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(54) VEHICLE HEADLAMP FOR HIGH MOUNT APPLICATIONS

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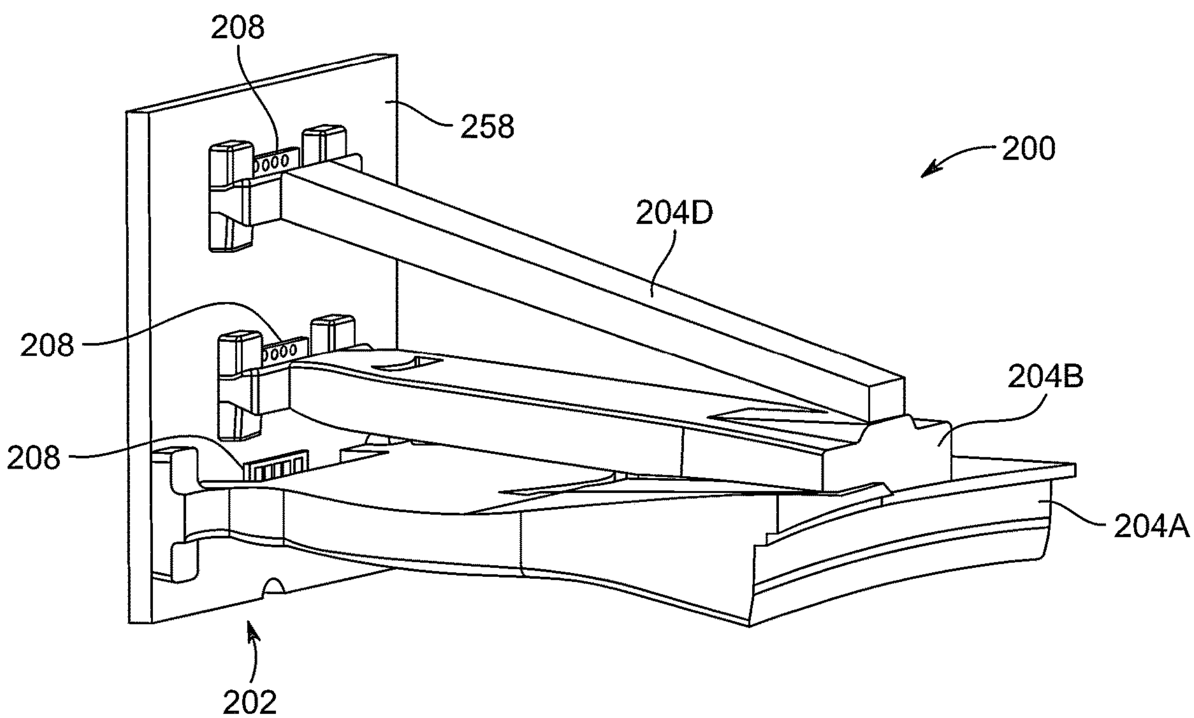
(57) **ABSTRACT**

A lighting system for a vehicle includes an LED light source and first, second and third waveguides, each being configured to receive the light emitted from the light source at a first end and output an intermediate light pattern at an opposing second end. A projection lens is disposed adjected the second end of the waveguides to receive the light pattern and project it in front of the vehicle. At least one of the waveguides may include a refracting surface array configured to shape the light received from the LED light source. The lighting system may be mounted to the vehicle at an elevated location above an implement associated with the vehicle to illuminate areas in front of the implement.



