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(54) **LED LIGHT SOURCE DEVICE**

(57) An LED light source device (20) is disclosed, comprising: (a). a plurality of first LED devices (22) configured to emit white light, (b). at least one second LED device (23) configured to emit far red light, and (c). at least one third LED device (24) configured to emit UV light; wherein the plurality of first, second and third LED devices (22, 23, 24) are arranged in a circuit, the circuit comprising first and second terminals (25, 26) for connection with a single current source; the circuit further comprising a plurality of parallel first current paths (30, 30', 30"), each first current path (30) comprising a number of first LED devices (22) connected in series; a first group of first current paths (30) being arranged in series with a second current path (31), comprising at least one second LED device (23); and a second group of first current paths (30') being arranged in series with a third current path (32), comprising at least one third LED device (24).

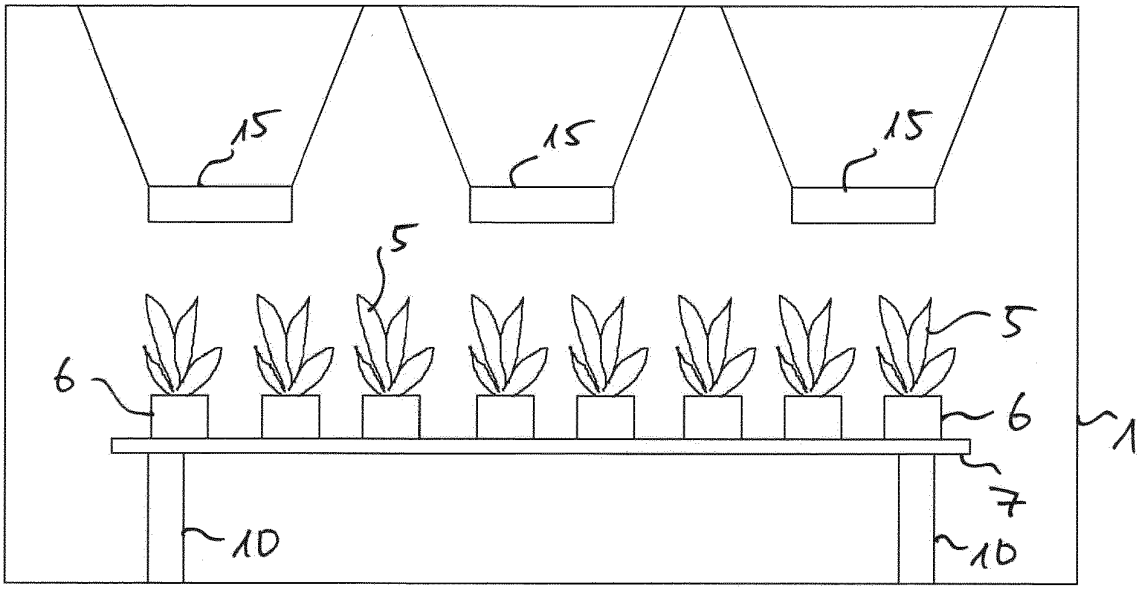

Fig. 1

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Description

[0001] This disclosure generally relates to LED light source devices. More specifically, this disclosure relates to LED light source devices for horticultural applications.

[0002] In modern horticultural applications, light source devices are used to provide plants with optimal lighting conditions for growth and well-being. While traditional horticulture depended on use of sunlight, classical artificial light source devices like incandescent or fluorescent light source devices have made horticulture independent from weather conditions and, to some extent, seasonal changes.

[0003] However, classical artificial light source devices suffer from technical shortcomings like poor energy efficiency, short service life span, and so on. Modern LED light source devices provide great improvements to this regard.

[0004] Research has shown that for optimal growing conditions, LED light sources for horticultural applications should provide a light spectrum similar to the spectrum of sunlight. This includes, beside the light spectrum already used in "white" LED light source devices optimized for a good colour rendering index (CRI), significant light emission in a far-red wavelength area of approx. 730nm, and in a near-UV wavelength area of approx. 385nm.

[0005] While LED light source devices for the respective spectral areas are readily available, they are difficult to combine in a simple LED light source device, as they have differing electrical characteristics like driving current I_d and forward voltage U_f.

[0006] It is therefore an object of this disclosure to provide an LED light source device suitable for horticultural applications, which has a simple design and can be produced at low costs.

[0007] This object may be achieved by an LED light source device according to the appended claims.

[0008] An LED light source device according to this disclosure may comprise: a plurality of first LED devices configured to emit white light, at least one second LED device configured to emit far red light, and at least one third LED device configured to emit UV light; wherein the plurality of first, second and third LED devices are arranged in a circuit, the circuit comprising first and second terminals for connection with a single current source; the circuit further comprising a plurality of parallel first current paths, each first current path comprising a number of first LED devices connected in series; a first group of first current paths being arranged in series with a second current path, comprising at least one second LED device; and a second group of first current paths being arranged in series with a third current path, comprising at least one third LED device.

[0009] The circuit design according to this disclosure may allow balancing of different driving currents and forward voltages of the respective LED devices in a single circuit, which can be driven by a single current source. Therefore, the complexity and manufacturing costs of the LED light source device can be reduced.

[0010] Each of the first current paths may comprise a current regulator. The current regulators may reduce current fluctuations due to electrical tolerances of individual LED devices. Each of the current regulators may provide an equal driving current.

[0011] Each of the LED devices may comprise a lead frame, a substrate being attached to the lead frame, and a stacked semiconductor structure being disposed on the substrate and being connected to the lead frame.

[0012] Each of the first LED devices may further comprise a phosphor layer covering the stacked semiconductor structure. The phosphor layer may serve to convert a first light spectrum emitted by the stacked semiconductor structure into a second light spectrum to be emitted by the first LED device. The second light spectrum may be a white spectrum having a colour temperature of approx. 5000K.

