



(51) International Patent Classification:

F2IS 41/16 (2018.01) *F2IS 45/47* (2018.01)
F2IK 9/64 (2016.01) *F2IV 29/502* (2015.01)
F2IV 9/30 (2018.01) *F2IV 29/505* (2015.01)
F2IV 9/32 (2018.01)

(21) International Application Number:

PCT/EP2019/066157

(22) International Filing Date:

19 June 2019 (19.06.2019)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

18179728.3 26 June 2018 (26.06.2018) EP

(71) Applicant: **LUMILEDS HOLDING B.V.** [NL/NL]; The Base, Tower B5 unit 107, Evert van de Beekstraat 1, 1118 CL Schiphol (NL).

(72) Inventors: **GOLDMANN, Claudia**; c/o Lumileds Germany GmbH, Intellectual Property, Philipsstr. 8, 52068 Aachen (DE). **GIERTH, Rainald**; c/o Lumileds Germany GmbH, Intellectual Property, Philipsstr. 8, 52068 Aachen (DE). **HECHTFISCHER, Ulrich**; c/o Lumileds Germany GmbH, Intellectual Property, Philipsstr. 8, 52068 Aachen (DE). **SCHUG, Josef**; c/o Lumileds Germany GmbH, Intellectual Property, Philipsstr. 8, 52068 Aachen (DE).

(74) Agent: **RUEBER, Bernhard**; Lumileds Germany GmbH, Philipsstr. 8, 52068 Aachen (DE).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,

(54) Title: LIGHT CONVERTING DEVICE WITH CERAMIC PROTECTION LAYER

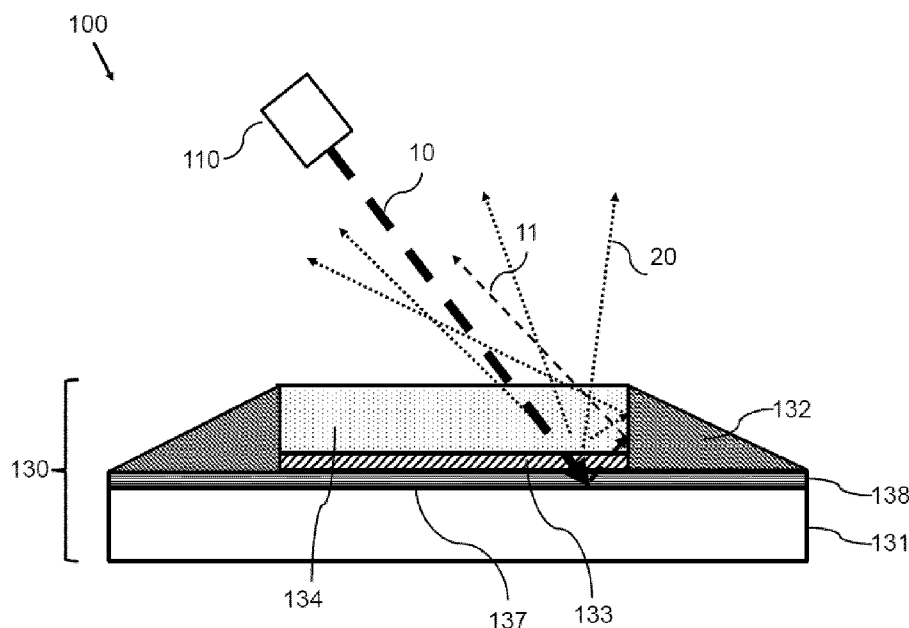


Fig. 1

(57) Abstract: Light converting device (130) comprising: - a substrate (131) functioning as a heatsink, - a light converter (134) adapted to convert laser light (10) to converted light (20) having a longer wavelength than the laser light (10), wherein the light converter (134) comprises a light entrance surface, a bonding surface opposite to the light entrance surface and at least one side surface, wherein the bonding surface is mechanically and thermally coupled to the substrate (131), - a reflective structure (137) attached to or part of the substrate (131) and comprising at least one reflective metal surface arranged to reflect laser light (10) and converted light (20), wherein the reflective structure (137) is arranged on the side of the substrate (131) facing the light converter (134), and - a translucent ceramic protection layer (138), arranged between the reflective structure (137) and the light converter (134), and having a thickness of less than 50 micrometres.



CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP,
KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME,
MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,
SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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

Published:

— *with international search report (Art. 21(3))*

LIGHT CONVERTING DEVICE WITH CERAMIC PROTECTION LAYER

FIELD OF THE INVENTION

5 The invention relates to a light converting device with a ceramic protection layer, a laser-based light source comprising such a light converting device and a vehicle headlight comprising such a laser-based light source.

BACKGROUND OF THE INVENTION

10 In high luminance light sources often a light converting device is used that is excited by e.g. blue light emitted by a laser. A phosphor of the light converting device is coupled to a heatsink e.g. by means of a layer of glue or solder which is provided between the heatsink and the phosphor. Alternatively, as e.g. disclosed in US20170137706A1, the phosphor may be sandwiched in-between heat dissipating layers with a higher thermal conductivity than the phosphor, the heat dissipating layers conducting the heat generated in the phosphor away from the phosphor.

15 Still, the high-intensity especially of blue laser light and the high temperature caused by the light conversion by means of the phosphor may cause reliability issues. Furthermore, reliable heat dissipation e.g. by means of a substrate in combination with high optical efficiency (low absorption) is an issue.

20

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved light converting device.

25 According to a first aspect a light converting device is provided. The light converting device comprises a light converter. The light converter is adapted to convert laser light to converted light. A peak emission wavelength of the converted light is in a longer wavelength range than a laser peak emission wavelength of the laser light. The light converter comprises a light entrance surface, a bonding surface opposite to the light entrance surface and at least one side surface. The bonding surface is mechanically and thermally coupled to a substrate functioning as a heatsink for the light converter. The light converting device further comprises a reflective structure attached to or part of the substrate. The reflective structure comprises at least one reflective metal surface arranged to reflect laser light and converted

30

light. The reflective structure is arranged on the side of the substrate facing the light converter. The light converting device further comprises a translucent ceramic protection layer. The ceramic protection layer is arranged between the reflective structure and the light converter such that the reliability of the reflective structure is increased. The ceramic protection layer may inhibit mechanical damage of the reflective structure. The ceramic protection layer may further inhibit chemical reactions (e.g. corrosion) of the metallic surface comprised by the reflective structure. The ceramic protection layer may be arranged to scatter the laser light and converted light. The ceramic protection layer may, for example, comprise scattering structures (e.g. particles or pores) with a size between 10 nm and 10 μm (size of scattering structures and layer thickness of the ceramic protection layer are adapted such that the ceramic protection layer avoids direct exposure of the reflective structure). The reflectivity of the reflective structure is preferably more than 90%, more preferably more than 95% and most preferably more than 98% in the respective wavelength range (wavelength range of laser light and converted light). The reflective structure may be specular reflective especially in case of sufficient scattering of the laser and converted light already been provided by means of the light converter and/or the ceramic protection layer. The, for example, blue laser light and the converted light may alternatively or in addition be diffusely reflected by means of the reflective structure or a combination of the reflective structure and corresponding scattering elements within, for example, the light converter or the ceramic protection layer.

The light converter may, for example, be a thin (e.g. between 25 μm and 200 μm thick) rectangular or circular plate (maximum lateral extension e.g. less than 5 cm in scanning applications).

The substrate is arranged to dissipate heat, thus functions as a heatsink.

The ceramic protection layer may cover the reflective structure. The ceramic protection layer may, for example, be deposited or laminated on the metal surface to avoid degradation of the metal surface. The ceramic protection layer may, for example, be provided by means of plasma deposition, sol-gel processing or any other suitable deposition or lamination method.

