior art features keep heat development close to or at the end caps low.

The prior art publication of US-5258896 is acknowledged here, where it is noted that at least the features defined in the characterizing portion of the single appended independent claim are novel relative to this prior art publication.

According to the present disclosure, the optics are designed to generate a plurality of augmenting, complementary and potentially overlapping illumination intensity profiles, which illuminate different and/or potentially overlapping regions of the body along the length thereof. This provides for a more even spread of heat development in the elongate body as well as improved homogeneity of light emitted from the elongate body over the length thereof. In particular, though not exclusively, in combination with heat generating conversion of impinging light into emissive light in the phosphoric layer, for example based on stokes losses coming from phosphoric light conversion, a more even spread of heat development in the elongate body over the length thereof may have for an effect that the average temperature is decreased and thereby the thermal quenching of luminescent material in the phosphoric layer, for example phosphor, is decreased, allowing the luminescent material in the phosphoric layer to be more efficient.

Preferred embodiments of the present disclosure can exhibit the feature, that the optics are designed to direct light emitted by the at least one light source to directly impinge on the diffusion, scattering or phosphoric layer at a distance from the end cap. This is to say that viewed from an end cap light emitted by the at least one light source does not directly impinge the diffusion, scattering or phosphoric layer in or on the tube over a first small distance from the end cap, so that heat generated in the diffusion, scattering or phosphoric layer as a result of being directly impinged does not or hardly raise the temperature of the end cap. In particular, though not exclusively, in combination with heat generating conversion of impinging light into emissive light in the diffusion, scattering or phosphoric layer, for example based on stokes losses coming from phosphoric light conversion, this feature may have for an effect that the light device can operate without (a need for) a heat sink or the like in the end cap, or only a smaller heat sink than in conventional configurations. Consequently, the end caps can be reduced in size, or accommodate more optics and/or more light sources and/or illuminating power and/or omit (more of the) heat dissipating means, such as a heat sink and/or cooling fins.

In a more particular embodiment, the distance can be defined in more detail as the distance from the end cap, where the first light emitted by the at least one light source impinges on the diffusion, scattering or phosphoric layer, which is defined to be larger or more than one centimetre, preferably more than two centimetres and even more preferably in a range between 2,5 and 5 centimetres, and most preferably in case of for instance an elongate tubular body, that is comparable in length with a fluorescent lamp, approximately 3 centimetres. It should be noted, that scattered or diffuse light, which is not in a main or central beam angle originating from the light sources, is anticipated to be sufficient to excite phosphor or initiate scattering or diffusion in a region closer to the end cap than beyond that distance, where direct impingement is effected. For example, it is to be expected that by using optics, a part of the light coming from the LED’s will be diffusely scattered by the optics. Thus, surprisingly, use of even relatively very simple optics has a beneficial effect that scattered or diffuse light from the LED’s is used to light up for instance the first three centimetres of a tube. Even in case of more complex optics approximately 10% or less of the total amount of scattered light generated by the LED’s can be used to light up the first part of the tube, of for instance the first 3 centimetres. Thus, although relatively simple optics may already provide a means to the ends of the present invention, care should be taken to limit the amount of scattered light to avoid that the first part or length of the lighting device is unevenly lit in comparison with other parts along the length of the lighting device.

In a further embodiment, as an alternative for or in addition to above preferred embodiments, a light device can exhibit the feature that the at least one light source comprise at least one LED light source. Such a LED light source can produce light with a wavelength peak at 380-480nm ((near) ultraviolet light or blue light), which can be generated in a very cost and energy efficient manner, and still suffice to excite phosphor into generating (white) light.

In a further embodiment, as an alternative for or in addition to above preferred embodiments, a light device can exhibit the feature that the at least one light source comprise five light sources. Any other number of light sources is also possible, for instance two, three or four, or six or more. However, in particular a combination of five light sources lends itself very well to combination, if desired, with a multiplexer. However, multiplexing can be effected very usefully, in particular a voltage regulated multiplexer, to drive as few as at least two light sources, where each light source may represent one channel (or several light sources may represent one channel) of the multiplexer, wherein each one light source can further be a multiple LED. However, currently commercially available multiplexers are very suitable for four to six channels, and the above mentioned exemplary number of five channels may be extended down to at least two channels. By the use of a multiplexer, it has become possible to employ higher-voltage LED’s, when connected to the multi-channel multiplexer, which allows drive of selected ones or groups or the total number of such LED’s, to improve Power Factor and Light Flicker, because the current will follow relatively evenly the voltage. Also system complexity of the electronic system/driver of the lamp will be reduced, since these may be implemented in a small IC-solution.

In a further embodiment, as an alternative for or in addition to above preferred embodiments, a light device can exhibit the feature that the optics is designed to generate at least one batwing shaped light distribution profile. An alternative definition of the shape from the light distribution profile could be a centreline symmetrical “heart-shape”. Either of these two indications or an alternative therefore is intended to indicate that light propagating along a central longitudinal axis of the body or tube should be less than light oriented at the wall of the body or tube, so that direct impingement of light and by this evenly distributed impingement and for example associated activation of the phosphor and therefore even light output and heat distribution on the body or tube can be achieved. In such an embodiment, a further feature can be that the optics are designed to generate multiple overlapping and complementary batwing or heart shaped profiles, which illuminate different and/or potentially overlapping regions of the body along the length thereof. For such an embodiment, individual light sources can be provided with a corresponding optics per light source, in order to establish the regions or ranges where light from the distinct light sources is to impinge on the body or tube, for instance to excite phosphor evenly along the length of the body or tube. However, it is equally possible to employ optics in combination with a single light source to generate the plurality of augmenting complementary and potentially overlapping illumination intensity profiles.

It is noted here that although a batwing or heart shaped beam or illumination intensity profile, i.e. a beam or illumination intensity profile with an intensity decrease at a tube’s centre line, is particularly advantageous, any, preferably centreline symmetrical, beam or illumination intensity profile having an intensity decrease at a tube’s centre line relative to a Lambertian or balloon shape, for instance a Lambertian or balloon shape with a flattened top, could be advantageous employed to decrease the amount of light propagating along a central longitudinal axis of the body or tube. Furthermore, it is noted here that near field illumination intensity profiles will have a smaller range or reach. Especially longer range or reach illumination intensity profiles are preferably heart or batwing shaped, to avoid that centreline light impinges on an opposing end cap. Alternatives may exhibit a form of for example a curved mirror opposing the end cap with the light source or sources, to disperse any light from the light source in the opposing end cap that reached the curved mirror, which could have the shape or form of a ball, when opposing end caps each have a light source or plurality of light sources emitting light in a direction of mirrors, which may then be centrally positioned in the tube or elongate body.

In a further embodiment, as an alternative for or in addition to above preferred embodiments, a light device can exhibit the feature that the optics are arranged immediately on or against the at least one light source. The optics may even be formed by primary optics integrated into or forming a part of the LED’s. This feature includes the possible embodiment that several light sources are combined with a single optics element, to establish a very elongate batwing profile or heart shaped profile, or alternatively still provide separate ranges or regions where light from separate sources is to impinge on the body or tube.

In a further embodiment, as an alternative for or in addition to above preferred embodiments, a light device can exhibit the feature that the diffusion layer comprises phosphor. It should be noted that embodiments of the present disclosure can have a phosphor layer, wherein light can be generated on the basis of impinging other light, as a diffusion layer, for one of a common, more general indication to encompass diffusion, phosphoric responses, scattering and the like.

In a further embodiment, as an alternative for or in addition to above preferred embodiments, a light device can exhibit the feature that the light sources in operation emit blue light, UV light or near UV light. As previously indicated, blue and/or UV light can be generated highly efficient. LED’s for generating blue, near-UV and UV light in fact do contribute to the generation of heat in the end caps. Further, in particular the feature of distance between the light sources and up to where the body or tube is directly impinged (within a primary beam angle of a nearest of the plurality of illumination intensity profiles), heat development in the end cap and/or in the direct vicinity thereof may be minimized. In fact, a considerable portion (50 - 80%) of heat generated in light devices having a UV/blue light source and phosphor layer inside the body is generated by the LED. The remainder of heat generated by these potential embodiments of light devices according to the invention is generated by the phosphor layer. By spatially separating these distinct causes of heat generation, heat generation at the end caps is reduced. Consequently, design requirements with respect to handling such heat can be reduced correspondingly, in particular if the material of the body is capable of discharging the heat generated by the layer.

Moreover, as a rule of thumb, it is noted that when light is converted from short, high-energy wavelengths, such as blue and UV, into longer wavelengths, such as yellow, green and red, the resulting spectrum is assembled from the exciting and the excited light. In case of lighting devices, the resulting spectrum is normally desired to be as white as possible, but in the present disclosure other colours are not to be excluded. Further, when using LED’s as light sources, it is preferable to use common LED’s and/or LED’s that are designed to emit a light beam centred on a single wavelength to include wavelengths within a small range or band, for example 380 - 475 nm. As used LED’s may be very common, these can be obtained at relatively very low cost in comparison with more complex LED’s. LED’s that generate light with a bandwidth of 10 - 100nm or more preferably 20 - 60nm are may be employed according to the present disclosure. State of the art LEDs with a peak-wavelength of 450-470nm are very common, highly efficient and are mass produced, so these LED’s are available at very low costs. UV-LED supply and use at approximately 380-420nm is increasing because of the lower "droop-effect" at these wavelengths, so it’s foreseeable that also these wavelength-range could be used in the future for embodiments of and/or in the present disclosure. Lower droop effect means that the efficiency of the LEDs doesn’t drop as much as normally when the current that passes through them is increased.

Embodiments of the present disclosure are above indicated in general terms, corresponding with the features defined in the appended set of claims. Below, more detailed embodiments will be described, referring to the appended drawings, where specific features, effects, components and aspects are presented merely by way of example, to which the scope of protection for the disclosed embodiments in the claims is by no means to be limited. In the drawings the same features, aspects, components and elements may be designated using the same reference numerals, and:

FIG. 1 shows a potential embodiment of the present disclosure;

FIG. 2 shows a potential embodiment of the present disclosure;

FIG. 3 exemplifies the difference between light distribution according to embodiments of the present disclosure relative to prior art light devices;

FIG.’s 4 and 5 present further features of prior art light devices;

FIG.’s 6 and 7 exhibit a phosphor layer based mechanism of generating emissive light;

FIG.’s 8 and 9 exemplifies separate embodiments of the present disclosure;

FIG.’s 10 - 12 exemplify an embodiment of the present disclosure, based on primary LED lenses/optics, and showing multiple overlapping and complementary heart shaped beams;

FIG.’s 13 - 14 exemplify a single embodiment of the present disclosure, based on Mini TIR lenses;

FIG.’s 15 - 16 exemplifies a single embodiment of the present disclosure, based on a TIR lens accommodating a single high power LED source;

FIG. 17 exemplifies a light profile obtainable with an embodiment like the one of FIG.’s 15-16 or an alternative embodiment;

FIG.’s 18 - 19 exemplify a single embodiment of the present disclosure, based on a common Multi-TIR lens accommodating a plurality of LED sources;

FIG. 20 exemplifies a combined embodiment comprising a Multi-TIR lens as in FIG.’s 18, 19 and additional optic elements thereon;

FIG.’s 21 - 22 exemplify a single embodiment of the present disclosure, based on a Fresnel lens accommodating a plurality of LED sources;

FIG.’s 23 - 24 exemplify a single embodiment of the present disclosure, based on a freeform silicon lens accommodating a plurality of LED sources;

FIG.’s 25 - 27 exemplify a single embodiment of the present disclosure, based on a combination of primary optics of different types accommodating a plurality of LED sources;

FIG.’s 28, 29 exemplify a single embodiment of the present disclosure, based on a silicon ball inserted into a tube or body of a light device;

FIG.’s 30, 31 and 32 exhibit exemplary characteristic graphs of light emitted by each one of several phosphor-materials, when light from a LED source impinges thereon having a wavelength of 455 nm;

FIG. 33 exhibits a graph of a heart or batwing shaped light distribution graph setting out intensity against direction, to clarify the disclosure of FIG. 3 and other figures showing or referring to the heart or batwing shape;

FIG. 34 exemplifies a single embodiment of the present disclosure, based on a TIR lens accommodating a single high power LED source;

FIG. 35 exhibits a graph of the light distribution over a length of the tube or elongate body of the light device that may result from the TIR lens of figure 34.

General idea of lighting the tube

This below description will refer – by way of example – to different optic(s)/LED setups in light devices like the lamp 1 in FIG. 1, that are integrated in a transparent tube 3 equipped with a remote phosphor layer 6 or tube. The expression that the phosphor layer 6 or tube is “remote” is intended to signify that the light from a source 5 or sources needs to impinge thereon also at considerable distances from the source 5 or sources.

The phosphor layer can be arranged in any known or new manner. For example reference is made here to a process of up-flushing, which is known to be used for applying a cover layer or coat of phosphor on the inside of a glass or polycarbonate tube.

