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(54) **A LIGHTING DEVICE AND CORRESPONDING METHOD FOR CHROMATIC COMPENSATION**

(57) A lighting device (10), comprising:
 - a first light radiation source (141) emitting white light radiation with a first color temperature,
 - a second light radiation source (142) emitting white light radiation with a second color temperature, different from the first color temperature of the first light radiation source (141), and
 - a third light radiation source (143) emitting non-white

light radiation of a green color,
 The first (141), second (142) and third (143) light radiation sources, e.g. LEDs, are arranged adjacent to each other on a support member (12), with the light radiation of the first (141), second (142) and third (143) light radiation sources, which are mixed in a white mixing light radiation, having a color temperature between the first and second color temperature.

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DescriptionTechnical field

The description refers to lighting techniques

[0001] One or more embodiments may be applied to lighting devices using electrically-powered light radiation sources, for example, solid-state light radiation sources such as LED sources.

Technological background

[0002] The possibility of varying the Correlated Color Temperature (CCT) is a characteristic that can be provided in solid state light radiation sources such as LED sources.

[0003] This characteristic (in practice, the possibility of adjusting the "color" of the white light emitted from the source) can be implemented using, for example, in an LED module, two (or more) LEDs with different CCT values and then mixing the emitted light radiations, giving rise to a combined radiation having the required CCT value.

[0004] A drawback of this solution lies in the fact that the obtainable CCT points or loci are (only) those lying on the segment that connects the points corresponding to the CCTs of the LEDs used on the CIE 1931 diagram.

[0005] As is known, the CIE 1931 diagram corresponds to the color space, defined in 1931 by the Commission Internationale de l'Eclairage, which is able to include all the colors visible to the human eye.

[0006] For example, using LEDs with CCT values of 2000 K and 4000 K, respectively, it is possible to obtain a resultant CCT value equal, for example, to 3000 K. The points or loci actually obtained (for example, in the range of 2400 K to 3200 K, corresponding to that most appreciated, for example, for interior lighting applications) end up, however, deviating quite significantly from the Black Body emission curve. The resulting light, therefore, ends up assuming a pinkish hue, which is not particularly appreciated for lighting applications, especially for high quality ones.

[0007] It is also possible to resort to more sophisticated solutions for adjusting or tuning the white light (TW) or to trichromatic schemes of the RGB type similar to those used, for example, for decorative purposes.

[0008] Solutions of this type end up, however, being fairly expensive and complex, also because they may require the use of e.g. five independent channels for generating respective chromatic components, with these channels designed to be driven in correspondingly different ways.

Object and summary

[0009] One or more embodiments aim to provide solutions for compensating the correlated color tempera-

ture (CCT) that are able to overcome the drawbacks outlined above.

[0010] According to one or more embodiments, this object can be achieved thanks to a device having the characteristics referred to in the following claims.

[0011] One or more embodiments may concern a corresponding method.

[0012] The claims form an integral part of the technical disclosure provided here in relation to the embodiments.

[0013] One or more embodiments may make it possible to achieve one or more of the following advantages:

- possibility of producing, for example, LED lighting modules capable of emitting white light radiation with the possibility of adjusting the CCT following the emission curve in the black body over virtually the entire adjustment range;
- possibility of producing high quality lighting modules, for example LED lighting modules, which can be appreciated by designers and architects;
- possibility of producing the color compensation in a simple way by providing, for example, the regulation of three generators/channels: one that emits "warm" white light, another that emits "cold" white light, and a third that operates in the green field; all this giving rise to a system that is compatible with current RGB controllers without requiring the development of special controllers, for example, with four or five channels, such as those provided for RGB-WO and RGB-TW applications;
- reduction of costs compared to RGB-TW modules for achieving a white color compensation function that can be easily achieved with a "small" LED operating in the green region, therefore, with low costs compared to an RGB LED system;
- applicability both to modules with constant voltage drive and to modules with constant current drive;
- possibility of improving the characteristics of the emitted light radiation, for example, at high emission levels, even without pursuing a complete adaptation to the emission curve of the black body;
- possibility of creating simplified solutions that do not require an additional compensation channel, intervening only on the drive modes of a standard module and/or in order to be compatible with dimming functions.

Brief description of the attached figures

[0014] One or more embodiments will be now described, purely by way of non-limiting example, with reference to the attached figures, wherein:

- Figure 1 exemplifies an operating principle which can be adopted in one or more embodiments,
- Figures 2 and 3 illustrate, with reference to the CIE 1931 diagram, possible operation modes of embodiments,

- Figures 4 and 5 exemplify possible operating conditions of embodiments,
- Figure 6 exemplifies a possible implementation of embodiments, with Figure 7 representing a possible implementation at the circuit level,
- Figure 8 exemplifies a possible implementation of embodiments, with Figure 9 representing a possible implementation at the circuit level,
- Figure 10 is an additional exemplary diagram of a possible application context of embodiments,
- Figure 11 exemplifies a possible circuitual implementation of embodiments that can be used in the context presented in Figure 10, and
- Figure 12 exemplifies possible operation modes of embodiments as exemplified in Figure 11.

Detailed description

[0015] The following description illustrates various specific details in order to provide a thorough understanding of various examples of embodiments according to the description. The embodiments can be obtained without one or more of the specific details, or with other methods, components, materials, etc. In other cases, known structures materials or operations are not illustrated or described in detail so that the various aspects of the embodiments and not rendered unclear.

[0016] The reference to "an embodiment" in the context of the present description indicates that a particular configuration, structure or characteristic described in relation to the embodiment is included in at least one embodiment. Thus, sentences such as "in an embodiment", which may be present at various points in the present description, do not necessarily refer to exactly the same embodiment. Moreover, particular configurations, structures or characteristics can be combined in any suitable way in one or more embodiments.

[0017] The references used here are provided simply for convenience and therefore do not define the field of protection or scope of the embodiments.

[0018] In Figure 1, reference 10 indicates a lighting device comprising electrically-powered light radiation sources.

[0019] One or more embodiments may concern solid-state light radiation sources such as LED sources (to which constant reference will be made in the following present description for illustrative simplicity and without limiting intent).

[0020] According to criteria known in the art, as adopted, for example, in the production of the LED lighting modules called "flex" modules, the device 10 may comprise a substrate 12 (substantially similar to a Printed Circuit Board - PCB) of a planar shape, for example, elongated and ribbon-like.

[0021] Light radiation sources are arranged on the substrate 12, which can be mounted on the substrate with known techniques (for example with surface-mount technology techniques).

