

LIGHTING DEVICE, ELEMENT THEREOF AND A VEHICLE HEADLAMP

Field of technology

[001] The present invention generally relates to lighting devices, particularly light emitting semiconductor devices, and vehicle headlamps comprising such devices.

Background

[002] Light emitting semiconductor devices (LESDs), such as light emitting diodes (LEDs) and laser diodes, and packages containing LESDs, have found myriad applications in vehicle lighting in recent years, including vehicle headlamps, daytime lighting strips and interior decorative lighting. Compared to conventional tungsten or high intensity discharge bulbs, LESDs offer advantages of low power consumption, no need for an inert atmosphere, higher light intensity per unit energy, shock resistance, longer operating lifetimes, and lower light output degradation over time. Due to these advantages, retrofitting conventional light bulbs with LESDs has become popular with vehicle users.

[003] Several considerations exist in retrofitting conventional light sources with LED light sources. An efficient thermal management system for the LED light source within the confines of the cramped space in a vehicle headlight compartment is necessary. Although less heat is generated by LESDs per unit light, high powered LESDs generate enough heat on the circuit substrate to degrade lighting performance and potentially damage adjacent cable assemblies in the headlamp. Furthermore, control of the light distribution pattern in a way that complies with international and local vehicle headlamp regulations is another important requirement. LED light sources need to be designed to comply with such requirements in order to be street legal.

[004] Aftermarket LED bulbs currently comprise arrays of LEDs mounted on conventional rigid circuit board substrates. These are relatively bulky, inflexible structures with conventional soldering of electrical connections beneath the rigid substrates. Limited flexibility exists to control light distribution. Heat extraction features are typically non-existent, consequently limiting illumination power.

[005] It will be desirable to provide a headlamp with increased LED unit carrying capacity, with an efficient thermal management design as well as increased functionality, such as selective LED illumination, within a single lighting device.

Summary of Invention

[006] In one aspect, there is provided a lighting device for a vehicle headlamp, comprising: a single, continuous strip of flexible circuit comprising a plurality of light emitting semiconductor devices (LEDs), a frame supporting the flexible circuit, the frame comprising a plurality of mounting surfaces for mounting the LEDs onto the frame, the flexible circuit having a shape configured to extend over each mounting surface, and the LEDs having a layout on the flexible circuit configured to position one or more LEDs over each mounting surface.

[007] In another aspect, a vehicle headlamp is provided, comprising a light reflector, a lens fitted over the light reflector, and a lighting device arranged between the light reflector and the lens via an aperture in the light reflector, the lighting device comprising: a single, continuous strip of flexible circuit comprising a plurality of light emitting semiconductor devices (LEDs), a frame supporting the flexible circuit, the frame comprising a plurality of mounting surfaces for mounting the LEDs onto the frame, the flexible circuit having a shape configured to extend over each mounting surface, and the LEDs having a layout on the flexible circuit configured to position one or more LEDs over each mounting surface.

[008] In a further aspect, a lighting element is provided, comprising a single, continuous strip of flexible circuit comprising a plurality of light emitting semiconductor devices (LEDs), the flexible circuit having a shape configured to extend over a plurality of mounting surfaces of a frame, and the LEDs having a layout on the flexible circuit configured to position one or more LEDs over each mounting surface.

[009] These and other aspects of the invention are described in the detailed description below. In no event should the above summary be construed as a limitation on the claimed subject matter which is defined solely by the claims as set forth herein.