Glass tubes exhibit advantages in that heat conduction and dissipation thereby are presently higher than that of plastics, glass can be manufactured very economically, and expansion of glass against in temperature variations is minimal compared with plastics, like polycarbonate. Nevertheless, plastics like polycarbonate are by no means excluded from embodiments according to the present disclosure.

Upflushed phosphor material may have also a further advantage compared to phosphor embodied in a plastic. Extruded phosphor-plastic will have an even, glare surface, off which light will easily reflect off, especially when hitting the surface in a stall angle. In contrast a microstructure of upflushed phosphor is anticipated to exhibit a more rough surface where the light will not reflect off easily. Consequently a higher ration of the blue/UV light can enter the phosphor without being reflected in first place, and more of the radiant power will be converted. The UV/blue-light left after going through the phosphor will be partly reflected off the inner surface of the glass tube because of the stall angle, entering the phosphor again. Therefore, this choice of carrier material of phosphor + carrier material of the phosphor layer (tube body glass) is expected to work best, where a UV/blue wavelength is hitting the phosphor in a stall angle. The objective of converting most of the lower wavelength excitation spectrum into the higher wavelength emission spectrum that then will radiate in all three dimensions can thereby be better achieved, in particular for even light-distribution in a room, where the lamp is installed, or for even light distribution of the lamp in general or total (regardless of the surrounding), as the light is not influenced by the fact that the light source is only arranged in the end caps.

Figures 30, 31, and 32 exhibit responses of several materials to blue light from a LED based on InGaN. Any of these materials $Lu_3Al_5O_{12}$:Ce(1%), $Lu_3Al_5O_{12}$:Ce(1%) + CaS:Eu(SiO_2) and $Lu_3Al_5O_{12}$:Ce(1%) + $Sr_2Si_5N_8$:Eu, or any other suitable material may be arranged in a coat or cover on the inside of a glass or other tube in combination with LED light sources, to generate white light or light of any suitable and/or desired colour.

Other mechanisms than phosphor for emitting light out of the body shaped in these embodiments as a tube, are by no means excluded, such as scattering, diffusion and the like, provided the light source 5 or sources generate light with sufficient intensity, to be emitted out of the body or tube 3 and provide sufficient light to fulfil a desired function for lighting.

The tube 3 is closed with end caps 2 containing driving circuitry 4 and end caps 2 are equipped with for example UV LED’s 5 forming the light sources 5 that are placed in and more particularly on both of the end caps 2 on the tube 3 of the light device 1. Alternatively, blue or near-UV LED’s may be employed. Since the remote phosphor 6 will be activated by UV light (or blue or near-UV light) hitting its surface, the key objective is to create an even spread or distribution of light (360 deg.) throughout the phosphoric surfaces 6 of the tube 3, similar to the lighting behaviour of a generic fluorescent tube (not shown).

When placing LEDs 5 in the end caps 2 of the light device 1, the general lighting pattern will, without further measures / features, be balloon shaped as indicated with the balloon 7 exhibited in FIG. 1. Such a shape is generally referred to as a Lambertian radiator, which is the default radiation pattern of most common LED's, although herein below reference may be made to a balloon shape.

As can be noticed, most of the light will be concentrated in the extremities of the tube. This will cause an uneven spread of light along the length of the tube. Moreover, much of the light generated by the LED's 5 is directed longitudinally relative to the elongate shape of the tube 3 and is not impinging the tube's diffusing, scattering or phosphoric layer 6.

To address this, in the light device 10 of FIG. 2 having end caps 12 accommodating drive circuitry 14 with electrical contact pins 11 and LED's 15, and a tube 13 carrying a phosphor layer 16, optics 18 are provided in or on the end caps 12 or even on LED's 15 to direct the light from the LED's 15 to where light is needed most, as indicated in FIG. 3, exhibiting a comparison of the spread in intensity without optics (Lambertian or balloon shape 7) as in FIG. 1, and a potentially achievable spread in intensity using optics as shown by way of example in FIG. 2. Adding optics 18 in or over the LEDs 15 will result in more focussed beam patterns 19, 20 that can illuminate the tube 13 more evenly, as is evident from the supplementary, augmenting or complementary 3-Dimensional heart shaped or batwing shaped forms 19, 20 of light distribution, also in FIG. 3. This shape is referred to as a batwing shape in side view, and is more explicitly depicted in an exemplary embodiment in FIG. 33. The actual shape is 3-Dimensional in that the side view shape is line symmetrical for rotation around the central axis of the shape, which coincides with or is parallel to the longitudinal axis of the tube 3. Herein below, it will be clarified there are many alternatives for the optics 18 exemplified in FIG. 3 to be Mini TIR lenses 18.

Additionally it's noted here that FIG. 3 shows a plurality of beam shapes or illumination intensity profiles, which are beneficially all heart or batwing shaped but are not limited to these shapes. Of these multiple beam shapes or illumination intensity profiles preferably at least the farthest oriented beam shape or illumination intensity profile may be batwing or heart shaped with an intensity decrease at a tube’s centre line, to reduce the amount of light that would follow the centre line of the tube at an opposing end cap or at a centre ball (figures 28, 29). Although a batwing or heart shaped beam or illumination intensity profile, i.e. a beam or illumination intensity profile with an intensity decrease at a tube’s centre line, is particularly advantageous, any, preferably centreline symmetrical, beam or illumination intensity profile having an intensity decrease at a tube’s centre line relative to a Lambertian or balloon shape, for instance a Lambertian or balloon shape with a flattened top, could be employed to reduces the amount of light that would follow the centre line of the tube. Furthermore, it is noted that more of the beam shapes or illumination intensity profiles closer to the end cap having the light source or light sources, from which the beam shapes or illumination intensity profiles are configured, may have a Lambertian or balloon shape like closest field beam of profile 7 in FIG. 3, or any other shape. Of a higher importance is that the beams or illumination intensity profiles augment, complement and/or potentially overlap, but in a merely preferred embodiment, at least some of these beams or profiles are batwing or heart shaped and then preferably at least farther oriented ones of those beams or profiles may have such a batwing or heart shaped profile.

Benefits of using phosphor light spreader

As exhibited in FIG.’s 4 and 5, when using white LED’s 5 to light up a tube 3 without a phosphorous or phosphoric layer 16, rays 8 of light will have to travel through the material of the tube 3 over long distances d1 in FIG. 5, after the beams 8 impinge on the surface of the material of the tube 3 at steep angles, as can be seen in FIG.s 4 and 5.

With the phosphor layer 16 in FIG.’s 6 and 7, light beam 22 of blue light (see below) impinging on the phosphor layer 16 in FIG. 2, 6 and 7 will at least partly be converted into broad bandwidth (white) visible light 21 by the phosphor layer 16. This converted light 21 will radiate in all directions, as shown in

FIG.'s 6 and 7. A similar effect of avoiding the long path through material of the tube 13 can be achieved using an alternative scattering or diffusing layer.

Residual reflected blue light beam 23 will continue in the tube 13 to impinge on phosphor further down into the tube 13, and generate white light there. White light 24 from the phosphor layer 16, directed into the tube 13, will emit out of the tube 13 or will also impinge on phosphor layer 16 opposite to the location where the white light 21, 24 was generated by the phosphor, to also generate a reaction from the phosphor layer 16 and generate more white light 25.

Since the conversion reaction within phosphor decreases the distance that light will have to travel through the material of the tube 13, remote phosphor systems can be much more efficient than non-phosphoric systems.

Light that is scattered outwards is direct useful light. Light that is reflected 23 or scattered 24 back into the tube will cause another conversion reaction 25 in other areas of the tube 13. This is also the case for light 23 that is directly reflected off the phosphoric layer. This light will travel through the tube until it hits the tube wall in another spot 26 and cause a conversion reaction there (or scatters again, etc.).

Below several optic systems are presented that can be employed in embodiments, for example in conjunction with the above described phosphoric layer based tubular light device.

Below, manners of distributing the light effectively along the tube's inner phosphoric layer are disclosed, but it should be emphasized that the herein disclosed configurations lend themselves very well to useful application in the framework of other mechanisms than phosphor based light generation, such as diffusion or scattering based light devices.

Optical properties

Optic configurations disclosed below and shown in appended drawings each exhibit their own specific way of lighting the tube efficiently. A common but not limiting feature of the embodiments in the following description is that a first part, for example over a distance of preferable 30 mm from the end caps with the LED's, of the tube immediately next to the LED's 15 or other light sources is not illuminated directly, as depicted with d2 in FIG. 8. There with it is possible to employ primary optics or for example mini TIR lenses 27 as secondary optics and d3 in FIG. 9, employing for example a TIR, Multi TIR, Fresnel or Freeform silicon lens 28 as secondary optics.

A distance d2, d3 from the end cap 12, over which light emitted by the at least one light source 15 impinges on the diffusion, scattering or phosphoric layer 16 in the tube 13, is - if such a distance is embodied - more than one centimetre, preferably more than two centimetres and even more preferably in a range between 2,5 and 5 centimetres, and most preferably in case of for instance an elongate tubular body comparable in length with a fluorescent lamp approximately 3 centimetres.

Since 5 - 20% of the light (or less or more thereof) in an optic system is not maintained within the beam angle, but distributed or scattered diffusely, this diffuse light (not indicated in the figures, but inherently present) will impinge on the tube closer to the end cap(s) 12 for illuminating the extremities of the tubes.

Especially in combination with the use of a phosphoric layer 16, excited through impinging light from at least one source 15, such as at least one LED source 15, to generate light emission from the tube shaped embodiment of an elongate body, the excitation of the phosphor in layer 16 and resulting conversion of light encompassing all wavelengths to generate (more or less) white light therein is known to generate considerable amounts of heat. This mechanism accounts for 15-30% of the total heat generated by the light device, but the actual percentage may vary with or depending on the color temperature: higher color temperature will require less phosphor/conversion, leading to less losses in the conversion process. Thus, heat of the conversion process may be summarized to amount to about 15% at approximately 6000K, compared to about 30% at approximately 2700K.

The feature and effect of directing the beam angle such as to impinge on the phosphoric layer only at a (considerable) distance from the end cap(s) 12 safeguards the end caps 12 and the ends of the tube near the end caps 12 from being subjected to excessive amounts of heat resulting from light conversion, but in the end cap(s) heat is still generated by the LED’s. Nonetheless, this feature already allows for countermeasures, such as heat sinks and the like, to be omitted or at least decreased by employing smaller heat sinks, cooling fins or the like, or allow for more light output / more LED’s, et cetera. It is however noted that in view of heat generating aspects this feature may be employed, but for scattering or diffusion based devices these consideration may be less important and the beam angle of at least one combination of a LED and corresponding optics can then be wider to allow light to impinge directly from the LED’s 15 on a scattering or diffusing layer of the tube 13 closer to the end caps 12. By purposefully directing a main beam angle such, that a direct beam impinges on the interior of the body only at a considerably distance from the end cap(s), account is cleverly taken of the fact that scattered light from the light sources, the optics or from the environment will still suffice to excite the phosphor closer to the end caps than the borders of the main beam angle.

Optic systems

Several embodiments of optic systems have been developed to produce light patterns that are expected to satisfy the requirements as described above. The follow types of optic systems have been developed within the framework of and bounds according to the appended claims, and will be explained below:

- Primary optic
- Secondary optics
  - TIR
  - Mini TIR
  - Multi TIR
  - Fresnel
  - Freeform silicon lens

– multiple-stage systems

These are all examples of systems which may be used to create the plurality of augmenting, complementary and potentially overlapping beam shapes or illumination intensity profiles, that may be heart shaped or batwing shaped beam shapes or illumination intensity profiles.

Primary optics of LED's

A possible embodiment for distributing light 22 in a correct way as indicated by profiles 19, 20 in FIG.'s 3, 12 is by using the primary optics of the LED's itself.

Every one of the LED's 15 is assigned with its own specific area that needs to be lighted along the length of the tube 13. Therefore, every optic for each LED needs to be correspondingly designed. In order to maximize the light output of the tube, the shape 28 of lenses of the LED's 15 themselves may be designed to resemble a 'donut' shape (FIG.'s 10 and 11). By using this donut shape 28, the lenses of LED's 15 generate centre symmetrical shaped beams, as depicted in FIG. 12. The separate beams 19 - 20 in FIG. 12 can be generated by different lenses 28, one for each of the five LED light sources 15, combined with the corresponding one of the LED's 15. Each LED 15 has a lens therewith to achieve for each LED separately a different profile length 19 - 20. As such, FIG. 12 substantiates how the different embodiments of lenses can adapt the light beam profile of the corresponding light source in correspondence with and depending on a length of the tube 13 forming the body of the light device.

