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(54) Title: HIGH LUMINANCE CRISP WHITE LED LIGHT SOURCE

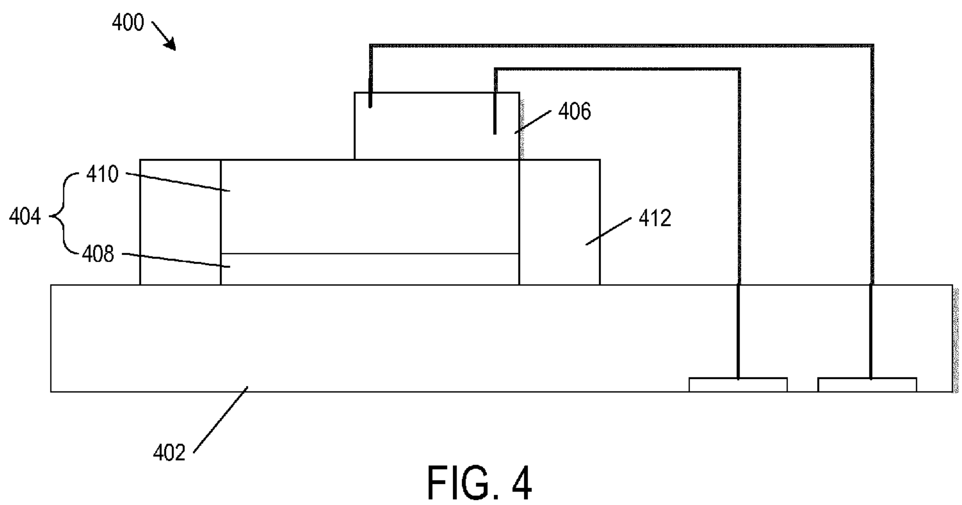

FIG. 4

(57) Abstract: A light-emitting diode or device (LED) package includes a substrate, a white LED above the substrate, and a violet LED or laser above a wavelength converter of the white LED or laterally offset from the wavelength converter.

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HIGH LUMINANCE CRISP WHITE LED LIGHT SOURCE

FIELD OF THE INVENTION

The present disclosure relates to semiconductor light-emitting diodes or device (LEDs), and more particular to LED lamps.

BACKGROUND

When illuminated by daylight, untreated white items, such as fabrics made from natural fibers, tend to appear yellow or ivory to the naked eye. These fibers absorb the blue content of incident white light, resulting in a reflected light that appears yellowish.

Designers incorporate Fluorescent Whitening Agents (FWAs) into dyes, inks and even laundry detergent to brighten fabrics. These agents absorb photons with wavelengths in the near ultraviolet, violet, and deep blue spectrum, which are difficult for the human eye to see. The energy of the absorbed photons is re-emitted by the fabric in the form of photons with longer wavelengths, typically in the blue spectrum. By incorporating FWAs into fabrics, designers can compensate for the natural deficiency of the blue spectral content in reflected light from white fabrics.

Traditional white light-emitting diodes or devices (LEDs) produce white light from blue emitting LEDs covered with a yellow emitting phosphor. Such white LEDs do not have sufficient spectral content in the near ultraviolet, violet, and deep blue spectrum to activate the FWAs in white objects.

US 2015/0049459 discloses a light emitting module with a first light emitting element having an emission peak in the wavelength range of 400-440 nm and a second light emitting elements having an emission peak in the wavelength range from 440-460nm. The first and the second light emitting element are located below a wavelength converting element. The wavelength converting element is arranged to receive light from the first light emitting element and being capable of emitting light having an emission peak in the green to red wavelength range. The module provides white light with a “crisp white” effect.

SUMMARY

One or more examples of the present disclosure, a light-emitting diode or device (LED) package includes a substrate, a white LED above the substrate, and a violet LED above a wavelength converter of the white LED or laterally offset above the wavelength converter.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

Fig. 1 shows the emission spectrum of a white light-emitting diode or device (LED) package.

Fig. 2 shows the absorption spectrum for yttrium aluminum garnet (YAG) phosphors and the human eye sensitivity curve.

Fig. 3 shows emission spectrum of such a LED package with a violet LED in examples of the present disclosure.

Figs. 4, 5, 6, 7, and 8 illustrate LED packages in examples of the present disclosure.

Use of the same reference numbers in different figures indicates similar or identical elements.