[0022] In the example presented in Figure 1 (relative to a module 10 which, in itself, can be seen as an elongated element of indefinite length), there are several sources (for example three: this is, of course, a purely exemplary value) with each of the three light radiation sources visible in Figure 1 comprising - in turn - a group of light radiation generators, e.g. LEDs arranged adjacent to each other with:

- a first light radiation generator 141 which emits radiation with a "high" correlated color temperature (for example 4000 K), thus a "cold" white light radiation,
- a second light radiation generator 142 which emits radiation with a "low" correlated color temperature (for example 2000 K), thus a "warm" white light radiation,

[0023] It will be appreciated, however, that the definitions "high" and "low" are to be understood in a relative sense (in the sense that a temperature of 4000 K is higher than a temperature of 2000 K). Likewise, the reference to "cold" or "warm" white light is essentially qualitative.

[0024] In one or more embodiments, in addition to the first two generators 141, 142, the (or each) group of generators visible in the figures also comprises a third light radiation generator 143 which emits light in the green region, and which is assigned a compensation function of the CCT of the light radiation resulting from mixing of the light radiations emitted by the generators 141, 142 and 143 as a consequence, for example, of the fact that the generators 141, 142 and 143 are arranged adjacent to each other.

[0025] For example, the generator 143 can be a (small) LED generator interposed or placed on the support 12 between the generators 141 and 142 so that the radiations emitted by the generators 141, 142 and 143 are mixed together.

[0026] The diagram of Figure 2 exemplifies a possible solution in which the light radiations emitted by the sources 141, 142 and 143 correspond to three points of the CIE 1931 colorimetric diagram indicated, for simplicity, with the same numerical references.

[0027] Operating according to criteria widely used in driving light radiation sources, including light radiation generators, for example LEDs, with light emissions in different fields (i.e. around different wavelengths), it is possible to drive the generators 141, 142 and 143 by means of respective drive signals sent, respectively, on three channels indicated with CW - "cold" light, WW - "warm" light and CC - compensation of the CCT - in order to vary the color point corresponding to the light radiation resulting from the mixing of the emitted light radiations from the sources of the generators 141, 142, 142.

[0028] As exemplified in Figures 2 and 3, thanks to the presence of the third generator 143, it is possible to ensure that the color point corresponding to the light radiation resulting from mixing the light radiations emitted by the sources of the generators 141, 142, 142 can be

placed on the CIE 1931 colorimetric diagram:

- not only on the segment connecting the points indicated with 141 and 142, deviating from the emission curve of the black body, represented by the BB curve passing through points 141 and 142, as would occur if there were only generators of the first type and of the second type, namely 141 and 142,
- but also at the curve BB, for example, at a point corresponding to the MacAdam ellipse - indicated with A in Figure 2 - and corresponding to a point having a color temperature (CCT) of 3000 K lying on the emission curve of the black body.

[0029] Figure 3 exemplifies the possibility (feasible by adjusting the relative intensities of the emissions of the generators 141, 142 and 143 - for example by intervening on the PWM drive modes of the generators) to move the point corresponding to the light radiation deriving from mixing the light radiations of the three generators 141, 142 and 143 at virtually any point of the curve BB between the points indicated with 141 and 142. In this way, it is possible to "cover" practically the entire CCT range between 2000 K and 4000 K, remaining at the BB curve.

[0030] The diagrams of Figures 4 and 5 exemplify the possibility of obtaining this result by adjusting the intensities:

- of the radiation emitted by the generator 141 (continuous line),
- of the radiation emitted by the generator 142 (dotted and dashed line),
- of the radiation emitted by the generator 143 (dashed line with two dots),

[0031] In particular, the diagrams of Figures 4 and 5 show a common x-axis scale quoted in CCT values (in degrees Kelvin or K), instead reporting on the y-axis:

- in Figure 4: the output level percentage OL% of the various generators, and
- in Figure 5: the relative normalized output level NOL.

[0032] Observing these figures, it can be seen how the compensation contribution of the generator 143, which is relevant in terms of the normalized level, can be fairly contained at a percentage level (with reference to a constant output flow).

[0033] Figures 6 and 7 exemplify the possibility of applying the solution presented in general terms with reference to Figure 1 to a lighting device 10 with driving of the generators 141, 142 and 143 "at constant voltage".

[0034] Once again, a device 10 can be considered of the type exemplified above with reference to Figure 1. For this reason, in Figures 6 and 7 (and successive figures) parts or elements already presented discussing Figures 1 to 5 are indicated with the same references, without repeating them here in the detailed description,

for brevity.

[0035] As exemplified in Figure 6, in a constant voltage drive solution, the lines CW (cold light), WW (warm light) and CC (CCT compensation) as well as a general LED+ power supply line can be connected to a controller 14.

[0036] This may be, for example, a three-channel PWM controller 14 supplied between a power supply voltage $+V_{CC}$ and a ground line GND.

[0037] Figure 7 illustrates a possible circuitry configuration in which the various generators 141 (cold light), 142 (warm light) and 143 (compensation) can be arranged (according to criteria known per se) in strings of generators connected in series with each other, which are associated with respective current regulators 1410, 1420 and 1430 interposed (therefore connected in series) with the generators of the respective strings.

[0038] The required CCT value for the light radiation resulting from the mixing can be achieved (with the corresponding compensation action carried out by the generators 143) by operating - according to criteria known per se - on the controller 14, which is able to perform a PWM modulation function of the current on the three channels operating, for example, between the LED+ terminal (common to the three channels) and with the three lines - WW, CW and CC - selectively connected to a reference value (conventionally definable as LED-) with required duty-cycle values so as to regulate the emission of each group of generators 141, 142 and 143 according to methods substantially corresponding to those exemplified by the diagrams of Figures 4 and 5.

[0039] A solution, as exemplified in Figures 6 and 7, lends itself to being implemented both in the form of a source concentrated on a single board 12, for example, PCB, so as to act as a localized "light engine", or in the form of a modular type source, for example, of elongated, rigid or flexible shape, for example, in the form of a so-called LED strip.

[0040] Figures 8 and 9 exemplify a so-to-speak "dual" solution, with "constant current" drive. Once again, in Figures 8 and 9 (and successive figures), parts or elements already presented discussing the previous figures are indicated with the same references, without repeating them here in the detailed description, for brevity.

[0041] Also in this case, the light radiation generators 141, 142 and 143 can be arranged in strings with a common LED- terminal (see, for example, Figure 9) supplied, for example, by a drive unit once again indicated with 14.

[0042] In embodiments as exemplified in Figures 8 and 9, the drive function can be implemented by means of a constant current driver CC or by an output of a constant current multichannel LED driver.

[0043] In this case, achieving a required CCT value, with color compensation obtained by the generators 143 operating in the green region, can be implemented with a corresponding current regulation for each group of generators 141, 142 and 143.

[0044] Figure 8 exemplifies the possible implementation of the device 10 in the form of a so-called light engine

mounted on a single board (for example, PCB) 12, which is a solution frequently used in combination with a constant current drive.

