(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 November 2009 (19.11.2009)

PCT

(10) International Publication Number
WO 2009/138894 A1

(51) International Patent Classification:
H05B 33/08 (2006.01) *F21Y 101/02* (2006.01)
F21V 29/00 (2006.01)

(21) International Application Number:
PCT/IB2009/051791

(22) International Filing Date:
1 May 2009 (01.05.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/052,329 12 May 2008 (12.05.2008) US

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(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, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, 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,

[Continued on next page]

(54) Title: LIGHT SOURCE HAVING LIGHT-EMITTING CLUSTERS

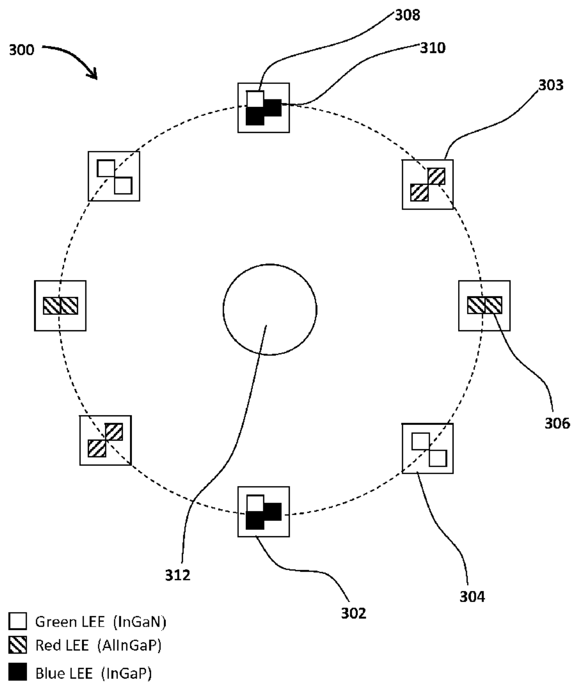

FIGURE 2

(57) Abstract: Disclosed herein is a light source (300) including a plurality of light-emitting elements configured to provide a desired level of thermal management in a cost-effective manner. The light source may include two or more light-emitting clusters (302), each comprising one or more light- emitting elements (306, 308, 310), such that, each cluster has a respective temperature dependency, wherein the respective thermal management system with each of light-emitting cluster (302) has been configured in order to enable a desired thermal management efficiency for each light-emitting cluster.

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GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (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, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

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

LIGHT SOURCE HAVING LIGHT-EMITTING CLUSTERS

FIELD OF THE INVENTION

[0001] The present invention pertains to the field of lighting and, more particularly, to a light source employing clusters of light-emitting elements.

BACKGROUND

[0002] Advances in the development and improvements of the luminous flux of light-emitting devices such as solid-state semiconductor and organic light-emitting diodes (LEDs) have made these devices suitable for use in general illumination applications, including architectural, entertainment, and roadway lighting. Functional advantages and benefits of LEDs include high energy conversion and optical efficiency, durability, lower operating costs, and many others, making LED-based light sources increasingly competitive with traditional light sources, such as incandescent, fluorescent, and high-intensity discharge lamps. Also, recent advances in LED technology and ever-increasing selection of LED wavelengths to choose from have provided efficient and robust white light and colour-changing LED light sources that enable a variety of lighting effects in many applications. Some of the fixtures embodying these sources feature a lighting module, including one or more LEDs capable of producing different colors, e.g. red, green, and blue, as well as a processor for independently controlling the output of the LEDs in order to generate a variety of colors and colour-changing lighting effects, for example, as discussed in detail in U.S. Patent Nos. 6,016,038 and 6,211,626, incorporated herein by reference.

[0003] In order to reduce manufacturing costs, a solid-state light source typically employs one or more identical clusters of light-emitting diodes, for example one or more LED packages each having the same combination of LEDs emitting certain colours (*e.g.* red, green and blue LEDs, red, green, amber and blue LEDs, *etc.*). Because the clusters generate substantially equivalent amounts of heat, they generally require the same level of thermal management, which may increase manufacturing costs and fragility of the light source, and reduce a level of utilization of a particular LED. In addition, as each cluster has a set of the same colours of LED, there is a consistent level of thermal impact which a particular LED has on each of the other LEDs in the cluster. This inter-thermal impact within a cluster may cause shifts in the light emissions of one or more of the LEDs in a particular cluster, which, in turn, may result in a diminished luminous flux output from the light source in order to maintain a desired chromaticity value.

[0004] Therefore, there is a need for an improved LED-based light source that addresses one or more of the drawbacks of known light sources, including those identified above.

[0005] This background information is provided to reveal information believed by the applicant to be of possible relevance to the present invention. No admission is necessarily intended, nor should be construed, that any of the preceding information constitutes prior art against the present invention.

SUMMARY OF THE INVENTION

[0006] Having appreciated certain limitations of known approaches, Applicants have discovered and recognized that configuring one or more clusters of light-emitting elements of a light source based on the temperature sensitivity and heat generation of the respective light-emitting elements may provide, among other benefits, a desired level of control of the light output from the light source with a reduced level of feedback or feed-forward control of the operation of the light-emitting elements.

[0007] In various embodiments and implementations of the technology disclosed herein, the light-emitting elements of a light-emitting cluster are selected in order to enable a substantial optimization of the thermal management system associated with light-emitting cluster. In particular, a format of a thermal management system may have its own associated costs and robustness, and so by configuring one or more of the light-emitting clusters for thermal coupling to a thermal management system having a desired level of efficiency, cost savings and increased reliability may be obtained. In some embodiments, the selection of the light-emitting elements of a particular cluster is based on the thermal loading generated by those light emitting elements. In other embodiments, the selection of the light-emitting element of a particular cluster is based on the relative thermal sensitivity of the light-emitting elements of the cluster. In still other embodiments, the selection of the light-emitting elements for a particular cluster is based on both the thermal loading and the thermal sensitivity of the light-emitting elements within the cluster.