DETAILED DESCRIPTION

Fig. 1 shows the emission spectrum of a white light-emitting diode or device (LED) package. As can be seen, the spectral content below 430 nanometer (nm) is very low. A measure for the spectral content in this wavelength range called “whiteness W” is calculated according to the following equation.

$$W = \frac{\int_{380}^{430} I(\lambda)(430 - \lambda)d\lambda}{\int_{380}^{780} I(\lambda)d\lambda}$$

Table 1 provides the performance data for the emission spectrum shown in Fig. 1.

Table 1

CCT	Flux(lm)	CRI	R9	LE	u'	v'	x	y	Whiteness
5887.1	680.6	68.5	-35.2	330.4	0.200	0.478	0.324	0.344	0.13

LUXEON Chip on Board (CoB) with CrispWhite Technology from Lumileds of San Jose, California, is designed to provide more light in the deep blue spectrum to activate the fluorescent whitening agents found in nearly all clothing, fabrics, and paints. Like traditional white LEDs, LUXEON CoB with CrispWhite Technology relies on blue LEDs with a typical peak wavelength of 455 nm and coats them with phosphors to emit yellow-green and red wavelengths. The combination of the blue, yellow-green, and red light creates the desired white light.

To excite the FWAs, LUXEON CoB with CrispWhite Technology includes some die that emits violet light with a lower peak wavelength less than 430 nm, and covering both the blue and the violet LEDs with the phosphors. The second peak is deep blue, between 400 nm and 415 nm. This wavelength is short enough to stimulate the FWAs as well as far enough towards the edge of the eye's wavelength sensitivity curve that it has little effect on the perceived light with items that have not been treated with FWAs.

A LED package that places both the blue and the violet LEDs below the phosphors has the disadvantage that its white flux is reduced because flux and luminance are limited by the size of the blue LED, which usually takes up the entire emitting area. The violet LED does not contribute because the phosphors hardly absorb light with wavelengths less than 430 nm and the human eye sensitivity is low for light with wavelengths less than 430 nm. Fig. 2 shows the absorption spectrum for yttrium aluminum garnet (YAG) phosphors and the human eye sensitivity curve.

In examples of the present disclosure, a LED package includes a blue LED, a wavelength converter above the blue LED, and a violet LED that is above or laterally displaced from the wavelength converter. Fig. 3 shows emission spectrum of such a LED package with a violet LED having peak emission, e.g., at 405 nm in examples of the present disclosure.

Table 2 provides the performance data for the emission spectrum shown in Fig. 3.

Table 2

CCT	Flux(lm)	CRI	R9	LE	u'	v'	x	y	Whiteness
6055.7	680.8	68.7	-31.4	296.4	0.200	0.474	0.321	0.337	2.49

Comparing the data for both emission spectra in Tables 1 and 2 shows that the color point is shifted very little, the whiteness W increased from 0.13 to 2.49, and the emitted flux stays substantially constant.

Fig. 4 illustrates a LED package 400 in examples of the present disclosure. Package 400 includes a substrate 402, a white emitting LED 404 above substrate 402, and a violet emitting LED 406 above white LED 404. As used herein, "above" includes an element being mounted directly on another element.

Substrate 402 may be a submount or a circuit board.

White emitting LED 404 has a peak wavelength greater than 430 nm, such as between 430 and 480 nm (e.g., 455 nm). White emitting LED 404 includes a blue emitting LED die 408 and a wavelength converter 410 above blue LED die 408. Blue emitting LED die 408 may be a vertical or a thin-film flip-chip (TFFC) die that is formed on a pattern sapphire substrate (PSS).

Violet emitting LED 406 is located above wavelength converter 410. Violet emitting LED 406 emits violet light onto wavelength converter 410, which scatters and emits the violet light with the white light. In some cases, wavelength converter 410 may include phosphors (e.g., red phosphors) that absorb part of the violet light and emit a red light. Violet emitting LED 406 has a peak wavelength less than 430 nm, such as between 400 nm and 415 nm (e.g., 405 nm). Violet emitting LED 406 is transparent to light emitted by white emitting LED 404. Violet LED 406 may be a lateral die having electrical contacts on a top side of the die, which may be electrically connected (e.g., by bonding wires) to contacts in substrate 402.

Wavelength converter 410 includes yellow-green phosphors, red phosphors, or a combination of yellow-green and red phosphors. Wavelength converter 410 may be a YAG ceramic phosphor plate, such as Lumiramic from Lumileds of San Jose, California.