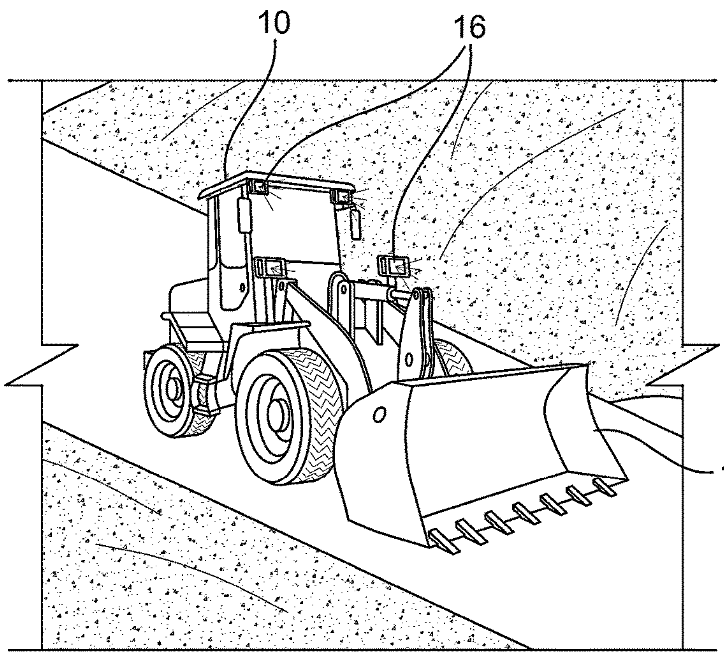


FIG. 1

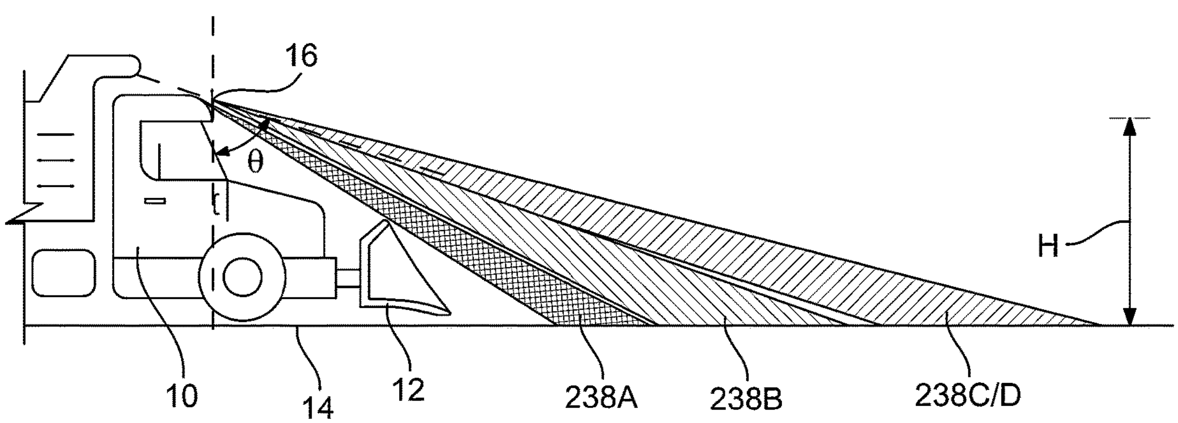


FIG. 2

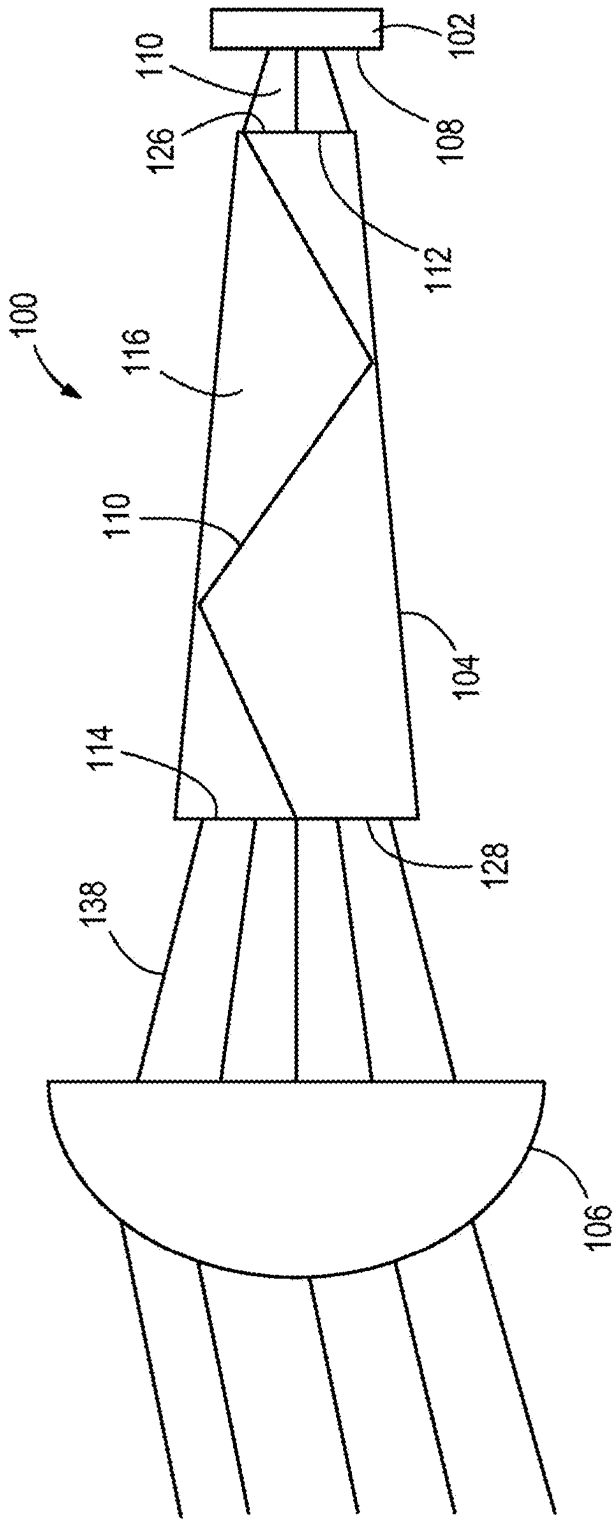


FIG. 3

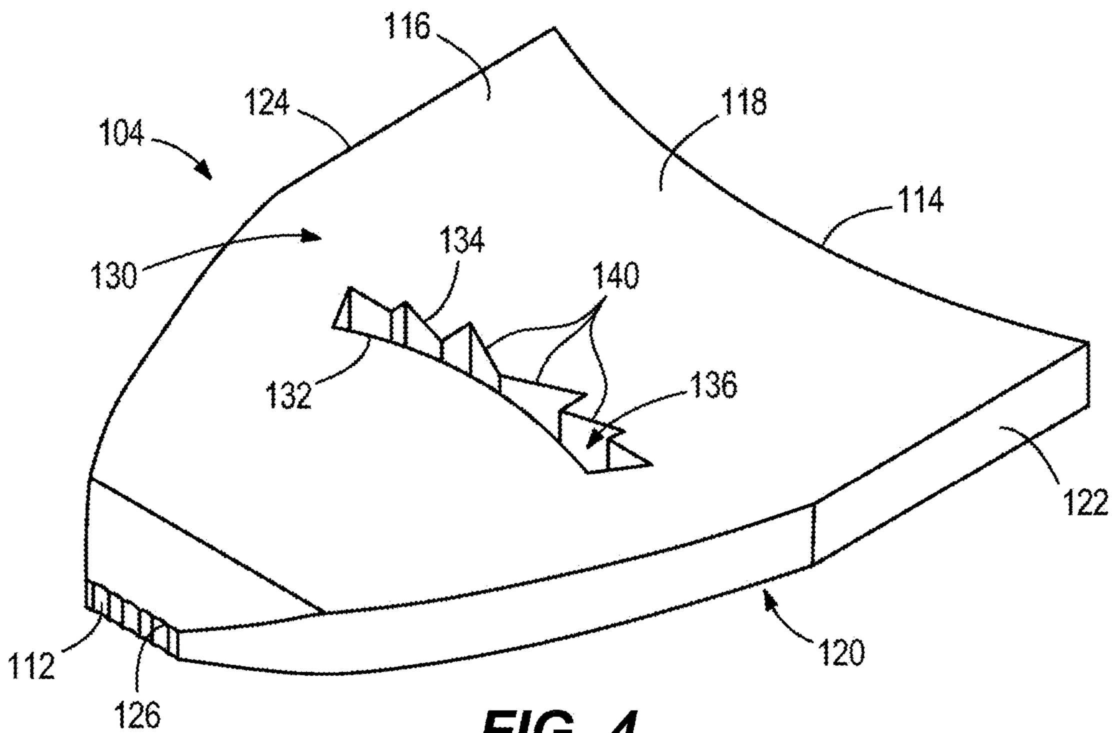

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FIG. 4

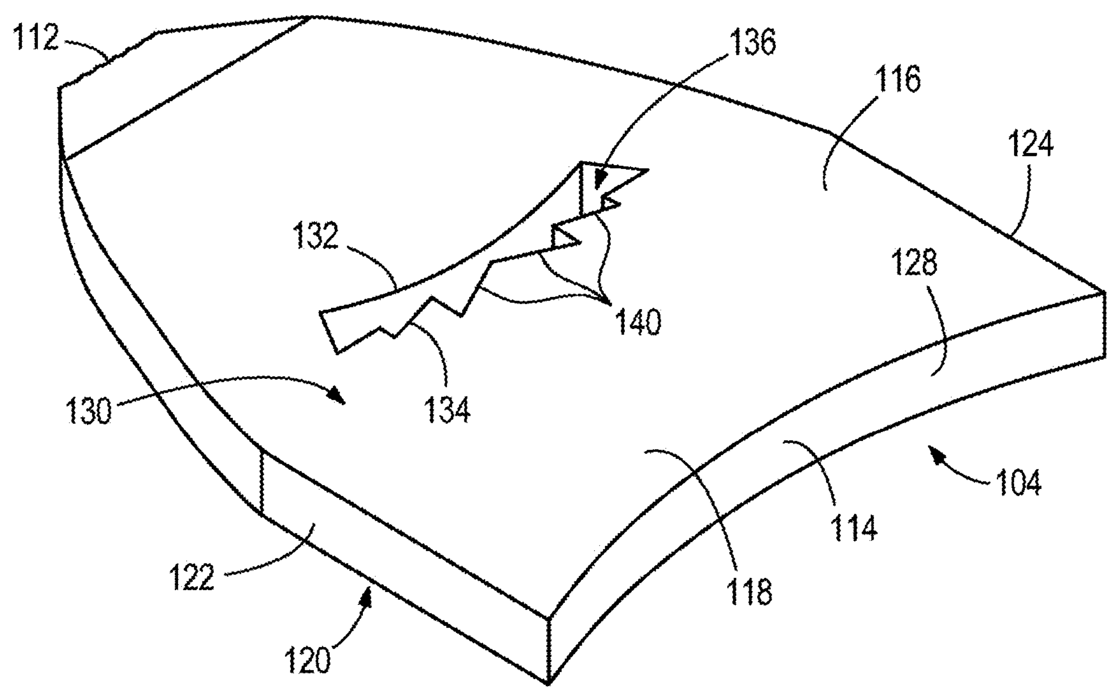
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FIG. 5

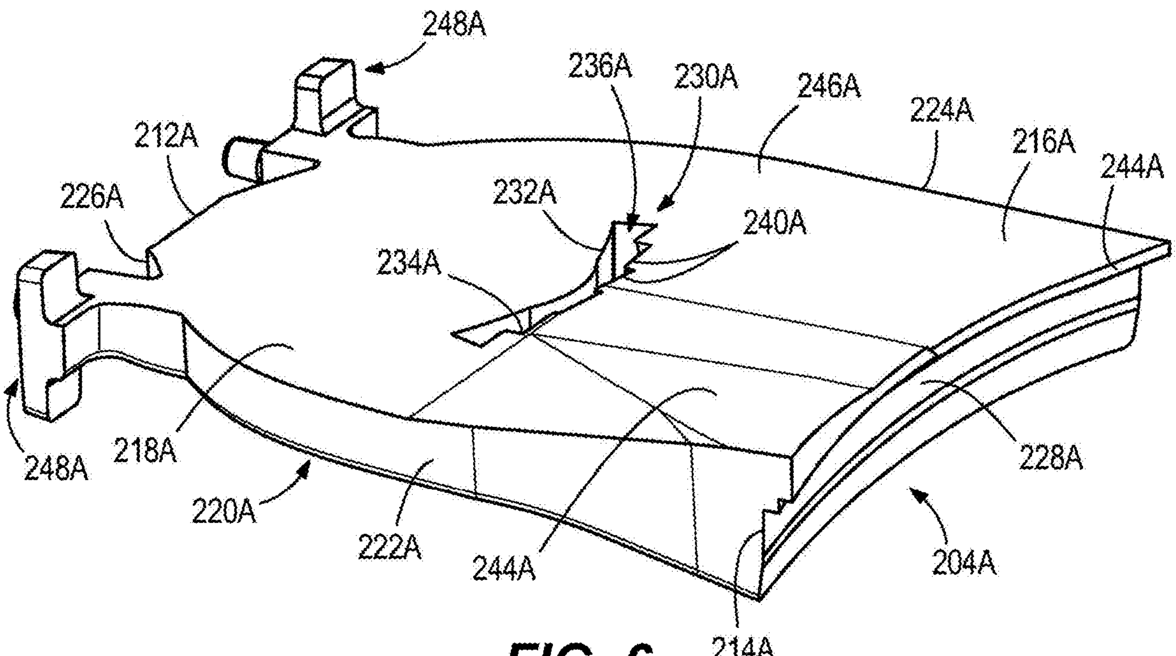
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FIG. 6

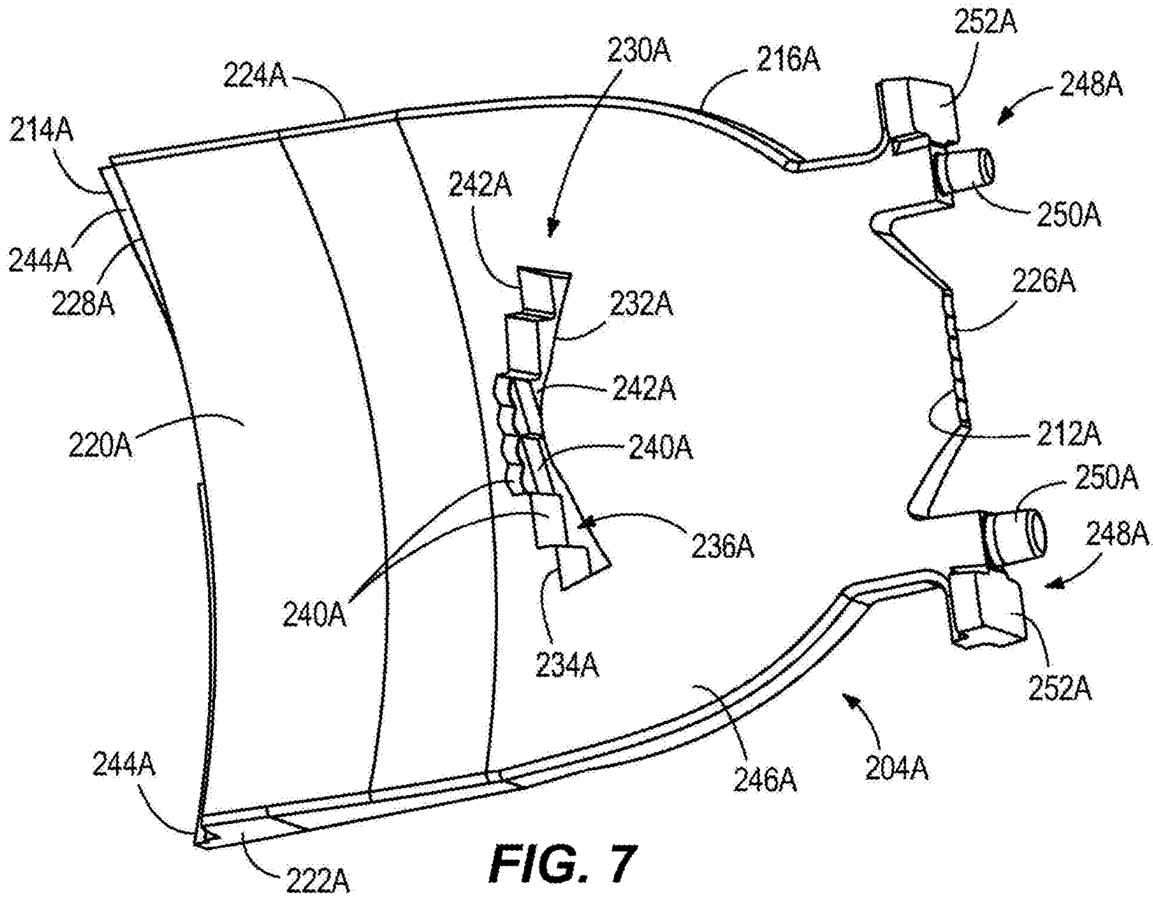
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FIG. 7