[0045] However, in this case as well, it is possible to implement different construction forms, for example, by using flexible LED modules.

[0046] For example, in this case, it is possible to connect several strings in parallel for each type of generator (141, 142 and 143). All this has the possibility of providing balancing elements of the current (for example, resistors, PTC thermistors or similar components), for example, in series with the generators 141, 142 and 143, in order to facilitate correct distribution of the current on the various strings of generators.

[0047] Figures 10 to 12 exemplify the possibility of resorting to a solution according to one or more embodiments in a context such as that described in the Italian patent application no. 102017000095581 assigned to the same Assignees of the present application and not yet accessible to the public at the time of filing the present application.

[0048] This solution envisages the use of a first and a second set of light radiation generators having a "high" CCT (for example 4000 K, as in the example here referring to generators 141) and a lower CCT (for example 2000 K, as in the example here referring to generators 141), respectively.

[0049] This solution aims to implement a "warm" dimming mechanism, for example, in the context of an LED module powered by constant voltage, for example, between LED+ and LED- voltages (see the diagram in Figure 11).

[0050] In such a solution, starting from a condition in which the two strings of generators (respectively of "cold" light 141 and "warm" light 142) are operated with a dimming level equal to 100% - which conventionally corresponds to the fact that both sets of generators emit their maximum light flux - it is possible to implement a dimming function going from 100% (point indicated with SL in the diagram of Figure 10) to a minimum level of light flux moving towards point 142, with the string(s) of light generators with higher CCT ("cold" light) subjected to more rapid dimming than generators with lower CCT ("warm" light), giving rise to an effect of warm dimming, driven by a turn-on delay circuit 16. The action of the circuit 16 causes the generators 141 to be turned on "late", and end up having a lower duty-cycle, emitting less radiation and being dimmed to a greater extent with respect to the generators 142.

[0051] Still referring to the CIE 1931 diagram, this operation mode corresponds to implementing the aforesaid warm-dimming action starting from the initial point SL of Figure 10, that is to say, a point on the segment which connects points 141 and 142, at a certain distance from the curve of the black body BB, thus giving rise, in particular around temperature values in the order of 3000 K, to the effect of pinkish light at the highest brightness levels. An effect that, as already mentioned above, may

not be appreciated for various applications.

[0052] In the diagram of Figure 11 as well (substantially similar to the diagram of Figure 7, of which in Figure 11 for the sake of simplicity, the same numerical references for indicating parts and elements already described are reported), it is possible to introduce a light radiation source (for example, a string of generators 143) operating in the green region, and capable of performing a color temperature compensation action, which is completely similar to that described above.

[0053] For example, this can occur according to the modes shown in Figure 12 where it can be seen that, by operating on the string of compensation generators 143 (capable of being driven by the same turn-on delay circuit 16, intended to drive the radiation generators 141), it is possible to move the starting point of the warm dimming action from the point SL, exemplified in Figure 10, to the point SL' of Figure 12, i.e. to a point located on the curve of the black body BB.

[0054] This is all carried out by modalities substantially similar to those described above (for example, with reference to Figures 3 to 5), for example, by fixing the output level of the compensation radiation generators 143 at an light flux output level equal to approximately 8% of the light flux output level of the generators 141 (i.e. those with higher CCT values).

[0055] In this way, the warm-dimming action can take place along a segment (the one connecting the point SL' with the point 142 in Figure 12) which, although in itself does not strictly follow the curve of the black body BB, is able to prevent the negative effects described above (pinkish light) in consideration of the fact that the segment that goes from the point SL' to the point 142 is closer to the curve of the black body BB compared to the segment that goes from the point SL to point 142.

[0056] At least in principle, one could think of implementing a more refined compensation action in this case, by operating on the compensation generator(s) 143 so as to cause the warm-dimming action to exactly follow the curve of the black body.

[0057] However, even the "approximate" operation mode exemplified in Figure 12 makes it possible to achieve various advantages, such as one or more of the following advantages:

- improvement of the quality of the output brightness at high light flux levels (for example for CCTs above 2700 K);
- reduction of the pinkish light effect in the intermediate portion of the CCT range: e.g. it has been verified that the distance between the places or loci of the CCT arranged on the segment that goes from the point SL' to the point 142 and the curve of the black body BB is always lower than three steps or ellipses of MacAdam;
- possibility of implementing the exemplified solution in Figure 11 without adding additional channels in the LED module: from the user's point of view, the

module in question can continue to have the normal LED+ and LED- terminals for power supply application with PWM modulation (see, for example, the diagram of Figure 7).

[0058] A lighting device (e.g. 10) according to one or more embodiments may comprise:

- a first light radiation source (e.g. 141) emitting white light radiation with a first color temperature (e.g. CCT),
- a second light radiation source (e.g. 142) emitting white light radiation with a second color temperature (e.g. CCT), different from the first color temperature of the first light radiation source, and
- a third light radiation source (e.g. 143) emitting non-white light radiation of a green color,
- the first, second and third light radiation sources arranged on a support member (e.g. a PCB 12) wherein light radiation emitted from the lighting device (10) is mixed light radiation from the first, second and third light radiation sources having a color temperature (e.g. 3000 K) between the first color temperature of the first light radiation source (e.g. 4000 K) and the second color temperature of the second light radiation source (e.g. 2000 K).

[0059] One or more embodiments may comprise a plurality of groups of light radiation sources, with each group in the plurality of groups comprising at least one said first light radiation source, at least one said second light radiation source and at least one said third light radiation source.

[0060] One or more embodiments may comprise:

- a plurality of said first light radiation sources,
- a plurality of said second light radiation sources, and
- a plurality of said third light radiation sources.

[0061] In one or more embodiments, said plurality of light radiation sources may comprise:

- an equal number of first light radiation sources, second light radiation sources and third light radiation sources, and/or
- strings of electrically-powered light radiation sources comprising light radiation sources arranged electrically in series.

[0062] In one or more embodiments:

- the light radiation sources may comprise electrically-powered light radiation sources, wherein the emitted light flux is selectively variable as a function of the voltage and/or current applied thereto (e.g. with constant voltage supply - see, for example, Figures 6 and 7 - or with constant current supply - see, for example, Figures 8 and 9),

- a driver circuit (e.g. 14) can be provided coupled to the light radiation sources to selectively vary the light flux of the light radiation sources by varying the voltage and/or current applied thereto.

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[0063] In one or more embodiments, the driver circuit can be configured for:

- supplying the light radiation sources with pulse width modulated signals having a variable duty-cycle, and
- reducing (with a dimming action) the light radiation emitted from the light radiation sources by reducing the duty-cycle of said pulse width modulated signals from an upper value (see, for example, point SL' in Figure 12) to a lower value (see, for example, point 142 in Figure 12) by keeping the duty-cycle of the supply signals to the first and third radiation sources smaller than the duty-cycle of the supply signal to the second light radiation source (e.g. with the delay circuit 16 of Figure 11).