To increase luminance, package 400 may include a reflective side coating 412 on lateral surfaces of white emitting LED 404 (i.e., on lateral surfaces of blue emitting LED die 408 and wavelength converter 410).

Fig. 5 illustrates a LED package 500 in examples of the present disclosure. Package 500 includes substrate 402, white emitting LED 404 above substrate 402, and a violet emitting LED 502, and an optic 504.

Violet emitting LED 502 is laterally offset from wavelength converter 410 of white emitting LED 404. Violet LED 502 is transparent to light emitted by white emitting LED 404. Violet LED 502 may be a lateral die having electrical contacts on a top side of the die.

Optic 504 images violet light from violet LED 502 onto wavelength converter 410. Optic 504 may be an imaging mirror.

Wavelength converter 410 includes yellow-green phosphors, red phosphors, or a combination of yellow-green and red phosphors. Wavelength converter 410 may be YAG phosphors mixed into a silicone matrix material.

Package 500 may include reflective side coating 412 on lateral surfaces of white emitting LED 404 (i.e., on lateral surfaces of blue emitting LED die 408 and wavelength converter 410).

Fig. 6 illustrates a LED package 600 in examples of the present disclosure. Package 600 includes substrate 402, white emitting LED 404 above substrate 402, a violet emitting LED 602, and a dichroic combiner 604.

Violet emitting LED 602 is laterally offset from wavelength converter 410 of white emitting LED 404. Violet emitting LED 602 is mounted above substrate 402 next to white emitting LED 404. In some examples, dichroic combiner 604 may be a dichoric plate or mirror mounted at an angle (e.g., 45 degrees) to the horizontal emitting surface of white emitting LED 404 and the vertical emitting surface of violet emitting LED 602 to combine their light. In other examples, dichroic combiner 604 may be a dichroic cube with bottom and lateral surfaces facing the emitting surfaces of white emitting LED 404 violet emitting LEDs 702, respectively.

Package 600 may include reflective side coating 412 on lateral surfaces of white emitting LED 404 (i.e., on lateral surfaces of blue emitting LED die 408 and wavelength converter 410).

Fig. 7 illustrates a LED package 700 in examples of the present disclosure. Package 700 includes substrate 402, white emitting LED 404 above substrate 402, a violet emitting laser 702, a light guide 704, and a focus lens 706.

Violet emitting laser 702 is coupled to one end of light guide 704, and focus lens 706 is coupled to the other end of light guide 704. Violet emitting laser 702 emits violet light into light guide 704, which is directed by focus lens 706 onto wavelength converter 410 of white LED 404. Wavelength converter 410 scatters and emits the violet light with the white light.

Package 700 may include reflective side coating 412 on lateral surfaces of white emitting LED 404 (i.e., on lateral surfaces of blue emitting LED die 408 and wavelength converter 410).

Fig. 8 illustrates a LED package 800 in examples of the present disclosure. Package 800 includes substrate 402, white emitting LED 404 above substrate 402, a violet emitting LED 802, and a focus lens 804.

Violet emitting LED 802 mounted above substrate 402 next to white emitting LED 404. Violet emitting LED 802 may be mounted at an angle so its emitting surface is directed toward the emitting surface of white LED 404. Focus lens 804 is mounted to the emitting surface of violet emitting LED 802. Violet emitting LED 802 emits violet light, which is directed by focus lens 804 onto wavelength converter 410 of white LED 404. Wavelength converter 410 scatters and emits the violet light with the white light.

Package 800 may include reflective side coating 412 on lateral surfaces of white emitting LED 404 (i.e., on lateral surfaces of blue emitting LED die 408 and wavelength converter 410).

Various other adaptations and combinations of features of the embodiments disclosed are within the scope of the invention. Numerous embodiments are encompassed by the following claims.

CLAIMS:

1. A light-emitting diode or device (LED) package, comprising:

a substrate;

a white LED above the substrate, the white LED comprising a wavelength converter; and

a violet LED or laser

wherein the violet LED or laser is located above the wavelength converter or laterally offset above the wavelength converter.

2. The structure of claim 1, wherein:

the white LED further comprises a blue LED die mounted on the substrate;

the wavelength converter is mounted on the blue LED die; and

the violet LED is mounted on the wavelength converter.

3. The structure of claim 2, wherein the violet LED comprises a lateral die having electrical contacts on a top side of the die.