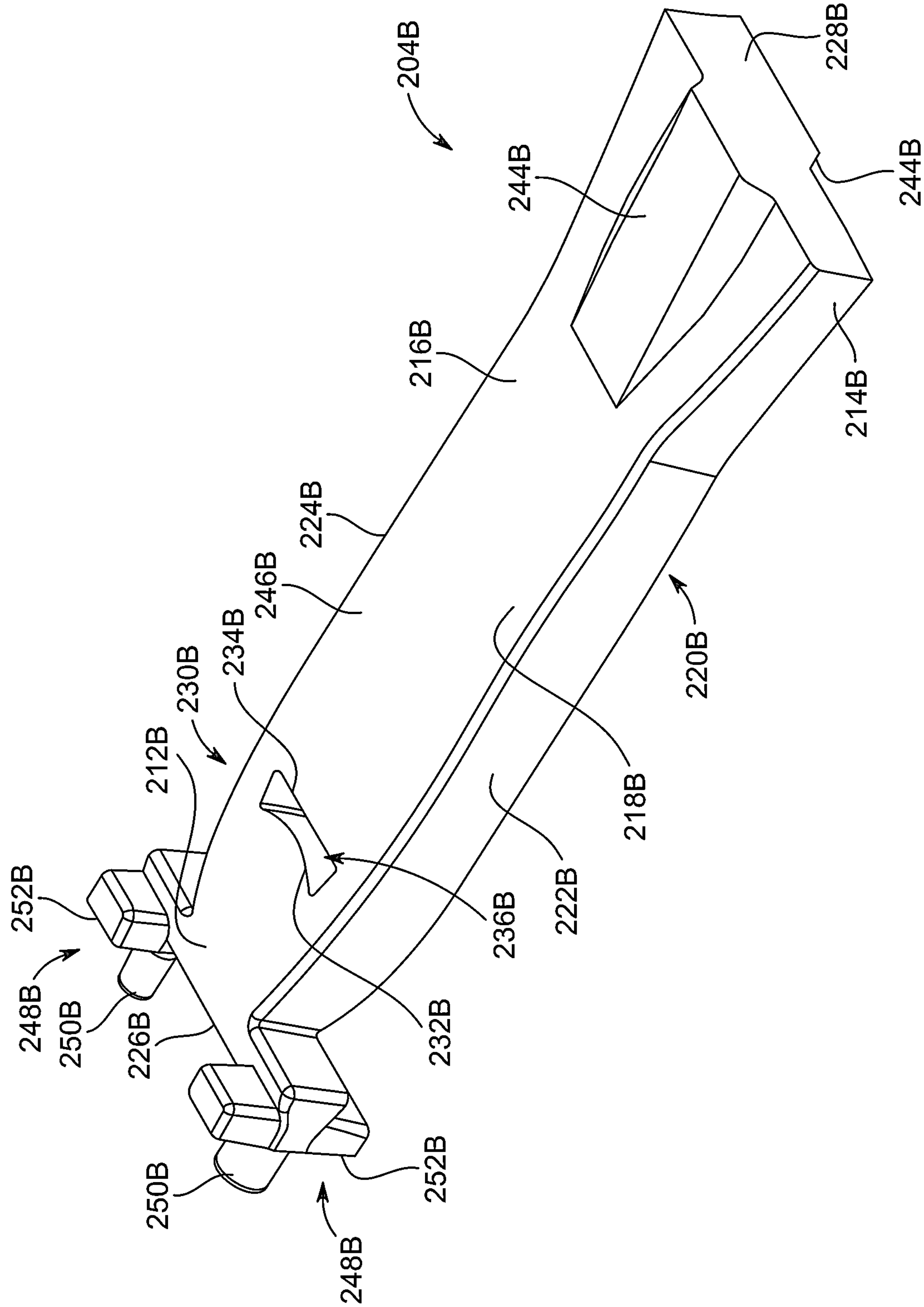
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FIG. 8

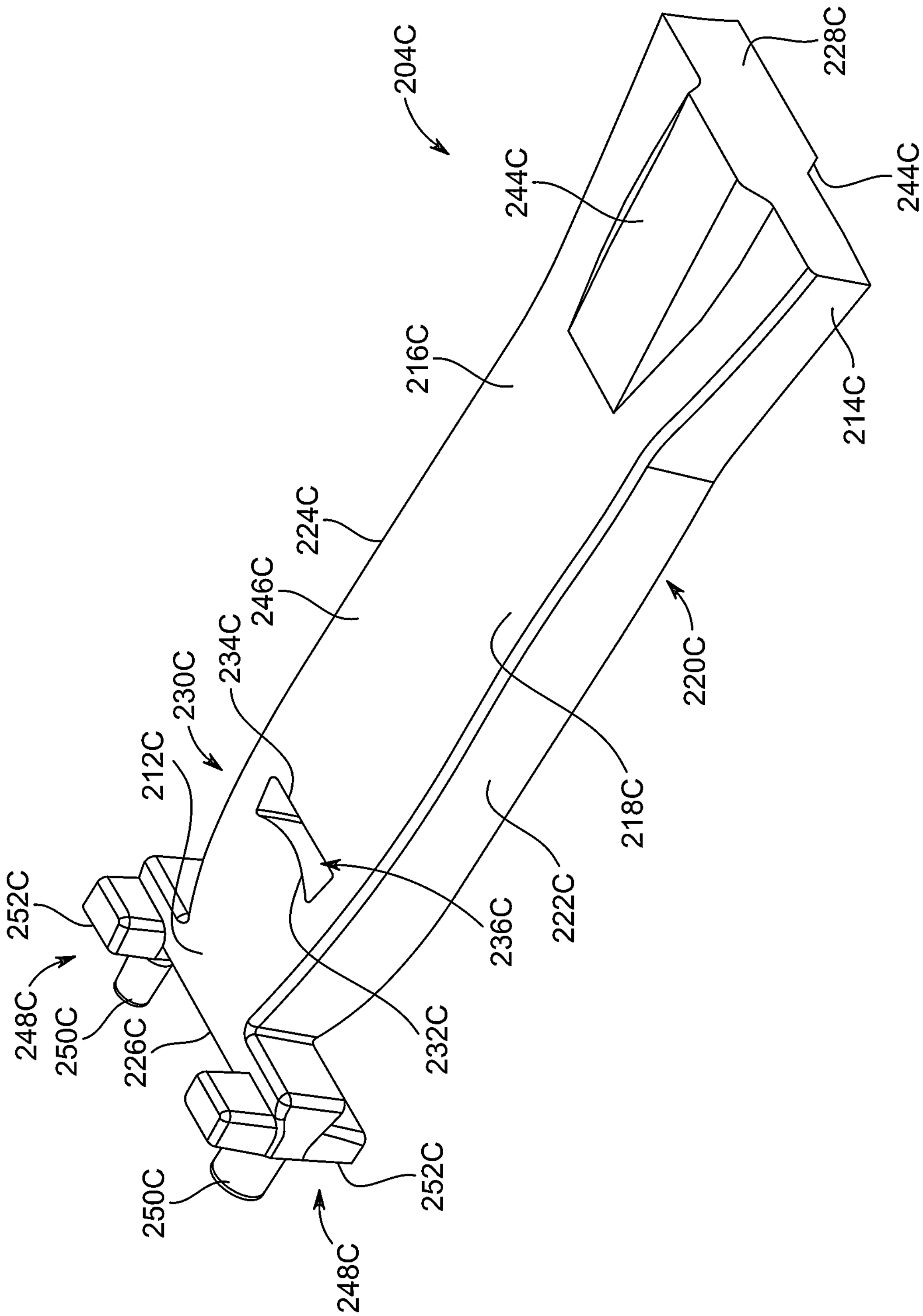
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FIG. 9

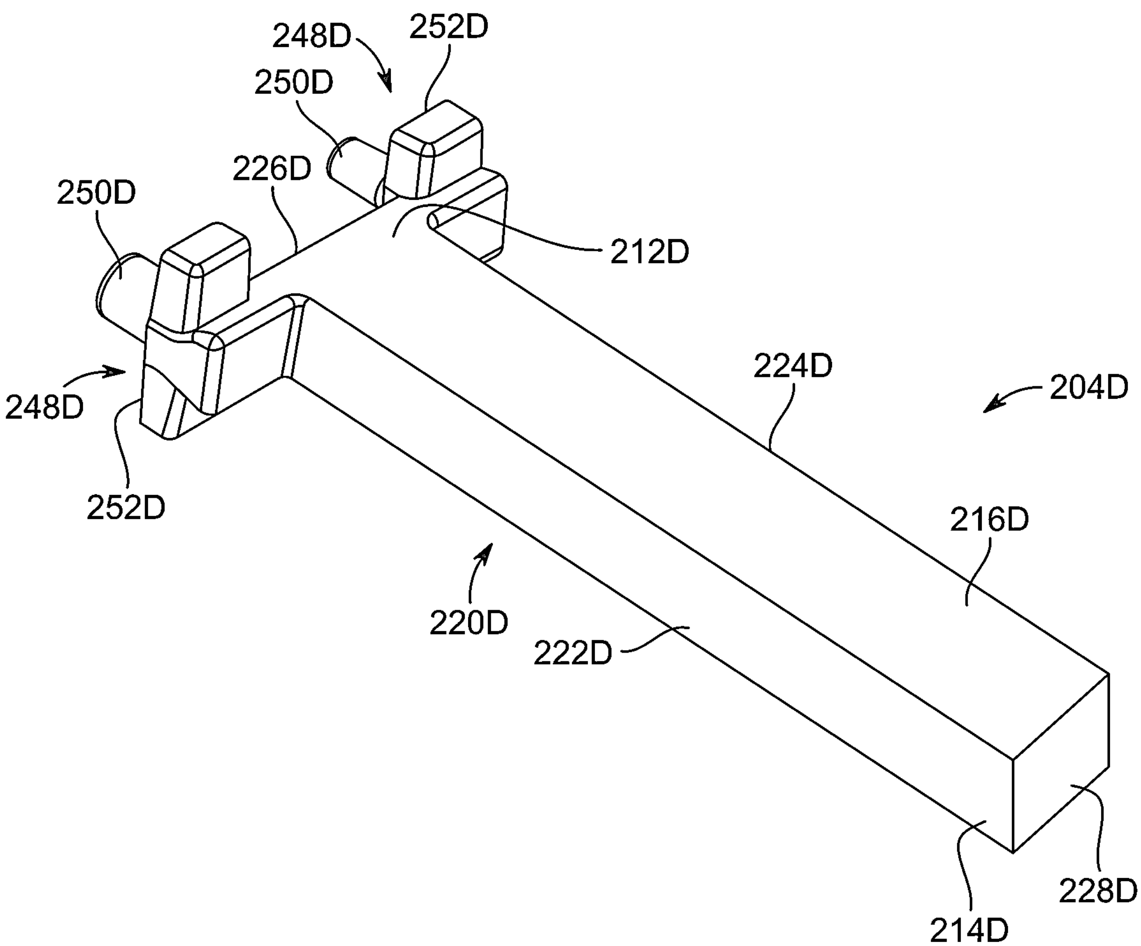
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FIG. 10