[0013] At least one of the second and/or third LED devices may further comprise a lens covering the stacked semiconductor structure. The lens may serve to shape a light emission beam of the second and/or third LED device. The lens may comprise silicon.

[0014] A first end of each of the first current paths may be connected to the first terminal. A second end of the second group of first current paths may connected to a first end of the third current path, and a second end of the third current path may be connected to the second terminal.

[0015] A second end of a first group of first current paths may be connected to a first end of the second current path, and a second end of the second current path may be connected to the second terminal. The number of first current paths in the first group first current paths may be smaller than the number of first current paths in the second group of first current paths.

[0016] A second end of the first group of first current paths may be connected to a first end of the second current path, and a second end of the second current path may be connected to the first end of the third current path.

[0017] A second end of a third group of first current paths may be connected to the second terminal.

[0018] Each of the first current paths may comprise the same number of first LED devices. The number of first LED devices in each first current path of the second group of first current paths may be greater than the number of first LED devices in each first current path of the first group of first current paths.

[0019] The number of first LED devices in each first current path of the third group of first current paths may be greater than the number of first LED devices in each first current path of the second or first group of first current paths.

[0020] The number of first current paths may be 6. The the number of first current paths in the first group of first current paths may be 2, and the number of first current paths in the second group of first current paths may be

4. The number of first current paths in each of the first, second, and third group of first current paths may be 2.

[0021] Possible light source devices according to this disclosure are explained in more detail below, and are depicted in the appended drawings. The embodiments shown in the drawings are provided only for better understanding, and are not intended to limit the scope of the invention in any way.

[0022] The drawings show:

Fig. 1: a horticultural installation with a light source device,

Fig. 2: an LED light source device in an isometric view,

Fig. 3: a possible spectrum of an LED light source device,

Fig. 4: a circuit of a first LED light source device,

Fig. 5: a circuit of a second LED light source device,

Fig. 6: a circuit of a third LED light source device,

Fig. 7: a circuit of a fourth LED light source device,

Fig. 8: an LED device,

Fig. 9: a further LED device.

[0023] Figure 1 shows a horticultural installation inside a facility 1, which may be a greenhouse. A plurality of plants 5 in respective containers 6 is placed on a table device 7. The table device 7 may be elevated by posts 10, in order to make plants 5 readily accessible for human workers, e.g. for harvesting plant products.

[0024] While walls of the facility 1 may be transparent for sunlight to some extent, light source devices 15 are provided in the facility, to provide for optimal lighting conditions for growth and well-being of the plants 5. The light source devices 15 may be suspended from a ceiling of the facility 1, or mounted in any other suitable manner.

[0025] Each of the light source devices 15 may comprise one or more LED light source devices.

[0026] In Fig. 2, an LED light source device 20 is shown in an isometric view. The LED light source device comprises a plate-like carrier 21, which may be a single- or multi-layered printed circuit board.

[0027] On the carrier device, a number of first LED devices 22 is arranged in an array-like pattern. In the shown example, the array-like pattern consist of six rows with eight first LED devices 22 each, so that the total number of first LED devices in the LED light source device 20 is 48.

[0028] A second LED device 23 and a third LED device 24 are also mounted on the carrier device 21, for example between the first LED devices 22.

[0029] Conductive tracks in or on the carrier device 21 connect the first, second, and third LED devices with a first terminal 25 and a second terminal 26 of the carrier device, which can be connected to a currents source for the first, second, and third LED devices. The conductive tracks are not shown in Figure 2.

[0030] The LED light source device 20 is designed to provide optimal lighting conditions for plants 5. Therefore, the LED light source device 20 emits light with a spectrum as shown in Figure 3.

[0031] Figure 3 shows a possible spectrum of light emitted by LED light source device 20. On the horizontal axis, the wavelength of the light is indicated in nm. On the vertical axis, the light intensity is indicated in arbitrary units.

[0032] It can be seen that the spectrum has a very broad wavelength range, with a plateau reaching from about 400nm to about 700 nm, which represents white light with a colour temperature of approx. 5000K. This plateau is emitted by the first LED devices 22, and contains about 90% of the total light energy emitted by the LED light source device 20. The spectrum of the first LED devices is indicated by the dashed line in Figure 3.

[0033] The light spectrum emitted by the first LED devices 22 is already of a very good quality, if employed for technical lighting, e.g. in shop-floor or office applications. While while light emitting LED devices are known for some time, many of these LED devices provide a spectrum with a significant blue peak emission, and have a significant drop of light emission in the area of green light. The first LED devices 22 preferably have a more balanced spectrum, which is closes to natural sunlight. The first LED devices may be LED devices as described in US patent application US2019/0305192A1, which is incorporated herein by reference for all purposes.

[0034] However, the spectrum of natural sunlight also comprises significant portions of near UV light in the range of approx. 385nm, and far red light in the range of approx. 730 nm. These portions of the spectrum are also needed by plants 5 for optimal growth and well-being.

[0035] For this purpose, second and third LED devices 23, 24 are provided. The second LED device 23 provides light emission in the near UV wavelength range, i.e. approx. 385nm. The third LED device 24 provides light emission in the far-red range, i.e. approx. 730nm. The isolated spectral emissions of the second and third LED devices 23, 24 are indicated in Figure 3 by dash-dotted lines. The second and third LED devices 23, 24 each provide approx. 5% of the total light energy emitted by the LED light source device 20.

[0036] The electrical characteristics of first, second, and third LED devices 22, 23, 24 differ significantly, e.g. with respect to driving current I_d and forward voltage U_f. Therefore, first, second, and third LED devices 22, 23, 24 are difficult to integrate into a simple circuit.

[0037] A possible circuit 100 for integrating first, second, and third LED devices 22, 23, 24 is shown in Figure 4.

[0038] The circuit 100 shown in Figure 4 comprises six

first current paths 30 ,30', 30", which are parallel to each other. Each of the first current paths 30, 30' ,30" comprises eight first LED devices 22 connected in series. A first end of each of the first current paths 30, 30', 30" is connected to the first terminal 25.