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[0064] In one or more embodiments, said second color temperature can be lower than said first color temperature (e.g. 2000 K relative to 4000 K).

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[0065] In one or more embodiments said light radiation sources may comprise solid-state light radiation generators, optionally LED generators.

[0066] In one or more embodiments, a method for generating light radiation may comprise:

- generating a first white light radiation with a first color temperature,
- generating a second white light radiation with a second color temperature different from the first color temperature of the first light radiation,
- generating a third non-white light radiation of green color, and
- mixing the first, second and third light radiations (e.g. putting the relative sources close to each other), generating a mixed light radiation with a color temperature between the first and the second color temperatures.

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[0067] One or more embodiments may envisage adjusting the intensity of the third light radiation of green color by moving the color point of the mixed light radiation in the CIE 1931 diagram onto the black body emission curve (e.g. BB).

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[0068] Without prejudice to the underlying principles of the invention, the details of construction and the embodiments may vary, even significantly, with respect to those illustrated here, purely by way of non-limiting example, without departing from the scope of the invention.

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[0069] The scope of protection is determined by the attached claims.

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LIST OF REFERENCE SIGNS

Lighting device	10
Support member	12
First light radiation sources	141
Second light radiation sources	142
Third light radiation sources	143
Cold light	CW
Warm light	WW
Compensation of the temperature	CC
MacAdam ellipse	A
Emission curve of the black body	BB

Claims**1.** A lighting device (10), comprising:

- a first light radiation source (141) emitting white light radiation with a first color temperature,
- a second light radiation source (142) emitting white light radiation with a second color temperature, different from the first color temperature of the first light radiation source (141), and
- a third light radiation source (143) emitting non-white light radiation of a green color,
- the first (141), second (142) and third (143) light radiation sources arranged on a support member (12) wherein light radiation emitted from the lighting device (10) is mixed light radiation from the first (141), second (142) and third (143) light radiation sources having a color temperature between the first color temperature of the first light radiation source (141) and the second color temperature of the second light radiation source (142).

2. The lighting device (10) of claim 1, comprising a plurality of groups of light radiation sources, with each group in the plurality of groups comprising at least one said first light radiation source (141), at least one said second light radiation source (142) and at least one said third light radiation source (143).**3.** The lighting device (10) of claim 1 or claim 2, comprising:

- a plurality of said first light radiation sources (141),
- a plurality of said second light radiation sources (142), and
- a plurality of said third light radiation sources (143).

4. The lighting device (10) of claim 3, wherein said pluralities of light radiation sources (141, 142, 143) comprise:

- an equal number of first light radiation sources (141), second light radiation sources (142) and third light radiation sources (143), and/or
- strings of electrically-powered light radiation sources (141, 142, 143) comprising light radiation sources (141, 142, 143) arranged electrically in series.

5. The lighting device (10) of any of the previous claims, wherein:

- the light radiation sources (141, 142, 143) comprise electrically-powered light radiation sources wherein the emitted light flux is selectively variable as a function of the voltage and/or current applied thereto,
- a driver circuit (14) is provided coupled to the light radiation sources (141, 142, 143) to selectively vary the light flux of the light radiation sources (141, 142, 143) by varying the voltage and/or current applied thereto.

6. The lighting device (10) of claim 5, wherein the driver circuit (14) is configured to:

- supply the light radiation sources (141, 142, 143) with pulse width modulated signals having a variable duty-cycle, and
- perform dimming of light radiation from the light radiation sources (141, 142, 143) by reducing the duty-cycle of said pulse width modulated signals from an upper to a lower value by keeping the duty-cycle of the supply signals to the first (141) and third (143) radiation sources smaller than the duty-cycle of the supply signal to the second (142) light radiation source.

7. The lighting device (10) of any of the previous claims, wherein said second color temperature is lower than said first color temperature.**8.** The lighting device (10) of any of the previous claims, wherein said light radiation sources (141, 142, 143) comprise solid-state, preferably LED, light radiation generators.**9.** A method for generating light radiation, the method comprising:

- generating a first white light radiation with (141) a first color temperature,
- generating a second white light radiation with (142) a second color temperature different from the first color temperature of the first light radiation (141),
- generating a third non-white light radiation (143) of green color, and
- mixing the first (141), second (142) and third

(143) light radiations, generating a mixed light radiation with a color temperature between the first and the second color temperatures.

10. The method of claim 9, comprising adjusting the intensity of the third light radiation of green color (143) by moving the color point of the mixed light radiation in the CIE 1931 diagram onto the black body emission curve (BB).