In this manner light output on the sides (walls) of the tube 13 is increased, while less light is directed to the centre regions of the tube along the centre axis thereof, as light 22 passing along this centre axis will not be converted by the phosphor. This is to say that a parallel beam along a longitudinal axis of the tube 13 is less desired and beam components along that axis are attenuated through the use of the above referred to lenses 28 of the LED's 15, which result in the beams exhibited in FIG. 12. It is noted here that such beams 19 - 20 are also useful in light devices based on other light sources than LED's, and light generating or distributing or diffusing or scattering mechanisms, like scattering or diffusing surfaces on or in the tube forming the body of the light device, et cetera.

It is further noted that in the embodiment of FIG. 10, multiplex connectors 65 are shown, for four channels and an additional connector. The use of a multiplexer, for which the connectors 65 are shown, can contribute to lowering heat generation. Such connectors 65 are shown in many of the embodiments in the appended figures, described below, without further detailed attention to these connectors 65 at the location below of description of such other embodiments in the following description

Mini TIR lens optics

In the embodiment of FIG. 14, five LED modules 15 are mounted in each of the end caps 12. On top of each of these LED modules 15 sits a small mini TIR lens 29, shown in an enlarged representation in FIG. 13. TIR stands for “Total Inner Reflection”. The objective is again to generate multiple (here: five) beams 19 – 20, as shown for instance in FIG. 12, using five LED modules 15 and associated mini TIR lenses 29, one lens 29 for each LED module 15.

Each LED/lens module 15 is responsible for mainly illuminating a designated area of the tube, as represented in FIG. 12. As a result of this custom light distribution per combination of a LED module 15 with a corresponding mini TIR lens 29 arranged on the LED modules 15, each of the TIR lenses 29 is to have a different, tailor made shape, corresponding with one of the five profiles 19 - 20 in FIG. 12. In order to maximize the light output of the tube (light device), all lenses 29 have generally a donut shape, as shown in FIG.’s 13 and 14, which is however different from the donut shape of the LED lens 28 shown in FIG.’s 10 and 11.

By using this shape or a similar shape, the combinations of LED modules 15 and individual corresponding lenses 29 will produce five centre symmetrical shaped beams 19 – 20, as shown in FIG. 12. This lens shape results in high intensity light on the side walls of the tube at different distances along the length of the tube

13, and less intense light in the centre areas (along the longitudinal axis) of the tube, as depicted also in FIG. 12.

The exemplifying mini TIR lenses 29 have a curved outer surface 30 and depression 31 relative to an upper edge 32, with a wave shaped ridge 33 in the depression 31. In a bottom of the TIR lens 29 a cavity 34 is formed to accommodate or be placed over the LED module 15.

TIR lens optics

In the embodiment of FIG.’s 15, 16 a single TIR lens 35 is employed in combination with a high power LED light source, preferably a cluster of relatively small high flux LED’s 36. The exemplifying TIR lens 35 has a straight diverging outer surface 37 and a straight walled depression 38 relative to an upper edge 39, with a wave shaped ridge 40 in the depression 38. In a bottom of the TIR lens 37 a cavity 41 is formed so that the TIR lens can be placed over the LED light source 36. The centre of the TIR lens 35 should be shaped in order to direct light that is emitted in the centre beam angle of the LED light source towards a certain region of the tube’s inner body, preferably to the near regions that are closest to the optics (FIG. 17), while light that is emitted in the outer beam angle of the LED light source is directed towards a region of the tube’s body, preferably to the far regions of tube’s inner body that are located further away from the optics. Alternatively described, this optic creates complementary, overlapping beam shapes coming from both ends of the tube that create an overlapping light distribution that will result in a uniform spread of light that impinges the phosphor scattering layer.

FIG. 34 shows a further design of a TIR lens 66 in combination with a light source 67 to configure beams 68 and 69. The beams 68 and 69 provide augmenting, complementary and potentially overlapping beam shapes or illumination intensity profiles, which illuminate different and/or potentially overlapping regions of the body along the length thereof. With a TIR lens 66 in combination with a light source 67 as shown in FIG. 34 a relatively homogenous light distribution as shown in FIG. 35, over a length of the tube or elongate body of the light device can be achieved.

Multi TIR lens optics

The Multi TIR 43 shown in FIG.'s 18 and 19 is comparable with a regular TIR lens of FIG.'s 15 and 16, except for curved outer surface 47 and for an extra ring shaped cavity 44 in the bottom of the Multi TIR lens 43. This extra ring shaped cavity 44 accommodates a circular array of LED's 45 that directly radiates to a planar top section of the lens 43. An inner region of the Multi TIR lens 43 is concavely shaped to achieve a centre symmetrical shaped light pattern in the centre of the tube, comparable with the one of the above described TIR lens 35, as shown in FIG. 17.

Further control over light beams emitted from the Multi TIR lens 43 can be achieved by adding additional optic elements 46 on the Multi TIR lens 43, as shown in FIG. 20.

Fresnel lens optics

When using a Fresnel lens 48 in combination with a circular array of LED's 49, as depicted in FIG.'s 21 and 22, the different rings 50, 51, 52 of the Fresnel lens 48 can be used to direct light to where it is needed, e.g. to achieve the profile as depicted in FIG. 12. In this embodiment, a three ring Fresnel lens 48 is used to create three centre symmetrical beams 53, 54, 55, instead of the five profiles 19 - 20 shown in FIG. 12. A five ring Fresnel lens would result in the profile of FIG. 12.

Freeform silicon lens

By using a freeform silicon lens 56, as shown in FIG.'s 23 and 24, a single pre-calculated optic element 57 can be moulded to comprise separate optics 58 for each of the five LED's 59. This way, every LED 59 can have an individually corresponding optics chamber inside a singular lens 56. With respect to a resulting distribution of light, this configuration means that light can be directed in a similar way as with the primary optics or the mini TIR lenses, described above. In this case however, only one lens 56 with integrated individual lenses 58 for the separate LED's 59 is required to achieve this objective of individual ranges for the separate LED’s 59. As the configuration of FIG.’s 23, 24 comprises five LED’s, the generated profile is intended to resemble that of FIG. 12.

Multiple-stage systems

Installing any of the lens systems of FIG.’s 13 – 24 on top of the primary lenses of FIG.’s 10 and 11 allows for even more accuracy in beam control, as shown generally in FIG.’s 25 – 27. Since the primary optics in FIG.’s 10 and 11 are already tailored to create centre symmetrical light beams, the secondary optics can be designed and employed specifically to direct the light to the areas where (for example in terms of distance from the end caps) it is needed. These secondary optics can be similar to the optic systems that are discussed in the previous sections, e.g. Fresnel lenses (FIG. 21, 22 combined with FIG.’s 10, 11, resulting in configuration of FIG. 27), freeform silicone (FIG.’s 23 and 24 combined with FIG.’s 10, 11, resulting in configurations of FIG.’s 25, 26), miniTIR (FIG.’s 13, 14), or any other additional lens system on the primary lenses (FIG.’s 10 – 12)of the individual LED’s.

Silicon ball

Referring to the light device 60 in FIG.’s 28 and 29, all lens systems described above are such that most of the light emitted by LED’s on end caps 61 is directed to the sides or wall of the tube 62. However, due to reflection and scattering some light will cross (more than) a half of (with opposing end caps) or the entire tube length (in case of a single end cap) without being converted to functional light that is emitted out of the light device’s body or tube 62.

Since light that reaches the other side of the tube will hit the opposing end cap and normally be absorbed there, this amount of light will not contribute to additional light.

To prevent light from the (LED) light sources from being wasted in this manner, a reflective or scattering silicon ball 63 can be placed at an end (single cap with LED’s) or in the centre 64 (in case of opposing end caps) of the tube. This ball 63 is added in addition to the lens optical systems described above, when necessary.

With the ball 63 in place, light that reaches the centre 64 of the tube will be reflected back into the tube 62. Because of the spherical shape of the ball 63, reflected light will be directed towards the phosphoric layer, as can be seen in FIG.'s 28 and 29. Alternatively, the ball 63, which may be manufactured from silicon, may have a scattering characteristic. Then, light that reaches the centre will be scattered and mainly distributed to the middle of the tube.

Light normally has difficulty reaching the middle of the tube, using optical systems, especially when the tube is very long. Because of this, a light collecting ball that scatters the light mainly towards the middle can be very helpful to reach an even light distribution along the tube.

Alternatively, end caps may have a diffusing, reflective or other layer to prevent light from LED's on an opposing end cap from being absorbed by the end cap on which the light impinges.

Such a ball may be replaced by an upright eye shaped mirror, to achieve the same reflections over a larger length of the tube 62. Other embodiments than those of the preceding description and appended drawing are also possible within the scope of protection as defined in the appended claims. In particular combined embodiments comprising features from separately presented embodiments are possible, as well as alternatives for specific features, unless these alternatives are excluded in accordance with the appended claims defining the scope of protection for the specifically presented and other alternative embodiments.

CLAIMS

1. A light device, comprising:

- an elongate, preferably tubular body having at least one open end and a diffusion, scattering or phosphoric layer to emit light out of the body after being impinged by light propagating in and through the body;
- an end cap arranged on the end of the body and carrying at least one light source to emit light into the body; and
- optics near the open end of the body, and arranged in or on the end cap or in or on the at least one light source,
- wherein the optics is designed to direct light, emitted by the at least one light source, into the body to directly impinge in a substantially evenly distributed manner on the diffusion, scattering or phosphoric layer,

CHARACTERIZED IN THAT

the optics are designed to generate a plurality of augmenting, complementary and potentially overlapping beam shapes or illumination intensity profiles, which illuminate different and/or potentially overlapping regions of the body along the length thereof.

2. The light device according to claim 1, wherein the optics are designed to direct light emitted by the at least one light source within a main beam angle to directly and preferably as evenly as possible impinge on the diffusion, scattering or phosphoric layer at a distance from the end cap.

3. The light device according to claim 2, wherein the distance from the end cap, where the first light within the main beam angle emitted by the at least one light source impinges on the diffusion, scattering or phosphoric layer, is more than one centimetre, preferably more than two centimetres and even more preferably in a range between 2,5 and 5 centimetres, and most preferably in case of for instance an elongate tubular body comparable in length with a fluorescent lamp approximately 3 centimetres.

4. The light device according to any of the preceding claims, wherein the at least one light source comprise at least one LED light source.

5. The light device according to any of the preceding claims, comprising four to six and preferably at least five light sources.

6. The light device according to any on the preceding claims, wherein the optics are designed to generate at least one of the plurality of augmenting, complementary and potentially overlapping illumination intensity profiles with an intensity decrease at the centre line of the elongate body, preferably at least an illumination intensity profile oriented at a furthest location along the length of the elongate body.

7. The light device according to any on the preceding claims, wherein the optics are designed to generate at least one batwing or heart shaped illumination intensity profile , wherein preferably at least an illumination intensity profile oriented at a furthest location along the length of the elongate body is batwing or heart shaped.

8. The light device according to any of the preceding claims, wherein the optics are arranged immediately on or against the at least one light source, such as primary optics of LED light sources.

9. The light device according to any of the preceding claims, wherein the layer comprises phosphor.

10. The light device according to claim 9, wherein the phosphor comprises at least one of the materials from the group, comprising: $Lu_3Al_5O_{12}$:Ce(1%); $Lu_3Al_5O_{12}$:Ce(1%) + CaS:Eu(SiO_2); and $Lu_3Al_5O_{12}$:Ce(1%) + $Sr_2Si_5N_8$:Eu, and is designed to be preferably arranged in or on the elongate and preferably tubular body using an upflush process.

11. The light device according to any of the preceding claims, wherein the light sources in operation emit blue light, UV light or near UV light, preferably from any of the wavelength ranges of between 450 and 475 nm, and between 380 and 420 nm.

12. The light device according to any of the preceding claims, wherein the end cap comprises a ceramic material as a heat conductive and electrically isolating material.

13. The light device according to any of the preceding claims, wherein the end cap comprises a heat conductive and electrically isolating plastic material.

14. The light device according to any of the preceding claims, further comprising a multiplexer connected to the light sources for driving thereof.

15. The light device according to any of the preceding claims, wherein the diffusion, scattering or phosphoric layer of the elongate and preferably tubular body is arranged in the body using an upflush process.

