(54) Title: LED WITH IMPROVE LIGHT EMITTANCE PROFILE

(57) Abstract: The present invention relates to a LED comprising at least one red light emitting and/or conversion layer, which emits light in the wavelength of > 550 nm or < 750 nm, preferably > 630 nm or < 700 nm, and/or at least one blue light emitting layer, which emits light in the wavelength of > 400 nm or < 550 nm, preferably > 420 nm or < 500 nm, and/or at least one green and/or yellow emitting luminescence material, which emits light in the wavelength > 530 nm to < 510 nm, whereby the at least one green and/or yellow emitting luminescence material is capable of absorbing light which is emitted by the at least one blue light emitting layer, characterized in that the red light emitting and/or conversion layer is made of a semiconductor material.
LED with improved light emittance profile

This invention relates to the field of LED's. A LED is a semiconductor device that can produce an emission in a brilliant color highly efficient in spite of its very small size. Furthermore the emission produced by an LED has an excellent monochromatic peak. However, it is still a problem to produce white light by LED's. In order to obtain white light by LEDs, various techniques have been discussed. Usually, in order to produce white light by diffusing and combining the emissions of multiple LEDs, a color mixing process is needed. For example, three LEDs, each producing an emission at a wavelength in the red, green or blue range of the visible spectrum (which will be herein called red, green and blue LEDs, respectively), can be placed closely to each other. However, each of these LEDs has an excellent monochromatic peak. Accordingly, the white light produced by mixing these colors with each other is often uneven. i.e. that the color point of the white light does not fall on the black body line or the white light does not represent a spectral distribution that can is equivalent to black body radiation.

That is to say, where the emissions in the three primary colors cannot be combined together in a desired manner, the resultant white light will be uneven. To eliminate this problem of color unevenness, a technique of producing white light by using a blue LED and a yellow emitting phosphor in combination was developed e.g. as disclosed in the EP1160883 and prior art cited therein

However, all the LED’s as presented in the prior art were unable to produce a white light which is even. Therefore there is an object of the present invention to provide for a LED which has an improved white light performance.

This object is achieved by a LED as taught by Claim 1 of the present invention. Accordingly, a LED is provided, comprising at least one red light emitting and/or conversion layer, which emits light in the wavelength of ≥ 550 nm to ≤ 750 nm, preferably ≥ 630 nm to ≤ 700 nm, and/or at least one blue light emitting layer, which emits light in the wavelength of ≥ 400 nm to ≤ 550 nm, preferably ≥ 420 nm to ≤ 500 nm, and/or at least one green and/or yellow emitting luminescence material, which emits light in the wavelength of ≥ 530 nm to ≤ 610 nm, whereby the at least one red and/or yellow emitting luminescence material is capable of absorbing light which is
emitted by the at least one blue light emitting layer, characterized in that the red light emitting and/or conversion layer is made of a semiconductor material.

Preferably the at least one red light emitting and/or conversion layer emits light in the wavelength of \( \geq 630 \text{ nm} \) to \( \leq 700 \text{ nm} \), preferably the at least one blue light emitting layer emits light in the wavelength of \( \geq 420 \text{ nm} \) to \( \leq 500 \text{ nm} \), preferably the at least one green and/or yellow emitting luminescence material emits light in the wavelength of \( \geq 540\text{nm} \) to \( \leq 600\text{nm} \), most preferred of \( \geq 545 \text{ to } \leq 595\text{nm} \).

The inventors have studied the problem of "unevenness" and found out that it is advantageous to use a semiconductor material as red light emitting and/or conversion layer. By doing so, especially the quality of the emitted light in the "red range" of the LED is improved.

The term "semiconductor material" according to the present invention means in particular that the material can be deposited as a film structure, and/or has a bandgap according to the above specified range of emission or larger; and/or has high photoluminescence quantum efficiency, i.e. over \( \geq 50\% \) and \( \leq 100\% \), more preferably \( \geq 60\% \), most preferred \( \geq 70\% \).

The material can consist of multiple atoms as well encompass doped materials, where the emission is not restricted to band to band transition, including embedded nanostructures or color centres.

According to a preferred embodiment of the present invention, the at least one red light emitting and/or conversion layer is capable of absorbing light which is emitted by the at least one blue light emitting layer. By doing so, a better spectrum of the LED may be obtained.