The ceramic protection layer may comprise at least one ceramic material selected out of the group of aluminum oxide, magnesium oxide, titanium oxide, and zirconium oxide, preferably Al_2O_3 or TiO_2 . The material and/or the thickness of the ceramic material is chosen such that the ceramic protection layer does not substantially absorb relevant parts of the laser

light and the converted light. The absorption of laser light and converted light passing the ceramic protection layer is preferably less than 3%, more preferably less than 1% and most preferably less than 0.5%.

5 The substrate may, for example, comprise or consist of a metal like, for example, aluminum, copper, or steel. A surface of the metal may comprise at least one reflective metal surface forming the metal surface of the reflective structure. The metal surface may, for example, be a polished surface of the metal. The ceramic protection layer covers in this embodiment the polished surface as described above.

10 The reflective structure may alternatively comprise at least one metal layer deposited on a surface of the substrate facing the light converter. The metal layer may, for example, be a thin aluminum or silver layer. The ceramic protection layer covers in this embodiment the metal layer attached to the substrate.

15 The thickness of the ceramic protection layer is less than 50 μm and preferably less than 10 μm . The thickness is chosen such that optical performance and thermal conductivity to the substrate including the ceramic layer are sufficient to enable a highly efficient and reliable light converting device.

20 The light converter may be mechanically and thermally coupled to the substrate by, for example, a thin bonding layer (thickness preferably less than 3 μm , more preferably less than 1 μm) arranged between the bonding surface of the light converter and the ceramic protection layer. The bonding layer may, for example, be silicone glue dispensed on at least a part of the surface of the ceramic protection layer. The bonding layer may alternatively be a thin layer of glass melting at low temperatures (e.g. melting temperature being between 200°C and 300°C). The bonding layer is preferably highly transparent in order to avoid optical losses and corresponding heating of the bonding layer and the light converter. The limited thickness of the bonding layer may limit heating of the bonding layer.

25 The light converting device may further comprise a reflective side coating covering the at least one side surface of the light converter. The reflective side coating is arranged to reflect laser light and converted light such that optical losses via the at least one side surface of the light converter may be reduced. The reflective side coating may, for example, be a white coating. The reflective side coating may, for example, comprise an optical silicone filled with e.g. titanium oxide particles.

The substrate may according to an alternative embodiment comprise a slot. The slot is arranged to host the light converter. The light converter is positioned in the slot such

that the bonding surface faces an inner bottom surface of the slot. The reflective structure is in this embodiment arranged at the bottom surface and optionally at the side surface of the slot such that laser light and converted light can be reflected by means of the reflective structure. The reflective structure is covered by the ceramic protection layer. A depth of the slot may be at least 80% or, more preferably, may be the same as a thickness of the light converter perpendicular to the bonding surface. The slot (or cavity) is slightly larger than the light converter. The light converter may be bonded to the reflective structure by means of a bonding layer. The bonding layer may, for example, comprise glue like silicone glue between the reflective structure and the light converter which is hardened by curing. The configuration of the bonding layer may be similar to the one as described above.

According to a further aspect, a laser-based light source is provided. The laser based light source comprises a light converting device as described above and at least one laser which is adapted to emit the laser light.

The laser-based light source may comprise two, three, four or more lasers (e.g. in the form of an array) emitting, for example, blue laser light.

According to a further aspect, a vehicle headlight is provided. The vehicle headlight comprises at least one laser-based light source as described above. The vehicle headlight may comprise two, three, four or more laser-based light sources as described above. The light converter may in this case comprise or consist of a yellow phosphor garnet (e.g. $\text{Y}_{(3-0.4)}\text{Gd}_{0.4}\text{Al}_5\text{O}_{12}:\text{Ce}$). A mixture of blue laser light and yellow converted light may be used to generate white light. Around 21% of the blue laser light may be reflected, and the remaining blue laser light may be converted to yellow light. This enables a ratio of 26% blue laser light and 74% yellow converted light in the mixed light emitted by the laser-based light source by taking into account, for example, Stokes losses in the phosphor.

It shall be understood that a preferred embodiment of the invention can also be any combination of the above described embodiments.

Further advantageous embodiments are defined below.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

The invention will now be described, by way of example, based on embodiments with reference to the accompanying drawings.