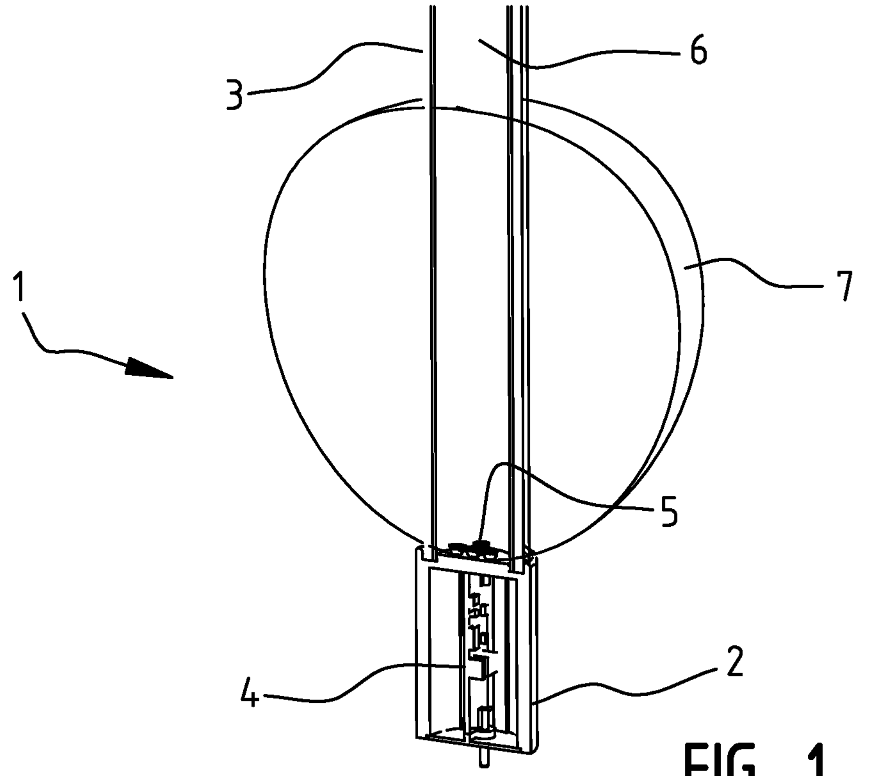

FIG. 1

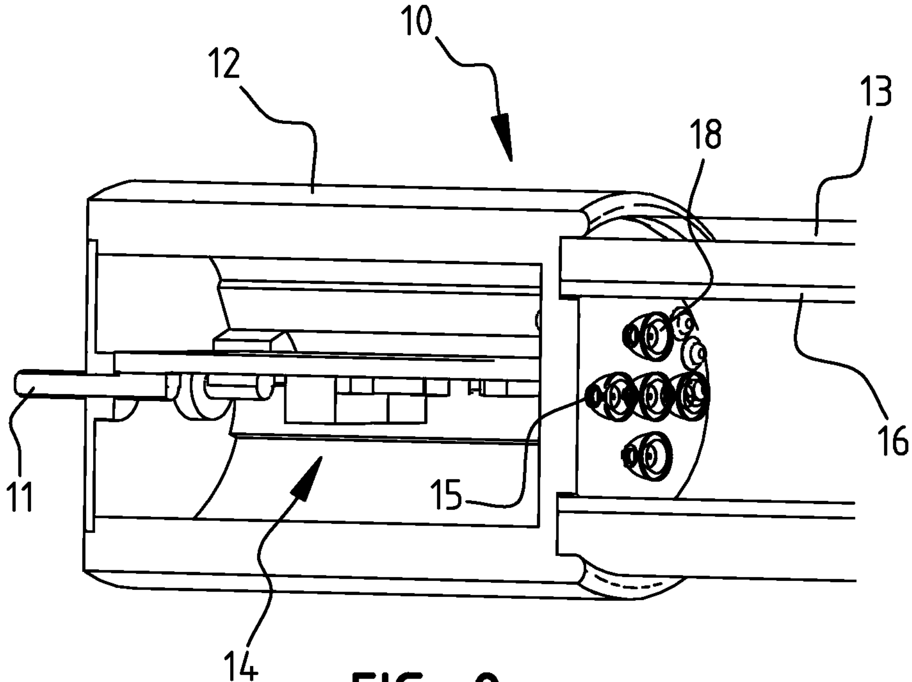

FIG. 2

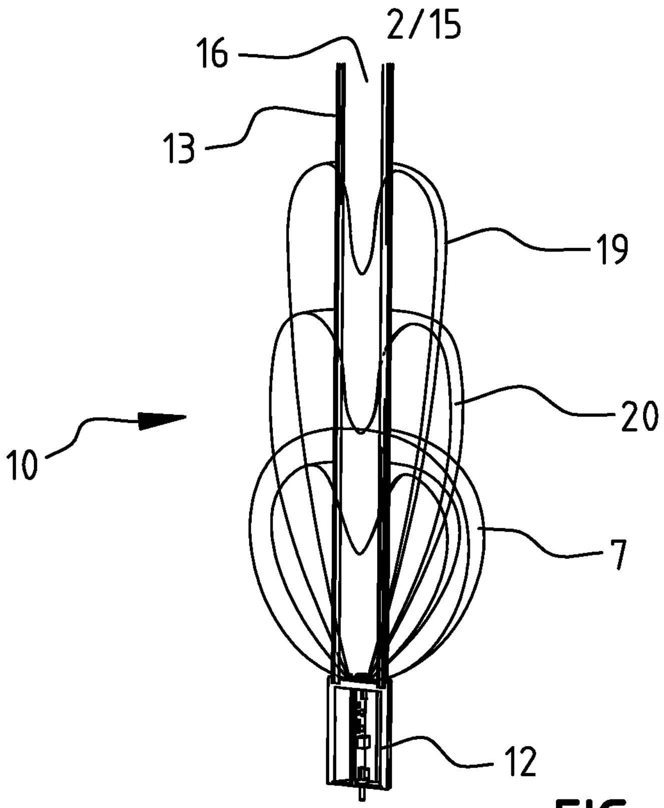

FIG. 3

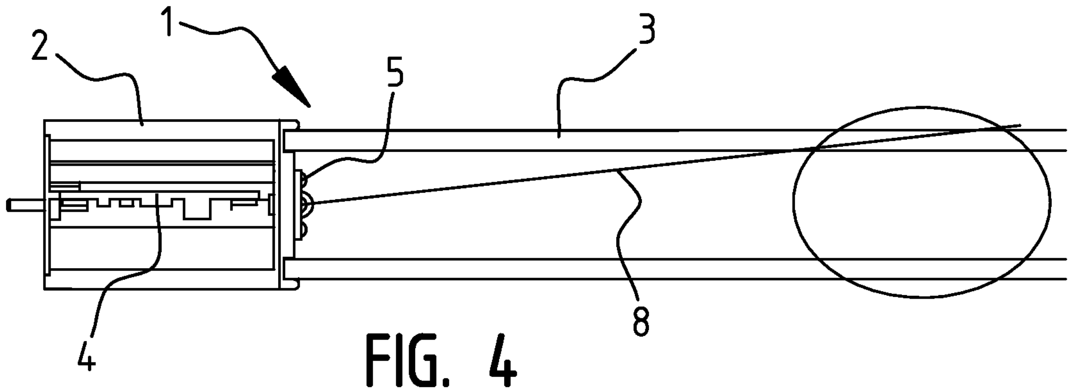

FIG. 4

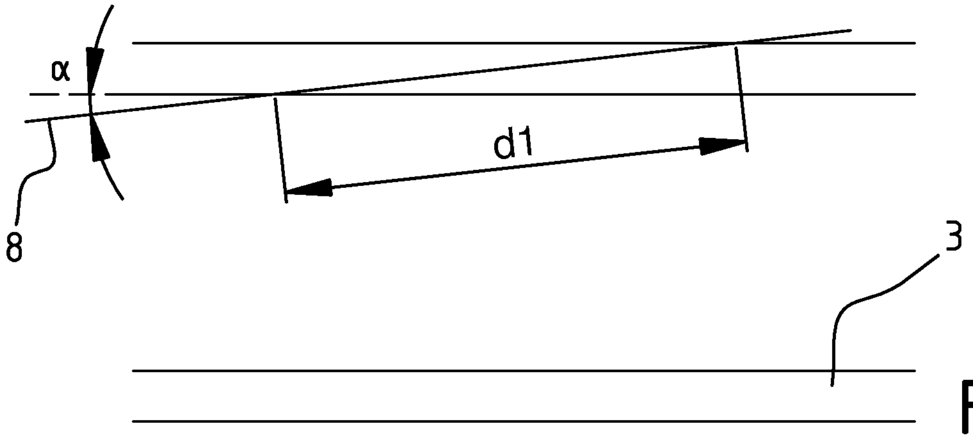

FIG. 5

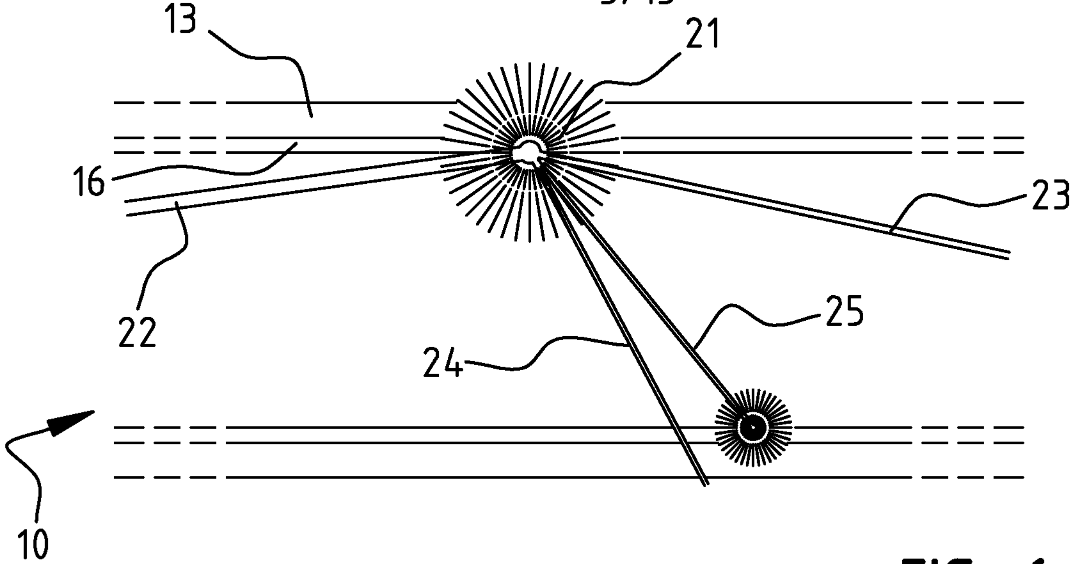

FIG. 6

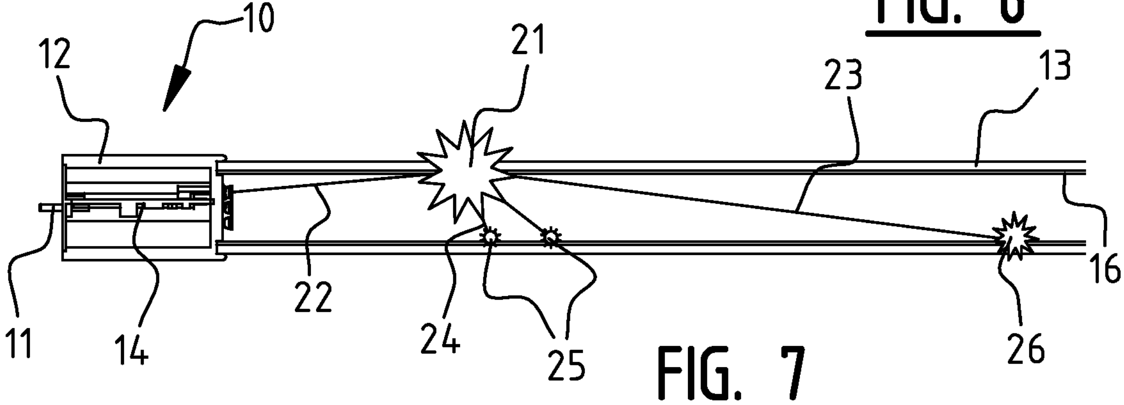

FIG. 7

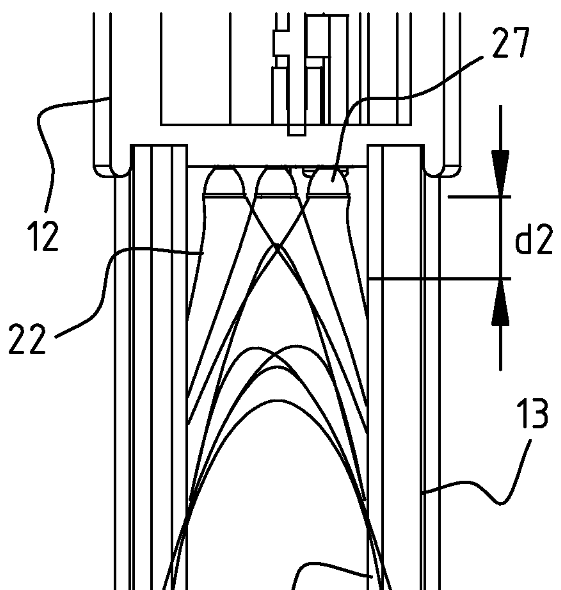

FIG. 8

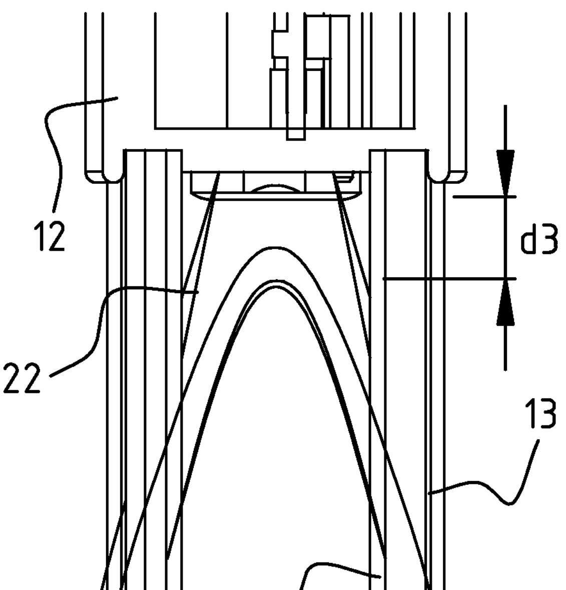

FIG. 9