According to a preferred embodiment of the present invention, the red light emitting and/or conversion layer is selected from a group comprising \( \text{Al}_x\text{In}_y\text{Ga}_z\text{P} \) \((x+y+z=1), \text{Al}_x\text{Ga}_{1-x}\text{P} \) \((x \geq 0 \text{ and } \leq 1), \text{Al}_x\text{Ga}_{1-x}\text{As}_y\text{P}_{1-y} \) \((x \geq 0 \text{ and } \leq 1; \ y \geq 0 \text{ and } \leq 1), \text{Al}_x\text{Ga}_{1-x}\text{In}_{z}\text{As}_y\text{P}_{1-y} \) \((x+y+z=1; \ u \geq 0 \text{ and } \leq 1)\) or mixtures thereof; and/or the blue light emitting layer is selected from a group comprising \( \text{Al}_x\text{In}_y\text{Ga}_z\text{P} \) \((x+y+z=1), \text{Al}_x\text{Ga}_{1-x}\text{P} \) \((x \geq 0 \text{ and } \leq 1), \text{Al}_x\text{Ga}_{1-x}\text{As}_y\text{P}_{1-y} \) \((x \geq 0 \text{ and } \leq 1; \ y \geq 0 \text{ and } \leq 1), \text{Al}_x\text{Ga}_{1-x}\text{In}_{z}\text{As}_y\text{P}_{1-y} \) \((x+y+z=1; \ u \geq 0 \text{ and } \leq 1)\) or mixtures thereof; and/or the green and/or yellow light emitting luminescence material is selected from a group comprising \( \text{Ba}_x\text{Sr}_{1-x}\text{Ga}_2\text{S}_4;\text{Eu} \) \((x \geq 0 \text{ and } \leq 1), \text{Ba}_x\text{Sr}_{1-x}\text{SiO}_4;\text{Eu} \) \((x \geq 0 \text{ and } \leq 1), \text{SrSi}_2\text{N}_2\text{O}_2;\text{Eu} \) \((x \geq 0 \text{ and } \leq 1), (Y_x\text{Gd}_1-$$}
\((x)\)\((Al_{1-x}Ga_y)_{3}O_{12}:Ce (x \geq 0 \text{ and } \leq 1; y \geq 0 \text{ and } \leq 1), (Y_{x}Gd_{1-x})_{3}(Al_{1-x}Ga_y)_{3}O_{12}:Ce:Ce,Pr (x \geq 0 \text{ and } \leq 1; y \geq 0 \text{ and } \leq 1)\) or mixtures thereof.

In case doped compounds are used for or within the red light emitting and/or conversion layer, the blue light emitting and/or conversion layer and/or the green and/or yellow light emitting luminescent material, the preferred doping level is between \(\geq 0.1\) and \(\leq 20\) \%, more preferred between \(\geq 0.5\) and \(\leq 5\) \%.

According to a preferred embodiment of the present invention, the LED has in the colour temperature range of \(\geq 2000\) to \(\leq 6000\), preferably \(\geq 2500\) to \(\leq 5000\) K a color rendering Ra of \(\geq 80\), preferably \(\geq 85\), more preferably \(\geq 90\) and most preferred \(\geq 95\) and \(\leq 100\).

By doing so, a LED with a far more better white light emittance behaviour than from known LEDs out of the prior art can be obtained.

According to a preferred embodiment of the present invention, the LED has a light efficacy of \(\geq 10\) lumen/W and \(\leq 200\) lumen/W, preferably \(\geq 20\) lumen/W and \(\leq 150\) lumen/W and most preferred \(\geq 30\) lumen/W and \(\leq 120\) lumen/W.

According to a preferred embodiment of the present invention, the light emission spectrum of the LED comprises a light emittance band in the wavelength range of \(\geq 400\) nm to \(\leq 550\) nm, preferably \(\geq 420\) nm to \(\leq 500\) nm with a maximum emission intensity of \(\geq 2\) W optical to \(\leq 30\) W optical, more preferably \(\geq 5\) W optical to \(\leq 30\)

W optical, and most preferred \(\geq 15\) W optical to \(\leq 30\) W optical, and a full width at half maximum of \(\geq 15\) and \(\leq 100\) nm, more preferred \(\geq 15\) and \(\leq 50\) nm, yet more preferred \(\geq 15\) and \(\leq 35\) nm and most preferred of \(\geq 15\) and \(\leq 20\) nm.