4. The structure of claim 3, wherein the wavelength converter comprises a ceramic phosphor.

5. The structure of claim 4, further comprising a reflective side coating on lateral surfaces of the blue LED and the wavelength converter.

6. The structure of claim 1, further comprising an optic to direct light from the violet LED onto the wavelength converter, wherein the optic comprises a focus lens mounted on an emitting surface of the violet LED or mirror.

7. The structure of claim 1, further comprising a dichroic combiner that combines light from the violet LED and the white LED, wherein the dichroic combiner comprises:

a plate mounted at an angle relative to emitting surfaces of the white LED and the violet LED; or

a dichroic cube with bottom and lateral surfaces facing the emitting surfaces of the white LED and the violet LED, respectively.

8. The structure of claim 1, further comprising a light guide and a focus lens, wherein:
the violet laser is mounted to a first end of the light guide;
the focus lens is mounted to a second end of the light guide; and
the focus lens direct light from the violet laser onto the wavelength converter.

9. A method for a light-emitting diode or device (LED) package to generate light, comprising:
generating a white light with a white LED, the white LED including a wavelength converter; and
generating a violet light with a violet LED or laser,
wherein the violet LED or laser is located above the wavelength converter or laterally offset above the wavelength converter.

10. The method of claim 9, wherein:
the white LED further comprises a blue LED die mounted on the substrate;
the wavelength converter is mounted on the blue LED die; and
the violet LED is mounted on the wavelength converter.

11. The method of claim 10, wherein the violet LED is transparent to light emitted by the white LED.

12. The method of claim 11, wherein the violet LED comprises a lateral die having electrical contacts on a top side of the die.

13. The method of claim 12, wherein the wavelength converter comprises a ceramic phosphor.

14. The method of claim 13, further comprising reflecting light on lateral surfaces of the blue LED and the wavelength converter with a reflective side coating.

15. The method of claim 11, further comprising directing light from the violet LED onto the wavelength converter or combining light emitted by the white LED and the violet LED with a dichroic plate or cube

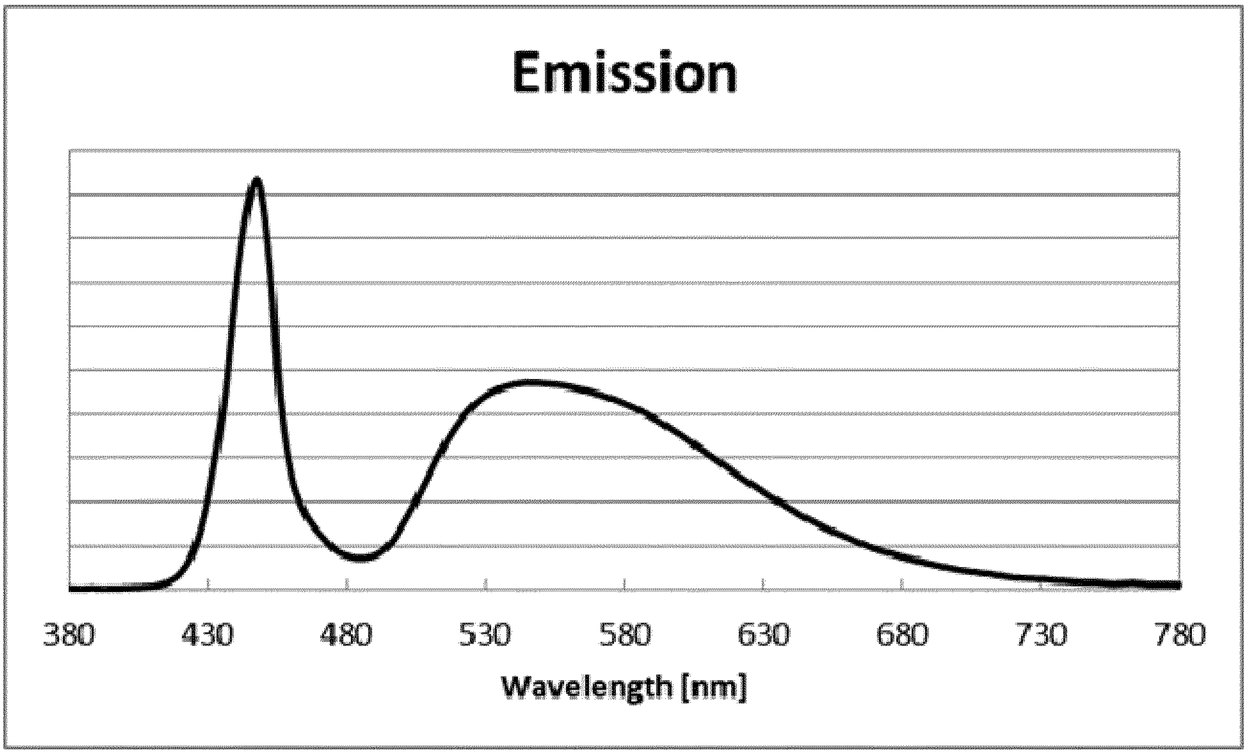
Emission
380
430
480
530
580
630
680
730
780
Wavelength [nm]