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FIG. 1

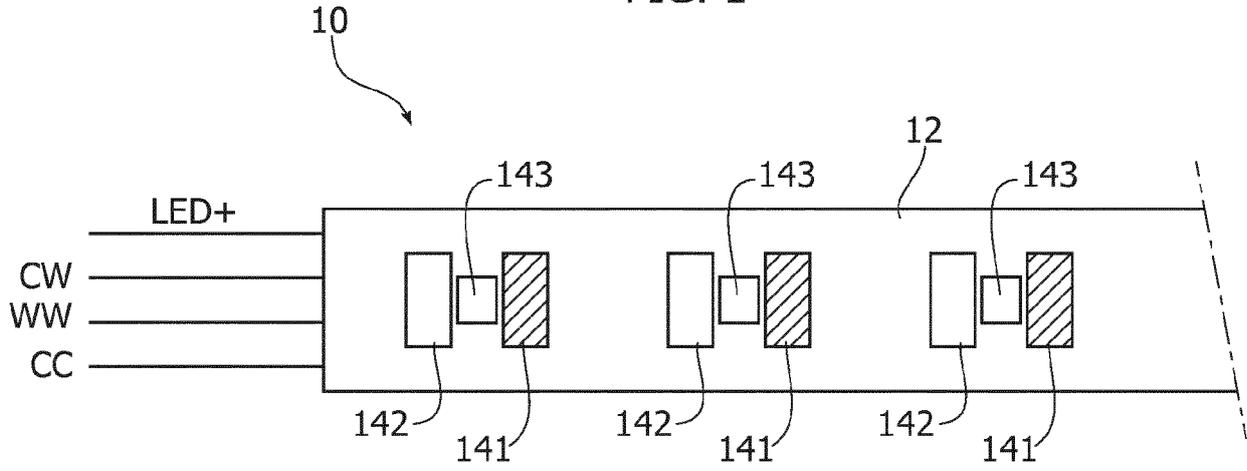
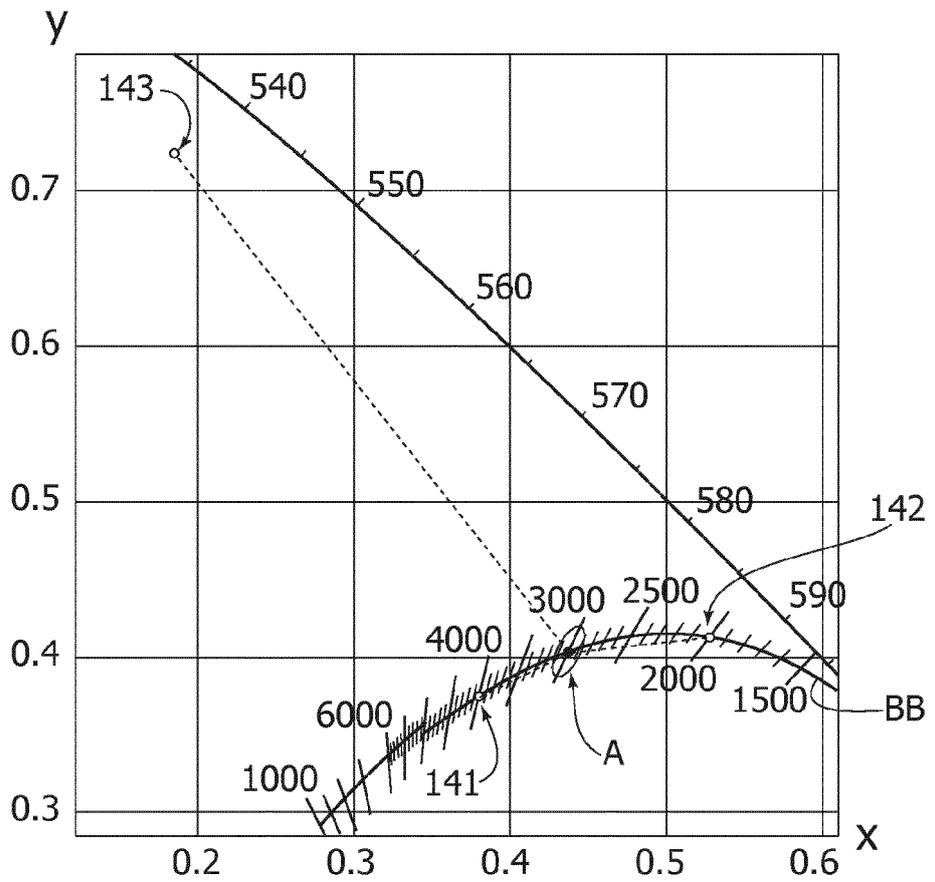


FIG. 2



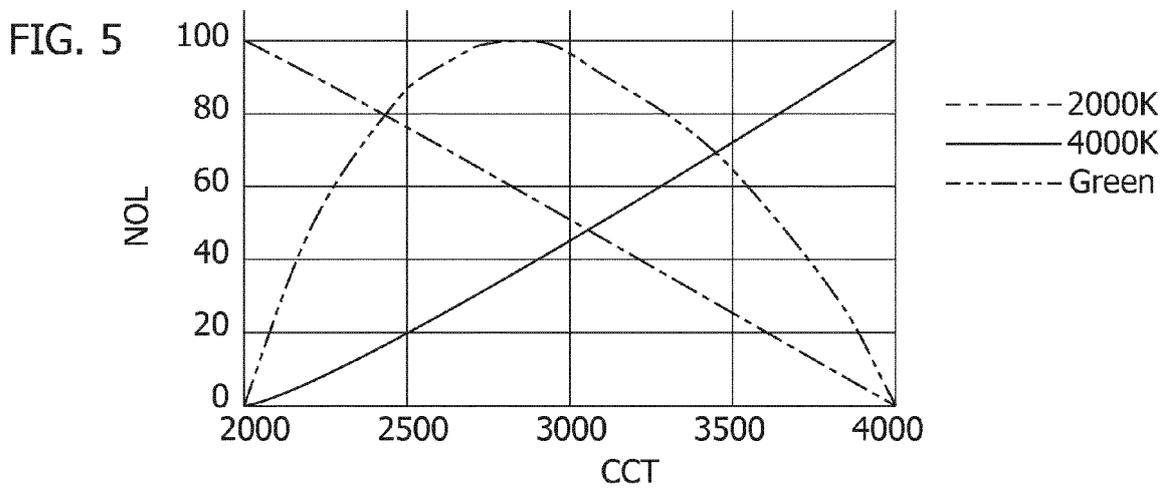
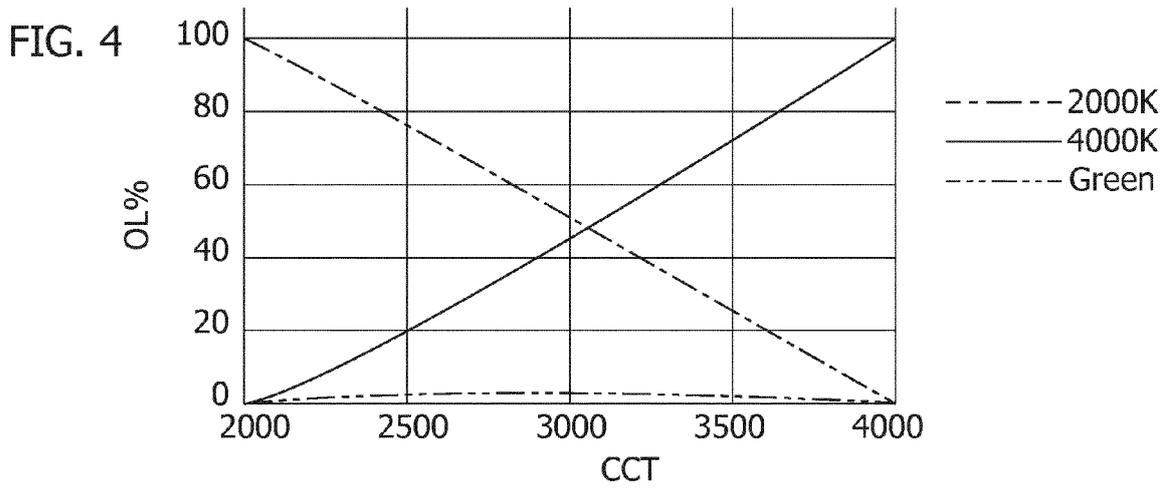
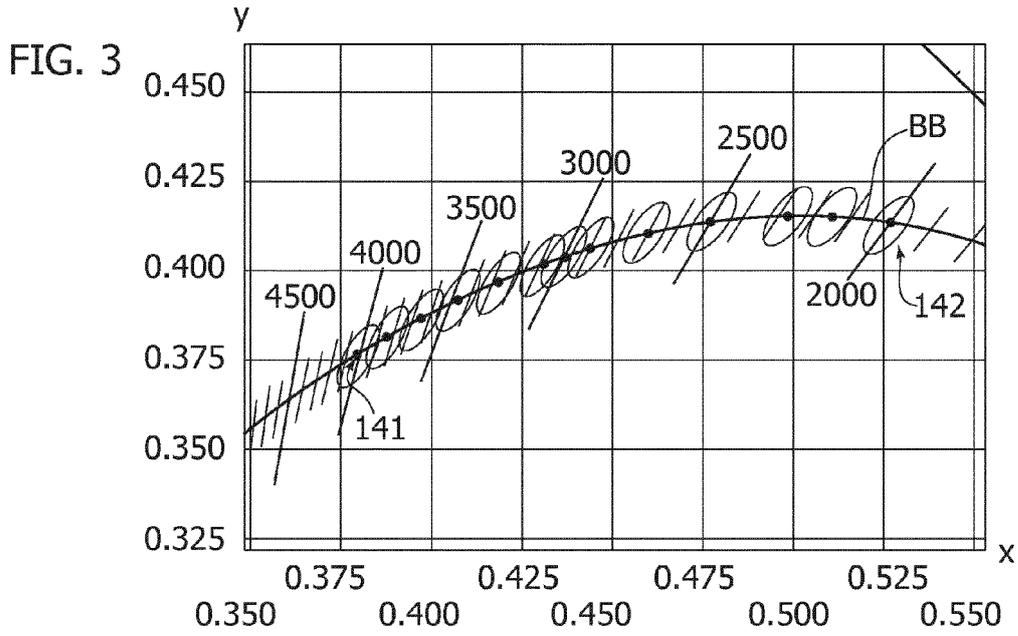