According to a preferred embodiment of the present invention, the light emission spectrum of the LED comprises an emission band in the wavelength range of \(\geq 550\) nm to \(\leq 750\) nm, preferably \(\geq 600\) nm to \(\leq 650\) nm with a maximum emission intensity of \(\geq 2\) W optical to \(\leq 30\) W optical, more preferably \(\geq 5\) W optical to \(\leq 30\) W optical, and most preferred \(\geq 15\) W optical to \(\leq 30\) W optical, and a full width at half maximum of \(\geq 15\) and \(\leq 100\) nm, more preferred \(\geq 15\) and \(\leq 50\) nm, yet more preferred \(\geq 15\) and \(\leq 35\) nm and most preferred of \(\geq 15\) and \(\leq 20\) nm.

According to a preferred embodiment of the present invention, the LED comprises at least one red light emitting and/or conversion layer, which emits light in the wavelength of \(\geq 550\) nm to \(\leq 750\) nm, preferably \(\geq 630\) nm to \(\leq 700\) nm, and/or at
least one blue light emitting layer, which emits light in the wavelength of \( \geq 400 \, \text{nm} \) to \( \leq 550 \, \text{nm} \), preferably \( \geq 420 \, \text{nm} \) to \( \leq 500 \, \text{nm} \), and/or at least one green and/or yellow emitting luminescence material.

According to a preferred embodiment of the present invention, the LED comprises a LED chip with a substrate, whereby the substrate is coated and/or covered with at least one red light emitting and/or conversion layer on one first surface and with at least one blue light emitting layer on the surface which is opposite the first surface. "coated and/or covered" in the sense of the present invention means in particular that on the substrate several layers may be located, one or more of which being the light emitting and/or conversion layer, whilst several other layers may serve for other purposes.

According to a preferred embodiment of the present invention, the LED chip is surrounded by and/or partly or completely covered with the at least one green and/or yellow emitting luminescent material. "Surrounded and/or partly covered" means in particular that

- The LED chip is surrounded by and/or partly covered with a covering material, which comprises the at least one green and/or yellow emitting luminescent material. This covering material can be a polymer and/or a ceramic material. In case a polymer is used, preferably the polymer comprises a material chosen from the group comprising silicone polymers, PMMA, PS, PTFE, PC or mixtures thereof.
- The at least one green and/or yellow emitting luminescent material is brought up on the LED chip, e.g. as a layer or a cover, which surrounds the LED chip totally or partly. This can be done in various ways. Preferably the at least one green and/or yellow emitting luminescent material is brought up by electrophoresis and/or sedimentation.

According to a preferred embodiment of the present invention, the LED comprises a LED chip with at least one red and at least one blue light emitting layer, a polymer coating located around the silicon chip and a mirror, whereby the polymer comprises at least one green and/or yellow emitting luminescent material and the mirror reflects light emitted from the LED chip.
According to a preferred embodiment of the present invention, the polymer coating comprises a material chosen from the group comprising silicone polymers, PMMA, PS, PTFE, PC or mixtures thereof.

According to a preferred embodiment of the present invention, the concentration of the luminescent material inside the polymer coating is $\geq 0.1 \text{ wt\%}$ to $\leq 50 \text{ wt\%}$, preferably $\geq 1 \text{ wt\%}$ to $\leq 20 \text{ wt\%}$.

According to a preferred embodiment of the present invention, $\geq 90 \text{ %}$ to $\leq 100 \text{ %}$, preferably $\geq 95 \text{ %}$ nm to $\leq 100 \text{ %}$ of the photons emitted by the red light emitting and/or conversion layer leave the LED unabsorbed.

A LED according to the present invention can be used in a variety of systems amongst them systems being used in or as one or more of the following applications: household applications, shop lighting, home lighting, accent lighting, spot lighting, theater lighting, museum lighting, fiber-optics applications, projection systems, self-lit displays, pixelated displays, segmented displays, warning signs, medical lighting applications, indicator signs, and decorative lighting, office lighting, illumination of workplaces, automotive front lighting, and automotive interior lighting.