In the drawings:

Fig. 1 shows a principal sketch of a first embodiment of a laser-based light source with a light converting device.

Fig. 2 shows a principal sketch of a second embodiment of a laser-based light source with a light converting device.

Fig. 3 shows a principal sketch of a third embodiment of a laser-based light source with a light converting device.

In the Figures, like numbers refer to like objects throughout. Objects in the Figures are not necessarily drawn to scale.

DETAILED DESCRIPTION OF EMBODIMENTS

Various embodiments of the invention will now be described by means of the Figures.

Fig. 1 shows a principal sketch of a first embodiment of a laser-based light source 100 comprising a light converting device 130. A light converter 134 like a rectangular phosphor platelet is glued by means of a bonding layer 133 to a substrate 131 which acts as a heatsink. The surface of the substrate 131 (being e.g. an aluminum substrate) the rectangular phosphor platelet is mounted on is highly reflective (obtained e.g. by polishing) and forms a reflective structure 137. A ceramic protection layer 138 consisting of Al_2O_3 with a layer thickness of around 20 μm is deposited on top of the reflective structure 137 such that the ceramic protection layer is arranged between the bonding layer 133 and the substrate 131. A reflective side coating 132 (e.g. titanium oxide filled optical silicone) covers the side surface or surfaces of the light converter 134. A laser 110 is arranged to emit blue laser light 10 which enters the light converter 134 (yellow phosphor garnet) via a light entrance surface of the light converter 134 which comprises an anti-reflective coating (not shown) avoiding reflection of light in the wavelength range of the laser light 10 and optionally the converted light 20. A part of the blue laser light 10 is converted to yellow converted light 20. A mixture of reflected blue laser light 11 which e.g. is reflected at the reflective structure 137 and converted light 20 is emitted via the light entrance surface. The laser-based light source 100 is arranged to emit white light which comprises the mixture of reflected laser light 11 and converted light 20.

Fig. 2 shows a principal sketch of a second embodiment of a laser-based light source 100 with a light converting device 130. The light converting device 130 comprises a

substrate 131 which acts as a heatsink. The substrate 131 further comprises a reflective structure 137. The reflective structure 137 comprises a reflective metal layer (e.g. silver layer) which is deposited on the surface of the substrate 131 on which a light converter 134 is mounted. The reflective metal layer is protected by means of a ceramic protection layer 138 (e.g. 10 μm aluminum oxide or titanium oxide) which is deposited on top of the reflective metal layer. The light converter 134 is clamped by means of a reflective side coating 132 on the ceramic protection layer 138 such that the ceramic protection layer 138 is arranged between the light converter 134 and the reflective structure 137.

The light converter 134 may alternatively be bonded to the ceramic protection layer 138 by means of, for example, a thermocompression bonding or ultrasonic bonding without any adhesive or bonding layer or by means of a bonding layer as described above.

Fig. 3 shows a principal sketch of a third embodiment of a laser-based light source 100 with a light converting device 130. The substrate 131 consists in this embodiment of a block of metal in which a cavity or slot is provided (e.g. by deep-drawing). Other methods to shape the metal are well known to those skilled in the art. The metal may be in this case aluminum. The bottom of the cavity and the sidewalls are polished surfaces forming the reflective structure 137. The bottom of the cavity, the side walls and the top surface of the block surrounding the cavity are covered by a ceramic protection layer 138 (e.g. 10 μm Al_2O_3 with TiO_2 scattering particles). A small droplet of glue is dispensed in the cavity and the light converter 134 (e.g. platelet of $500 \times 500 \mu\text{m}^2$) which is slightly smaller than the cavity is placed on top of the glue. Thickness of the platelet (e.g. 50-100 μm) and depth of the cavity are preferably arranged such that the light entrance surface of the light converter 134 and the surrounding surface of the substrate 131 are on the same level. Small deviations may be acceptable. Both steps may be carried out in a dispense/p&p tool as typically used in the LED industry equipped with an ultra-high precision dispense valve. Afterwards the glue is cured, which typically implies an oven batch process.