[0008] Generally, in one aspect, the invention features a light source for producing light, the light source comprising: one or more first light-emitting clusters, each one of which comprising a first combination of one or more light-emitting elements of one or more colours, said first light-emitting clusters having a first temperature dependency, wherein a first thermal management system operatively coupled to the first light-emitting cluster is dependent on the first temperature dependency; one or more second light-emitting clusters, each one of which comprising a second combination of one or more light-emitting elements of one or more colours, said second light-emitting clusters having a second temperature dependency, wherein a second thermal management system operatively coupled to the second light-emitting cluster is dependent on the second temperature dependency; and a driving element for driving said light-emitting clusters.

[0009] In various embodiments, the first temperature dependency is indicative of material composition of light-emitting elements of the first light-emitting cluster and the second temperature dependency is indicative of material composition of light-emitting elements of the second light-emitting cluster. The first temperature dependency can be greater than the second temperature dependency. Also, the first light-emitting cluster and/or the second light-emitting cluster may include one or more phosphor coated light-emitting elements.

[0010] In some embodiments, the light source further includes a first sensing element for sampling a portion of light emitted by the first light-emitting cluster and the second light-emitting cluster. In other embodiments, the light source further includes a second sensing element for sampling a temperature of the first and/or the second light-emitting cluster.

Definitions

[0011] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs.

[0012] The term “light-emitting element” is used to define a device that emits radiation in a region or combination of regions of the electromagnetic spectrum for example, the visible region, infrared and/or ultraviolet region, when activated by applying a potential difference across it or passing a current through it, for example. Therefore a light-emitting element can have monochromatic, quasi-monochromatic, polychromatic or broadband spectral emission characteristics. Examples of light-emitting elements include semiconductor, organic, or polymer/polymeric LEDs, optically pumped phosphor coated light-emitting diodes, optically pumped nano-crystal light-emitting diodes or other similar devices as would be readily understood by a worker skilled in the art. Furthermore, the term light-emitting element is used to define the specific device that emits the radiation, for example a LED die, chip or other such device as will be readily understood by the person of skill in the art, and can equally be used to define a combination of the specific device that emits the radiation together with a dedicated or shared substrate, driving and/or optical output means of the specific device(s), or a housing or package within which the specific device or devices are placed.

[0013] The terms “spectral power distribution” and “spectral output” are used interchangeably to define the overall general spectral output of a light source, of a light-emitting element cluster thereof, and/or of the light-emitting element(s) thereof. In general, these terms are used to define a spectral content of the light emitted by the light source/light-emitting element cluster/light-emitting element(s).

[0014] The term “colour” is used to define the overall general output of a light source, of a light-emitting element cluster thereof, and/or of the light-emitting element(s) thereof, as perceived by a human subject. Each colour is usually associated with a given peak wavelength or range of wavelengths in a given region of the visible or near-visible spectrum, for example, between and including ultraviolet to infrared, but may also be used to describe a combination of such wavelengths within a combined spectral power distribution generally perceived and identified as a resultant colour of the spectral combination.

[0015] Further, as used herein for purposes of the present disclosure, the term "LED" should be understood to include any electroluminescent diode or other type of carrier injection/junction-based system that is capable of generating radiation in response to an electric signal. Thus, the term LED includes, but is not limited to, various semiconductor-based structures that emit light in response to current, light emitting polymers, organic light emitting diodes (OLEDs), electroluminescent strips, and the like.

[0016] In particular, the term LED refers to light emitting diodes of all types (including semi-conductor and organic light emitting diodes) that may be configured to generate radiation in one or more of the infrared spectrum, ultraviolet spectrum, and various portions of the visible spectrum (generally including radiation wavelengths from approximately 400 nanometers to approximately 700 nanometers). Some examples of LEDs include, but are not limited to, various types of infrared LEDs, ultraviolet LEDs, red LEDs, blue LEDs, green LEDs, yellow LEDs, amber LEDs, orange LEDs, and white LEDs (discussed further below). It also should be appreciated that LEDs may be configured and/or controlled to generate radiation having various bandwidths (e.g., full widths at half maximum, or FWHM) for a given spectrum (e.g., narrow bandwidth, broad bandwidth), and a variety of dominant wavelengths within a given general color categorization. For example, one implementation of an LED configured to generate essentially white light (e.g., a white LED) may include a number of dies which respectively emit different spectra of electroluminescence that, in combination, mix to form essentially white light. In another implementation, a white light LED may be associated with a phosphor material that converts electroluminescence having a first spectrum to a different second spectrum. In one example of this implementation, electroluminescence having a relatively short wavelength and narrow bandwidth spectrum "pumps" the phosphor material, which in turn radiates longer wavelength radiation having a somewhat broader spectrum.

[0017] It should also be understood that the term LED does not limit the physical and/or electrical package type of an LED. For example, as discussed above, an LED may refer to a single light emitting device having multiple dies that are configured to respectively emit different spectra of radiation (e.g., that may or may not be individually controllable). Also, an LED may be associated with a phosphor that is considered as an integral part of the LED (e.g., some types of white LEDs). In general, the term LED may refer to packaged LEDs, non-packaged LEDs, surface mount LEDs, chip-on-board LEDs, T-package mount LEDs, radial package LEDs, power package LEDs, LEDs including some type of encasement and/or optical element (e.g., a diffusing lens), etc.