Furthermore, a method of preparing a LED according to the present invention is proposed, comprising the steps of: a) providing a LED chip which has a substrate, b) coating and/or covering a first surface of the substrate with at least one red light emitting and/or conversion layer; c) coating and/or covering the surface of the substrate which is opposite to the first surface with at least one blue emitting layer, whereby the steps b) and c) may also be conducted in reverse order, d) partly or totally covering and/or surrounding the LED chip with the at least one green and/or yellow emitting luminescent material, e) providing the LED chip and the polymer material in a mirror cup in such a way that the red light emitting and/or conversion layer of the LED chip is projected towards one of the mirrors of the mirror cup. It should be noted that in particular the steps b) and c) may be achieved in various ways:

One way to combine the LED chip with the conversion layer is by direct deposition of the conversion material on the substrate of the LED chip.

Another way is to remove the original substrate and replace it either with a different substrate and deposit the conversion layer on the replacement substrate or to
directly mount the LED chip on the conversion layer, which might be on a support or not.

It is also envisioned, that the conversion layer itself is built or mounted in a way, that it could mechanically support the LED epitaxial (active) layer, which is in this embodiment the at least one blue emitting layer. The technologies to mount the LED active (epitaxial) layer and the conversion layer and a potential additional support layer include, van-der-Wals bonding, thermal fusing, organic or inorganic adhesion materials, wafer fusion using metals or other inorganic or organic materials, ultrasonic fusion or optically induced adhesion techniques, e.g. UV catalyzed fusion.

The aforementioned components, as well as the claimed components and the components to be used in accordance with the invention in the described embodiments, are not subject to any special exceptions with respect to their size, shape, material selection and technical concept such that the selection criteria known in the pertinent field can be applied without limitations.

Additional details, characteristics and advantages of the object of the invention are disclosed in the subclaims and the following description of the respective figures—which in an exemplary fashion—show several preferred embodiments of the LED according to the invention.

Fig. 1 shows a LED chip of a LED according to a first and second embodiment of the present invention, and

Fig. 2 shows a LED arrangement with the chip of Fig. 1.

Fig. 3: Light emission spectrum of the LED according to the first embodiment of the present invention

Fig. 4: Light emission spectrum of the LED according to the first embodiment of the present invention

As can be seen from Fig. 1, the LED chip comprises a substrate 10 a blue light emitting layer 20 and a red light emitting and/or conversion layer 30. In the present embodiment, the substrate consists essentially out of a Al₂O₃ sapphire substrate, which is essentially transparent. This allows photons emitted out of the blue light emitting layer 20 to enter the red light emitting and/or conversion
layer 30, where they are converted to red light. However, also emitting layers, which emit red light "from themselves" may be used within the present invention.

Fig. 2 shows a LED arrangement with the chip of Fig. 1. As can be seen from Fig. 2, the LED comprises a polymer coating 40 around the LED chip for protection. In the present embodiment, this polymer coating consists essentially out of a silicone polymer, however, other materials such as PMMA, PS, PTFE, and/or PC or mixtures of these materials with or without silicone polymer may also be used within the present invention. The LED furthermore comprises a mirror cup 50. The mirror cup 50 and the LED chip are so located to each other that photons, which leave the LED chip towards the mirror cup 50 are reflected. In the present embodiment, the photons emitted out of the red light emitting and/or conversion layer 20 are reflected. Since the photons out of this layer have the least energy, they are not absorbed by any materials inside the LED, so that >90 % of the photons are able to leave the LED unabsorbed, as described above.

The polymer coating 40 furthermore comprises a green and/or yellow light emitting luminescence material. This material absorbs photons emitted from the blue light emitting layer 20 and emits photons in the green and/or yellow wavelength range, i.e. between 520 and 600 nm. The concentration of the luminescence material inside the polymer coating is between 0.1 and 50%.

According to a first embodiment of the present invention, the following materials were chosen for the red light emitting and/or conversion layer, the blue light emitting layer, and the green and/or yellow emitting luminescence material: blue light emitting layer: In$_{0.2}$Ga$_{0.8}$N, red light emitting and/or conversion layer: In$_{0.45}$Ga$_{0.55}$P, green and/or yellow emitting luminescence material: Y$_3$Al$_2$O$_{12}$:Ce. This LED has a emission spectrum according to Fig. 3.