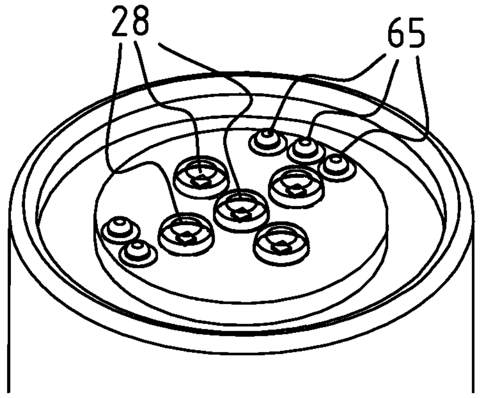

FIG. 10

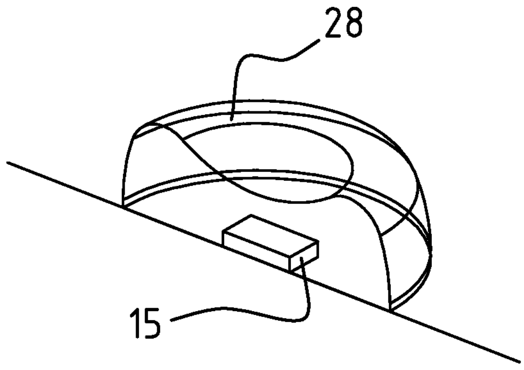

FIG. 11

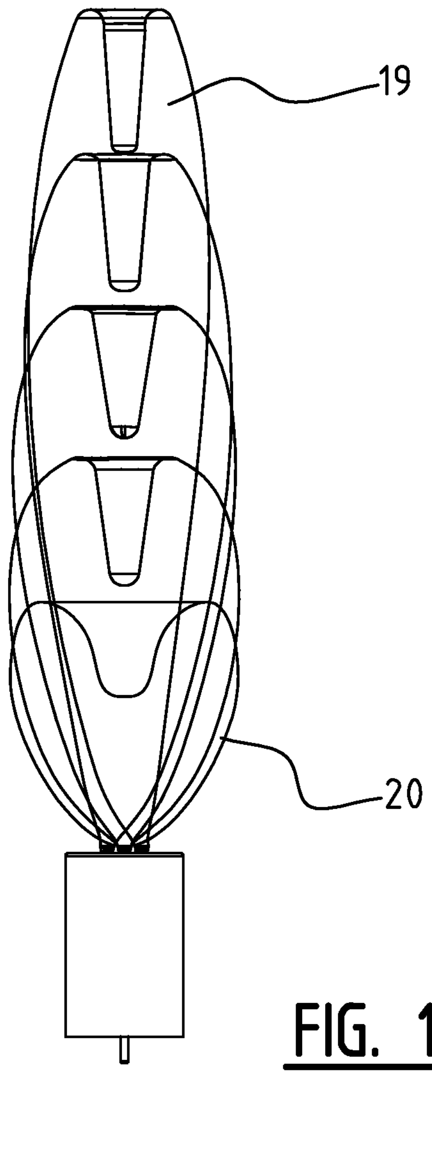

FIG. 12

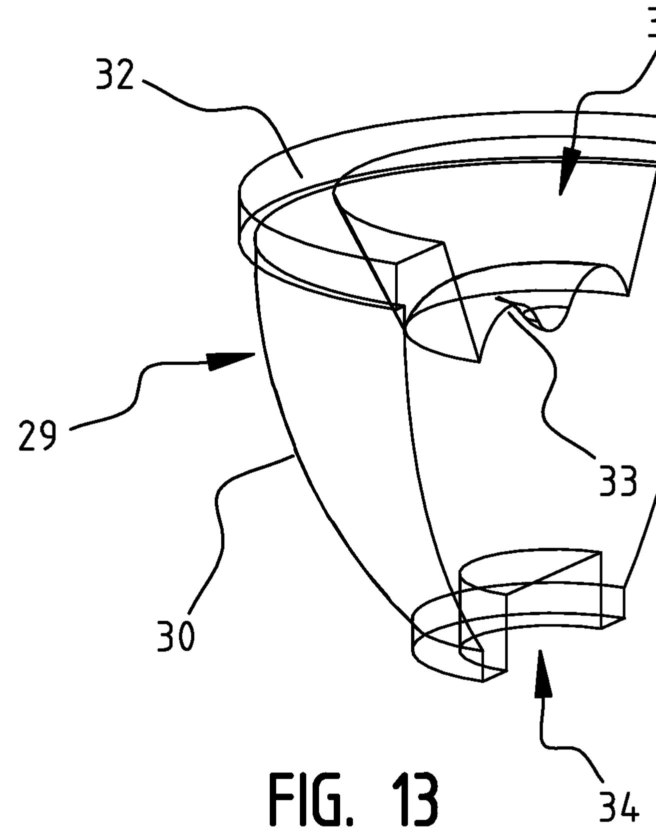

FIG. 13

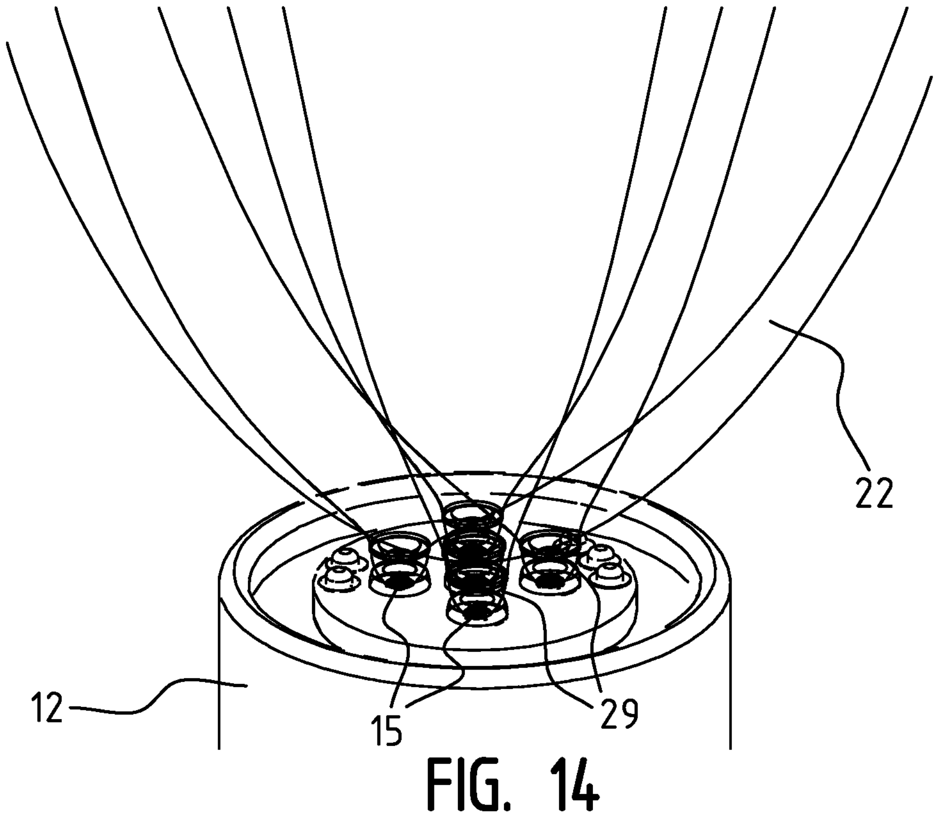

FIG. 14

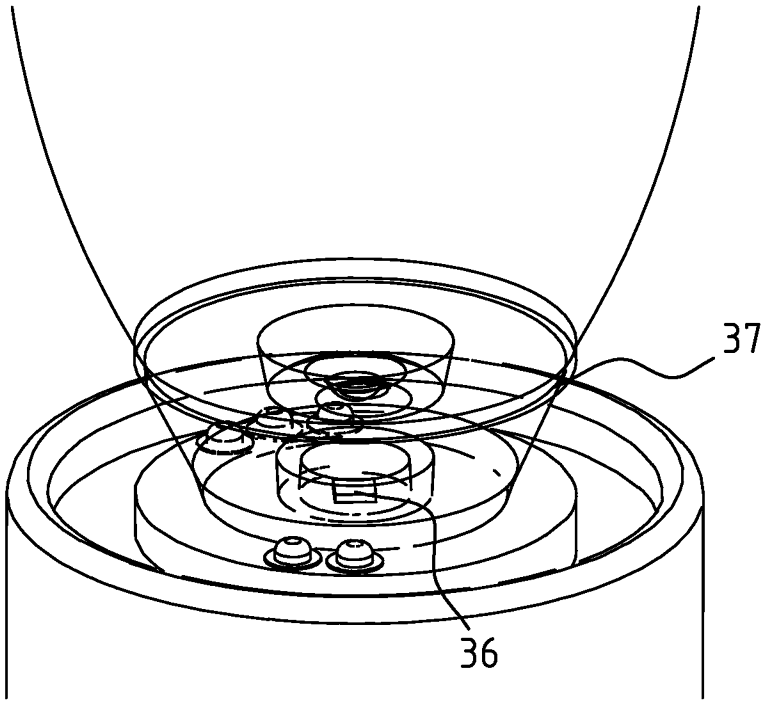

FIG. 15

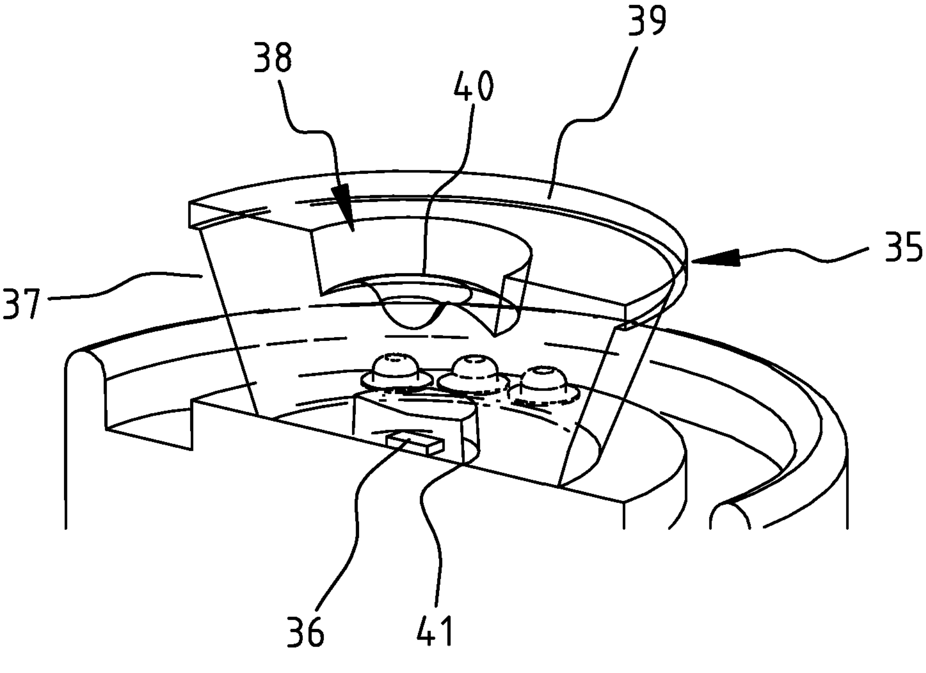

FIG. 16

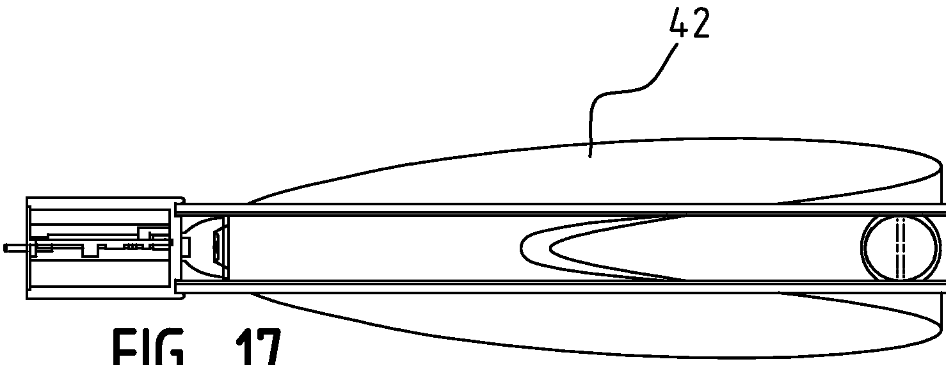

FIG. 17

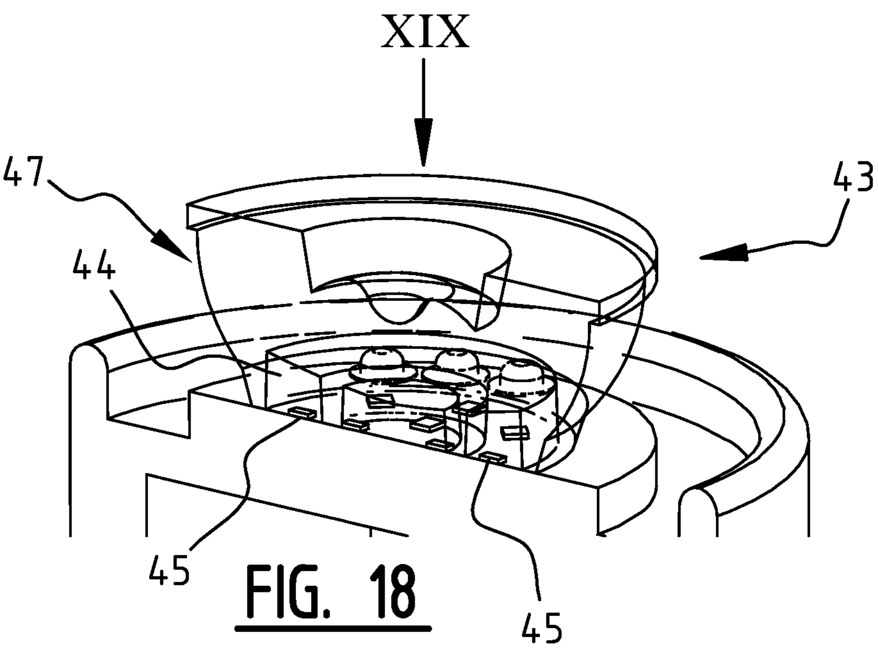

FIG. 18