FIG. 1

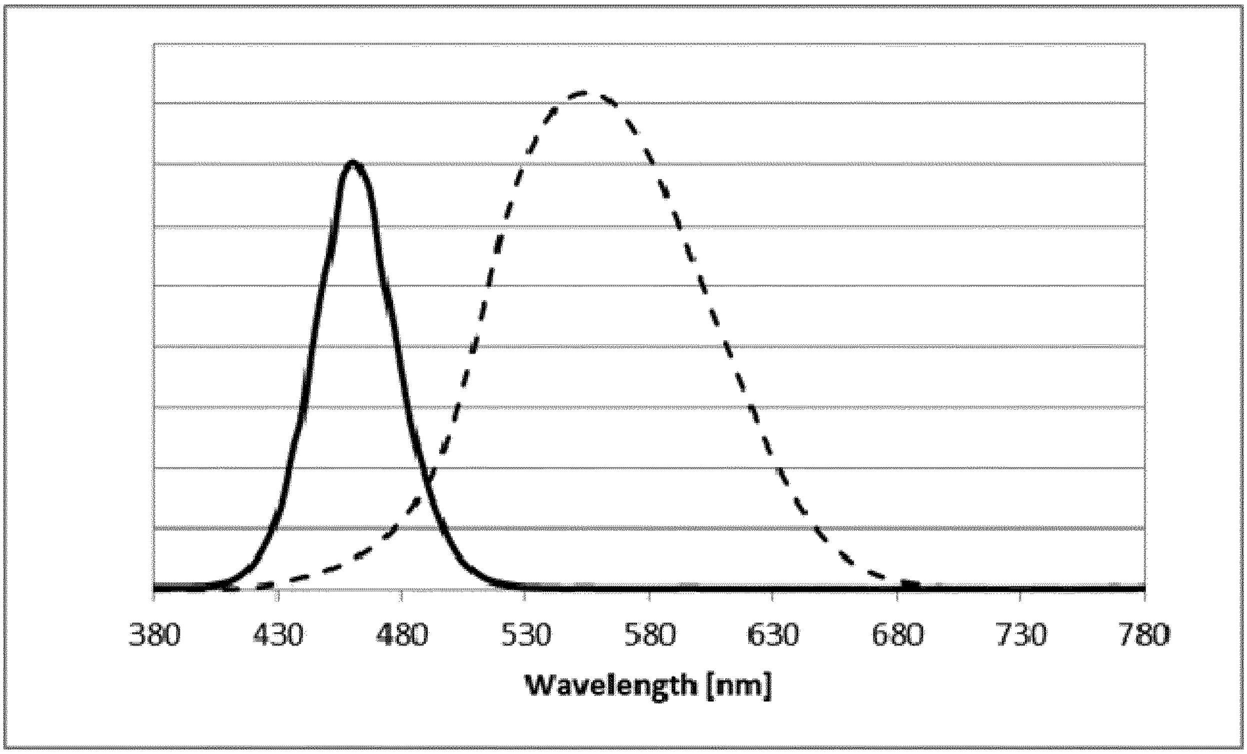
380
430
480
530
580
630
680
730
780
Wavelength [nm]