Brief Description of the Drawings

- [010] Fig. 1 shows a perspective view of a lighting device 100.
- [011] Fig. 2 shows a perspective view of a lighting device 102.
- [012] Fig. 3 shows a plan view of a lighting device comprising a base.
- [013] Fig. 4 shows the layout of a flexible circuit used in lighting device 100.
- [014] Fig. 5 shows a perspective view of a lighting device 200.
- [015] Fig. 6 shows the layout of a flexible circuit used in lighting device 200.
- [016] Fig. 7 shows a perspective view of a lighting device 300.
- [017] Fig. 8 shows the layout of a flexible circuit used in lighting device 300.
- [018] Fig. 9 shows a plan view of a lighting device 400
- [019] Fig. 10 shows the light distribution pattern of lighting device 400.
- [020] Fig. 11 shows a plan view of a lighting device 500.
- [021] Fig. 12 shows a plan view of a lighting device 600.
- [022] Fig. 13 shows perspective views of a lighting device 700.
- [023] Fig. 14 shows a layout of the flexible circuit for lighting device 700.
- [024] Fig. 15 shows various slope profiles of a mounting surface.
- [025] Fig. 16A, 16B show the light distribution pattern and corresponding lux values of a low beam from lighting device 700.

[026] Fig. 17A, 17B shows the light distribution pattern and corresponding lux values of a high beam from lighting device 700.

[027] The figures are not necessarily drawn to scale. However, it will be understood that the use of a numeral to refer to a component in a given figure is not intended to limit the component in another figure labeled with the same number.

DETAILED DESCRIPTION

[028] As used in this application, “LES” means light emitting semiconductor; “LESD” means light emitting semiconductor device, including light emitting diode (LED) device(s) and laser diode device(s). An LESD may be a bare LES die construction, a complete packaged LES construction, or an intermediate LES construction comprising more than the bare die, but less than all the components for a complete LES package, such that the terms LES and LESD may be used interchangeably and refer to one or all of the different LES constructions. The term "flexible LES device" or "flexible LESD" typically refers to the flexible article containing the bare die light emitting semiconductor, packaged LES construction, or intermediate LES construction. Examples of the type of complete packaged LES constructions that may be suitable for use in embodiments of the present invention include Golden DRAGON LEDs, available from OSRAM Opto Semiconductors GmbH, Germany; LUXION LEDs, available from Philips Lumileds Lighting Company, USA; and XLAMP LEDs, available from Cree, Inc., USA.

[029] Throughout the description and figures, “LESD” may refer to a single LESD unit, as well as a row or an array of multiple LESD units. An LESD as referred to herein may be of any voltage rating, exemplary ratings include 6V, 9V, 12V or 24V. LESDs may have a power consumption rating ranging from 1 Watt to 100 Watts or more. Generally it may conform to the nominal power ratings of standard vehicle headlamp bulbs, such as 35 Watts or 55 Watts, or more typically, less than 10 Watts per LESD unit.

[030] The present invention provides means to retrofit light bulbs in the headlamps of vehicles using a flexible circuit based LESD lighting device. As compared to hard substrate based LED bulbs, a flexible circuit based lighting device neatly carries multiple

circuit traces, and can be mounted on a heat sink frame to assist in the removal of heat generated during operation.

[031] The lighting device in accordance with the invention comprises a single, continuous strip of flexible circuit comprising a plurality of light emitting semiconductor devices (LESDs), and a frame supporting the flexible circuit. The frame comprises a plurality of mounting surfaces for mounting the LESDs onto the frame. The flexible circuit has a shape configured to extend over each mounting surface, and the LESDs have a layout on the flexible circuit configured to position one or more LESDs over each mounting surface. The frame may comprise top, bottom, lateral side and/or front facing mounting surfaces, so these mounting surfaces may be located on different planes. In one embodiment, the frame comprises a top mounting surface and a bottom mounting surface relative to a mounted position, the flexible circuit extending over the top mounting surface and the bottom mounting surface, the flexible circuit comprising a first LED group positioned on the top mounting surface for providing a high beam light source, and a second LED group is arranged on the bottom mounting surface for providing a low beam light source. In another embodiment, the frame comprises a front facing mounting surface relative to a mounted position, the flexible circuit extending over the front facing mounting surface, and the flexible circuit comprising a LED group positioned on the front facing mounting surface for providing a day time running light (DRL) source. In yet another embodiment, the frame comprises a lateral side mounting surface relative to a mounted position, the flexible circuit extending over the lateral side mounting surface, and the flexible circuit comprising a LED group positioned on the lateral side mounting surface.