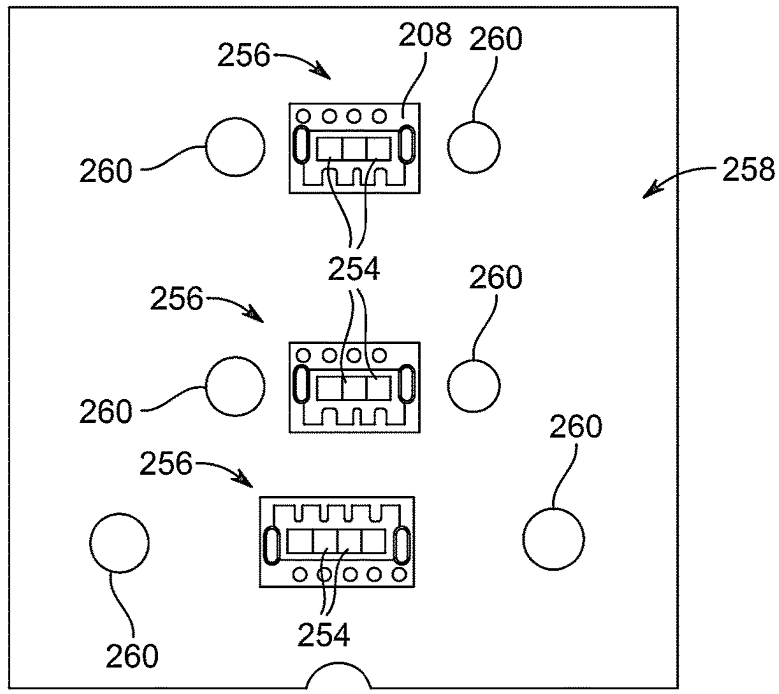
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FIG. 11

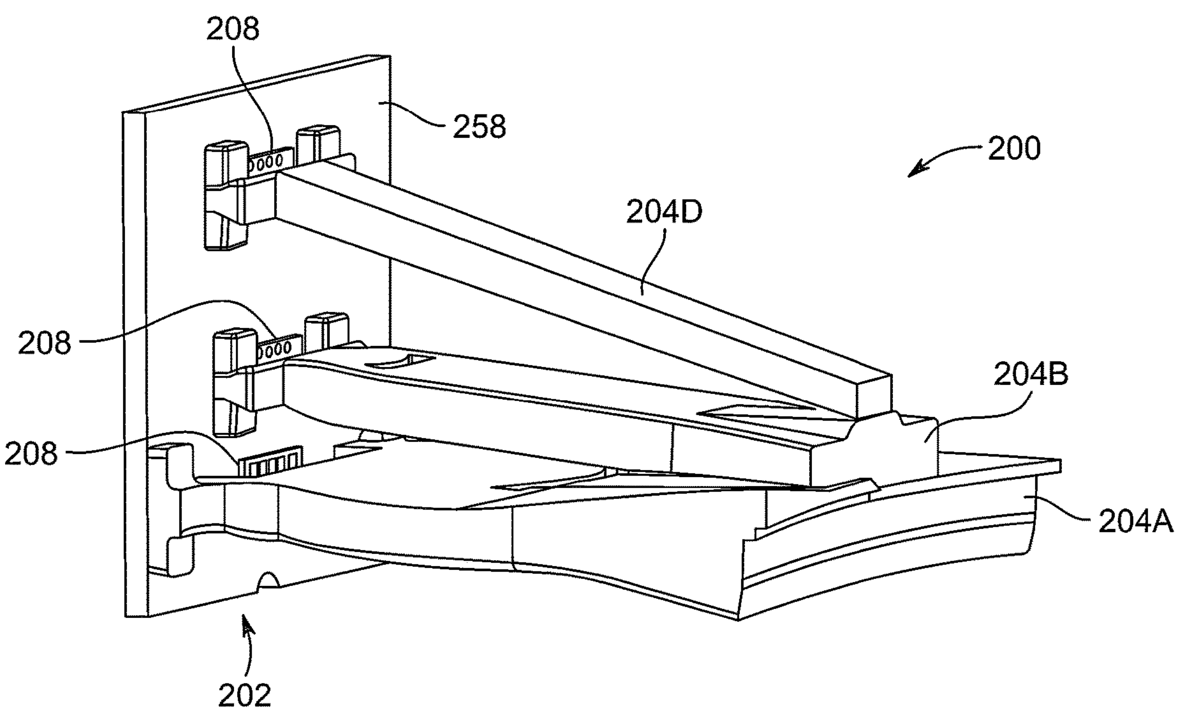
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FIG. 12

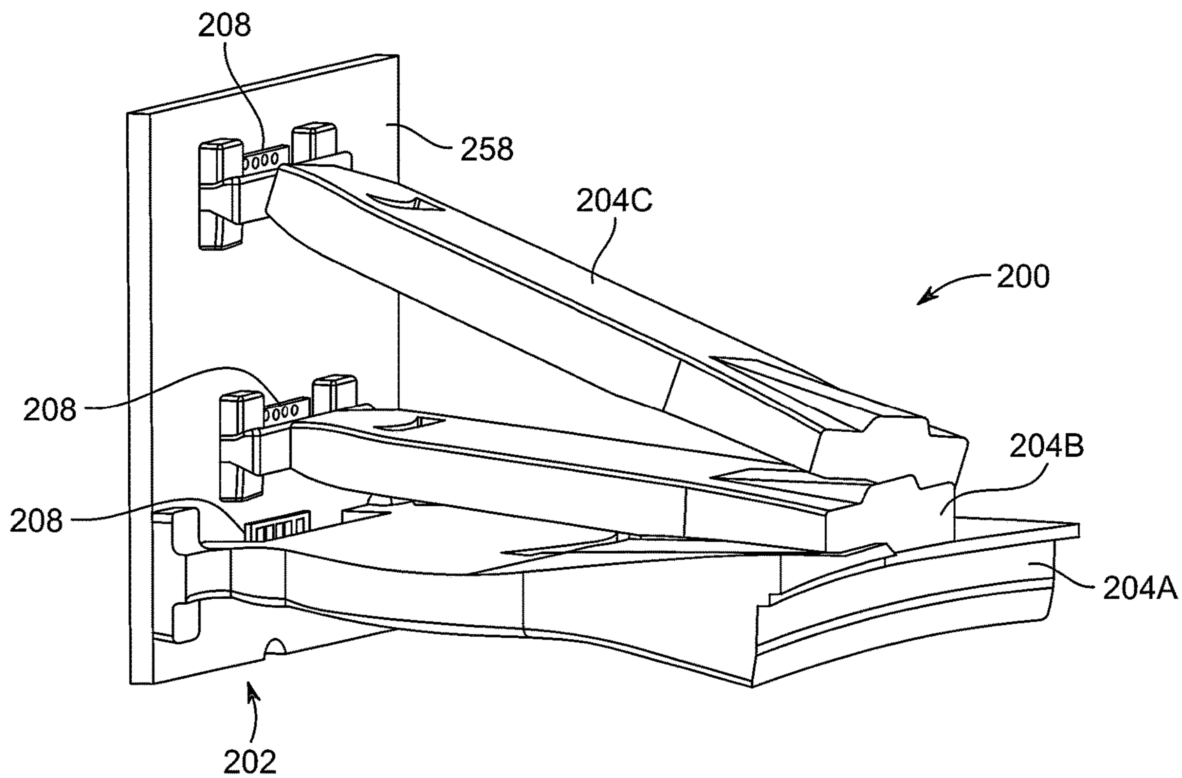
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FIG. 13

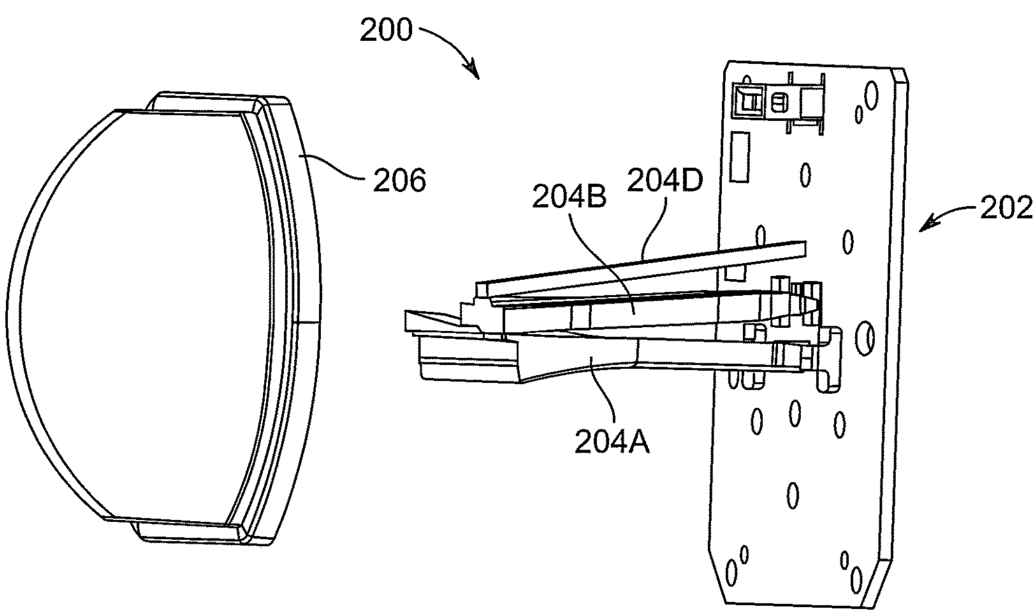
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FIG. 14