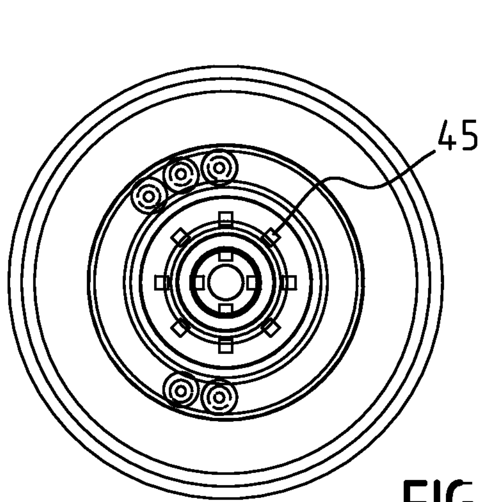

FIG. 19

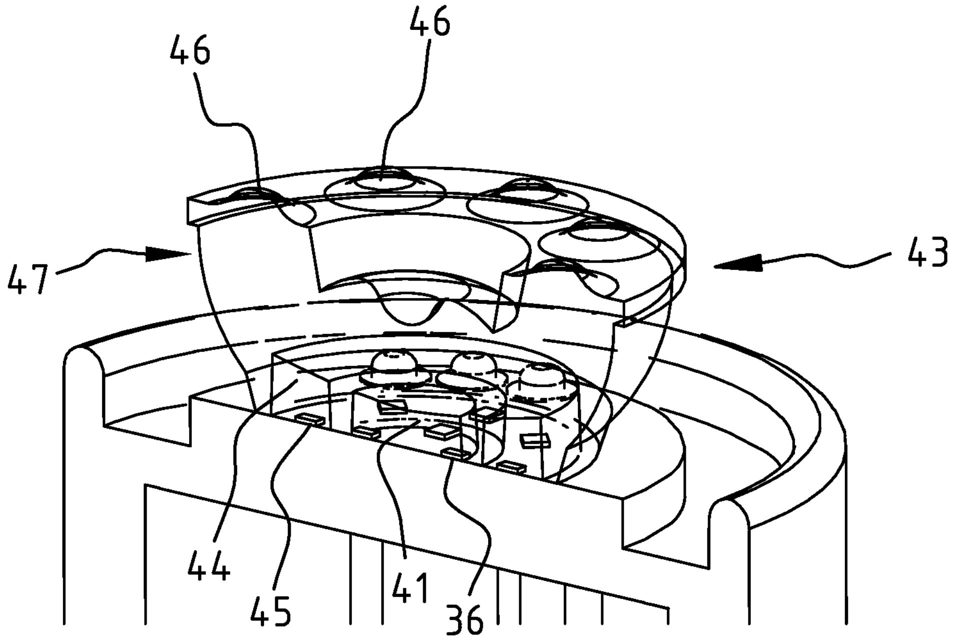

FIG. 20

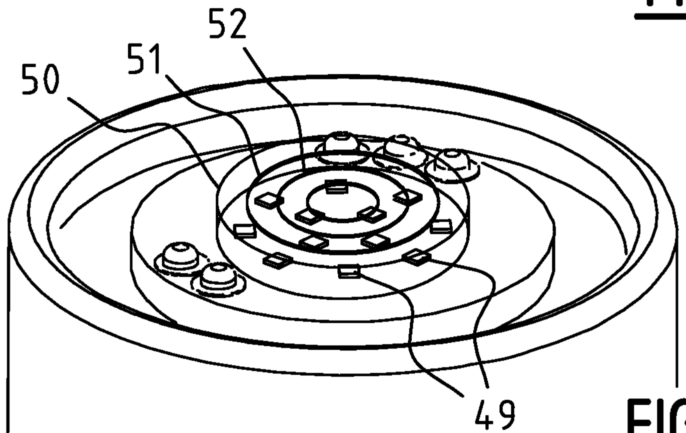

FIG. 21

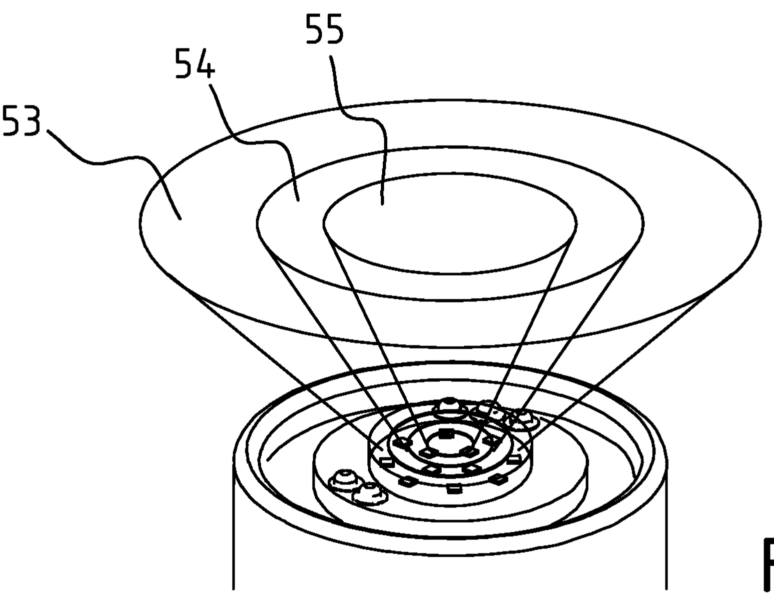

FIG. 22

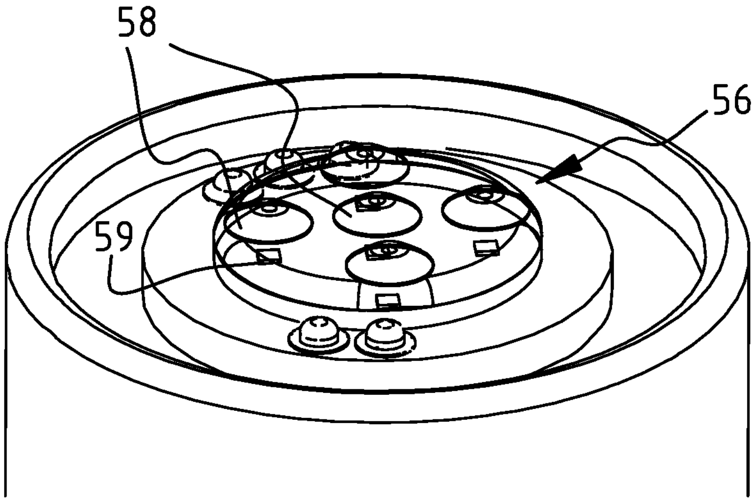

FIG. 23

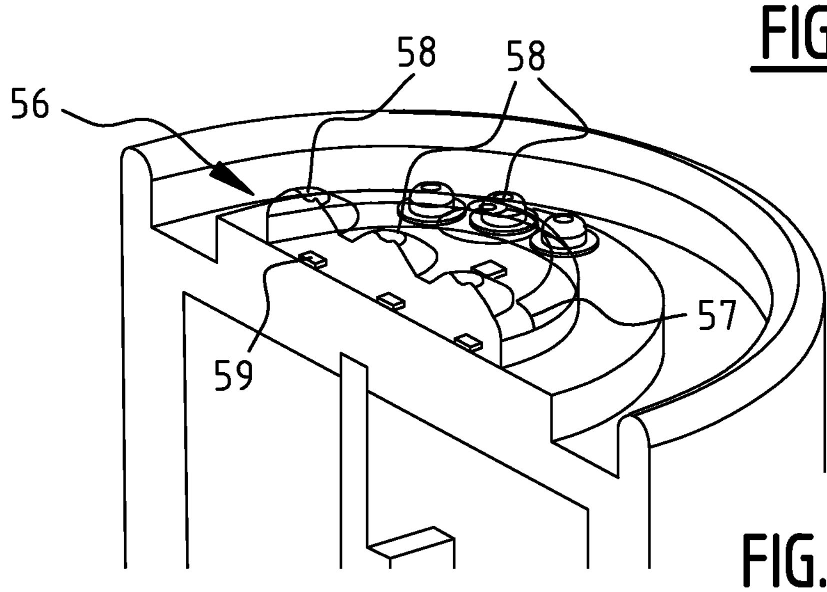

FIG. 24

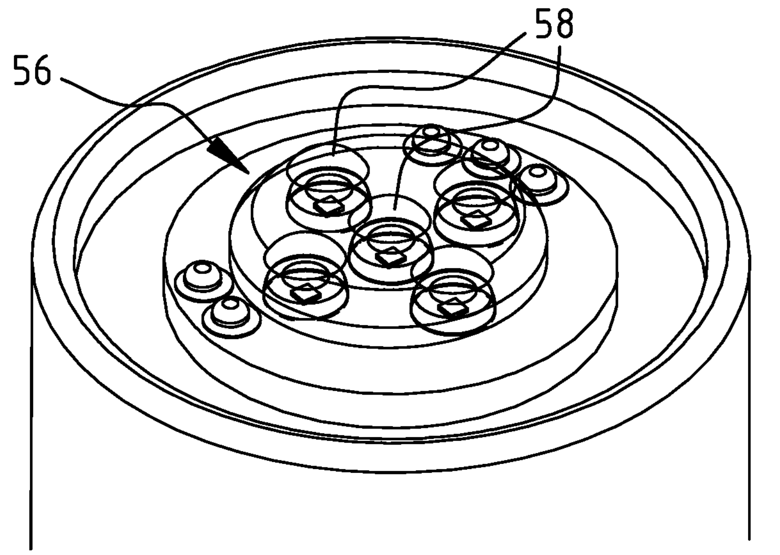

FIG. 25

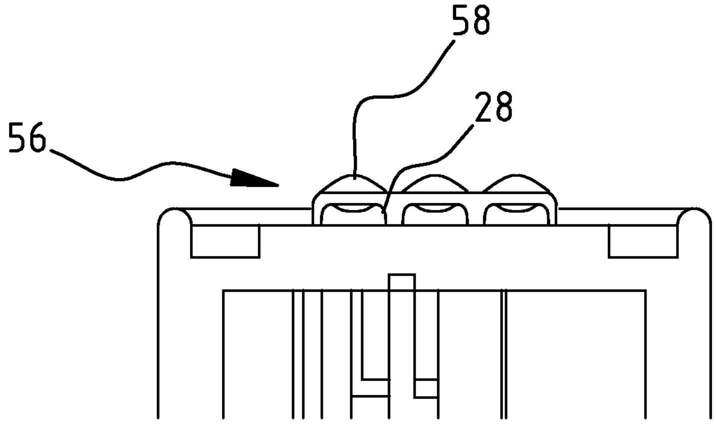

FIG. 26

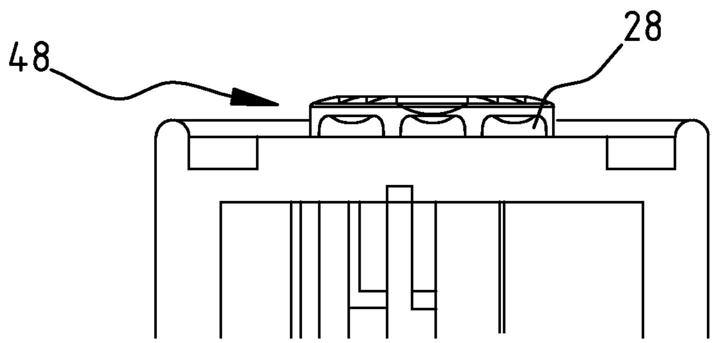

FIG. 27