[0039] A first group of first current paths 30 merge into a second current path 31, which is in series with the two first current paths 30 and contains the second LED device 23. A second group of first current paths 30' merge with the second current path 31 into a third current path 32, which is in series with the respective first current paths 30 and with the second current path 31. The third current path 32 contains the third LED device 24. A third group of first current paths 30' is directly connected to the second terminal 25.

[0040] Each of the first current paths 30, 30', 30" further comprises a current regulator 35, e.g. a constant current regulator. The current regulators 35 provide for balancing the currents in the first current paths 30, 30', 30" despite variations in the forward voltages of the first LED devices 22. Each of the current regulators 35 provides for the same driving current.

[0041] In the circuit 100 of Figure 4, each of the first LED devices 22 is provided with the same driving current, as regulated by the current regulators 35.

[0042] The driving current of the second LED device 23 is double the driving current of the first LED devices 22, as two of the first current paths 3 merge into the second current path. Due to the shorter emission wavelength, the second LED device has a slightly higher forward voltage than the first LED devices 22.

[0043] The driving current of the third LED device 24 is four times the driving current of the first LED devices 22, or double the driving current of the second LED device 23, as the second current path merges with two more first current paths into the third current path. At the same time, due to the much longer emission wavelength, the forward voltage of the third LED device 24 is only about half the forward voltage of the first or second LED devices 22, 23.

[0044] With half the forward voltage and double the driving current, the light energy emitted by the third LED device 24 is about the same as the light energy emitted by the second LED device 23, assuming similar efficiencies, or about two times the energy emitted by each of the first LED devices 22. The total contribution of the second and third LED devices 23, 24 to the light energy emitted by the LED light source device 20 is about 4% each, while the total contribution of the first LED devices 22 is about 92%.

[0045] The total forward voltage drop between the first and second terminals 25, 26 of the circuit 100 is the sum of the forward voltages of eight first LED devices 22, the forward voltage of the second LED device 23, and the forward voltage of the third LED device 24. Accordingly, the current regulators 35 in the second group of first current paths 30' absorb the forward voltage of the third LED device 23, while the current regulators 35 in the third group of current paths absorb the forward voltage of both the second and the third LED devices 23, 24.

[0046] A further possible circuit 200 for integrating first, second, and third LED devices 22, 23, 24 is shown in Figure 5.

[0047] In the circuit 200, the number on first LED devices 22 is different in first, second, and third groups of first current paths 130, 130', 130".

[0048] In the first group of first current paths 130, each first current path 130 contains six first LED devices 22. In the second group of first current paths 130', east first current path 130' contains seven first LED devices 22. In the third group of first current paths 130", each first current path 130" contains eight first LED devices 22.

[0049] By the different number of first LED devices 22 in each of the first current paths 130, 130', 130", the forward voltages in the separate current paths are balanced, so that less differences in forward voltage has to be absorbed by current regulators 135.

[0050] In a possible modification of circuit 200, which is not shown, the first group of first current paths can each have seven first LED devices, the second group of first current paths can each have eight first LED devices, and the third group of first current paths can each have nine first LED devices. This modified circuit has the same number of first LED devices as the circuit 100, while maintaining the balanced forward voltages of circuit 200.

[0051] Yet another further possible circuit 300 for integrating first, second, and third LED devices 22, 23, 24 is shown in Figure 6.

[0052] In the third circuit 300, a first group of two first current paths 230 are connected to the first terminal 25 at their first end, and merge into a second circuit path 231 at their second end. A second group of four first current paths 230' are connected to the first terminal 25 at their first end, and merge into a third current path 232 at their second end. The second and third current paths are each connected to the second terminal 26.

[0053] Each of the first circuit paths 130, 130' Comprises a current regulator 35 and eight first LED devices 22. The second current path 231 comprises the second LED device 23, and the third current path 232 comprises the third LED device 24.

[0054] In the circuit 300, the current regulators 35 only need to absorb the difference in forward voltage between the second LED device 22 and the third LED device 24.

[0055] Figure 7 shows a circuit 400, which is a further modification of the circuit 300 shown in Figure 6. Similar to the circuit 200 shown in Figure 5, the first current paths 330 of the first group of first current paths 330 in circuit 400 comprise a smaller number of first LED devices 22 than the first current paths 230' of the second group of first current paths 230'. Again, this can reduce the difference in forward voltage which has to be absorbed by current regulators 35.

[0056] A possible structural design of a first LED device 22 is shown in Figure 8.

[0057] Figure 8 shows a two-part lead frame 500 with

a substrate 501 fixed thereto. The substrate 501 may consist of any suitable material like sapphire, resin, ceramics, or the like.

[0058] The substrate 501 comprises a cavity 502, in which a stacked semiconductor structure 503 is placed. The stacked semiconductor structure 503 is connected to the two parts of the lead frame 500 by means not shown.

[0059] A phosphor layer 504 covers the semiconductor structure 503 in the cavity, and serves for converting the wavelength of light emitted by the semiconductor structure 503 in order to emit white light. Possible phosphor combinations are known to the skilled person, and are for example disclosed in patent application US2019/0305192A1.

[0060] A possible structural design of a second or third LED device 23, 24 is shown in Figure 9.

[0061] Figure 9 again shows a two-part lead frame 600, a substrate 601 with a cavity 602, and a stacked semiconductor structure 603.

[0062] The semiconductor structure 603 is covered by a lens 605, which may comprise suitable materials like silicon. The lens 605 may be a spherical lens like shown in Fig. 9, but may also comprise aspherical portions. The lens 605 serves to shape a light beam emitted by the semiconductor structure 603, in order to meet requirements of the LED light source device 20.