[0018] As used herein, the term “about” refers to a +/-10% variation from the nominal value. It is to be understood that such a variation is always included in any given value provided herein, whether or not it is specifically referred to.

BRIEF DESCRIPTION OF THE FIGURES

[0019] **FIG. 1** is a schematic cross-sectional view of a light source comprising light-emitting clusters, in accordance with some embodiments of the present invention.

[0020] **FIG. 2** is a schematic top view of a light source comprising light-emitting clusters, in accordance with other embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Overview

[0021] The present invention generally contemplates a light source employing a plurality of light-emitting elements arranged in order to provide desired thermal management efficiency in a cost-effective manner. For instance, in many embodiments of the present invention, the light source comprises two or more light-emitting clusters, each comprising one or more light-emitting elements, such that, each cluster has a respective temperature dependency, wherein the respective thermal management system with each of light-emitting cluster has been configured in order to enable a desired thermal management efficiency for each light-emitting cluster.

[0022] The light source of the present invention can provide the desired level of thermal management by using different combinations of clustered light-emitting elements, and in some embodiments, using different combinations of such light-emitting clusters. For instance, a desired level of thermal management can generally be achieved by arranging one or more light-emitting elements in a cluster such that the cluster has a particular temperature dependency, which can lead to a desired format of a thermal management system which that particular cluster. For example, the light source may comprise one or more clusters in each of two or more types, which may be generally defined by respective and generally distinct combinations of light-emitting elements, wherein the one or more light-emitting elements in a cluster can be selected based on their respective thermal sensitivity and/or their heat generation. In various embodiments of the present invention, the selection of the one or more light-emitting elements for a particular cluster is dependent on the materials from which the one or more light-emitting elements are manufactured.

[0023] As will be described in greater detail below, and with reference to the examples depicted in Figures 1 and 2, by proper selection of a combination of light-emitting elements to be used within each type of light-emitting cluster, and optionally, by selecting an appropriate number of light-emitting clusters of each type, a desired format of thermal management can be used. In one embodiment, the selection of the one or more light-emitting elements within a cluster can be based on the desired thermal management configuration together with the ability of the light source to generate a desired spectral output. Furthermore, by carefully selecting the light-emitting elements for each cluster type, as discussed below, the number of different types of clusters may be minimised so as to reduce manufacturing costs associated with the production of multiple or various types of light-emitting clusters.

[0024] In some embodiments of the present invention, a control element is also provided to further improve the operation of the light-emitting elements of the light source, for example, providing a fine tuning thereof without significant loss to a potential maximum output intensity available from the light-emitting elements. A feedback system, comprising for example, one or more sensing elements operatively coupled to such a control element, may also be provided in order to monitor an output of the light source and/or temperature and provide a feedback-driven control thereof to maintain the output within a predetermined range or tolerance from a desired output.

Thermal Grouping

[0025] According to the present invention, the selection of the light-emitting elements for one or more cluster configurations generally aims at obtaining a desired level of thermal management of the light source. In some embodiments, the selection of the light-emitting elements of a particular cluster is based, at least in part, on the thermal loading generated by those light emitting elements. In other embodiments, the selection of the light-emitting element of a particular cluster is based, at least in part, on the relative thermal sensitivity of the light-emitting elements of the cluster. In one embodiment, the selection of the light-emitting elements for a particular cluster is based on both the thermal loading and the thermal sensitivity of the light-emitting elements within the cluster.

[0026] As mentioned above, the one or more light-emitting elements of a light-emitting cluster can be selected based on the amount of heat generated thereby and/or respective thermal sensitivity of the light-emitting elements. For example, light-emitting elements comprising or consisting essentially of AlInGaP heterostructure, such as red LEDs or an amber LEDs, are highly sensitive to temperature fluctuations. In particular, luminous flux output of these devices may reduce by an undesirable amount at elevated temperatures and their respective spectral output may shift by an undesirable amount due to temperature changes. Conversely, light-emitting elements comprising or consisting essentially of InGaN heterostructure, for example, green LEDs, while generating more heat during operation when compared to AlInGaP-based light-emitting elements, are less sensitive to temperature fluctuations. Thus, configuring one or more clusters of light-emitting elements of a light source based on the temperature sensitivity and heat generation of the respective light-emitting elements may provide, among other benefits, a desired level of control of the light output from the light source with a reduced level of feedback or feed-forward control of the operation of the light-emitting elements.

[0027] In one embodiment of the present invention, the light-emitting elements of a light-emitting cluster are selected in order to enable a substantial optimization of the thermal management system associated with light-emitting cluster. For example, a format of a thermal management system can have its own associated costs and robustness, by configuring one or more of the light-emitting clusters for thermal coupling to a thermal management system having a desired level of efficiency, cost savings and increased reliability may be obtained.

[0028] For example, in some embodiments of the present invention, a cluster comprises one or more light-emitting elements which are sensitive to thermal gradients or temperature changes, and as such a cluster of this type can be thermally coupled to a thermal management system which efficiently extracts the heat from the cluster, for example a heat pipe, thermosyphon, electro-aerodynamic pump or ionic pump, active cooling system for example a fan or thermoelectric cooling, or other thermal management system capable of providing the desired level of thermal extraction.

[0029] In addition, in some embodiments, a light-emitting cluster comprises one or more light-emitting elements which are less sensitive to temperature gradients or temperature changes, and as such a cluster of this type can be thermally coupled to a thermal management system which removes heat from the cluster less efficiently when compared to a heat pipe, for example. This format of thermal management system can be a heat sink, heat fin system or other similar thermal management system as would be readily understood by skilled artisans.