FIG. 6

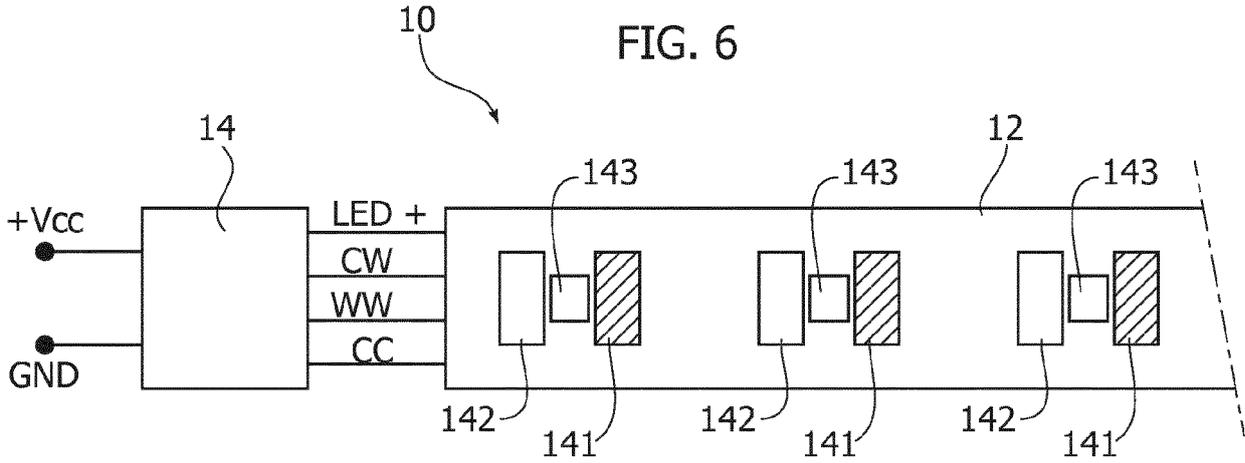


FIG. 7

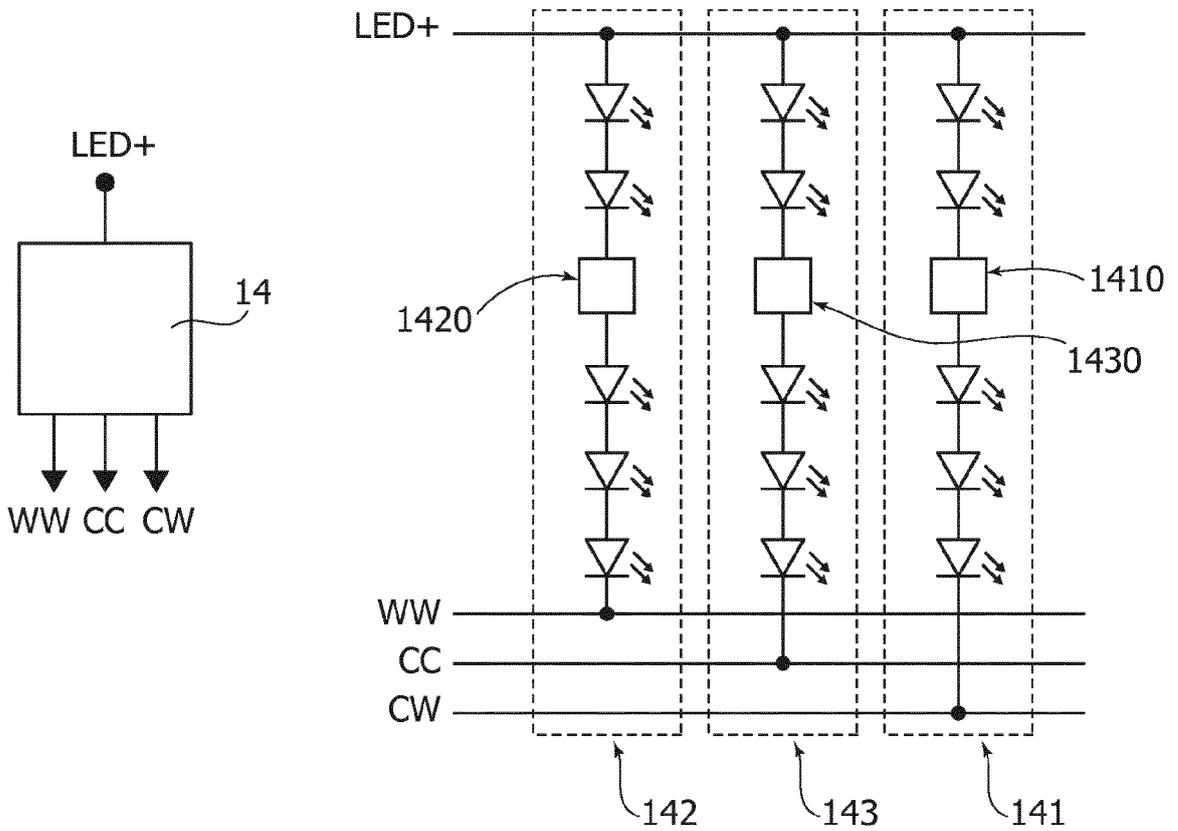


FIG. 8

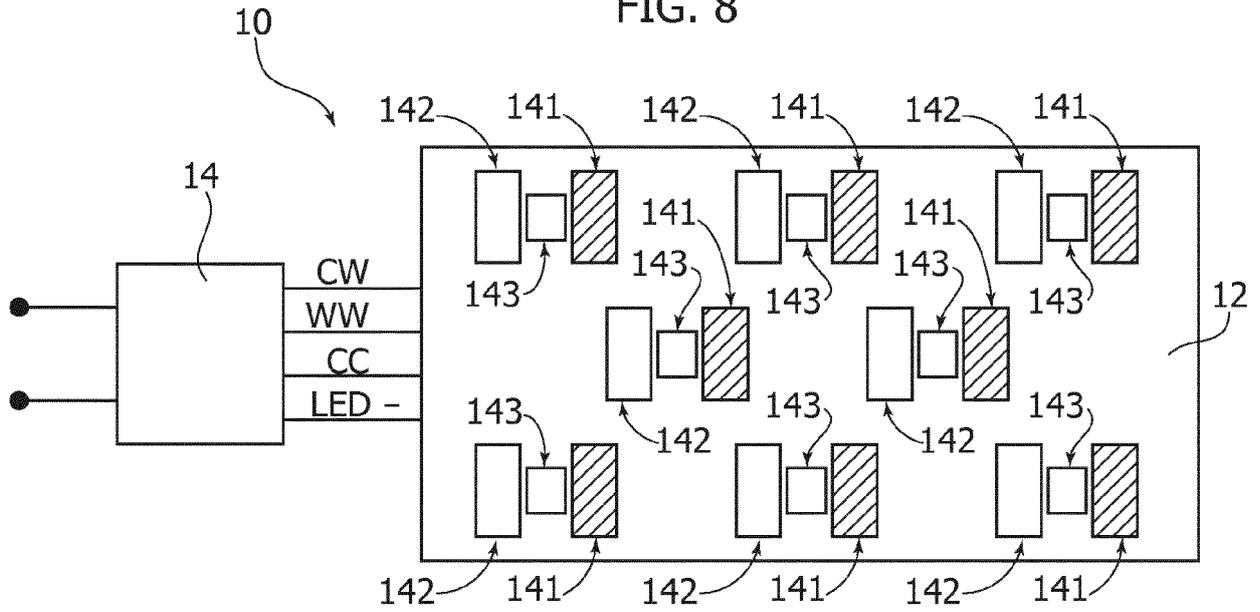