[032] FIG. 1 shows a lighting device 100 comprising a frame 120 in the shape of a flat rectangular support member 126 and a base 128 for supporting a single continuous strip of flexible circuit 110. Flexible circuit 110 is folded and mounted over the frame to extend over top mounting surface 122 and bottom mounting surface 124. Advantageously, flexible circuits may be routed over complex surface geometries, and may be creased or folded to conform to the shape of the frame. A first section 112 of the flexible circuit comprises a first LED group 132 arranged on the top mounting surface 122. A second section 114 of the flexible circuit comprises a second LED group 134 arranged on the

bottom mounting surface 124. Each LEDS group, as referred to throughout the description, may herein comprise a single LEDS unit, or a plurality of LEDS units. In general, in a vehicle headlamp, LEDSs located on a top surface of the frame 120 may advantageously provide a high beam light source, while LEDSs located on a bottom surface of the frame may provide a low beam light source.

[033] FIG. 2 shows a lighting device 102 wherein the frame 120 is of a similar structure as that in lighting device 100. In this embodiment, the flexible circuit 111 is a single continuous strip of flexible circuit comprising an LEDS group 131 arranged on a front facing mounting surface 129 of the frame relative to a mounted position, e.g. in a vehicle. Front facing LEDS units may advantageously serve as daytime running lights (DRL).

[034] In one embodiment, a base is attached to the frame, the base comprising mating features for mounting onto a light bulb socket of a vehicle headlamp assembly. Referring to FIG. 3, the base 128 of the frame 120 may comprise mating features 142 of standard bulb fixtures, such as standards conforming to Group 1, Regulation 37 of the Economic Commission for Europe, European World Forum for Harmonization of Vehicle Regulations. If the lighting device is to be installed in a motorcycle headlamp, the base 128 may correspond to any one of HS1, HS2, HS5, HS6, S2 or S3 bulbs as defined under Group 1, Regulation 37 of the Economic Commission for Europe, European World Forum for Harmonization of Vehicle Regulations. For installation in cars, the base 128 may comprise mating features corresponding to a H1, H2, H3 or H4 bulb, for example. The flexible circuit may be inserted through a slot located on the base 128 and comprise a connector 150 for connection with electrical driver of a vehicle to power up the LEDSs.

[035] FIG. 4 shows the configuration of the flexible circuit used in lighting device 100. The flexible circuit 110 comprises a single, continuous substrate with an L-shape configuration. Width of the flexible circuit may be of any suitable size, such as 5 mm, 10 mm or 18mm or 21 mm or more. In this embodiment, the flexible circuit is creased at each location where the flexible circuit is to be folded over an edge of the frame. Dotted line 152 represents the portion of the flexible circuit that is folded, or creased, so that the flexible circuit 110 is able to fit and conform to the surface geometry of the frame. The

layout of LESDs on the flexible circuit is configured to correspond with the LESDs' intended location on the mounting surfaces of the frame. In this case, the layout of the LESDs is configured to position a first and a second LED (or groups of LEDs, if desired), respectively, on the top and the bottom mounting surfaces of the frame 120.

[036] Another embodiment of a lighting device according to the invention is shown in FIG. 5. Lighting device 200 comprises a frame 220 in the shape of a hollow rectangular cuboid (base not shown) with an open surface 250 supporting a flexible circuit 210 on three surfaces of the frame 220. A first section 212 of the flexible circuit 210 comprising first LED 232 is arranged over top surface 222 of the frame, a second section 214 comprising second LED 234 is arranged over bottom surface 224 of the frame, and a third section 216 comprising third LED 236 is arranged over front facing surface 226 of the frame. In this embodiment, front facing LED 236 is arranged to emit light in a front facing direction, relative to a mounted position in a vehicle headlamp. In this embodiment, LEDs located on the top and the bottom mounting surfaces of frame 220 may provide high beam and low beam illumination, respectively, and LEDs located on the front facing surface of the frame may serve as DRL.