Claims

1. LED light source device (20), comprising:

   a. a plurality of first LED devices (22) configured to emit white light,
   b. at least one second LED device (23) configured to emit far red light, and
   c. at least one third LED device (24) configured to emit UV light;

   wherein the plurality of first, second and third LED devices (22, 23, 24) are arranged in a circuit, the circuit comprising first and second terminals (25, 26) for connection with a single current source;
   the circuit further comprising a plurality of parallel first current paths (30, 30', 30"), each first current path (30) comprising a number of first LED devices (22) connected in series;
   a first group of first current paths (30) being arranged in series with a second current path (31), comprising at least one second LED device (23); and
   a second group of first current paths (30') being arranged in series with a third current path (32), comprising at least one third LED device (24).

2. LED light source device according to claim 1, further comprising a current regulator (35) in each of the first current paths (30, 30', 30").

3. LED light source device according to claim 1 or 2, wherein each current regulator (35) is configured to provide equal driving current.

4. LED light source device according to any of claims 1 to 3, wherein each of the first, second and third LED devices (22, 23, 24) comprises:

   a. a lead frame,
   b. a substrate being attached to the lead frame, and
   c. a stacked semiconductor structure being disposed on the substrate and being connected to the lead frame.

5. LED light source device according to claim 4, wherein each of the first LED devices (22) further comprises a phosphor layer covering the stacked semiconductor structure.

6. LED light source device according to claim 4 or 5, wherein at least one of the second and/or third LED devices (23, 24) further comprises a lens covering the stacked semiconductor structure.

7. LED light source device according to claim 6, wherein the lens comprises silicon.

8. LED light source device according to any of the previous claims, wherein a first end of each of the first current paths (30, 30', 30") is connected to the first terminal (25).

9. LED light source device according to claim 8, wherein a second end of the second group of first current paths (30') is connected to a first end of the third current path (32), and wherein a second end of the third current path (32) is connected to the second terminal (26).

10. LED light source device according to claim 9, wherein a second end of a first group of first current paths (230) is connected to a first end of the second current path (231), and a second end of the second current path (231) is connected to the second terminal (26).

11. LED light source device according to claim 10, wherein the number of first current paths (230) in the first group of first current paths (230) is smaller than the number of first current paths (230') in the second group of first current paths (230').

12. LED light source device according to claim 9, wherein a second end of the first group of first current paths (30) is connected to a first end of the second current path (31), and a second end of the second current path (31) is connected to the first end of the third current path (32).

13. LED light source device according to any of claims 9 to 12, wherein a second end of a third group of first current paths (30") is connected to the second terminal (26).

14. LED light source device according to any of the previous claims, wherein each of the first current paths (30,30',30") comprises the same number of first LED devices (22).

15. LED light source device according to claim 12 or 13, wherein the number of first LED devices (22) in each first current path (30') of the second group of first current paths (30') is greater than the number of first LED devices (22) in each first current path (30) of the first group of first current paths (30).

16. LED light source device according to claim 13, wherein the number of first LED devices (22) in each first current path (30") of the third group of first current paths (30") is greater than the number of first LED devices (22) in each first current path (30, 30') of the second or first group of first current paths (30, 30').

17. LED light source device according to any of the previous claims, wherein the number of first current paths (30, 30', 30") is 6.

18. LED light source device according to claim 11, wherein the number of first current paths (230) in the first group of first current paths (230) is 2, and wherein the number of firs current paths (230') in the second group of first current paths (230') is 4.

19. LED light source device according to claim 13, wherein the number of first current paths (30, 30', 30") in each of the first, second, and third group of first current paths (30, 30', 30") is 2.