It can be clearly seen that this spectrum comprises two strong bands at 465 nm and 642 nm, which have an intensity of approx. 0.08 and 0.12 (at $T_c$ 2700 K) respectively and a full width at half maximum of $\geq$15 and $\leq$ 100 nm. These bands arise from the red and blue light-emitting layer. The emittance in the wavelength range between 500 and 600 nm arises essentially out of the green and/or yellow light emitting luminescence material.
According to a second embodiment of the present invention, the following materials were chosen for the red light emitting and/or conversion layer, the blue light emitting layer, and the green and/or yellow emitting luminescence material: blue light emitting layer: In_{0.2}Ga_{0.8}N, red light emitting and/or conversion layer: In_{0.45}Ga_{0.55}P, green and/or yellow emitting luminescence material: SrSi_{2}N_{2}O_{2}:Eu. This LED has an emission spectrum according to Fig.4.

It can be clearly seen that this spectrum comprises two strong bands at 465 nm and 642 nm, which have an intensity of approx. 0.13 (at T = 4000 K) and a full width at half maximum of ≥15 and ≤100 nm. These bands arise from the red and blue light emitting layer. The emittance in the wavelength range between 500 and 600 nm arises essentially out of the green and/or yellow light emitting luminescence material.

Measuring methods: The Ra_{8}-values were measured according to the CIE 1931 procedure (= ISO/CIE 10527-1991(E) Colorimetric observers).
CLAIMS:

1. A LED comprising :
   - at least one red light emitting and/or conversion layer, which emits
     light in the wavelength of ≥ 550 nm to ≤ 750 nm,
   - at least one blue light emitting layer, which emits light in the
     wavelength of ≥ 400 nm to ≤ 550 nm and
   - at least one green and/or yellow emitting luminescence material, which
     emits light in the wavelength ≥ 530 nm to ≤ 610 nm, whereby the at least one green
     and/or yellow emitting luminescence material is capable of absorbing light which is
     emitted by the at least one blue light emitting layer,
   10  characterized in that the red light emitting and/or conversion layer is
   made of a semiconductor material.

2. A LED according to claim 1, whereby the at least one red light emitting
   and/or conversion layer, is capable of absorbing light which is emitted by the at least
   one blue light emitting layer.

3. A LED according to claim 1 or 2, whereby
   - the red light emitting and/or conversion layer is selected from a group
     comprising \( \text{Al}_x\text{In}_y\text{Ga}_z\text{P} \) \((x+y+z=1)\), \( \text{Al}_x\text{Ga}_{1-x}\text{P} \) \((x≥ 0 \text{ and } ≤ 1)\), \( \text{Al}_x\text{Ga}_{1-x}\text{As}_y\text{P}_{1-y} \)
     \((x≥ 0 \text{ and } ≤ 1; \ y≥ 0 \text{ and } ≤ 1)\), \( \text{Al}_x\text{Ga}_y\text{In}_z\text{As}_{u}\text{P}_{1-u} \) \((x+y+z=1; \ u≥ 0 \text{ and } ≤ 1)\) or
     mixtures thereof; and/or
   - the blue light emitting layer is selected from a group comprising
     \( \text{Al}_x\text{In}_y\text{Ga}_z\text{P} \) \((x+y+z=1)\), \( \text{Al}_x\text{Ga}_{1-x}\text{P} \) \((x≥ 0 \text{ and } ≤ 1)\), \( \text{Al}_x\text{Ga}_{1-x}\text{As}_y\text{P}_{1-y} \) \((x≥ 0 \text{ and } ≤ 1; \ y≥ 0 \text{ and } ≤ 1)\), \( \text{Al}_x\text{Ga}_y\text{In}_z\text{As}_{u}\text{P}_{1-u} \) \((x+y+z=1; \ u≥ 0 \text{ and } ≤ 1)\) or mixtures thereof; and/or
the green and/or yellow light emitting luminescence material is selected
from a group comprising \( \text{Ba}_x\text{Sr}_{1-x}\text{Ga}_2\text{S}_4:\text{Eu} \) (\( x \geq 0 \) and \( \leq 1 \)), \( \text{Ba}_x\text{Sr}_{1-x}\text{SiO}_4:\text{Eu} \) (\( x \geq 0 \) and \( \leq 1 \)), \( \text{SrS}_2\text{N}_2\text{O}_2:\text{Eu} \) (\( x \geq 0 \) and \( \leq 1 \)), \( (\text{Y}_x\text{Gd}_{1-x})_3(\text{Al}_{1-y}\text{Ga}_y)_5\text{O}_{12}:\text{Ce} \) (\( x \geq 0 \) and \( \leq 1 \); \( y \geq 0 \) and \( \leq 1 \)), \( (\text{Y}_x\text{Gd}_{1-x})_3(\text{Al}_{1-y}\text{Ga}_y)_5\text{O}_{12}:\text{Ce,Pr} \) (\( x \geq 0 \) and \( \leq 1 \); \( y \geq 0 \) and \( \leq 1 \)) or mixtures thereof.