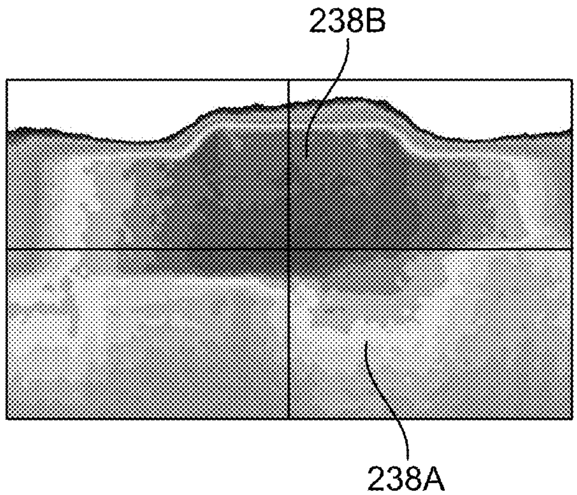

FIG. 15A

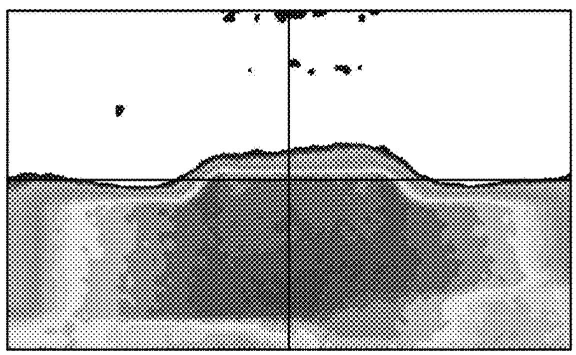

FIG. 15B

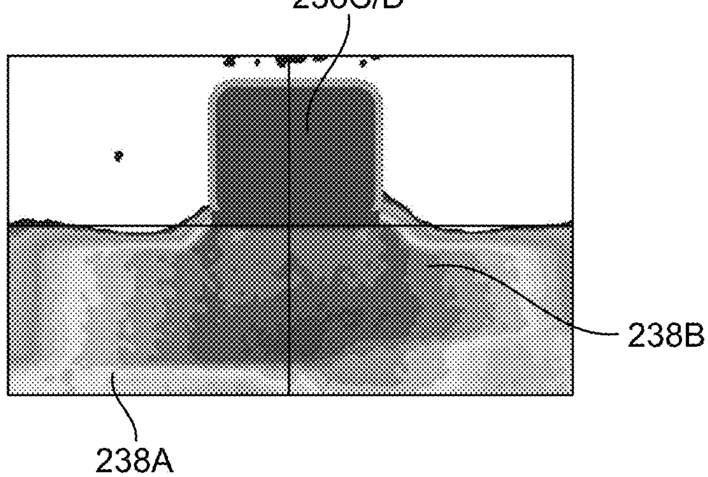

FIG. 15C

VEHICLE HEADLAMP FOR HIGH MOUNT APPLICATIONS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. provisional patent application Ser. No. 63/553,814 filed Feb. 15, 2024, the entire contents of which are hereby incorporated by reference.

BACKGROUND AND SUMMARY

[0002] This invention relates to vehicle lights, and more particularly to a high-mounted headlamp configured for use with commercial and industrial vehicles that includes a first, second, and third waveguide to form a beam pattern suitable for high beam and low beam vehicle headlights.

[0003] A vehicle is typically outfitted with a number of automotive lamps or lights that provide illumination in certain areas in and around the vehicle. Certain lights may be mounted and configured to illuminate areas within the vehicle interior while other lights may be mounted and configured to illuminate areas exterior to the vehicle. Typically, the interior lights may illuminate areas that facilitate operator ingress or egress, or operation and control of the vehicle. The exterior lights may also facilitate operator ingress or egress, and may also be configured to illuminate other external areas. For example, exterior vehicle lights such as headlights and fog lights may provide forward illumination for lighting a path of travel, and rearward or side illumination for safety or for providing an indication of a function, such as reverse indicator lights, directional indicators, taillights, and brake lights. In a work vehicle, exterior lights may also be provided for illuminating a work area, typically located forward of the cab of the work vehicle.

[0004] In the context of exterior vehicle lighting configured to provide forward illumination of the vehicle's path of travel while traveling in low light, dark areas or at night, vehicles often include a combination of both low beam and high beam headlights or headlamps. Low beams provide relatively short-range illumination as compared to high beams, and their illumination pattern is angled towards the ground so as to illuminate the roadway without adversely obscuring the field of vision of oncoming drivers. In contrast, high beams provide a long-range focus that are well suited for illuminating an area above and beyond that of the low beams, and are particularly well suited for roadways that lack street lighting or other overhead illumination.

[0005] In a conventional vehicle headlamp, in either of the low beam or high beam configuration a light source, such as a halogen bulb, may be located within a parabolic reflector. Light emitted from the bulb is predominantly collimated as it reflects outwardly off the interior surface of the parabolic reflector. A front lens then directs the emitted light onto a portion of the roadway, corresponding to the desired illumination pattern of either the low beam or high beam.

[0006] Prior efforts have been made to improve upon such systems and simplify the illumination of roadways including the use of a unitary reflector formed of a plurality of interior mirrored surfaces arranged in a stepwise fashion. However, all such prior embodiments continue to be limited in their ability to collimate and direct only the emitted light that contacts the reflector.

[0007] More recent developments in the improvement of vehicle headlamps have seen the introduction of dual-beam headlights, which incorporate both the low beam and the high beam into a single headlamp system. The original dual beam headlamps provide a single light bulb or other light generator, with a greater intensity than that of a traditional headlamp. The system may utilize an elliptical reflector that focuses the light at a focal point adjacent the front end of the reflector. A shaped shield may be selectively positioned at the focal point to alter the shape and brightness of light that passes through the focal point to a projector lens that transmits the emitted light onto the roadway. However, such conventional dual-beam systems continue to rely upon high-energy consumption and low-reliability halogen or xenon light bulbs. Compounded by the need for mechanical solenoid activation for modulation between low beam and high beam operation, such prior systems are susceptible to mechanical failures. Therefore, an improvement over this design has been to use a dual source in the dual beam headlight. One source, typically an LED, is shaped by a unitary reflector formed of a plurality of mirrored surfaces arranged in a stepwise fashion to produce the low beam and a second source can be mounted opposing the first with a second plural mirror surface arranged to produce the high beam. The interface between the two mirrored surfaces produces the necessary asymmetric cut-off shape to control the intensity distribution of the low beam. This system eliminates the use of unreliable and high-energy consuming bulbs or active mechanical components, but the dual reflectors occupy a relatively large volume. A further improvement on this design is a system using waveguides (total internal reflection optics) to form the shape and intensity of the beam, eliminating the need for the reflectors and drastically reducing size.

[0008] In the context of commercial and industrial vehicles, many such vehicles include forward mounted tools and accessories such as snowplow blades, bulldozer blades, front end loader buckets, tractor buckets, hydraulic arms or booms, etc. Low mounted headlights, such as those installed on traditional passenger vehicles are mounted approximately 0.6 to 1.0 meters above the roadway. Exclusive use of such traditional low-mounted headlights would result in the obstruction of the emitted lighting path by the forward mounted tools and accessories. To compensate for the blocked light from the low-mounted headlights on vehicles with the accessories described, so-called work lights (as opposed to road lights) can be mounted high on the vehicle, typically over the cab. The work lights, however, do not have true high and low beam functions, with comparatively wide illumination and no effective method to avoid dazzling oncoming traffic or to sufficiently illuminate further along the road when there is no oncoming traffic. Accordingly, there exists a need to develop a high mounted vehicle headlamp product that also realizes the benefits of a simplified solution for shaping and projecting the illumination pattern of both low beam and high beam lights according to national legal standards without the use of unreliable and high-energy consuming bulbs or active mechanical components.

[0009] The present invention contemplates an LED receiving waveguide with an integrated lens assembly to form a beam pattern suitable for a combination of high beam and low beam vehicle headlights in a high-mounted headlamp configured for use with commercial and industrial vehicles which are to be road-certified by the traffic authority of the country in which the vehicle is to be operated.

[0010] The high-mount headlight assembly for a vehicle according to the present invention may be in the form of a light system for use with a commercial and industrial vehicle. In one aspect, the light system may include at least one light emitting diode (LED) light source mounted to a vehicle that is configured to emit a light upon activation, and plurality of waveguides configured to receive the light emitted from the at least one LED light source at a first end and output a light pattern at an opposing second end. The plurality of waveguides may include at least one waveguide configured to emit an extended high beam light pattern. The plurality of waveguides may comprise a first waveguide configured to emit a low beam light pattern and a second waveguide configured to emit a standard high beam light pattern, in combination with a third waveguide configured to emit the extended high beam light pattern.

[0011] The high-mount headlight assembly may have one or more refracting surface arrays disposed within a body of at least one of the waveguides, located between the first and second ends. The refracting surface array may be configured to shape the light received from the LED light source to form the light pattern at the second end of the waveguide, which is presented to a projection lens disposed adjected the second end of the waveguide. The projection lens is configured to receive the light pattern and project the same in front of the vehicle towards a roadway. Generally, the waveguides of the present invention are configured to emit the light into a desired light pattern for use in vehicle headlights.

[0012] Specifically, then, one aspect of the present invention may include a first waveguide that is adapted to form a low beam light pattern at a high-mounted headlight of the vehicle, a second waveguide adapted to form at least a portion of a high beam light pattern, i.e., an intermediate beam, at the high-mounted headlight of the vehicle, and a third waveguide adapted to form at least an extended portion of a high beam light pattern at the high-mounted headlight of the vehicle.