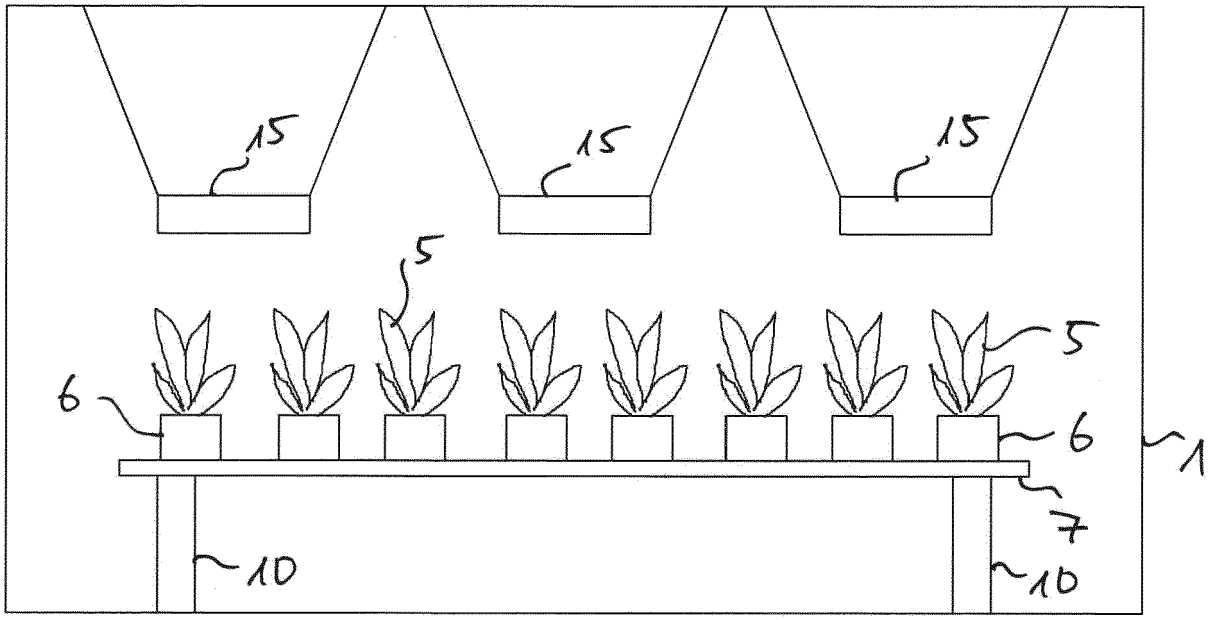

Fig. 1

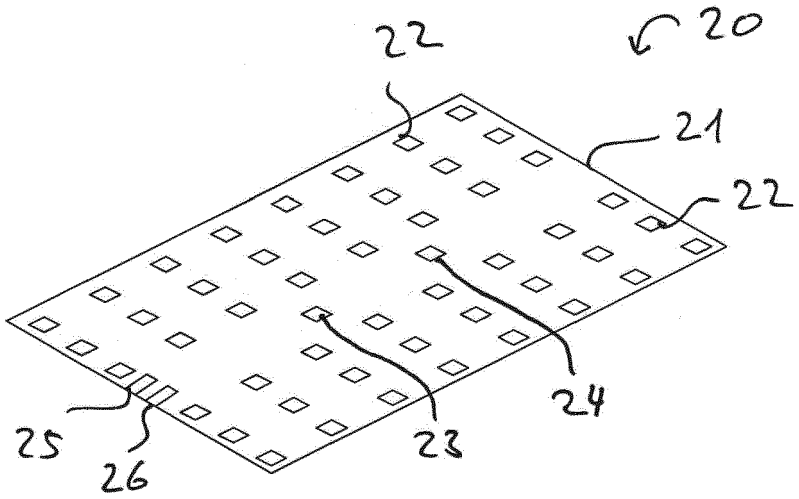

Fig. 2

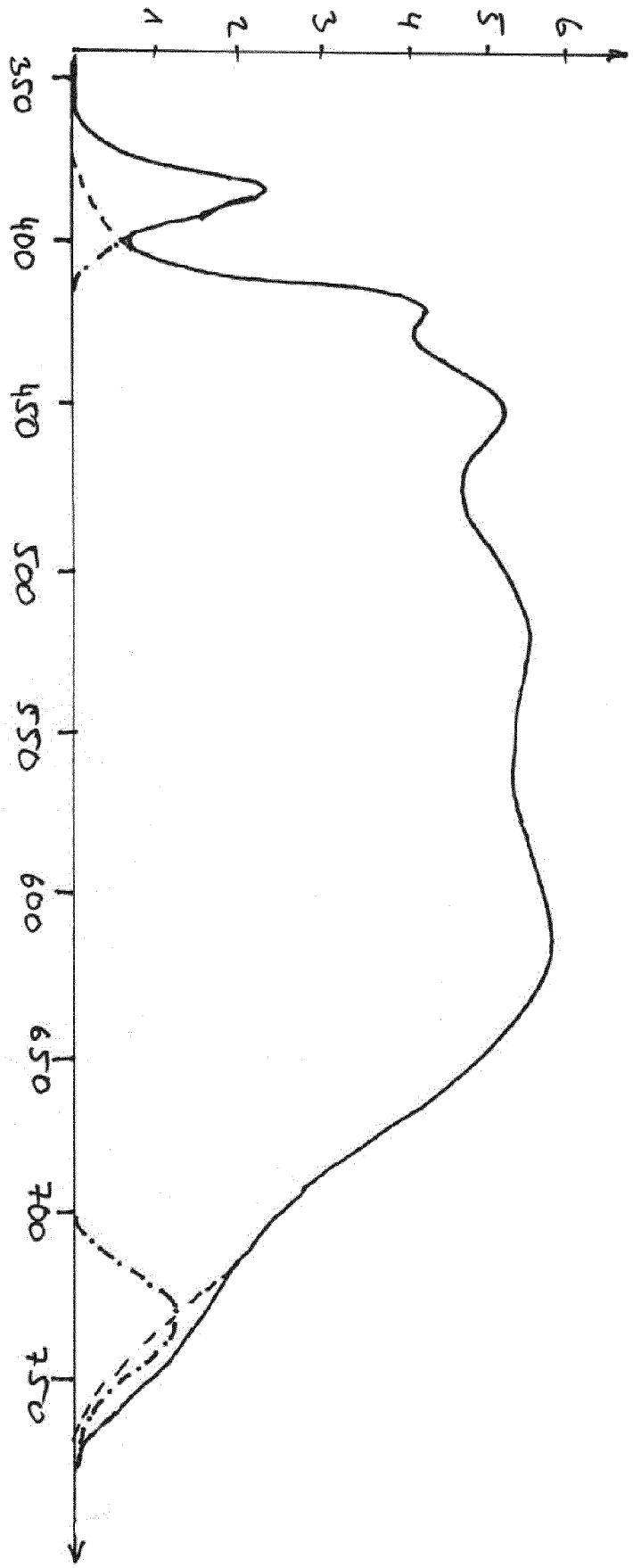

Fig. 3

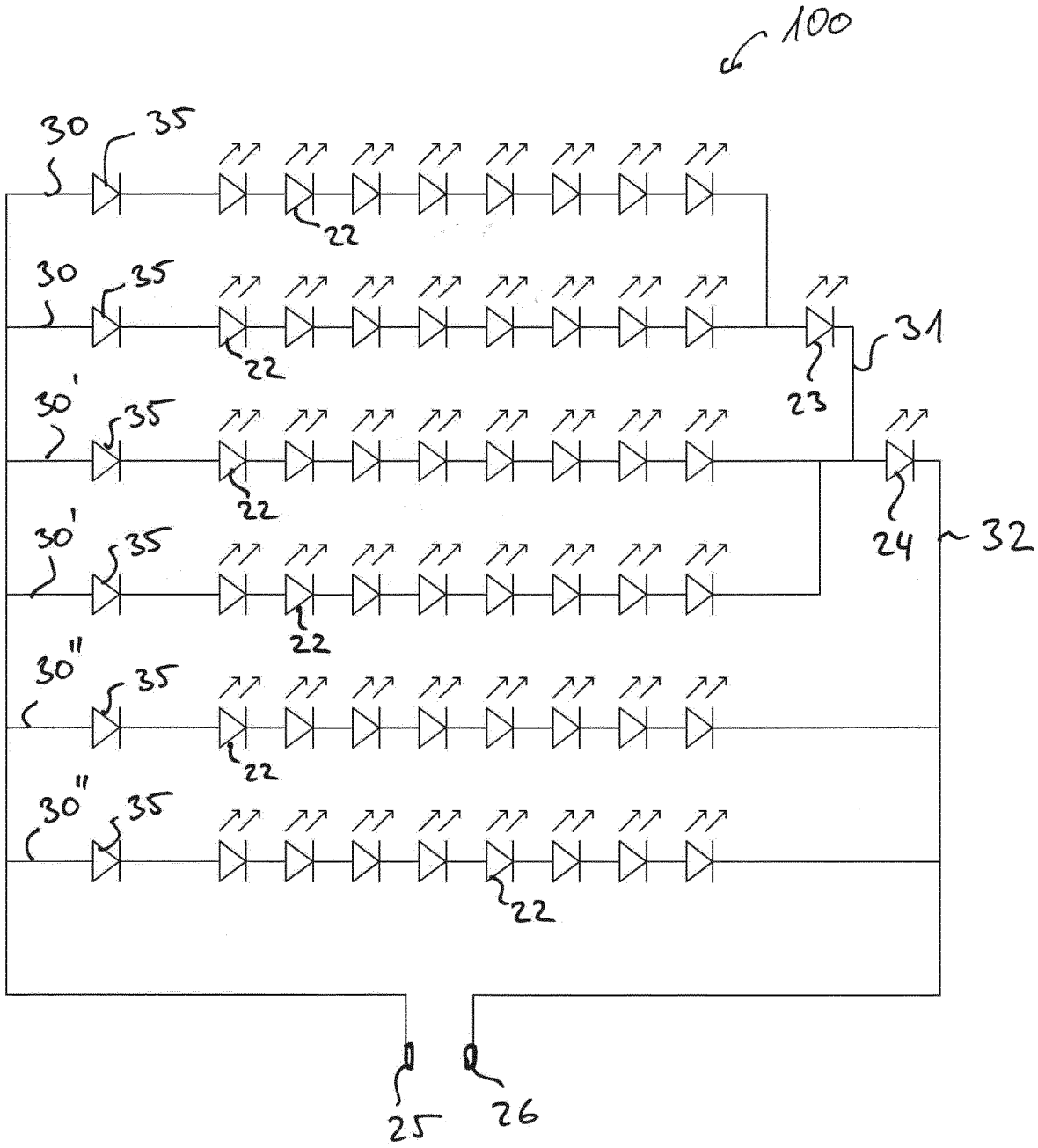