[037] FIG. 6 shows the configuration of the flexible circuit used in lighting device 200. The flexible circuit 210 comprises a single, continuous substrate with a straight layout, folded along dotted lines 252, 253. The layout of the LEDs is configured to position a first, second and a third LED (or groups of LEDs, if desired), respectively, on the top, front facing and the bottom mounting surfaces of the frame 220.

[038] FIG. 7 shows another embodiment of the lighting device according to the invention. Lighting device 300 comprises a frame 320 in the shape of a solid rectangular cuboid (base not shown) supporting a flexible circuit 310 and having five LEDs arranged on five mounting surfaces of the frame. A first LED 332 is arranged over top surface 322, a second LED 334 is arranged over bottom surface 324, and a third LED 336 is arranged over front facing surface 326. In this embodiment, the frame also comprises a lateral side mounting surface relative to a mounted position, and a LED group is arranged on the lateral side mounting surface. A fourth and a fifth LED 337, 338 are provided on surfaces 327, 328, which are on the lateral sides of the frame. In this

embodiment, the lateral side mounted LESDs 337, 338 are arranged to emit light in a right and left direction, respectively, relative to a mounted position from a vehicle driver's perspective. In some applications, these LESDs may be illuminated as high beam light source in conjunction with the first LED 332, thereby increasing high beam light intensity. In other possible applications, LESDs 337, 338 may comprise amber light emitting LESDs to serve as left/right directional lights, or as hazard lights, for example.

[039] FIG. 8 shows the configuration of the flexible circuit 310 used in lighting device 300. The flexible circuit 310 comprises a single, continuous substrate with a cross-shaped configuration, folded in sections along dotted lines 352 to 355. The layout of the LESDs is configured to position a first, second, third and fourth LED (or groups of LEDs, if desired), respectively, on the top, front facing, bottom and lateral side mounting surfaces of the frame 320.

[040] In the various layouts described above, each LED group present on the flexible circuit may be comprised in independent, separate circuit traces in the flexible circuit so that each LED group is independently operable from other LED groups. In one embodiment, this enables switching on and off of high beam, low beam and DRL light sources, and combinations thereof.

[041] Throughout the above examples, any type of LED that can be formed on a flexible circuit may be used. These include any variety of conventional red, orange, yellow, green, blue, violet, purple, UV or white LEDs based on semiconductor materials such as yellow phosphor, zinc selenide, indium gallium nitride, gallium arsenide, gallium nitride. In some embodiments, LEDs such as those described in WO2012112310 A1 and WO2012061183 A1 may be used in the present invention. For vehicle headlamp applications, white, orange ($590 < \lambda < 610$) or yellow ($570 < \lambda < 590$) LEDs are preferred for standard vehicle use.

[042] As is typical for semiconductor materials, the performance of the LEDs is dependent on its operating temperature; a given diode will produce more light at a low temperature than at a high temperature. Thus, in order to maintain a constant light output, the temperature of an LED must be kept relatively low and stable. In order to dissipate

heat produced by the LESDs, the frame may be a heat sink. Cooling fins may be incorporated on the surface of the frame to aid in convective heat transfer with the air around the frame, or alternatively, cooling fins may be incorporated on the base. A thermally conductive interface tape (e.g. 3M™ range of Thermally Conductive Adhesive, Transfer or Interface Tapes) may be provided between the flexible circuit and the frame, or more specifically, between each section of the flexible circuit comprising an LESD and the mounting surface of the frame on which the LESD is extended. Furthermore, the frame itself may comprise a thermally conductive material to conduct heat from the LESDs, such as a metal e.g. aluminum or stainless steel wherein thermal conductivity ranges from 15 W/mK to 100 W/mK; or a thermally conductive polymer, e.g. organic polymer composites such as polyamides, polyphenylene sulfides that include heat-conductive additives e.g. graphite carbon fibers and/or ceramics such as aluminum nitride and boron nitride, wherein thermal conductivity is above 15 W/mK, or more preferably about 20 to 30 W/mK. To further assist in thermal management, further heat extraction features may be incorporated on the base of the lighting device. In some embodiments, the frame and the base are integrally formed. The base may also incorporate active or passive cooling devices, such as cooling fins, or an electric fan, or a liquid coolant provided in a liquid jacket, to draw heat away from the frame during operation.