[0030] In one embodiment of the present invention, a light-emitting cluster can be configured in order to be coupled to a thermal management system having a predetermined efficiency level. In this embodiment, however, other considerations relating to the overall operation of the light source may also be considered, for example the spectral output and/or the luminous flux output of the light source. These additional considerations can result in one or more of the light-emitting clusters of the light source, while primarily configured for temperature management considerations, being adjusted in order to meet the other desired considerations. These additional considerations may result in one or more of the clusters potentially not achieving a desired level of thermal management, however this reduction may only be limited to one or more light-emitting clusters. As such, this less than ideal circumstance may have a limited impact on the operation of the light source, as other light-emitting clusters of the light source are operatively coupled to a thermal management system having a desired efficiency.

Light Source Spectral Output

[0031] In many embodiments of the present invention, the selection of the light-emitting elements and the cluster configurations thereof are further based on a requirement of generating a desired spectral output. A desired spectral output may be considered to comprise various optical and/or spectral outputs achievable by the combination of the respective outputs of the light source's light-emitting clusters and elements thereof. For instance, a desired spectral output may include, but is not limited to, a white or coloured light of a given colour temperature, chromaticity, colour rendering index, colour quality and/or of other such spectral, colour and/or colour rendering characteristics readily understood by the person skilled in the art.

[0032] In one embodiment, for example, the light source is configured to provide a desired spectral output substantially centred on the white point of the CIE 1931 colour space chromaticity diagram. In another embodiment, the light source is configured to achieve a given colour quality and/or colour rendering index. Other such desired spectral outputs would be apparent to the person of skill in the art and are thus not considered to depart from the general scope and spirit of the present disclosure.

[0033] Furthermore, it will be appreciated that a desired spectral output may be achieved to various degrees within a given range of acceptable outputs, possibly defined within the context, or by a given application for which the light source is to be used. For example, a light source may be designed such that, when the light-emitting clusters thereof are operated to provide a substantially maximum luminous flux output, the spectral output of the light source will provide an appropriately balanced spectral output for the application at hand. Such degree of balance or tolerance may be defined for example, to fall within a percentage variation from a reasonably achievable desired value, or again from a threshold value below which the light source may not be deemed adequate for the application at hand. Output specifications for a given light source, and acceptable variation therefrom for which the light source is to be used, can vary from application to application, and should be apparent to the person of skill in the art.

[0034] The person of skill in the art will readily understand that other considerations may be accounted for in determining and defining the desired spectral output for a given light source, and application for which it is to be used, without departing from the general scope and nature of the present disclosure. Such considerations may include, but are not limited to, spectral and/or operational limitations of certain types of light-emitting elements, light-emitting element materials, and/or optical components used in the fabrication of a given light source, the variation and/or fluctuation in the output characteristics of such components over time due to ageing, varying operating characteristics and/or environmental conditions (*e.g.* intensity fluctuations, spectral shifts and/or broadening, degradation of the optical components, *etc.*) and other such effects possibly induced by the light-emitting elements, for example, at high output intensities.

Light Source

[0035] The light source generally comprises two or more light-emitting clusters each comprising one or more light-emitting elements. In general, the one or more light-emitting elements of each cluster are configured to emit light toward an output of the light source, which may comprise one or more of a transparent window, a lens for directing the light source output, a filter for selecting a spectral component of the output, a diffuser for further mixing and combining the respective cluster outputs, and the like. In addition, in one embodiment, each light-emitting cluster comprises primary output optics such as a reflector, a lens, or the like. In another embodiment, each cluster further comprises a secondary optics for further combining and mixing the cluster's output.

[0036] In general, the light source is further configured to be driven by a driving element, which may include, but is not limited to, a driving module, a driving/control module, driving circuitry, hardware and/or software, and/or other such driving means, that allow for driving the light source to provide a desired spectral output and/or a desired luminous flux output, for example, as described in U.S. Patent No. 7,319,298, incorporated herein by reference.

[0037] Thermal management systems known in the art can be thermally coupled to the light-emitting clusters in order to provide thermal management of the light source. A thermal management system can be one or a combination of a heatsink, heat fin configuration active or passive cooling systems, for example heat pipes, thermosyphons, thermoelectric coolers, fans or other thermal management system as would be readily understood by skilled artisans.

[0038] Furthermore, an optional control element, which may include, but is not limited to, a micro-controller, a hardware, firmware and/or software platform, control circuitry and/or other such control means and/or modules, may also be operatively coupled to, or integrally provided as part of the driving element, to drive the light-emitting elements of the light-source's clusters with increased control, thereby providing increased control over the light-source's output. In one embodiment, the light source comprises a control/driving element configured to provide independent or interdependent intensity control for each type of cluster. For instance, a cluster of a first type comprising a first set of one or more light-emitting elements may be driven at a different intensity than a cluster of another type comprising another set of one or more light-emitting elements. In another embodiment, the light source comprises a control/driving element configured to provide independent or interdependent intensity control for each light-emitting element of each light-emitting cluster. As will be understood by the person skilled in the art, such refined intensity control may allow for fine or coarser tuning of the light-source's spectral output, and luminous flux output, based on desired criteria.

[0039] The light source may further optionally comprise a sensing element, comprising for example one or more optical sensors such as a photodetector or other such sensing means, for sensing a portion of the light emitted by the clusters and converting this light into an electrical signal representative of the light emitted by the clusters. Examples of optical sensors may comprise semiconductor photodiodes, photosensors or other optical sensors as would be readily understood by a worker skilled in the art, configured to detect light within one or more frequency ranges.