While the invention has been illustrated and described in detail in the drawings and the foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive.

From reading the present disclosure, other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in the art and which may be used instead of or in addition to features already described herein.

Variations to the disclosed embodiments can be understood and effected by those skilled in the art, from a study of the drawings, the disclosure and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality of elements or steps. The mere fact that certain
5 measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

Any reference signs in the claims should not be construed as limiting the scope thereof.

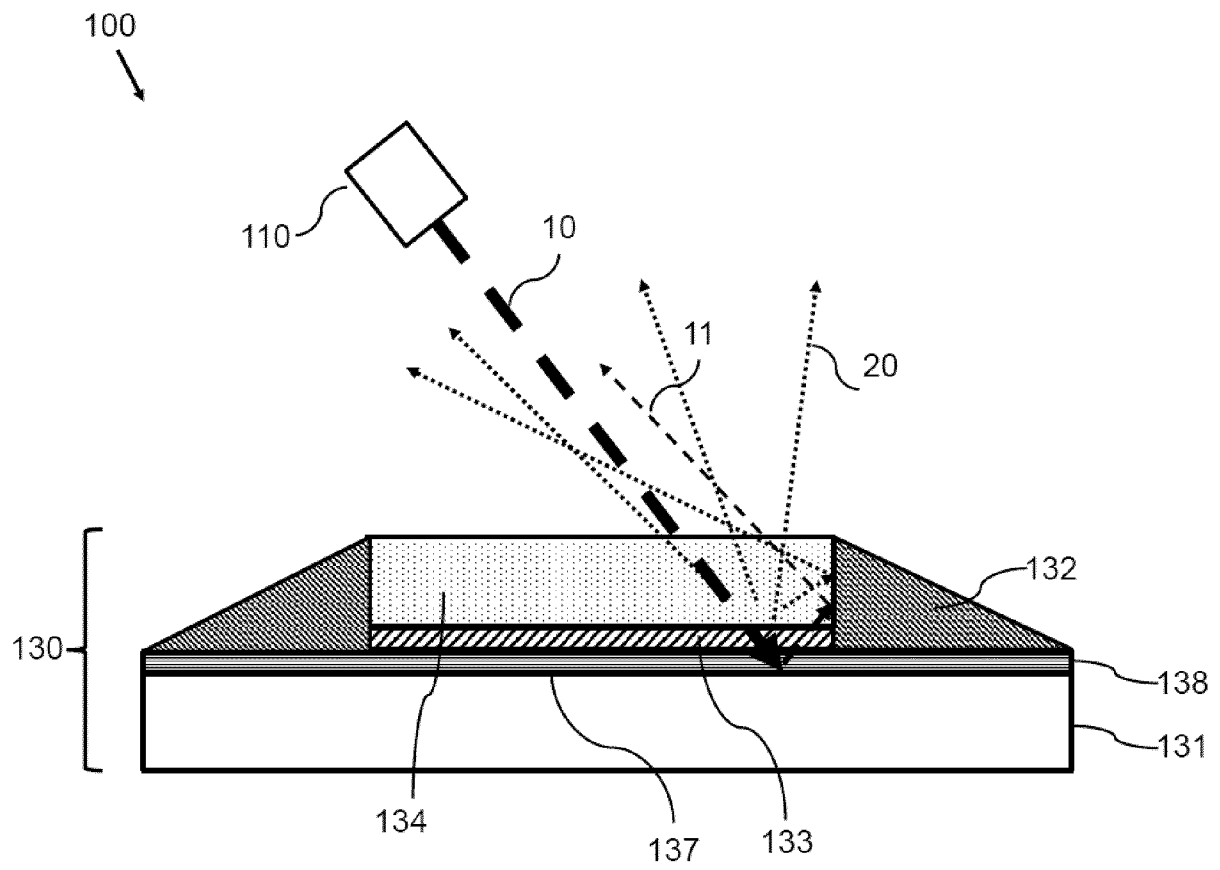
LIST OF REFERENCE NUMERALS:

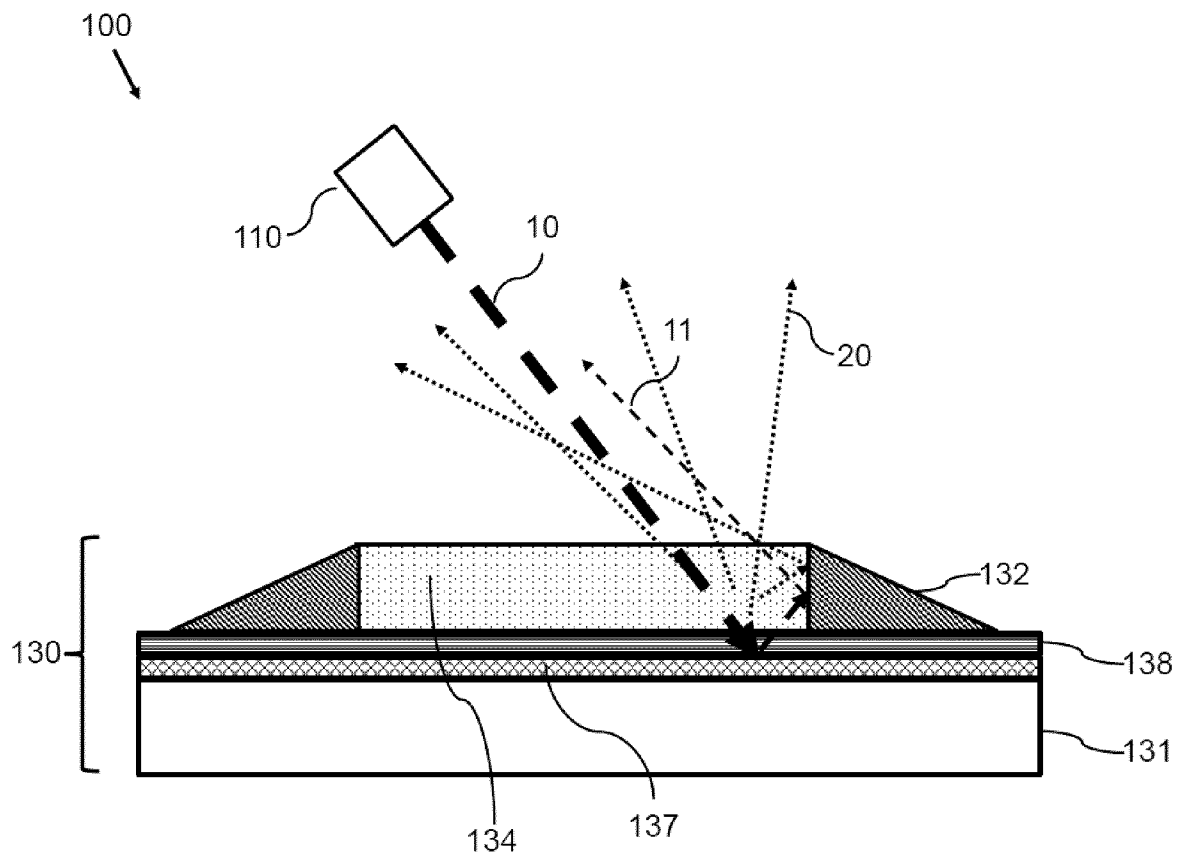
	10	laser light
	11	reflected laser light
5	20	converted light
	100	laser-based light source
	110	laser
	130	light converting device
	131	substrate
10	132	reflective side coating
	133	bonding layer
	134	light converter
	137	reflective structure
	138	ceramic protection layer
15		

CLAIMS:

1. A light converting device (130) comprising:
 - 5 - a substrate (131) functioning as a heatsink,
 - a light converter (134), wherein the light converter (134) is adapted to convert laser light (10) to converted light (20), wherein a peak emission wavelength of the converted light (20) is in a longer wavelength range than a laser peak emission wavelength of the laser light (10), wherein the light converter (134) comprises a
10 light entrance surface, a bonding surface opposite to the light entrance surface and at least one side surface, wherein the bonding surface is mechanically and thermally coupled to the substrate (131),
 - a reflective structure (137) attached to or part of the substrate (131), wherein the reflective structure (137) comprises at least one reflective metal surface arranged to
15 reflect laser light (10) and converted light (20), wherein the reflective structure (137) is arranged on the side of the substrate (131) facing the light converter (134), and
 - a translucent ceramic protection layer (138), arranged between the reflective
20 structure (137) and the light converter (134), and having a thickness of less than 50 μm .
2. The light converting device (130) according to claim 1, wherein the thickness of the ceramic protection layer (138) is less than 10 μm .
- 25 3. The light converting device (130) according to claim 1 or 2, wherein the ceramic protection layer (138) covers the reflective structure (137).
4. The light converting device (130) according to claim 1 or 2, wherein the ceramic protection layer (138) comprises at least one ceramic material selected out of the group
30 of aluminum oxide, magnesium oxide, titanium oxide, and zirconium oxide.
5. The light converting device (130) according to claim 1 or 2, wherein the ceramic protection layer (138) comprises scattering structures for scattering the laser light (10) and the converted light (20).

6. The light converting device (130) according to claim 1 or 2, wherein the substrate (131) comprises a metal, and wherein a surface of the metal comprises the at least one reflective metal surface.
- 5 7. The light converting device (130) according to claim 1 or 2, wherein the reflective structure (137) comprises at least one metal layer deposited on a surface of the substrate (131).
- 10 8. The light converting device (130) according to claim 1 or 2, wherein the bonding surface of the light converter (134) is mechanically and thermally coupled to the substrate (131) by means of a bonding layer (133), wherein the bonding layer (133) is arranged between the light converter (134) and the ceramic protection layer (138).
- 15 9. The light converting device (130) according to claim 1 or 2, wherein the light converting device (130) further comprises a reflective side coating (132) covering the at least one side surface of the light converter (134), wherein the reflective side coating (132) is arranged to reflect laser light (10) and converted light (20).
- 20 10. The light converting device (130) according to claim 1 or 2, wherein the substrate (131) comprises a slot, wherein the slot is arranged to host the light converter (134), and wherein the light converter (134) is positioned in the slot such that the bonding surface faces an inner bottom surface of the slot.
- 25 11. The light converting device (130) according to claim 10, wherein the reflective structure (137) and the ceramic protection layer (138) cover at least the inner bottom surface and a side surface of the slot.
12. A laser-based light source (100) comprising:
- 30 - the light converting device (130) according to any one of claims 1-11, and
- at least one laser (110), wherein the at least one laser (110) is adapted to emit the laser light (10).
13. A vehicle headlight comprising at least one laser-based light source (100) according to claim 12.
- 35