[043] The following embodiments depict complex structure frames that provide a plurality of mounting surfaces on which to mount LESDs, as well as heat sink fins formed on the frame to assist with cooling.

[044] FIG. 9 depicts a lighting device 400 comprising flexible circuit 420 supported by a circular frame 410 comprising base 440. Relative to a mounted position, LESD 432 is arranged on a curved, front facing mounting surface of the frame. LESDs 437, 438 are arranged on the lateral side facing mounting surfaces frame. In this embodiment, frame 420 comprises a circular structure with cooling fins 451 extending from a central hub 452 connecting to the inner surface of the frame.

[045] In order to investigate the lighting performance of lighting device 400, an actual prototype was evaluated. White LEDs with model numbers NCSW170A and NC2W170A were obtained from Nichia. The LEDs were bonded to a standard one-metal layer flexible

circuit using a standard reflow process. The frame and base were obtained by welding aluminum sections together to form an integral frame. The frame was cleaned thoroughly with isopropyl alcohol and dried. 3M™ Thermally Conductive Adhesive Transfer Tape 8805 tape was aligned and laid out on the aluminum frame. On to it was aligned the flexible substrate with LEDs and attached firmly on the tape as shown in the below figure. The electrical connections were routed through the base and connected to the power supply for electrically driving the LEDs.

[046] During performance evaluation, lighting device was fitted inside a standard motorcycle headlamp. Light was directed at a white wall at a distance of 10 meters from the light source. The room temperature was around 22.5 °C. The working electrical parameters for the lighting device were as follows: Voltage = 17.4 volts, Current = 0.25 A, Total Wattage = 4.35 Watts. FIG. 10 is a photograph showing the light distribution across a white wall. The measured light intensity levels are shown in Table 1:

Positions (approximate)	Lux Levels
HV(00)	4.6
Zone II	4.5
Zone IV	3.6
Zone 1	3.3
Position R1	2
Position L1	4

Table 1

[047] The temperature of the LED light engine was measured at different intervals of time and initial and final temperature taken at 30 minutes interval is recorded and shown below. The temperature were recorded using a thermocouples mounted at the fins 850 and the base 840. The results are shown in Table 2:

Temperature at fins	Temperature at base
69 °C	53 °C
65 °C	50 °C
62 °C	53 °C
62 °C	53 °C

Table 2

[048] FIG. 11 depicts lighting device 500 comprising a complex structure frame. In this embodiment, lighting device flexible circuit 520 is supported by a frame 510. Relative to a mounted position, LESD 532 is arranged on a top mounting surface of the frame, while LESD 534 is arranged on a bottom mounting surface of the frame. The top and bottom mounting surfaces are located on an elongated support member 541 of the frame which is connected to and extending from base 540. A circular member 550 provides a curved front facing mounting surface over which LESD 536 is arranged. Cooling fins 552 extend from a central hub 551, and connects to the inner surface of the frame.

[049] FIG. 12 depicts a lighting device 600 comprising a complex structure frame 610 comprising a front facing semi-circular member 611 which is connected to a central member 612, and rear sleeves 613 connecting the central member to the base 640. Flexible circuit 620 is supported by the frame 610. Relative to a mounted position, LESD 632 is arranged on a top mounting surface of the frame, LESD 634 is arranged on a bottom mounting surface of the frame, and LESD 636 is arranged on a front facing surface of the frame. LESD 637, 638 are arranged on a lateral side facing mounting surface of the frame. The flexible circuit 620 is routed from LESD 636 to LESD 632 to LESD 638 to LESD 634 and finally to LESD 637, and to the base 640.