[0013] Another aspect of the present invention may include a refracting surface array disposed within the corresponding waveguide that includes a void disposed within the body of one or more of the waveguides, a collector lens upstream of the void and a redistribution surface downstream of the void. The collector lens may be configured to asymmetrically distribute light about the refracting redistribution surfaces, and the redistribution surfaces may be configured to collimate the light received thereon.

[0014] In another aspect of the present invention the redistribution surface of the array may include a plurality of refracting surfaces of varying configurations and orientations, which redirect the light received thereon into an asymmetrical low beam or high beam light pattern.

[0015] Other aspects, features and advantages of the invention will become apparent to those skilled in the art from the following detailed description and accompanying drawings. It should be understood, however, that the detailed description and specific examples, while indicating certain embodiments of the present invention, are given by way of illustration and not of limitation. Many changes and modifications may be made within the scope of the present invention without departing from the spirit thereof, and the invention includes all such modifications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] A clear conception of the advantages and features constituting the present invention, and the construction and operation of typical mechanisms provided with the present invention, will become more readily apparent by referring to the exemplary, and therefore non-limiting, embodiments illustrated in the drawings accompanying and forming a part of this specification, wherein like reference numerals designate the same elements can be several views, and in which:

[0017] FIG. **1** is an illustration of an industrial vehicle including high-mounted headlights;

[0018] FIG. **2** is a left side illustration of an industrial vehicle including a high mount headlight that includes a first, second, and third waveguide to form a beam pattern including a low beam, high beam and extended high beam according to one embodiment of the present invention;

[0019] FIG. **3** is a side cross sectional view of the vehicle headlight system according to one embodiment of the present invention

[0020] FIG. **4** is a rear top perspective view of a waveguide according to one embodiment of present invention configured for use in a vehicle headlight;

[0021] FIG. **5** is a front top perspective view of the waveguide shown in FIG. **4**;

[0022] FIG. **6** is a front top perspective view of a low beam waveguide according to one embodiment of present invention configured for use in a vehicle headlight;

[0023] FIG. **7** is a bottom perspective view of the low beam waveguide shown in FIG. **6**;

[0024] FIG. **8** is a front top perspective view of a high beam waveguide according to one embodiment of present invention configured for use in a vehicle headlight;

[0025] FIG. **9** is a front top perspective view of an extended high beam waveguide according to a first embodiment of present invention configured for use in a vehicle headlight;

[0026] FIG. **10** is a front top perspective view of an extended high beam waveguide according to a second embodiment of present invention configured for use in a vehicle headlight;

[0027] FIG. **11** is a front elevation view of a low beam, a high beam and an extended high beam LED array affixed to a mounting surface configured to receive the low beam waveguide of FIG. **6**, the high beam waveguide of FIG. **8**, and the extended high beam waveguide of either FIG. **9** or **10**;

[0028] FIG. **12** is a front top perspective view of a vehicle headlight assembly according to one embodiment of the present invention, including a low beam waveguide, high beam waveguide, one embodiment of the extended high beam waveguide and corresponding LED arrays;

[0029] FIG. **13** is a front top perspective view of a vehicle headlight assembly according to one embodiment of the present invention, including a low beam waveguide, high beam waveguide, an alternative embodiment of the extended high beam waveguide and corresponding LED arrays;

[0030] FIG. **14** is a front perspective view of the vehicle headlight assembly of FIG. **12**, including a projection lens;

[0031] FIG. **15**A is a front elevation view of a light emission profile from a head light mounted at a standard passenger vehicle height, emitting both a low beam light pattern and a high beam light pattern;

[0032] FIG. **15**B is a front elevation view of a light emission profile from a high-mounted head light at a downward tilt angle of approximately 4.0°, emitting both a low beam light pattern and a high beam light pattern; and,

[0033] FIG. **15**C is a front elevation view of a light emission profile from a high-mounted head light of FIG. **14** at a downward tilt angle of approximately 4.0°, emitting a low beam light pattern, a high beam light pattern, and an extended high beam light pattern.

[0034] In describing the embodiments of the invention which are illustrated in the drawings, specific terminology will be resorted to for the sake of clarity. However, it is not intended that the invention be limited to the specific terms so selected and it is to be understood that each specific term includes all technical equivalents which operate in a similar manner to accomplish a similar purpose. For example, the words "connected," "attached," or terms similar thereto are often used. They are not limited to direct connection or attachment, but include connection or attachment to other elements where such connection or attachment is recognized as being equivalent by those skilled in the art.

DETAILED DESCRIPTION

[0035] The various features and advantageous details of the subject matter disclosed herein are explained more fully with reference to the non-limiting embodiments described in detail in the following description.

[0036] Referring to the following description in which like reference numerals represent like parts throughout the disclosure, and initially to FIGS. **1** and **2**, a vehicle **10**, being a commercial or industrial vehicle with a forward mounted accessory **12** such as a front end loader shovel is shown. Placement of the headlights at a height of approximately 0.6 to 1.0 meters above the roadway **14**, which is traditional for a passenger vehicle, would result in the forward mounted accessory **12** obscuring or blocking all or some of the light pattern emitted from the headlight. Accordingly, a headlight **16** according to the present invention is configured to be mounted to a vehicle at a height H, of approximately 2.0 to 3.5 meters above the roadway **14** or surface supporting the vehicle **10**. Elevation of the headlight **16** to height H allows for the emitted light pattern to be directed onto the roadway **14** in front of the vehicle **10** and the forward mounted accessory **12**. However, to avoid the emitted light pattern from adversely impacting oncoming drivers, i.e., "dazzling," it is necessary to downwardly tilt the angle of the low-beam light pattern emitted from headlight **16** so that, in accordance with current regulations, the driving beam light pattern strikes the driving surface of oncoming traffic within 30 meters from the front of the vehicle.

[0037] In a conventional system, downward tilting of the high-mounted headlight redirects the emitted light pattern to an area closer to the vehicle, undesirably limiting the range of high beam light pattern emitted. That is to say that reduction of "dazzling" shifts the emitted light pattern which has the undesirable side effects of reducing high beam light on the vehicle's driving lane.

[0038] Alternatively, providing a high-mounted headlight **16**, according to the present invention includes a plurality of waveguides include a first waveguide configured to emit a low beam light pattern **238**A, a second waveguide configured to emit a standard high beam, i.e., an intermediate beam, light pattern **238**B, and a third waveguide configured to emit an extended high beam light pattern **238**C/**238**D. By way of providing a third waveguide configured to emit extended high beam light pattern. The high-mounted headlight **16**, according to the present invention, may be mounted at a height H, of approximately 2.0 to 3.5 meters above the roadway **14**, with a downward tilt angle θ of approximately between 4.0° and 7.0° which provides an extended high beam light pattern **238**C/**238**D on the vehicle's driving lane at a distance of approximately 30 to 175 meters, while simultaneously minimizing "dazzling."

[0039] Turning now to FIGS. **3-5**, and initially FIG. **3**, a vehicle lighting system **100** according to one embodiment of the present invention includes an LED light source **102**, a waveguide **104**, and a projection lens **106**. The LED light source **102** may be a single light emitting diode (LED) or an array of LEDs arranged in a planar configuration. A state-of-the-art automotive LED array, for instance, may have a total emitting surface in the range of 0.5-5.0 mm^2. As opposed to conventional halogen or xenon vehicle headlamp bulbs **12**, the emitting surface **108** of the LED light source **102** is a flat, i.e., two-dimensional, surface emitter **108**, which emits light **110** predominantly in a forward-facing direction as opposed to about an arcuate surface of a curved bulb. Accordingly, the lack of light emissions about a curved or arcuate surface lessens the need for a conical reflector, such as the parabolic reflector **14**, **22** or elliptical reflector **24** utilized in prior vehicle headlamps.

[0040] Turning now to the waveguide **104**, the waveguide **104** extends from a first end **112** that is configured to receive input light **110** emitted from the LED light source **102** to an opposing second end **114** that is configured to output light **110** to the projection lens **106**. The body **116** of the waveguide **104** extends along a longitudinal axis from the first end **112** to the opposing second end **114** and generally defines a pathway through which the light **110** travels towards the second end **114**. The wave guide **104** may be formed of a highly transparent polymer material, for example polycarbonate (PC) or polymethyl methacrylate (PMMA), with a typical refractive index of 1.35-1.60, which is well suited for the internal reflection of light traveling from first end **102** to the second end **112**.

[0041] Turning now to FIGS. **4** and **5**, in which a detailed embodiment of the waveguide **104** according to one embodiment of the present invention is shown, the body **116** may further comprise a top **118**, a bottom **120**, and right and left sides **122**, **124**. The waveguide **104** is generally a planar structure that may have a thickness of between 2.0 and 10.0 millimeters, and a length of between 10.0 and 100.0 millimeters. However, it should be understood that any combination or variation of thickness and length, and selected to provide the desired shaping of the emitted light **110** as will be described in further detail below, are well within the scope of the present invention. As shown in FIGS. **3-5**, the right and left sides **122**, **124** and the top and bottom of the waveguide **104** are not parallel, but rather flared outwardly from the first end **112** towards the opposing second end **114** such that the waveguide **104** may form a general "V" shape, having a second end **114** of greater length than the first end **112**, while simultaneously maintaining internal reflection and/or total internal reflection of the light traveling through the body **116** until being emitted from the second end **114**. Furthermore, the thickness of the waveguide **104** may also increase from the first end **112** towards the second end **114**. As described in further detail below, variation in the width and thickness of the waveguide **104** along the length of the body **116** in order to achieve a desired shaping of the emitted light **110** is well within the scope of the present invention.

[0042] Still referring to the waveguide **104**, the first end **112** defines an input surface **126** that is configured to receive light **110** from the LED light source **102**. The input surface **126** may be configured to physically contact or nearly abut the surface emitter **108** of the LED light source **102**, so as to optimize coupling efficiency from LED to waveguide and direct a greater portion of the emitted light **110** into the waveguide **104**. Once received at the input surface **126**, the light transmits through the body **116** of the waveguide **104** towards the output surface **128** disposed about the second end **114**. While traveling through the body **116** of the waveguide **104**, all or most of the light may reflect off the top **118**, bottom **120**, and right and left sides **124**, **126**. Given that the atmosphere surrounding the waveguide **104** is a less optically dense material, i.e., one with a lower refractive index than that of the waveguide **104**, when the angles of incidence are larger than the critical angle, as defined by Snell's law, total internal reflection will occur such that a reflective or partially reflective coating need not be applied to the outer surfaces of the waveguide **104** in order to reflect light across its internal body **116** towards the output surface **128**.