FIG. 2

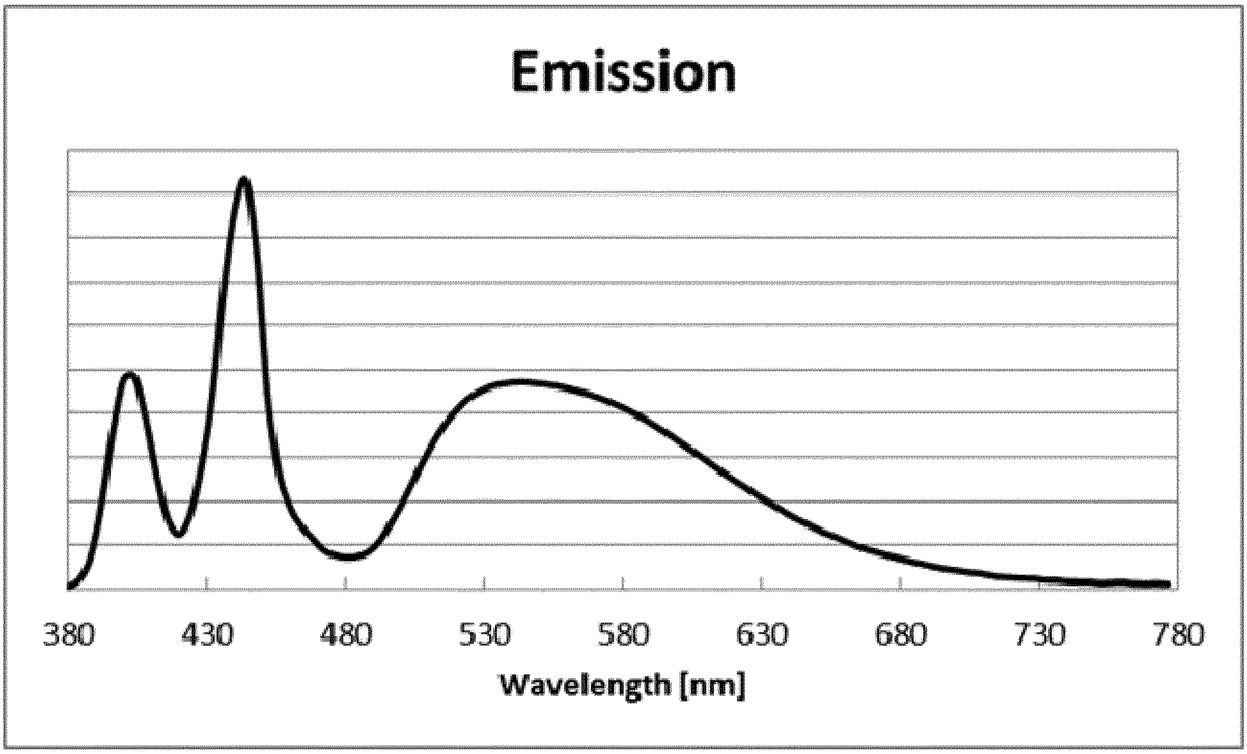
Emission
380
430
480
530
580
630
680
730
780
Wavelength [nm]