**Fig. 1**

**Fig. 2**

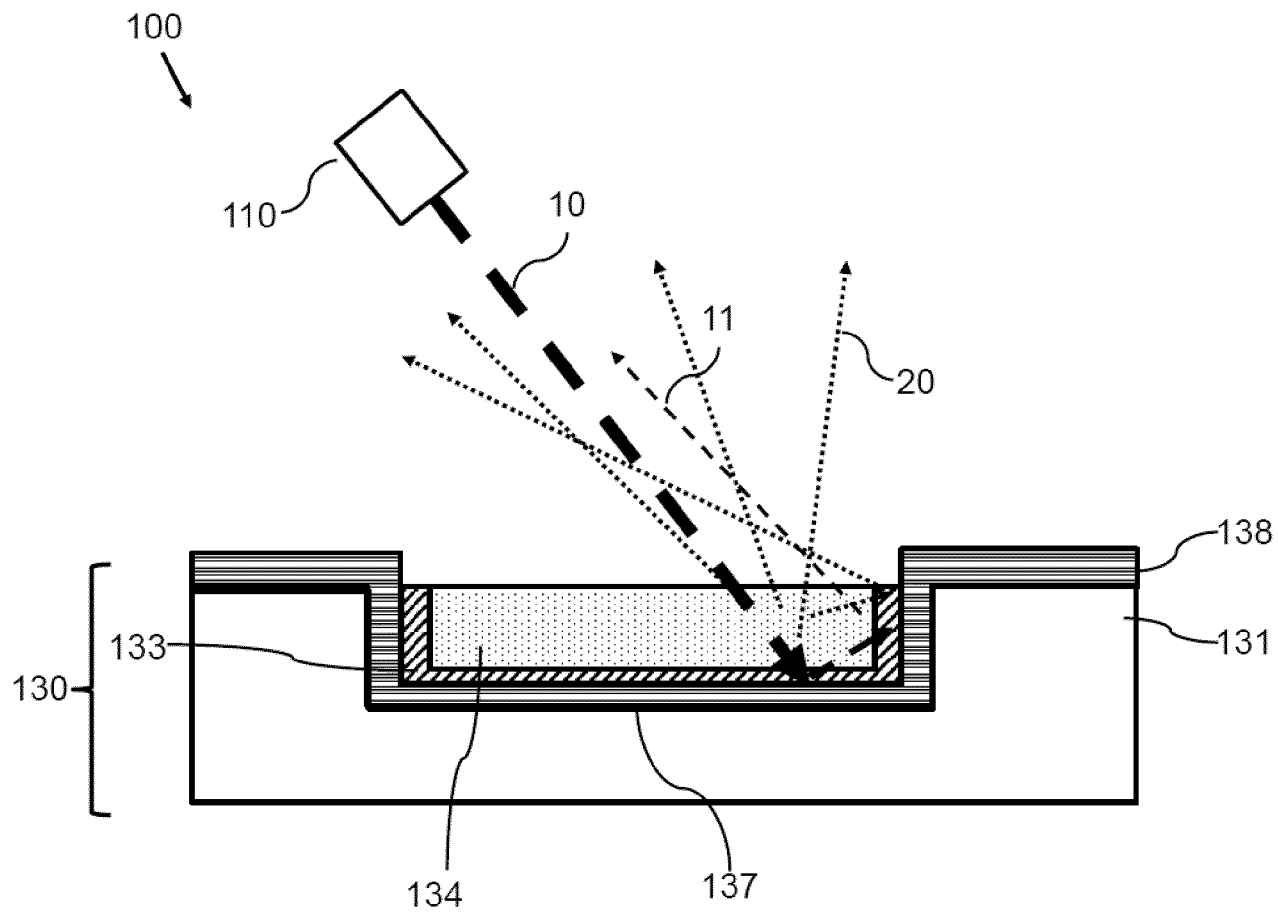


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/066157

A. CLASSIFICATION OF SUBJECT MATTER

INV. F21S41/16 F21K9/64 F21V9/30
ADD. F21V9/32 F21S45/47 F21V29/502 F21V29/505

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)

F21K F21S F21V

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2017/137706 A1 (FUJITA NAOKI [JP] ET AL) 18 May 2017 (2017-05-18) cited in the application paragraphs [0030], [0048], [0051], [0052], [0057], [0075] - [0084], [0086], [0093]; claim 15; figures 5-7 -----	1-13
A	EP 3 309 446 A1 (LUMILEDS HOLDING B V [NL]) 18 April 2018 (2018-04-18) paragraphs [0014], [0029] - [0031]; figures 1-2 -----	1-13



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

18 September 2019

Date of mailing of the international search report

26/09/2019

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

Menn, Patrick

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2019/066157

Patent document cited in search report		Publication date		Patent family member(s)		Publication date
US 2017137706	A1	18-05-2017	CN	106030835 A		12-10-2016
			EP	3147955 A1		29-03-2017
			JP	2016027613 A		18-02-2016
			TW	201608005 A		01-03-2016
			US	2017137706 A1		18-05-2017
			WO	2015178223 A1		26-11-2015

EP 3309446	A1	18-04-2018	CN	109804196 A		24-05-2019
			EP	3309446 A1		18-04-2018
			EP	3526513 A1		21-08-2019
			WO	2018073065 A1		26-04-2018