[0043] Still referring to the waveguide **104**, as shown in FIGS. **4** and **5**, a lens assembly **130** may be positioned within the body **116** of the waveguide **104**. The lens assembly **130** may comprise both a collector lens **132** and redistributor surface **134** disposed on opposing sides of a void **136** located within the body **116**. In combination with the surfaces of waveguide **104**, the lens assembly **130** is configured to shape the light **110** into a desired light output pattern **138** that is emitted from the output surface **128**. The lens assembly **130** furthermore may form relative areas of higher and lower light intensity within the desired output pattern **138**. That is to say that the lens assembly **130** both shapes the configuration and asymmetrically or variably alters the intensity of light within the output light pattern **138**. More specifically, the collector lens **132** is configured to collimate and collect the light **110** as it travels along the longitudinal plane of the waveguide **104**. Once collected and collimated, the light **110** travels across the void **136** where it is then received by redistribution surface **134**. As shown in FIGS. **4** and **5**, the redistribution surface **134** may include a plurality of linear portions or planar segments **140** of refracting surfaces. The respective length, thickness, surface area, and orientation along both the transverse and fontal planes, i.e., perpendicular to the longitudinal axis of the waveguide **104**, of each individual segment **140** of the redistribution surface **134** alters the resultant shape of the desired light output pattern **138** that is emitted from the output surface **128**. Furthermore, the asymmetrical amount of light provided to each segment **140**, as a function of one or more parameters of the collector lens **132**, e.g., focal length, may further impact the relative intensity of light within given portions of the light output pattern **138**.

[0044] Turning now to the projector lens **106** of the vehicle lighting system **100**, as shown in FIG. **3**, the projector lens **106** is configured to receive the light output pattern **138** from the output surface **128** located at the second end **114** of the waveguide **104**. The light output pattern **138**, which may be a low beam, high beam or extended high beam pattern, is projected outwardly and downwardly onto the roadway through the projection lens **106**. As a result of the compact LED light source **102**, which may include one or more LEDs positioned on a printed circuit board (PCB), and a waveguide **104** having a length of between typically 10 and 100 millimeters, the light output pattern **138** from the output surface **128** located at the second end **114** of the waveguide **104** is narrowly contained. Accordingly, the lens diameter of the projector lens **106** can be reduced to a distance of between 10.0 and 100.0 millimeters with a focal length also of between 10.0 and 100.0 millimeters. In totality, the relatively small diameter projection lens **106**, combined with a thin LED light source **102** and relatively short waveguide **104**, results in a vehicle lighting system **100** that is substantially more compact than a traditional vehicle light that utilized a halogen bulb **12** and reflector **14**, **22**, **24**.

[0045] Furthermore, the relatively minimal thickness of the waveguide **104**, of between 1.0 and 10.0 millimeters, allows for the compact stacking of multiple waveguides **104** within an alternative embodiment of the present invention. More specifically, in one alternative embodiment of the vehicle lighting system **200** according to the present invention, as shown in FIGS. **6-14**, the system **200** may comprise a first waveguide **200**B, a second waveguide **200**B, and a third waveguide **200**C or **200**D that are utilized in combination with either a common or discrete LED light source **202** and a common projection lens **206**. In the following description it should be understood that system **200** is generally similar to the previously described system **100**, and that like features are identified by like reference characters that have been adjusted to begin with the number "2" in the hundreds place, but for the primary substitution of the waveguide **104** with the first waveguide **204**A, a second waveguide **200**B, and a third waveguide **200**C or **200**D.

[0046] Turning now to FIGS. **6-15**, in system **200** the first waveguide **200**A may be configured to emit a first light pattern **238**A that corresponds to a low beam light pattern, a second waveguide **204**B may be configured to emit a second light pattern **238**B that corresponds to a high beam light pattern, and a third waveguide **204**C or **204**D that may be configured to emit a third light pattern **238**C that corresponds to an extended high beam light pattern. More specifically, as was described above, the lens assembly **230** disposed within one or more of the respective waveguides **214**A, **214**B, **214**C, **214**D is configured to shape the light **210** into desired light output patterns **238**A, **238**B, **238**C, **238**D that are emitted from the corresponding output surfaces **228**A, **228**B, **228**C, **228**D. A representation of the corresponding light output patterns **238**A, **238**B, **238**C, **238**D of system **200** is shown in FIG. **15**A-**15**C in which the profile of the first light pattern **238**A may be controlled as to conform to regulatory requirements through the shaping of the respective waveguide **204**A. More specifically, a first light pattern **238**A may selectively reduce illumination of the left side of a vehicle driver's field of view at a distance greater than approximately 30 meters from the vehicle so as to lessen illumination of the oncoming traffic across a roadway centerline. Similarly, as shown in FIG. **15**C, the profile of the second light pattern **238**B and third light pattern **238**C, **238**D may be controlled so as to conform to regulatory requirements through the shaping of the respective waveguide **204**B, **204**C, and **204**D respectively. More specifically, a second light pattern **238**B, which is a high beam light pattern that respectively incorporates the first light pattern **238**A therein, may provide additional illumination at an elevated height above the roadway at a distance from the vehicle of approximately 15-40 meters, while selectively tapering the high beam illumination of both the left and right side of a vehicle driver's field of view at a distance greater than approximately 30 meters from the vehicle so as to focus high beam illumination on the area ahead of the vehicle as shown in FIG. **15**A-**15**C. Similarly, the third light pattern **238**C, **238**D which is an extended high beam light pattern preferably of considerably higher intensity than the second light pattern **238**B, that respectively incorporates the first light pattern **238**A and high beam light pattern **238**B therein, may provide additional illumination when the head light is a high-mounted headlight, having an elevated height of approximately 2.0 to 3.5 meters above the roadway and a downward tilt angle of approximately 4.0 to 7.0 at a distance from the vehicle greater than 30 meters, while selectively tapering the high beam illumination of both the left and right side of a vehicle driver's field of view at a distance greater than approximately 30 meters but less than 75 meters from the vehicle so as to direct the high beam illumination on the area ahead of the vehicle as shown in FIG. **15**A-**15**C.

[0047] Still referring to FIGS. **6-14**, and more specifically FIGS. **6** and **7**, the first waveguide **204**A is configured for use when generating vehicle low beam lighting, while the second waveguide **204**B is configured for use, either independently or in combination with the first waveguide **204**B, when generating vehicle high beam lighting, and the third waveguide **204**C/**204**D is configured for use, either independently or in combination with the first waveguide **204**A and/or second waveguide **204**B, when generating vehicle extended high beam lighting. The first waveguide **204**A contains the features as were described above in the description of waveguide **104**, including a first end **212**A that is configured to receive input light **210** emitted from the LED light source **202** to an opposing second end **214**A that is configured to output light **210**A in the form of the light pattern **238**A from a second end **214**A to a projection lens **206**. The body **216**A of the waveguide **204**A extends along a longitudinal axis from the first end **212**A to the opposing second end **214**A and generally defines a pathway through which the light **210** travels towards the second end **214**A. The body **216**A may further comprise a top **218**A, bottom **220**A, and right and left sides **222**A, **224**A. The first end **212**A defines an input surface **226**A that is configured to receive light **210** from the LED light source **202**. The input surface **226**A may be configured to physically contact or nearly abut the surface emitter **208** of the LED light source **202**, so as to direct a greater portion of the emitted light **210** into the waveguide **204**A. Positioned within the body **216**A of the waveguide **204**A is a lens assembly **230**A. The lens assembly **230**A may comprise both a collector lens **232**A and a redistributor surface **234**A disposed on opposing sides of a void **236**A located within the body **216**A, as was described in the preceding discussion of system **100**.

[0048] Still further, in one embodiment of the present invention, as shown in FIGS. **6** and **7**, the first light pattern **238**A may be further modified by the redistribution surface **234**A comprised of a plurality of linear portions or planar segments **240**A. More specifically, segments **240**A may have a height less than that of the body **216**A, such that one or more discrete rows **242**A of segments **240**A may be incorporated into the redistribution surface **234**A in the lens assembly **230**A. That is to say that a segment **240**A of the redistribution surface **234**A need not extend the full width of the body **216**A of the waveguide **204**A. For example, as seen in FIG. **7**, the segments **240**A may have a thickness or depth less than that of the body **216**A, such that multiple segments **240**A are stacked atop one another as to provide for yet further customization of the first light pattern **238**A about its vertical axis as it is output from the waveguide **204**A. As described above, such customization of the output light pattern **238**A is particularly significant in the context of compliance with applicable vehicle safety regulations.

[0049] Furthermore, as is shown in FIGS. **6** and **7**, it should be noted that the first waveguide **204**A has a width greater than that of the second waveguide **204**B and the third waveguide **204**C/**204**D. The increase in relative width of the first waveguide **204**A corresponds to its relatively larger light output surface **228**A at the second end **214**A, opposite the LED light source **202**. The increase in the light output surface **228**A correlates to the wider area of roadway illumination exhibited by the vehicle's corresponding low beam or first light pattern **238**A, as discussed above.

[0050] In addition to its relatively greater width, first waveguide **204**A, as shown in FIGS. **6** and **7**, may also exhibit one or more asymmetrical extensions or protrusions **244**A about the outer surface **246**A of any one or more of its relative sides **218**A, **220**A, **222**A, **224**A and/or output surface **228**A. By way of nonlimiting example, the low beam waveguide **204**A may include a bulbous projection or protrusion **244**A of its outer surface **246**A positioned along the top **218**A adjacent a side **220**A, which corresponds to a medial portion of the low beam or first light pattern **238**A for a system **200** mounted in a left headlamp position. The protrusion **244**A generally exhibits an increase in thickness relative to the body **216**A of first waveguide **204**A. Resultantly, the corresponding low beam light output pattern **238**A may have greater height towards its medial portion, and relatively less height along its opposing perimeters or distal portion. In another nonlimiting embodiment, the first waveguide **204**A may also include a protrusion **244**A extending along a top edge of the second end **214**A at the light output surface **228**A, generally in the configuration of a shroud as shown in FIGS. **5** and **6**.