FIG. 3

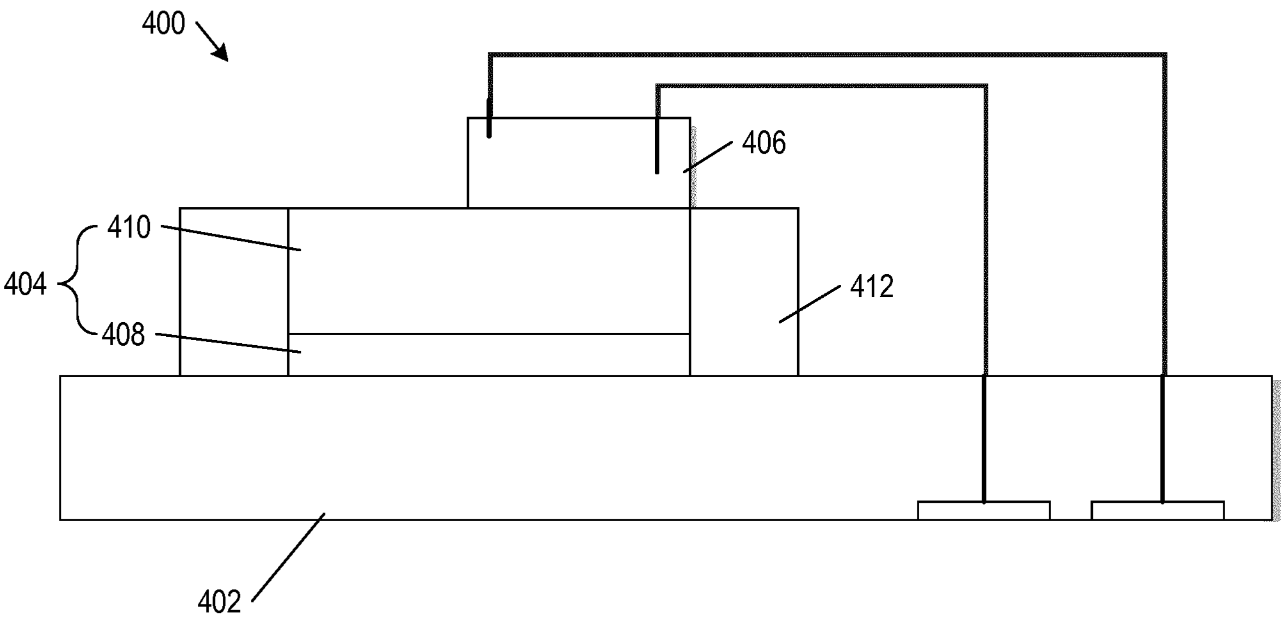
400
406
410
404
408
412
402

FIG. 4

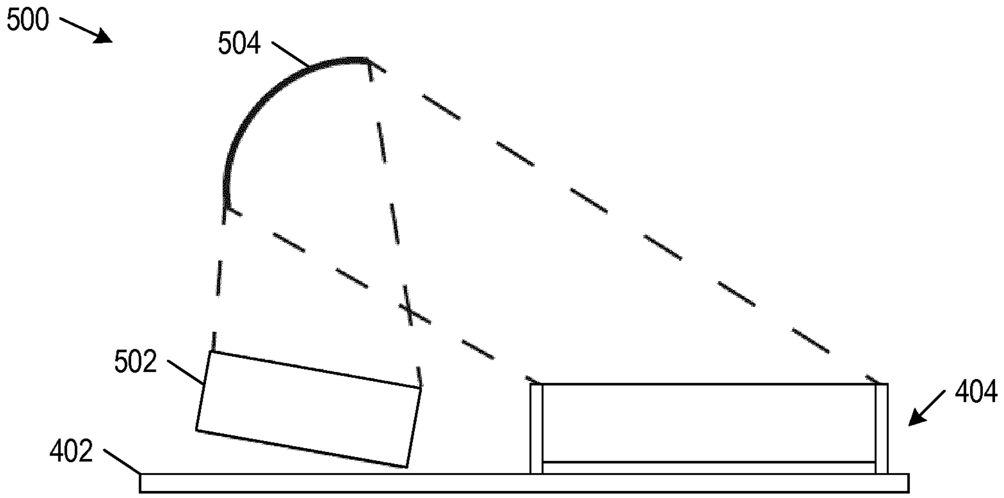

FIG. 5

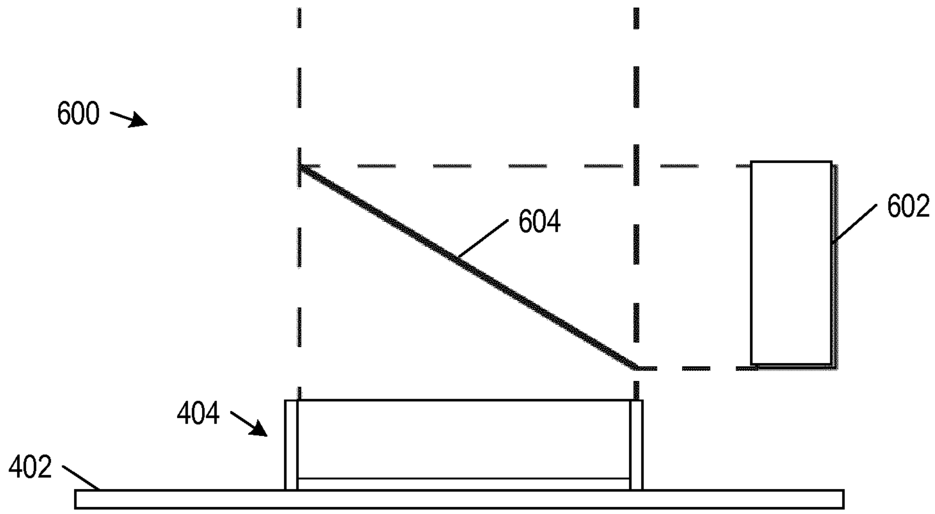

FIG. 6

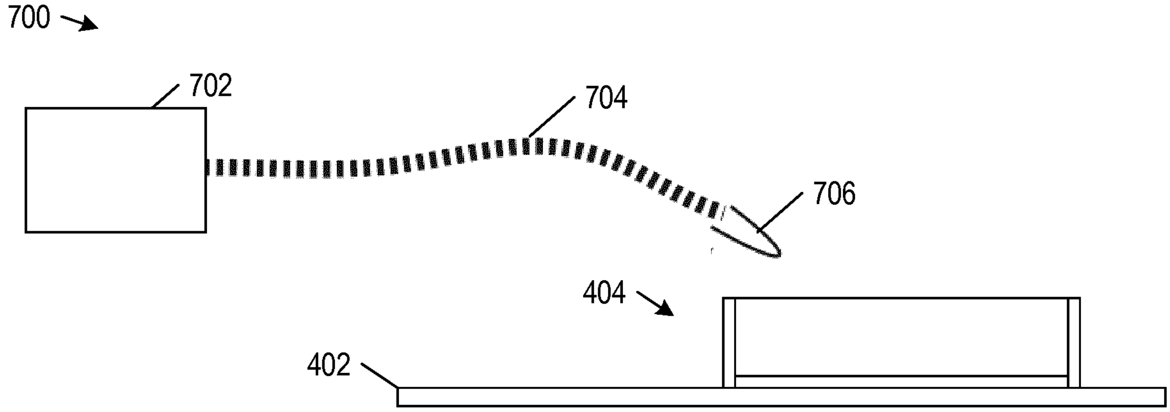

FIG. 7

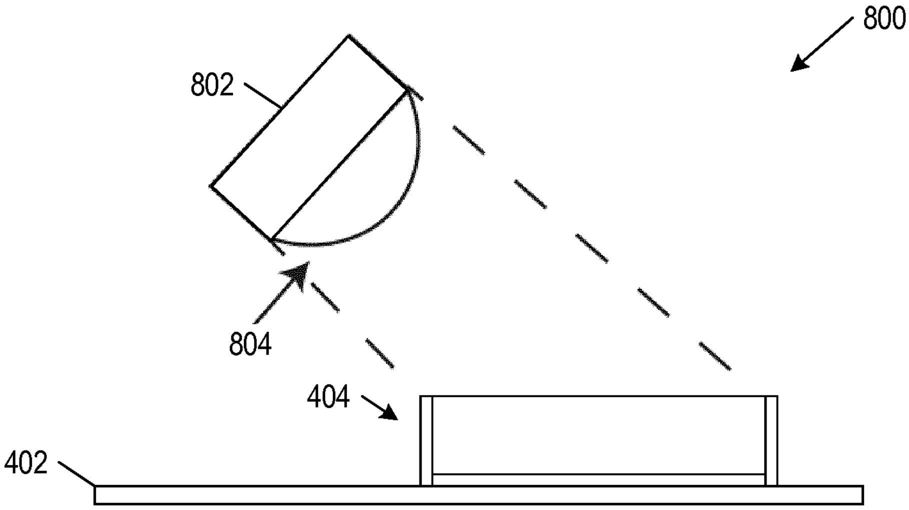

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/059499

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L25/075 F21K9/64
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L F21K

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2015/049459 A1 (PEETERS MARTINUS PETRUS JOSEPH [NL] ET AL) 19 February 2015 (2015-02-19) cited in the application paragraphs [0089] - [0092], [0128]; claim 1; figures 1,10-12 -----	1-15
Y	US 2009/134409 A1 (WANG LINGLI [NL] ET AL) 28 May 2009 (2009-05-28) paragraphs [0004] - [0008]; figure 1 -----	1-15
A	EP 2 650 918 A1 (KONINKL PHILIPS NV [NL]) 16 October 2013 (2013-10-16) paragraphs [0049], [0063]; claim 1; figures 4,7a ----- -/--	1-15

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
10 July 2017	21/07/2017

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/059499

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 682 207 B2 (WEBER ANDREAS G [US] ET AL) 27 January 2004 (2004-01-27) column 2, line 40 - column 3, line 25; figure 1 -----	1,7,9,15
A	US 2003/186165 A1 (GRIES WILLI-KURT [DE] ET AL) 2 October 2003 (2003-10-02) abstract -----	1,8,9

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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