[050] FIG. 13 show perspective bottom and top views, respectively, of yet another embodiment of a lighting device 700. Lighting device 700 comprises a frame 710 having front facing mounting surface 712, lateral side mounting surface 714, and top 718 and bottom 716 mounting surfaces. In this embodiment, top mounting surface 718 is recessed, so that light from LESD 732 is not visible to an oncoming vehicle user. FIG. 14 shows the layout of the flexible circuit 720 with four LESD groups 730 positioned at various locations on the flexible circuit, and a connector 780 located at an edge.

[051] In general, mounting surfaces of the frame may provide the desired angle at which light emits from each LESD. Since LESD units are planar structures, light emits in a direction orthogonal to the plane of the surface on which an LESD is placed. For example, a mounting surface comprising a horizontally flat surface will enable an LESD to emit light vertically upwards when mounted in a vehicle. Light incident on any surface of the light reflector is reflected and eventually exits along the optical axis of the light

reflector. Mounting surfaces of the frame of the lighting device may be modified to achieve the required light distribution characteristics. In order to avoid dazzling oncoming vehicle users, the mounting surface may be recessed so that the LEDS is obscured from direct view, and hence avoids direct emission of light. In one embodiment, the mounting surface comprises a backward sloping profile, i.e. slope angled towards the base of the light reflector in a headlamp as opposed to facing towards the direction of travel. This enables direct light emitting from the LEDS to be obscured from oncoming drivers' line of sight, and instead all light emitted from the LEDS is evenly reflected out of the headlamp. An appropriate sloping profile also helps to direct the reflected light at desired angle of projection, e.g. either raising or lowering the angle of projection. At least one of the top, bottom or lateral side mounting surfaces may comprise a slope profile. As shown in FIG. 15, a mounting surface comprising a slope profile may be selected from a fixed-angle slope profile 801, or a varying-angle slope profile such as a convex slope profile 802, or a concave slope profile 803, or a step-wise slope profile 804. A fixed slope profile having a fixed angle calculated to work with the known geometry and light distribution behavior of a light reflector may be adopted in design-in situations. Aftermarket devices may adopt varying slope profiles so that LEDS positions on the mounting surface may be adjusted according to the reflector geometry of the vehicle to achieve a desired light distribution pattern. A recessed indentation or protrusion with a sloping profile formed on the surface of a flat mounting surface may also provide these various slope profiles.

[052] Simulation studies were carried out on the illumination pattern of lighting device 600. The simulation results are shown in FIG. 16A, 16B, 17A and 17B. Simulation studies were carried out on the illumination pattern of lighting device 700. The simulation was realized with a commercial ray tracing software. According to UN/ECE Regulation 113 (hereinafter "ECE R113"), a test plane comprises a flat vertical screen placed at a distance of 25 meters forward of the lighting device. Such a test plane was adopted to study the illumination pattern produced by lighting device 700. Fig 16A is a light distribution pattern of a low beam illumination on the test plane. In this pattern, a clear top cut-off line is seen, which is required in ECE R113. In Fig 16B, a table of lux values of each test point is shown. The second and the third column is the required lux value according to ECE R113. Ray tracing simulation results show that the lux values of most test points meet the standard in ECE R113 (the green cell means the corresponding lux value meet

the standard and the red cell means fail to meet the standard). Fig. 17A and Fig. 17B show, respectively, the illumination pattern and table of lux values for a high beam. The simulation result shows that all test points meet the standard for high beam illumination.