[0040] The light source may further optionally comprise a sensing element, comprising for example one or more thermal sensors or other such temperature sensing means, for sensing the temperature associated with one or more of the clusters, light-emitting elements or other component of the light source and converting this temperature into an electrical signal representative thereof. Examples of thermal sensors may comprise thermocouples, thermistors or other thermal sensors as would be readily understood by those skilled in the art.

[0041] In one embodiment, the clusters may be arranged such that a portion of the light emitted from each cluster is directed to an optical sensor such that an output of the light source may be monitored, namely via an optional monitoring means operatively coupled to the sensing means. For example, the clusters may be substantially symmetrically disposed about a single optical sensor such that substantially equal portions of light emitted by the various clusters are incident thereon, or again a combination of optical sensors may be used co-operatively for respective clusters. Other such configurations should be apparent to the person of skill in the art and are thus not meant to depart from the general scope and nature of the present disclosure.

[0042] As will be understood by the person of skill in the art, various combinations of optional sensing, monitoring, control and driving means may be considered in the present context without departing from the general scope and nature of the present disclosure. For instance, a dedicated light collection element (*e.g.* a reflective element) may be included to redirect a portion of the light emitted by the light-emitting clusters to the one or more optical sensing elements, or light may be directed to the optical sensing element directly or indirectly by different types of guided and/or reflected outputs (*e.g.* light guide, internal reflection from a light source output optics, *etc.*).

Light-Emitting Clusters

[0043] Various arrangements of the light-emitting elements within each light-emitting cluster are possible to achieve the results taught by the present disclosure, as are numerous arrangements of the light-emitting clusters within the light source. In general, clusters contemplated in the present disclosure comprise one or more light-emitting elements, in one of a variety of combinations, when such a combination is conducive to use of a thermal management system having a desired efficiency. In addition, the variety of combinations can also be optionally be determined by a combination of desired efficiency of the thermal management system together with desired spectral output by the light source. A light source can comprise one or more different light-emitting cluster configurations.

[0044] In accordance with many embodiments of the present invention, a light-emitting cluster comprises one or more light-emitting elements in one or more colours. For example, a light-emitting cluster may comprise one or more light-emitting elements of a single colour and/or peak wavelength (*e.g.* all red (R), amber (A), green (G), blue (B), white (W) *etc.*), or light emitting elements of different colours and/or wavelengths, and possibly in different combinations (*e.g.* $G_1G_2G_1G_2$, RARA, WGB, GBGB, *etc.* – wherein subscripts identify different peak wavelengths for light-emitting elements emitting within similar colour ranges). Also, different types of light-emitting elements (*e.g.* semiconductor, organic, or polymer/polymeric light-emitting diodes, optically pumped phosphor coated light-emitting diodes, optically pumped nano-crystal light-emitting diodes, *etc.*) and light-emitting elements of different sizes may also be combined within a same cluster, wherein the selection of the type of light-emitting element for a particular cluster can be dependent on its inherent temperature sensitivity, which can be largely dependent on material from which it is manufactured.

[0045] In one embodiment, each light-emitting element of a given cluster is combined and manufactured within a single housing or package. For instance, a package may be manufactured to combine a cluster of light-emitting elements, which may all be of a same colour, of different colours, or in different combinations thereof. For example, a single packaged cluster could comprise one or more light-emitting elements, and optionally one or more of dedicated output optics, thermal management system, driving element and other components readily used and known by the person skilled in the art to manufacture a light-emitting element package. Such cluster packages could be pre-assembled and/or manufactured for quick and easy assembly in a given light source configuration. Use of such packaged clusters may also simplify, in certain embodiments, light-emitting element optics and electrical power connections to the clusters. As will be understood by the person skilled in the art, various combinations of clusters and packaged clusters may be considered without departing from the scope and nature of the present disclosure.

[0046] In one embodiment of the present invention, the one or more light-emitting elements of a light-emitting cluster are selected based on the amount of heat generated thereby and/or respective thermal sensitivity of the light-emitting elements. For example, light-emitting elements which are based on an AlInGaP material, for example a red light-emitting element or an amber light-emitting element, can be inherently sensitive to temperature, wherein for example their respective luminous flux output can reduce and/or spectral output can shift undesirable amounts due to changes in temperature.

[0047] In addition, for example light-emitting elements which are based on an InGaN material, for example green light-emitting elements and blue light-emitting elements, can be grouped together as less sensitive to temperature fluctuations. As such, this format of light-emitting cluster may not require as efficient thermal management system associated therewith.

[0048] The light-emitting elements within the clusters may emit other colours of light, wherein the selection of a particular light-emitting element for inclusion in a particular light-emitting cluster can be dependent on the temperature sensitivity of the light-emitting element compared to that of the light-emitting cluster. Also, numerous arrangements of the light-emitting clusters are possible. They could be arranged in a rectangular or square array, or in two or more concentric circles, or perhaps in two different planes. One or more linear arrays could also be used. The number of clusters may also be varied depending on the selected configuration, the intended ratio of the various light-emitting elements contained therein, and/or the total output intensity required for a given application.

[0049] The invention will now be described with reference to specific examples. It will be understood that the following examples are intended to describe embodiments of the invention and are not intended to limit the invention in any way.