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Fig. 4

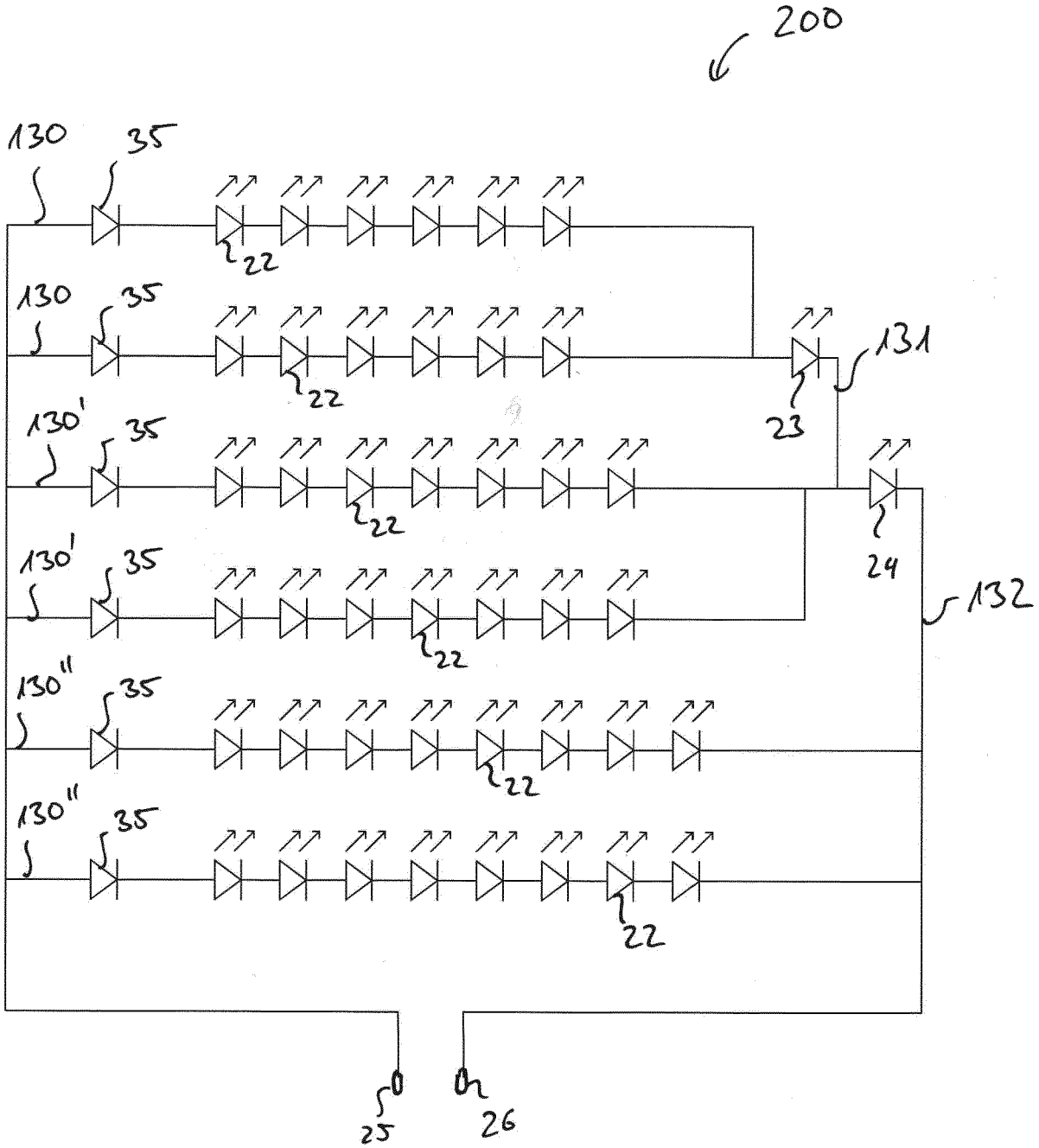
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Fig. 5