FIG. 9

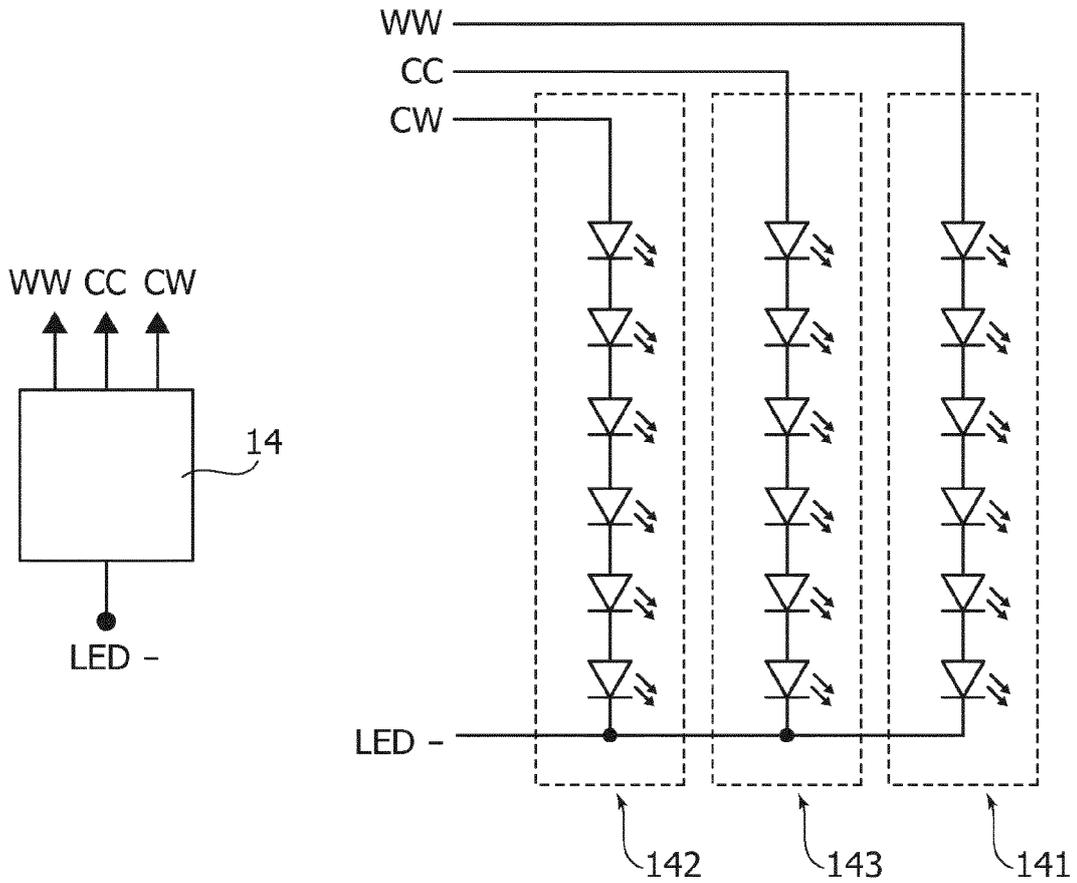


FIG. 10

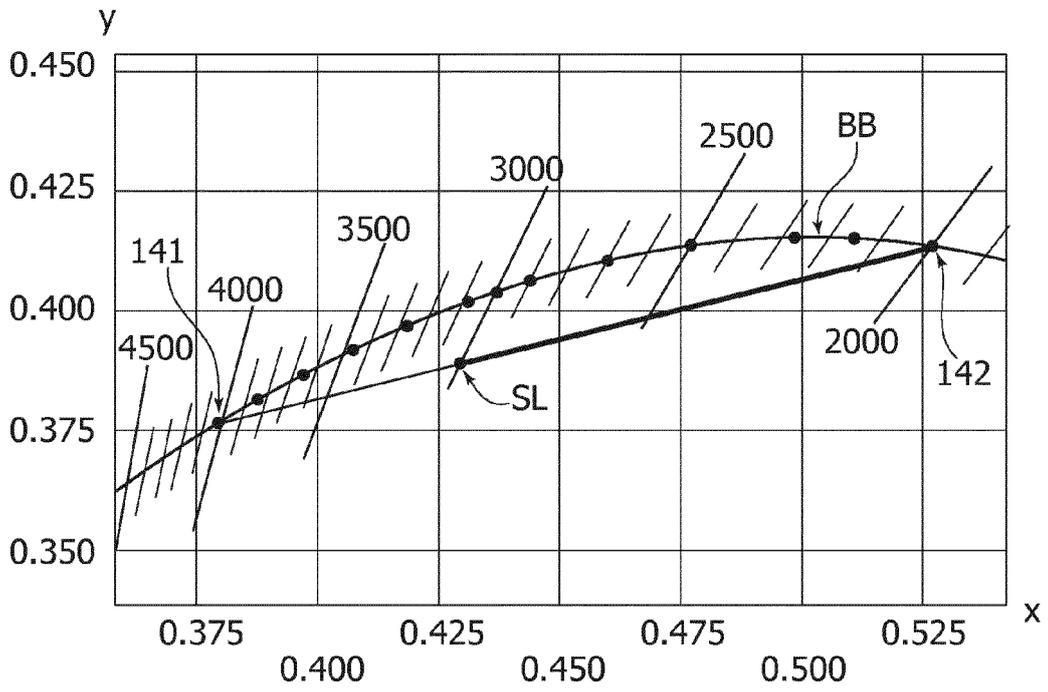


FIG. 11