EXAMPLES

EXAMPLE 1:

[0050] Referring now to **FIG. 1**, a light source, generally referred to using the numeral **100** and in accordance with an embodiment of the present invention, will now be described. The light source **100** generally comprises light-emitting clusters, namely a first type of cluster **102**, and of a second type of cluster **104**. In this embodiment, the first type of cluster can be configured to include light-emitting elements which are temperature sensitive, for example a combination or red and amber (AlInGaP) light-emitting elements, and the second type of cluster can include substantially temperature insensitive light-emitting elements, for example a combination of green and blue (InGaN) light-emitting elements. Wherein the light output from the combination of all of the light-emitting elements of the first type and second type of clusters enables the generation of a desired intensity and colour by the light source.

[0051] In general, the light-emitting clusters **102** and **104** are mounted on a substrate **111** together with respective and/or shared driving elements (not shown). If light-emitting clusters **102** comprise light-emitting elements which are temperature sensitive, the thermal management system which can be associated therewith can be configured to extract heat from this cluster relatively efficiently. For example the thermal management system can comprise heat pipe, or other passive or active cooling with the desired heat transfer capabilities. In addition as light-emitting clusters **104** generally comprise light-emitting elements which are temperature insensitive, the thermal management system which can be associated therewith can be configured to extract heat from this cluster in a less efficient fashion, relative to the first type of cluster **102**. For example this thermal management system can comprise a heat sink or heat fin assembly or other similarly operative thermal management system.

[0052] As illustrated in Figure 1, the clusters **102** and **104** can be arranged in alternation in a circular manner around an optional optical sensor **112** positioned on the centre axis of the light source **100** so to both collect and detect the light emitted from the clusters **102** and **104**. An optional control element (not shown), such as a microcontroller or other such control means readily known in the art, may be operatively coupled between the driving element and the sensor **112** and used to adjust the respective output intensity of the clusters **102** and **104**, and optionally of their respective light-emitting elements, to thereby adjust and/or substantially maintain an output colour balance of the light source **100**. Such control means may also be used to adjust and substantially maintain the light source's output intensity.

[0053] Each cluster **102** and **104** may also optionally comprise primary and secondary output optics **114** and **116**, respectively, for directing light emitted thereby to a light source output **118**, which may comprise a window, a lens, a diffuser, one or more filters and/or other such optical elements readily known to the person skilled in the art. The desired colour balance, though possibly not achieved in the near field where light from all the clusters **102** and **104** may not completely overlap, will generally be achieved once light is adequately mixed by one or more of the optional primary optics **114**, secondary optics **116** and/or light source output **118** (*e.g.* in the far field). The person of skill in the art will readily understand that various output optics may be considered in the present example. Namely, various optical elements integral or external to the various light-emitting clusters **102** and **104** may be considered to provide similar results, and as such, should not be considered to be outside the intended scope of the present disclosure.

EXAMPLE 2:

[0054] Referring now to Figure 2, a light source, generally referred to using the numeral **300** and in accordance with an embodiment of the present invention, will now be described. The light source **300** generally comprises eight light-emitting clusters, four of a first type of cluster, as in cluster **302**, and two each of a second type of cluster, as in cluster **303**, and of a third type of cluster, as in cluster **304**. Light-emitting clusters **302**, **303** and **304** are each comprised of one or more red, green and/or blue light-emitting elements, as in elements **306**, **308** and **310** respectively, wherein in this particular embodiment an output intensity (or output efficiency) of the blue light-emitting elements **310** is about 2 times higher than that of the red light-emitting elements **306** and about 1.5 times higher than that of the green light-emitting elements **308**. As such, to provide a desired spectral output which is substantially white light at a substantially maximum luminous flux output of each light-emitting element, light-emitting clusters **302** each comprise one green light-emitting element **308,** and two blue light-emitting elements **310**; light-emitting clusters **303** each comprise two red light-emitting elements **306**; and light-emitting clusters **304** each comprise two green light-emitting element **308**, resulting in a R:G:B ratio of about 4:3:2. Each of these clusters is configured such that light-emitting elements having similar temperature sensitivities are combined into a particular cluster. For this example, the red light-emitting elements are fabricated using AlInGaP, and are thus more temperature sensitive when compared to the blue light-emitting elements and the green light-emitting elements which in this example are fabricated using InGaN.

[0055] It will be appreciated by the person of skill in the art that a similar light source may also be used, for example, when a desired spectral output of the light source is defined by a spectral power distribution skewed toward a particular region of the visible spectrum if light-emitting elements are used which have correspondingly different relative output efficiencies.

[0056] Other considerations discussed in relation to the design and manufacture of the light source **100** of Example 1 may also apply to light source **300**, as will be readily understood by the person skilled in the art. For instance, the light-emitting clusters **302**, **303** and **304** may be mounted on a substrate together with respective and/or shared driving means and comprise respective and/or shared thermal management systems to dissipate heat from the light-emitting clusters **302**, **303** and **304** and respective light-emitting elements **306**, **308** and **310** thereof. In this example and in one embodiment of the present invention, light-emitting clusters **302** and **303** comprise light-emitting elements which can be temperature sensitive, and as such the thermal management system associated with these light-emitting clusters can be configured to extract heat therefrom in a relatively efficient manner. In addition, as light-emitting clusters **304** comprise light-emitting elements which are less sensitive to temperature, the thermal management system associated with these clusters may be a heat sink or heat fin configuration.

[0057] In this example, the clusters **302**, **303** and **304** are arranged in a circular design around an optional optical sensor **312** positioned on the centre axis of the light source **300** so to both collect and detect the light emitted from the clusters **302**, **303** and **304**. An optional control means may again be used to adjust the respective output intensity of the clusters **302**, **303** and

304, and optionally of their respective light-emitting elements **306**, **308** and **310**, to thereby adjust and substantially maintain an output colour balance and/or output intensity of the light source **300**.