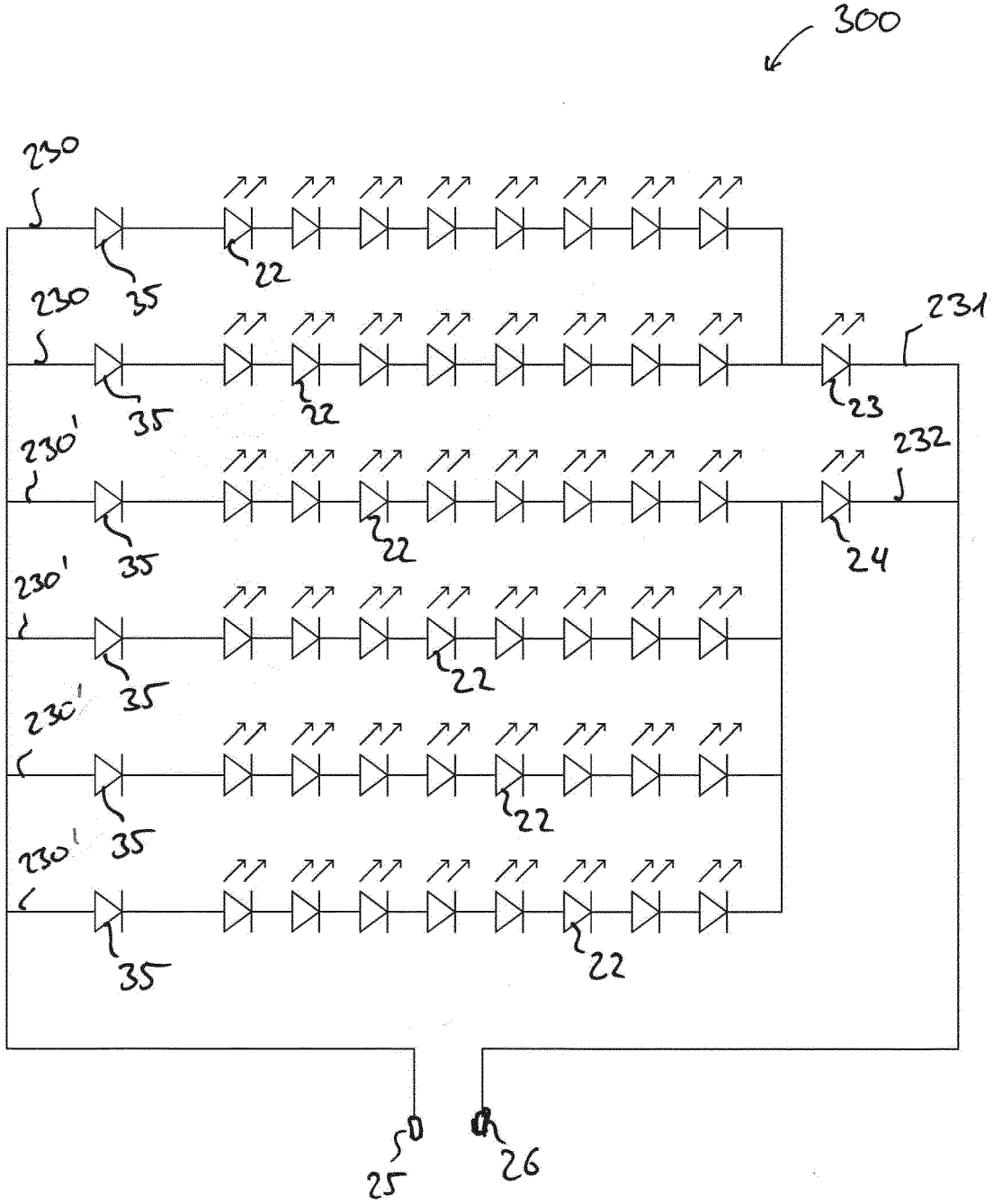
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Fig. 6