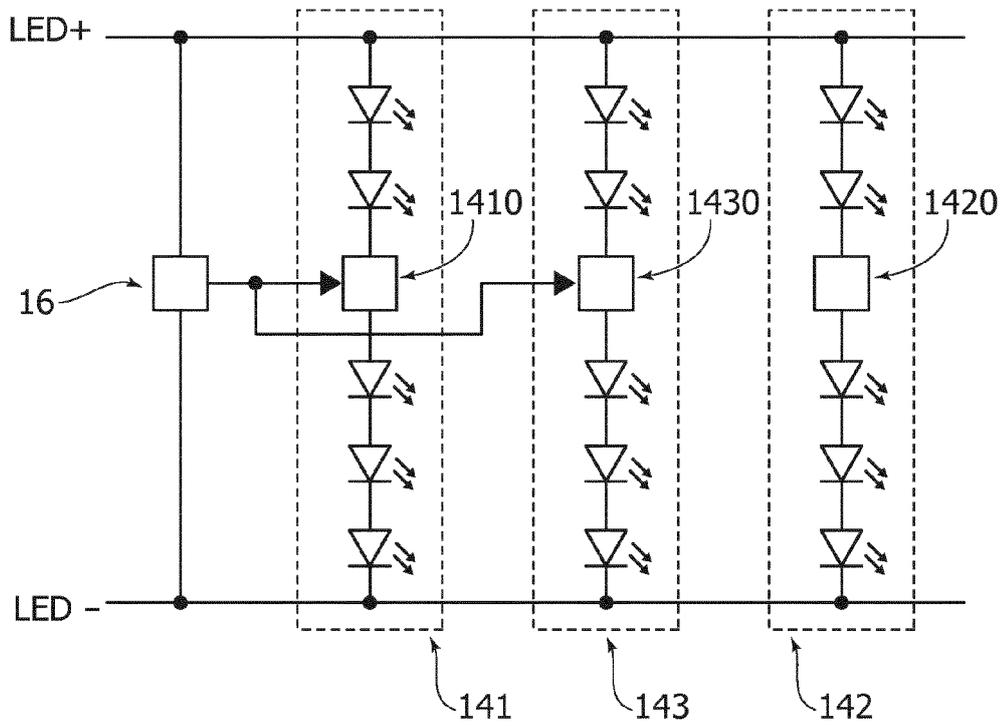
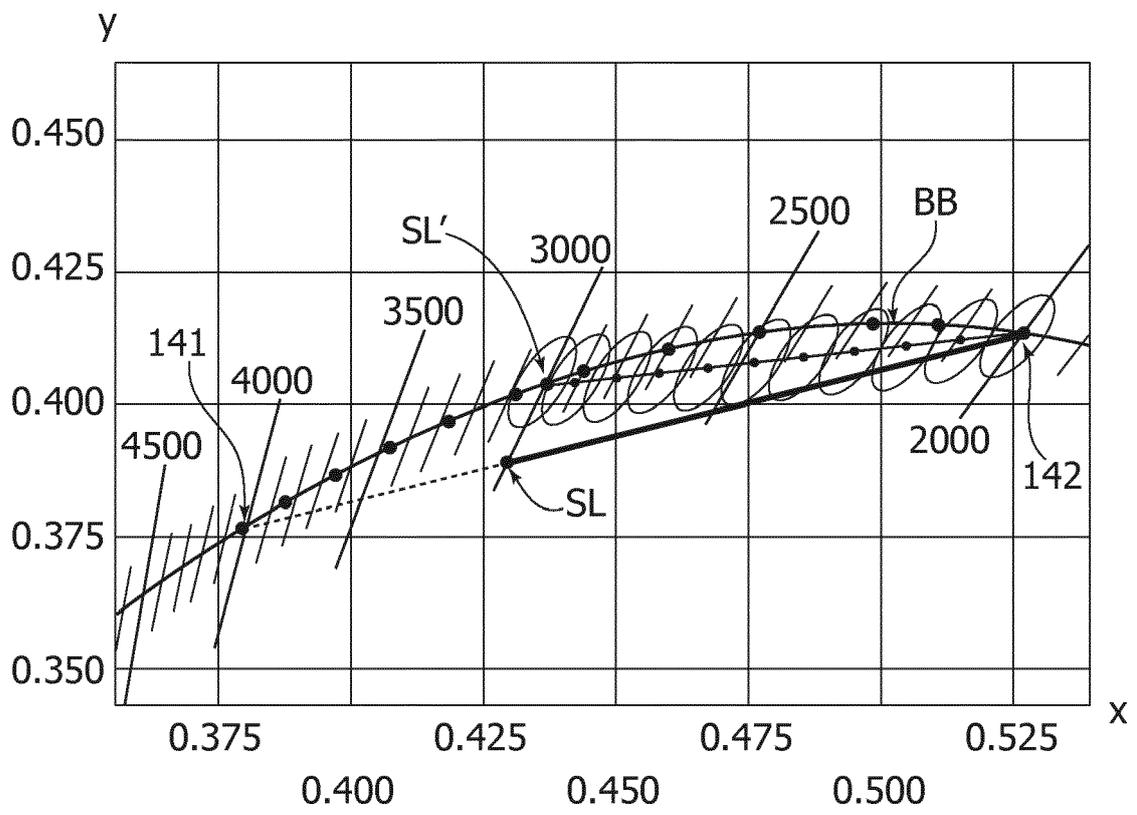


FIG. 12





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