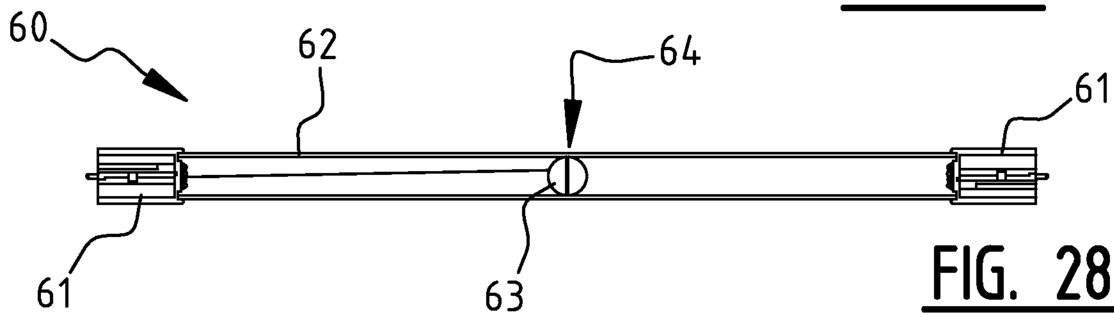

FIG. 28

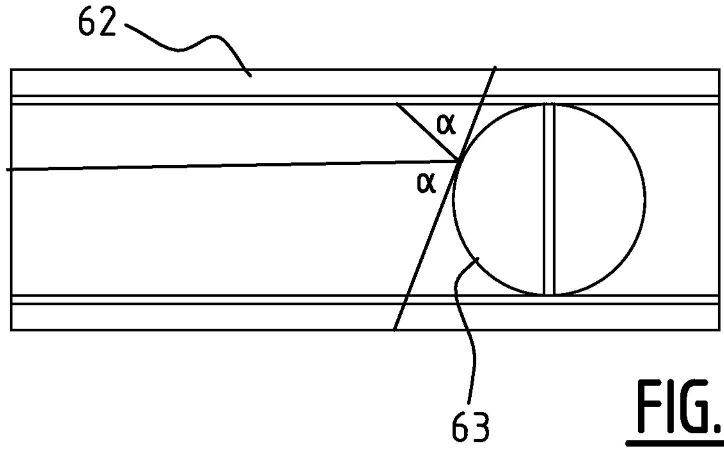

FIG. 29

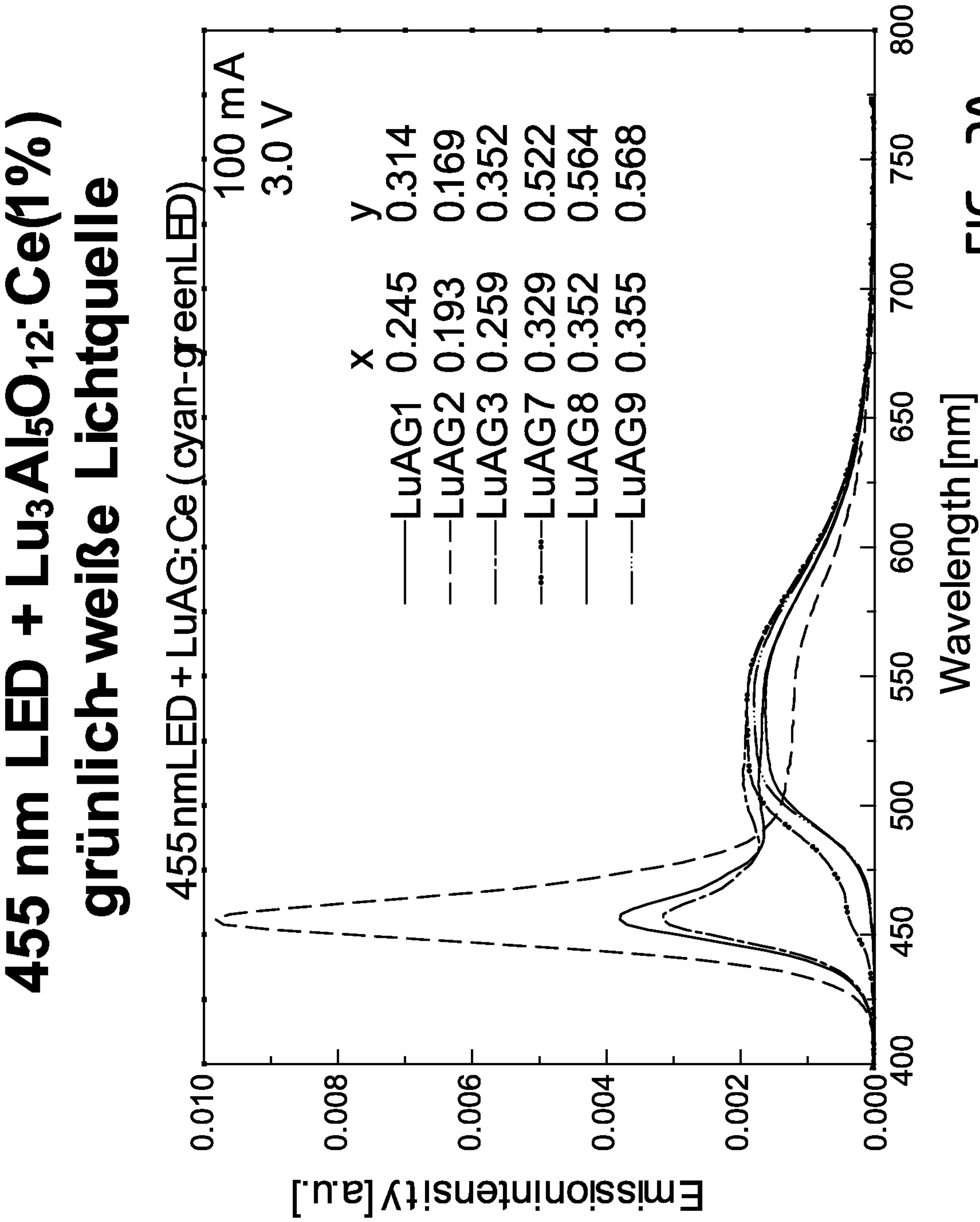
455 nm LED + Lu3Al5O12: Ce(1%)
grünlich-weiße Lichtquelle
455nmLED+LuAG:Ce (cyan-greenLED)
100 mA
3.0 V
x y
LuAG1 0.245 0.314
LuAG2 0.193 0.169
LuAG3 0.259 0.352
LuAG7 0.329 0.522
LuAG8 0.352 0.564
LuAG9 0.355 0.568
Emissionintensity [a.u.]
0.010
0.008
0.006
0.004
0.002
0.000
400
450
500
550
600
650
700
750
800
Wavelength [nm]