[0058] Each cluster **302**, **303** and **304** may also include primary optics, and optionally secondary optics, for directing light emitted thereby to the light source output, which may again comprise a window, a lens, a diffuser, one or more filters and the like. The person of skill in the art will again readily understand that various output optics may be considered in the present example, whether they be integral or external to the various light-emitting clusters **302**, **303** and **304**, to provide similar results, and as such, should not be considered to be outside the intended scope of the present disclosure.

[0059] In one embodiment of the present invention, and with continuing reference to Figure 2, the arrangement of the clusters in a substantially alternating configuration may not be required if the optics which are associated with the light source are capable of blending the light emitted by the light-emitting clusters to a desired level irrespective of the placement thereof within the light source. This can provide a means for easy and cost effective thermal coupling between the light-emitting clusters and their associated thermal management system. For example, light-emitting clusters **302** and **304** can be positioned proximate to each other thereby providing ease of thermal coupling to a heat sink or heat fin thermal management system.

[0060] The person of skill in the art will understand that the foregoing embodiments of the invention are examples and can be varied in many ways. Such present or future variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be apparent to one skilled in the art are intended to be included within the scope of the following claims.

WE CLAIM:

1. A light source for producing light, the light source comprising:
   a) one or more first light-emitting clusters, each one of which comprising a first combination of one or more light-emitting elements of one or more colours, said first light-emitting clusters having a first temperature dependency, wherein a first thermal management system operatively coupled to the first light-emitting cluster is dependent on the first temperature dependency;
   b) one or more second light-emitting clusters, each one of which comprising a second combination of one or more light-emitting elements of one or more colours, said second light-emitting clusters having a second temperature dependency, wherein a second thermal management system operatively coupled to the second light-emitting cluster is dependent on the second temperature dependency; and
   c) a driving element for driving said light-emitting clusters.

2. The light source according to claim 1, wherein the first temperature dependency is indicative of material composition of light-emitting elements of the first light-emitting cluster.

3. The light source according to claim 1, wherein the second temperature dependency is indicative of material composition of light-emitting elements of the second light-emitting cluster.

4. The light source according to claim 1, wherein the first temperature dependency is greater than the second temperature dependency.

5. The light source according to claim 4, wherein the first light-emitting cluster comprises one or more light-emitting elements having a material composition of AlInGaP.

6. The light source according to claim 4, wherein the second light-emitting cluster comprises one or more light-emitting elements having a material composition of InGaN.

7. The light source according to claim 4, wherein the first thermal management system is more efficient than the second thermal management system.

8. The light source according to claim 4, wherein the first thermal management system is selected from the group comprising a heat pipe, a thermosyphon, electro-aerodynamic pump, active cooling system and a thermoelectric cooler.

9. The light source according to claim 4, wherein the second thermal management system is a heat sink or a heat fin system.

10. The light source according to claim 1, wherein the first light-emitting cluster or the second light-emitting cluster are configured as preassembled cluster packages.

11. The light source according to claim 1, further comprising a sensing element for sampling a portion of light emitted by the first light-emitting cluster and the second light-emitting cluster.

12. The light source according to claim 1, further comprising a sensing element for sampling a temperature of the first light-emitting cluster.

13. The light source according to claim 1, further comprising a sensing element for sampling a temperature of the second light-emitting cluster.

14. The light source according to claim 1, wherein the first light-emitting cluster or the second light-emitting cluster or both comprise one or more phosphor coated light-emitting elements.