[053] To comply with “Regulation No. 72 of the Economic Commission for Europe of the United Nations (UN/ECE) — Uniform provisions concerning the approval of motor cycle headlamps emitting an asymmetrical passing beam and a driving beam and equipped with halogen lamps (HS1 lamps)”, hereinafter “UN ECE 72”, the lighting device may incorporate features to provide an asymmetrical light distribution pattern. For example, on left hand drive roads where oncoming traffic is on the right of the driver (from the perspective of the driver), in order to avoid dazzling oncoming vehicles on the right, LESD units may be provided on a sloping profile on the left side of the frame (from the driver’s perspective) facing away from oncoming traffic, hence shielding direct light from the LESD units from oncoming drivers. Likewise, on right hand drive roads where oncoming traffic is on the left (from the perspective of the driver), in order to avoid glare to oncoming vehicles on the right, LESD units may be provided on a sloping profile on the right side of the frame facing away from oncoming traffic, hence shielding direct light from the LESD units from oncoming drivers.

[054] In other embodiments, it may be desirable to provide colored lights, for aesthetic purposes. Examples include various red, green, blue, or amber lights (e.g. for hazard lights).

[055] In some embodiments, vibration damping tape is provided on the portions of the base contacting the light bulb socket of the vehicle headlamp. Vibrational stability of the lighting device when mounted on a moving vehicle may be achieved by providing a pre-cut vibration damping material on the base of the frame, which interfaces with the headlamp socket. When the lighting device is locked in position, the vibration damping material may help to minimize impacts that can lead to the dislodgment of the lighting device. Examples of usable vibration dampening materials include 3M™ Vibration Damping Tapes, which comprises pressure-sensitive viscoelastic polymers and aluminum foil constraining layer to effectively convert vibrational energy to negligible heat in order to reduce vibrational noise and decrease wear and tear on parts.

[056] In another aspect, the invention is directed to a lighting element, comprising a single, continuous strip of flexible circuit comprising a plurality of light emitting semiconductor devices (LESDs), the flexible circuit having a shape configured to extend over a plurality of mounting surfaces of a frame, and the LESDs having a layout on the flexible circuit configured to position one or more LESDs over each mounting surface of the frame. In one embodiment, a first section of the flexible circuit comprises a first LED group formed at a position on the flexible circuit corresponding to the upper mounting surface on the component, and a second section of the flexible circuit comprises a second LED formed at a position on the flexible circuit corresponding to the lower mounting surface on the component. In another embodiment, a section of the flexible circuit comprises a LED group formed at a position on the flexible circuit corresponding to the location of a front-facing mounting surface on the frame. In yet another embodiment, a section of the flexible circuit comprises a LED group formed at a position on the flexible circuit corresponding to the location of a lateral side surface on the frame. Each LED group may be electrically connected to a separate circuit trace in the flexible circuit so that each LED group is independently operable from other LED groups. A thermally conductive interface tape may be provided on a surface of the flexible circuit opposite the surface on which the LESDs are formed.

[057] The present specification is not limited to the specific examples or data set forth herein. The embodiments disclosed herein are capable of being made, practiced, used, carried out and/or formed in various ways expected of a skilled person in the field once an understanding of the invention is acquired. The use of any and all examples, or exemplary language (e.g., "such as") provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification, and no structures shown in the drawings, should be construed as indicating that any non-claimed element is essential to the practice of the invention. The use herein of the terms "including" "comprising" or "having" and permutations thereof, is meant to encompass the features defined thereafter and equivalents thereof, as well as additional items. Numerical indicators, such as first, second, and third, as used in the description and the claims to refer to various structures or method steps, are not meant to be construed to indicate any specific structures or steps, or any particular order or configuration to such structures or steps. All methods described

herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context.

[058] Although the present invention has been described with particular reference to preferred embodiments illustrated herein, it will be understood by those skilled in the art that variations and modifications thereof can be effected and will fall within the scope of this invention as defined by the claims thereto now set forth herein below.