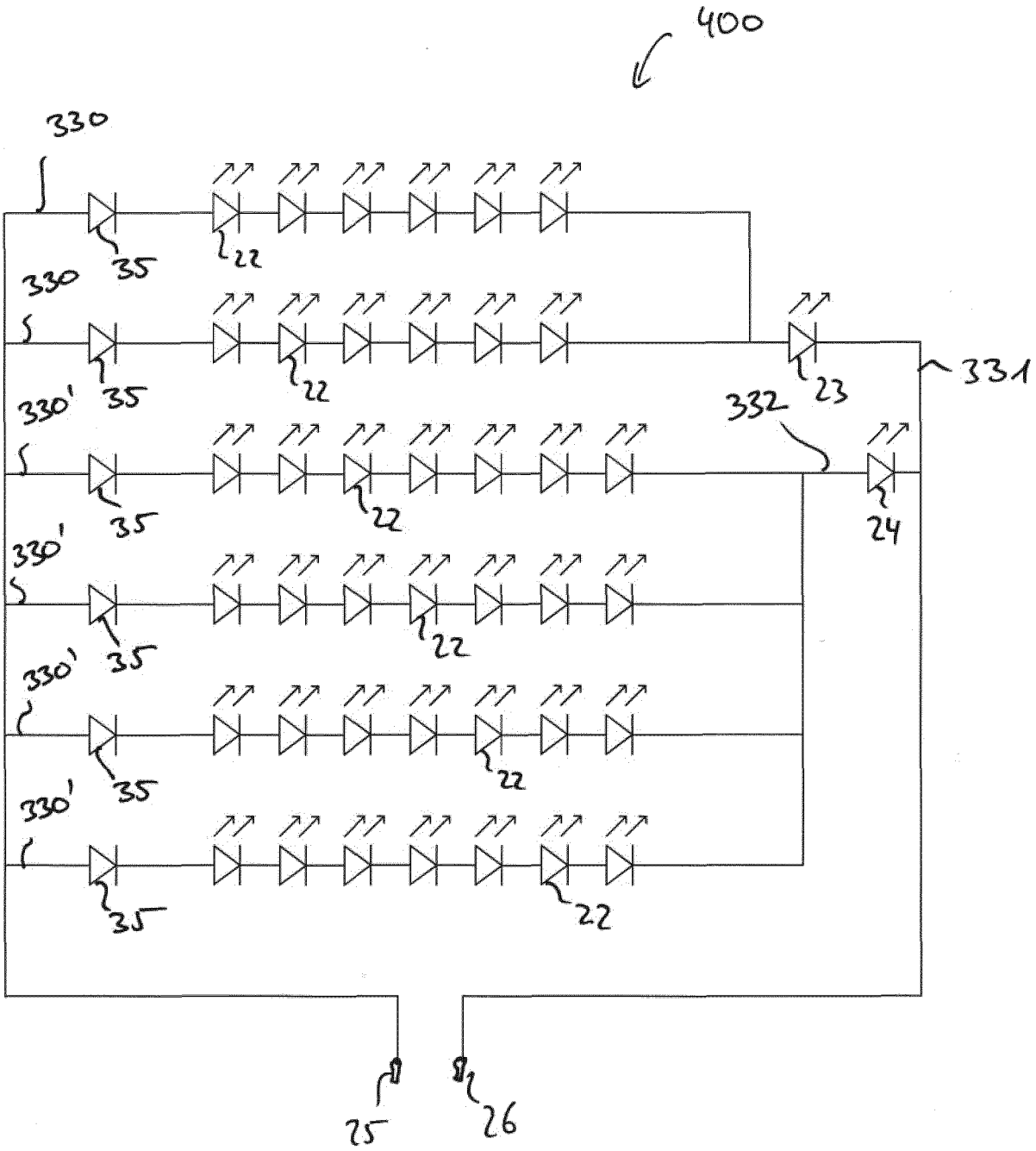
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Fig. 7

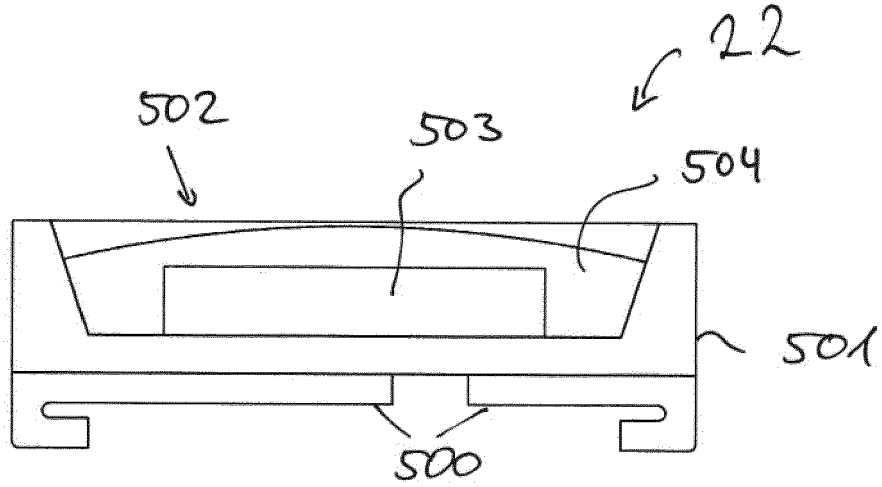

Fig. 8

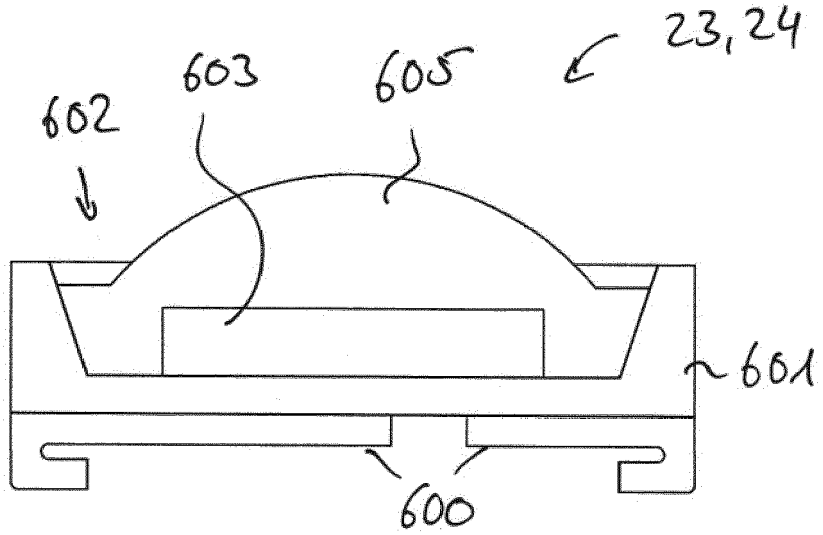

Fig. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 20 15 3197

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2011/157884 A1 (CHEN CHAO-HSING [TW] ET AL) 30 June 2011 (2011-06-30) * paragraphs [0050], [0053], [0056], [0071] - [0076]; figures 5,6B,24 *	1,8-19 2-7	INV. H05B45/40
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TECHNICAL FIELDS SEARCHED (IPC)

H05B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	16 June 2020	Henderson, Richard

CATEGORY OF CITED DOCUMENTS

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16-06-2020

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