FIG. 30

455 nm LED + $Lu_3Al_5O_{12}$:Ce(1%) + CaS:Eu(SiO_2)
weiße Lichtquelle

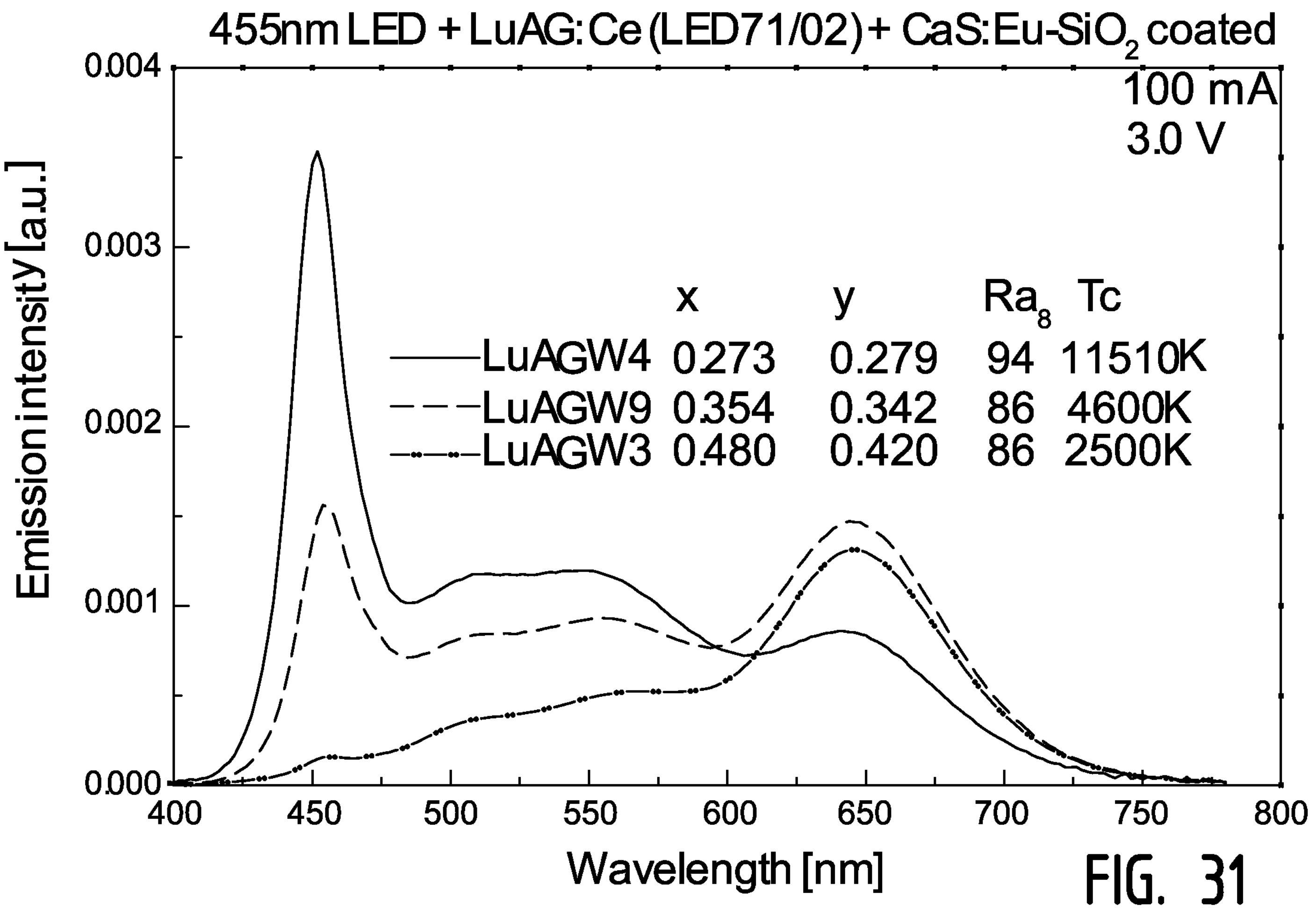

FIG. 31

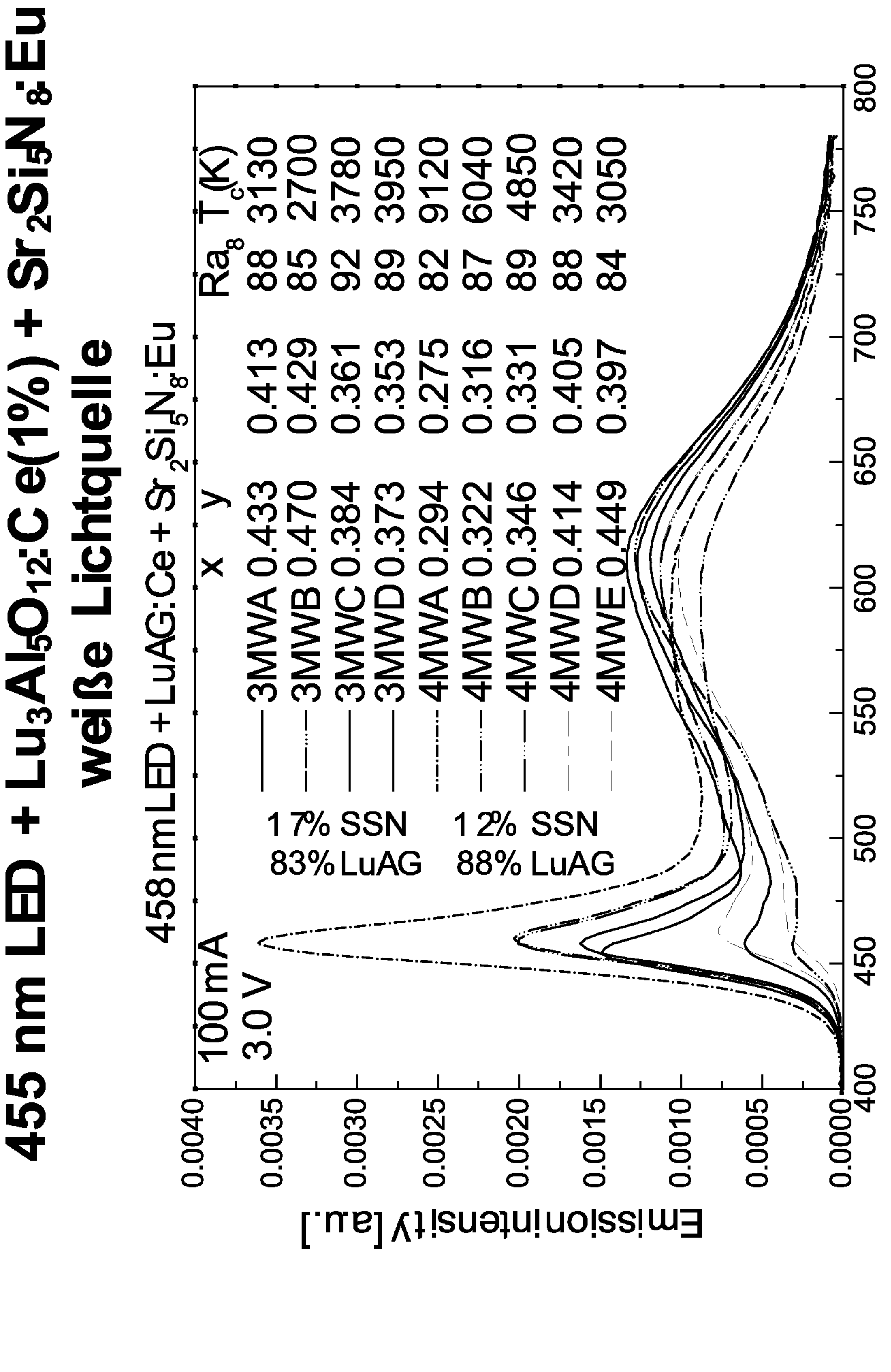
455 nm LED + Lu3Al5O12:Ce(1%) + Sr2Si5N8:Eu
weiße Lichtquelle
100 mA
3.0 V
458 nm LED + LuAG:Ce + Sr2Si5N8:Eu
x y Ra8 Tc(K)
3MWWA 0.433 0.413 88 3130
3MWWB 0.470 0.429 85 2700
3MWWC 0.384 0.361 92 3780
3MWWD 0.373 0.353 89 3950
4MWWA 0.294 0.275 82 9120
4MWWB 0.322 0.316 87 6040
4MWWC 0.346 0.331 89 4850
4MWWD 0.414 0.405 88 3420
4MWWE 0.449 0.397 84 3050
17% SSN
83% LuAG
12% SSN
88% LuAG
Emissionintensity [a.u.]
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
400
450
500
550
600
650
700
750
800
Wavelength [nm]

FIG. 32

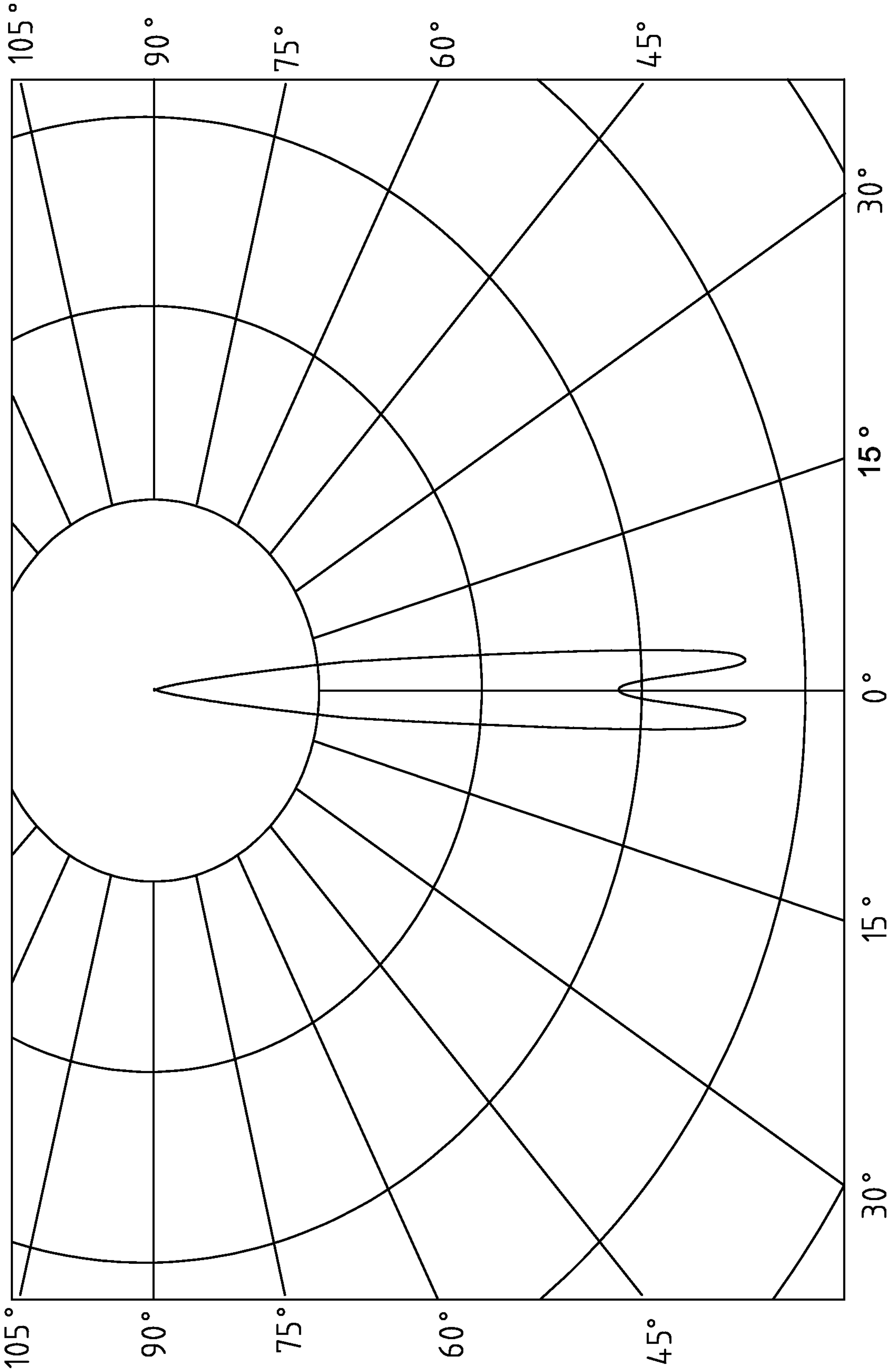

FIG. 33

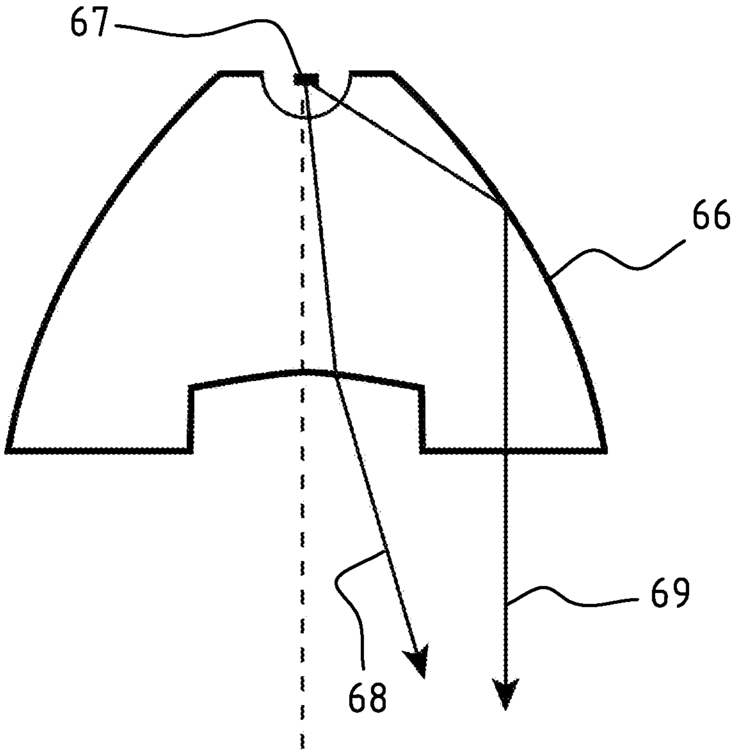
67
66
69
68

FIG. 34

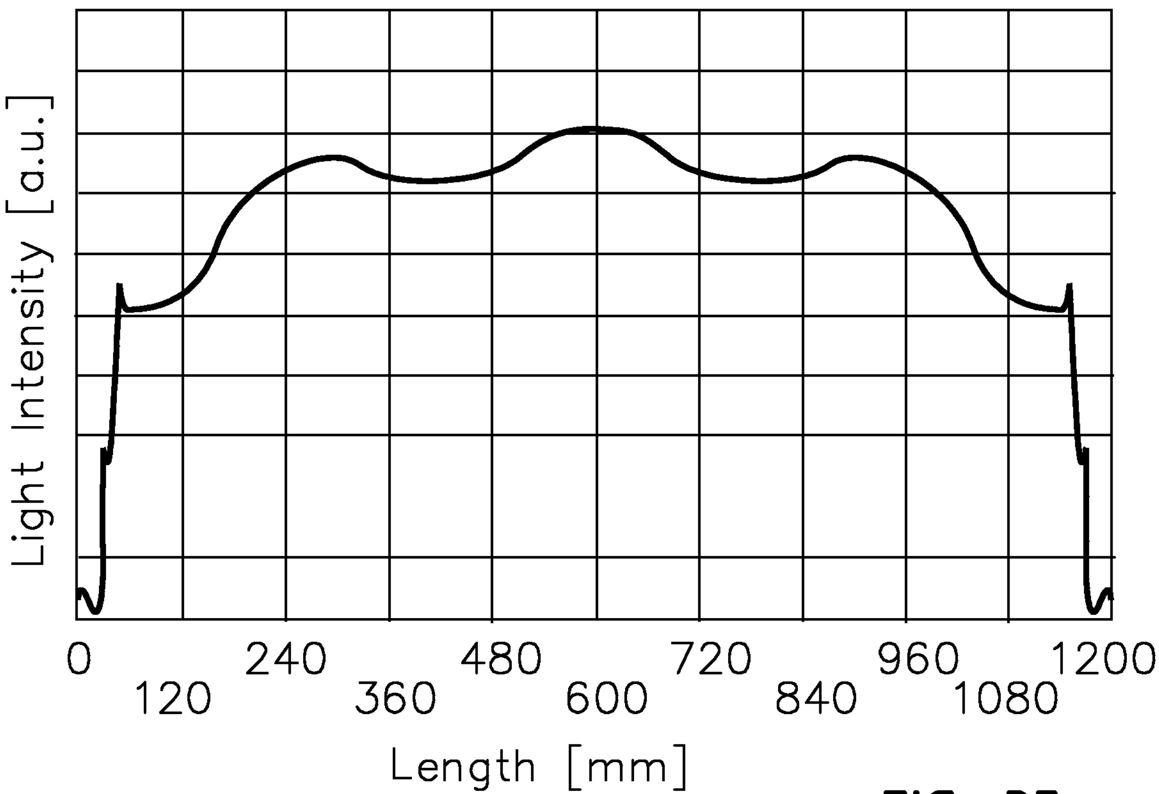
Light Intensity [a.u.]
0
120
240
360
480
600
720
840
960
1080
1200
Length [mm]

FIG. 35

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2015/050147

A. CLASSIFICATION OF SUBJECT MATTER
INV. F21K99/00 F21V3/04 F21V5/00 F21V5/04
ADD. F21Y101/02

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)
F21V F21K F21S G02B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 2010/213835 A1 (MO ANTHONY [US] ET AL) 26 August 2010 (2010-08-26) paragraphs [0042], [0043], [0044], [0050], [0054], [0055], [0056] figures 1,2a,2b,7,8 -----	1-15
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
18 May 2015	27/05/2015

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

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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