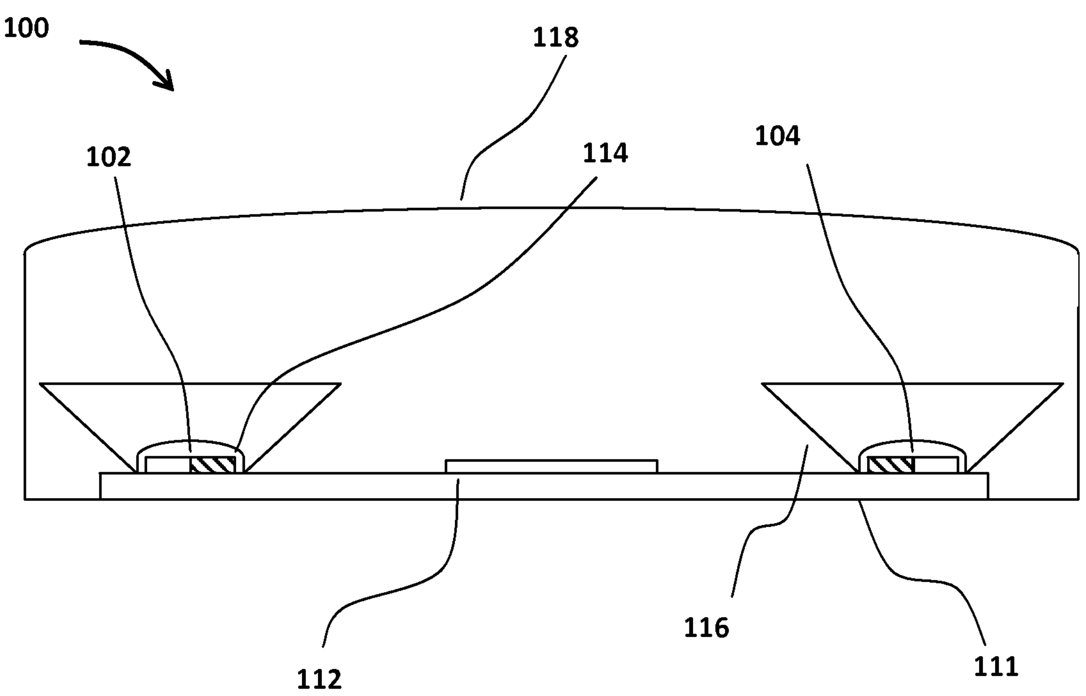

FIGURE 1

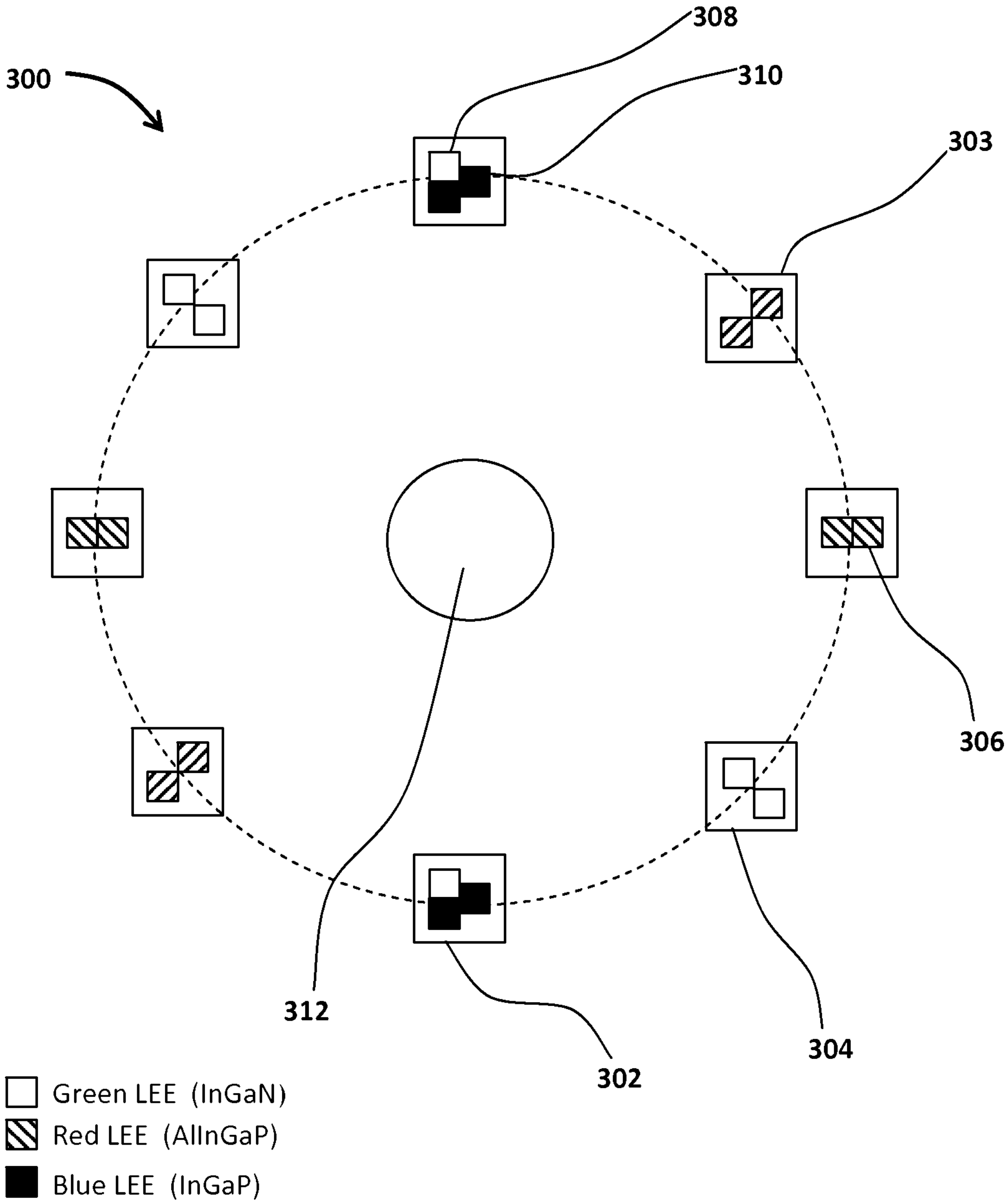
300
308
310
303
306
304
302
312
Green LEE (InGaN)
Red LEE (AlInGaP)
Blue LEE (InGaP)

FIGURE 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2009/051791

A. CLASSIFICATION OF SUBJECT MATTER
INV. H05B33/08 F21V29/00
ADD. F21Y101/02

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)
H05B 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 practical, 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.
X	US 2007/040512 A1 (JUNGWIRTH PAUL [CA] ET AL JUNGWIRTH PAUL [CA] ET AL) 22 February 2007 (2007-02-22) cited in the application paragraphs [0036], [0048], [0049] figure 1	1-14
X	WO 2006/056066 A (TIR SYSTEMS LTD [CA]; ASHDOWN IAN [CA]; JUNGWIRTH PAUL [CA]; ROBINSON) 1 June 2006 (2006-06-01) paragraphs [0045], [0053], [0054], [0130] figures 1,2,11	1-14

☐ 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 document 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	Date of mailing of the international search report
21 July 2009	31/07/2009

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2009/051791

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007040512 A1	22-02-2007	NONE	
WO 2006056066 A	01-06-2006	CA 2589238 A1 EP 1839463 A1 JP 2008522349 T	01-06-2006 03-10-2007 26-06-2008