4. A LED according to any of the claims 1 to 3, which has in the colour
temperature range of \( \geq 2000 \) to \( \leq 6000 \) a color rendering \( \text{Ra}_8 \) of \( \geq 80 \) and \( \leq 100 \).

5. A LED according to any of the claims 1 to 4 with a light efficacy of \( \geq 30 \) lumen/W and \( \leq 60 \) lumen/W, preferably \( \geq 35 \) lumen/W and \( \leq 55 \) lumen/W and most
preferred \( \geq 40 \) lumen/W and \( \leq 50 \) lumen/W.

6. A LED according to any of the claims 1 to 5 whereby

- the light emission spectrum of the LED comprises a light emittance
band in the wavelength range of \( \geq 400 \text{ nm} \) to \( \leq 550 \text{ nm} \), preferably \( \geq 420 \text{ nm} \) to \( \leq 500 \text{ nm} \) with a maximum emission intensity of \( \geq 2 \text{ W}_{\text{optical}} \) to \( \leq 30 \text{ W}_{\text{optical}} \) and a full width at
half maximum of \( \geq 15 \) and \( \leq 100 \text{ nm} \) and/or

- the light emission spectrum of the LED comprises a light emittance
band in the wavelength range of \( \geq 550 \text{ nm} \) to \( \leq 750 \text{ nm} \), preferably \( \geq 630 \text{ nm} \) to \( \leq 700 \text{ nm} \) with a maximum emission intensity of \( \geq 2 \text{ W}_{\text{optical}} \) to \( \leq 30 \text{ W}_{\text{optical}} \) and a full width at half
maximum of \( \geq 15 \) and \( \leq 100 \text{ nm} \).

7. A LED according to any of the claims 1 to 6, whereby the LED

comprises a LED chip with a substrate, whereby the substrate is coated and/or covered
with at least one red light emitting and/or conversion layer on one first surface and with
at least one blue light emitting layer on the surface which is opposite the first surface.

8. A LED according to any of the claims 1 to 7, whereby the LED

comprises a LED chip with at least one red and at least one blue light emitting layer
and whereby the LED chip is surrounded by and/or partly or completely covered with
the at least one green and/or yellow emitting luminescent material.

9. A LED according to any of the claims 1 to 8, whereby \( \geq 90\% \) to \( \leq 
5 \) 100\%, preferably \( \geq 95\% \) nm to \( \leq 100\% \) of the photons emitted by the red light emitting
and/or conversion layer leave the LED unabsorbed.

10. A system comprising a LED according to any of the claims 1 to 9, the
system being used in or as one or more of the following applications:

- household applications
- shop lighting,
- home lighting,
- accent lighting,
- spot lighting,
- theater lighting,
- museum lighting,
- fiber-optics applications,
- projection systems,
- self-lit displays,
- pixelated displays,
- segmented displays,
- warning signs,
- medical lighting applications,
- indicator signs, and
- decorative lighting.
- Office lighting
- Illumination of workplaces
- Automotive front lighting
- Automotive auxiliary lighting
- Automotive interior lighting
11. A method of preparing a LED according to any of the claims 1 to 9, comprising the steps of:
   a) providing a LED chip which has a substrate
   b) coating and/or covering a first surface of the substrate with at least one red light emitting and/or conversion layer;
   c) coating and/or covering the surface of the substrate which is opposite to the first surface with at least one blue emitting layer, whereby the steps b) and c) may also be conducted in reverse order
   d) partly or totally covering and/or surrounding the LED chip with the at least one green and/or yellow emitting luminescent material.
   e) providing the LED chip and the polymer material in a mirror cup in such a way that the red light emitting and/or conversion layer of the LED chip is projecting towards one of the mirrors of the mirror cup.