CLAIMS

1. A lighting device for a vehicle headlamp, comprising:

a single, continuous strip of flexible circuit comprising a plurality of light emitting semiconductor devices (LESDs),

a frame supporting the flexible circuit, the frame comprising a plurality of mounting surfaces for mounting the LESDs onto the frame,

the flexible circuit having a shape configured to extend over each mounting surface, and the LESDs having a layout on the flexible circuit configured to position one or more LESDs over each mounting surface.
2. The lighting device of Claim 1, wherein the frame comprises a top mounting surface and a bottom mounting surface relative to a mounted position, the flexible circuit extending over the top mounting surface and the bottom mounting surface, the flexible circuit comprising a first LESD group positioned on the top mounting surface for providing a high beam light source, and a second LESD group is arranged on the bottom mounting surface for providing a low beam light source.
3. The lighting device of Claim 1 or 2, wherein the frame comprises a front facing mounting surface relative to a mounted position, the flexible circuit extending over the front facing mounting surface, and the flexible circuit comprising a LESD group positioned on the front facing mounting surface for providing a day time running light (DRL) source.
4. The lighting device of any of Claims 1 to 3, wherein the frame comprises a lateral side mounting surface relative to a mounted position, the flexible circuit extending over the lateral side mounting surface, the flexible circuit comprising a LESD group positioned on the lateral side mounting surface.

5. The lighting device of any of Claims 2 to 4, wherein each LESD group is electrically connected to a separate circuit trace in the flexible circuit so that each LESD group is independently operable from other LESD groups.
6. The lighting device of any of Claims 1 to 5, wherein the plurality of mounting surfaces are located on different planes.
7. The lighting device of any of Claims 1 to 6, wherein at least one of the top, bottom or lateral side mounting surfaces has a slope profile.
8. The lighting device of any of Claims 1 to 7, wherein the flexible circuit is creased at each location where the flexible circuit is folded over an edge of the frame.
9. The lighting device of any of Claims 1 to 8, further comprising a base attached to the frame, the base comprising mating features for mounting onto a light bulb socket of a vehicle headlamp assembly.
10. The lighting device of Claim 9, wherein a vibration damping tape is provided on the portions of the base contacting the light bulb socket of the vehicle headlamp.
11. The lighting device of any of Claims 1 to 10, wherein the frame comprises a material having thermal conductivity of above 15 W/mK.
12. The lighting device of Claim 11, wherein the frame comprises heat dissipating features selected from the group consisting of cooling fins, an electric fan and a liquid coolant.
13. The lighting device of any of Claims 1 to 12, wherein a thermally conductive interface tape is provided between the flexible circuit and the mounting surfaces of the frame.
14. A vehicle headlamp, comprising a light reflector, a lens fitted over the light reflector, and a lighting device of any of Claims 1 to 13 arranged between the light reflector and the lens via an aperture in the light reflector.
15. A lighting element for a vehicle headlamp lighting device, comprising:

a single, continuous strip of flexible circuit comprising a plurality of light emitting semiconductor devices (LESDs), the flexible circuit having a shape configured to extend over a plurality of mounting surfaces of a frame, and the LESDs having a layout on the flexible circuit configured to position one or more LESDs over each mounting surface of the frame.

16. The lighting element of Claim 15, wherein

a first section of the flexible circuit comprises a first LED group formed at a position on the flexible circuit corresponding to the upper mounting surface on the component, and

a second section of the flexible circuit comprises a second LED formed at a position on the flexible circuit corresponding to the lower mounting surface on the component.

17. The lighting element of Claim 15 or 16, wherein a section of the layout comprises a LED group formed at a position on the flexible circuit corresponding to the location of a front-facing mounting surface on the frame.

18. The lighting element of any of Claims 15 to 17, wherein a section of the layout comprises a LED group formed at a position on the flexible circuit corresponding to the location of a lateral side surface on the frame.

19. The lighting element of any of Claims 16 to 18, wherein each LED group is electrically connected to an independent circuit trace in the flexible circuit so that each LED group is independently operable from other LED groups.

20. The lighting element of any of Claims 15 to 19, further comprising a thermally conductive interface tape is provided on a surface of the flexible circuit opposite the surface on which the LESDs are formed.