[0051] In addition to the protrusions **244**A present about the second end **214**A, the first waveguide **204**A may further include one or more mounting extensions **248**A extending outwardly from opposing first end **212**A as to allow the first waveguide **204**A to be securely fastened to the LED light source **202**, as will be described in further detail below. In one non-limiting embodiment the mounting extensions **248**A generally include pegs **250**A configured to be received within apertures of mounting surface upon which the LED light source **202** is positioned, and/or feet **252**A configured to engage the mounting surface upon which the LED light source **202** is positioned. As shown in FIG. **7**, the opposing pegs **250**A may have different circumferences, as to allow the first waveguide **204**A to be properly indexed, i.e., ensure that the top **218**A is positioned upwardly, during assembly of the system **200**.

[0052] Turning now to FIG. **8**, the second waveguide **204**B of system **200** is shown in isolation, and described in further detail below. As was described, the second waveguide **200**B may be configured to emit a second light pattern **238**B that corresponds to a high beam light pattern in system **200**. More specifically, the lens assembly **230**B disposed within the second waveguide **214**B is configured to shape the light **210** into a desired light output pattern **238**B that is emitted from the corresponding output surface **228**B. A representation of the corresponding light output patterns

238B of the second waveguide **204**B is shown in FIG. **15**A in which the profile of the second light output pattern **238**B may be controlled as to conform to regulatory requirements through the shaping of the respective waveguide **204**B. More specifically, the second light pattern **238**B, which is a high beam light pattern that respectively incorporates the first light pattern **238**A therein, may provide additional illumination at an elevated height above the roadway a distance from the vehicle greater than 30 meters, while selectively tapering the high beam illumination of both the left and right side of a vehicle driver's field of view at a distance greater than approximately 30 meters from the vehicle so as to focus high beam illumination on the area ahead of the vehicle.

[0053] Still referring to FIG. **8**, the second waveguide **204**B is configured for use when generating vehicle high beam lighting, either independently or in combination with the first waveguide **204**A. The second waveguide **204**B generally contains the features as were described above in the description of waveguide **104**, and first waveguide **204**A, including a first end **212**B that is configured to receive input light **210** emitted from the LED light source **202** to an opposing second end **214**B that is configured to output light **210**B in the form of the light pattern **238**B from a second end **214**B to a projection lens **206**. The body **216**B of the waveguide **204**B extends along a longitudinal axis from the first end **212**B to the opposing second end **214**B and generally defines a pathway through which the light **210** travels towards the second end **214**B. The body **216**B may further comprise a top **218**B, bottom **220**B, and right and left sides **222**B, **224**B. The first end **212**B defines an input surface **226**B that is configured to receive light **210** from the LED light source **202**. The input surface **226**B may be configured to physically contact or nearly abut the surface emitter **208** of the LED light source **202**, so as to direct a greater portion of the emitted light **210** into the waveguide **204**B. Positioned within the body **216**B of the waveguide **204**B is a lens assembly **230**B. The lens assembly **230**B may comprise both a collector lens **232**B and redistributor surface **234**B disposed on opposing sides of a void **236**B located within the body **216**B, as was described previously.

[0054] Still further, in one embodiment of the present invention, not shown, it should be understood that the second light pattern **238**B may be further modified by the redistribution surface **234**B comprised of a plurality of linear portions or planar segments, and more specifically segments that have a height less than that of the body, such that one or more discrete rows of segments may be incorporated into the redistribution surface **234**B in the lens assembly **230**B. That is to say that a given segment of the redistribution surface **234**B need not extend the full width of the body **216**B of the waveguide **204**B. For example, the segments may have a thickness or depth less than that of the body **216**B, such that multiple segments are stacked atop one another as to provide for yet further customization of the second light pattern **238**B about its vertical axis as it is output from the waveguide **204**B.

[0055] Furthermore, as is shown in FIG. **8**, it should be noted that in contrast to the first waveguide **204**A, the second waveguide **204**B has a relatively narrower width than that of the width of low beam waveguide **204**A. The relative decrease in the width of the high beam or second waveguide **204**B, as shown in FIG. **8**, correlates to its relatively smaller light output surface **228**B at its corresponding second end **214**B, opposite the LED light source **202**. This relative decrease in the light output surface **228**B of the second waveguide **204**B correlates to the narrower area of roadway and/or surrounding illumination exhibited by the vehicle's corresponding high beam light pattern **238**B, as shown in FIG. **15**A.

[0056] In addition to its relatively narrower width, second waveguide **204**B, as shown in FIG. **8**, may also exhibit one or more asymmetrical extensions or protrusions **244**B about the outer surface **246**B of any one or more of its relative sides **218**B, **220**B, **222**B, **224**B and/or output surface **228**B. By way of nonlimiting example, the high beam waveguide **204**B may include a bulbous projection or protrusion **244**B of its outer surface **246**B centrally positioned along the top **218**B adjacent the output surface **228**B, which corresponds to a central portion of the high beam or second light pattern **238**B for a system **200** mounted in a left headlamp position. The protrusion **244**B generally exhibits an increase in thickness relative to the body **216**B of first waveguide **204**B. Resultantly, the corresponding high beam light output pattern **238**B may have greater height towards its central portion, and relatively less height along its opposing perimeters or distal portions. Additionally, in another nonlimiting embodiment, the second waveguide **204**B may also include a protrusion **244**B extending along the bottom **220**B at a side **224**B, which when mounted together with the first waveguide **204**A, will form a mating or complementary engagement with the protrusion **224**A located on the top **218**A of the first waveguide **204**A.

[0057] In addition to the protrusions **244**B present about the second end **214**B, the second waveguide **204**B may further include one or more mounting extensions **248**B, as shown in FIG. **8**, extending outwardly from opposing first end **212**B as to allow the second waveguide **204**B to be securely fastened to the LED light source **202**, as will be described in further detail below. In one non-limiting embodiment the mounting extensions **248**B generally include pegs **250**B configured to be received within apertures of mounting surface upon which the LED light source **202** is positioned, and/or feet **252**B configured to engage the mounting surface upon which the LED light source **202** is positioned. As shown in FIG. **8**, the opposing pegs **250**B may have different diameters or shapes as to allow the second waveguide **204**B to be properly indexed, i.e., to ensure that the top **218**B is positioned upwardly during assembly of the system **200**.

[0058] Turning now to FIG. **9**, one embodiment of the second waveguide **204**C of system **200** is shown in isolation. It should be understood that in one embodiment, the third waveguide **204**C is generally similar to the previously described second waveguide **204**B, and that like features are identified by like reference characters that have replaced the letter designation "B" in the second wave guide **204**B with "C" in the third wave guide **204**C. Accordingly, a repetition of the common features of the third waveguide **204**C is not expressly included herein, but it should be understood that the preceding description of the second waveguide **204**B and its features identified by reference numbers ending in the letter designation "B" are equally applicable to the third waveguide **204**C and its features identified by similar reference numbers ending in the letter designation "C" in FIG. **9**.

[0059] Turning now to FIG. **10**, another embodiment of the third waveguide **204**D of system **200** is shown in isolation. It should be understood that in one embodiment, the third waveguide **204**D is generally similar to the previously described third wave guide **204**C and second waveguide **204**B, and that like features are identified by like reference characters that have replaced the letter designation "C" in the third wave guide **204**C with "D" in the third wave guide **204**D. Accordingly, a repetition of the common features of the third waveguide **204**D is not included herein, but it should be understood that the preceding description of the second waveguide **204**B and its features identified by reference numbers ending in the letter designation "B" are equally applicable to the third waveguide **204**D and its features identified by reference numbers ending in the letter designation "D" in FIG. **9**.

[0060] Of notable distinction, the third waveguide **204**D may have a body **216**D that is generally polygonal in shape, and more specifically a rectangular prism or cuboid shape. The third waveguide **204**D may be formed with a slight curvature or radius along its longitudinal axis. As shown in FIG. **10**, in one representative embodiment, the body **216**D may further comprise a top **218**D, bottom **220**D, and right and left sides **222**D, **224**D that generally intersect at approximately right angles. The first end **212**D of the body **216**D defines an input surface **226**D that is configured to receive light **210** from the LED light source **202**. Furthermore, third waveguide **204**D may be devoid of a lens assembly that corresponds to the lens assembly **230**A, **230**B, **230**C, that is or may be present in the corresponding first waveguide **204**A, second waveguide **204**B, or third waveguide **204**C. Accordingly, light **210** travels through the body **216**D and is emitted from the corresponding output surface **228**D into a desired light output pattern **238**C/**238**D that is emitted from the corresponding output surface **228**D at the second end **214**D. In one embodiment, the relatively narrow body **216**D of third waveguide **204**D, and its corresponding end **214**D are polygonal as to confine the emitted light pattern **238**D corresponding to the extended high beam light to the roadway.

[0061] In addition to its relatively narrower width, it should be understood that the generally polygonal body **216**D of the third waveguide **204**D may be combined with any one or more asymmetrical extensions or protrusions **244**C, as were shown in the alternative embodiment of the third waveguide **204**C in FIG. **9**. This includes but is not limited to those protrusions **244**C that are configured to alter or modify the emitted light pattern **238**C/**238**D, as well as those that might extend along the bottom **220**D which, when mounted together with the second waveguide **204**B, will facilitate a mating with the protrusion **224**B located on the top **218**B of the second waveguide **204**B so as to form an uninterrupted emitted light pattern.

[0062] Referring now to FIGS. **11-14**, and initially FIG. **11**, the LED light source **202** of system **200** is shown and described in further detail below. The LED light source **202**, according to one embodiment of the present invention includes light emitting surfaces **208** associated with each of the input surfaces **226**A, **226**B, **226**C of the first, second and third waveguides **204**A, **204**B, **204**C/**204**D, respectively. The light emitting surfaces **208** may include one or more individual LEDs **254** or an array **256** thereof. By way of the non-limiting example shown in FIG. **11**, the light emitting surface **208** corresponding to the input surface **226**A of the first waveguide **204**A may include an array **256** of four individual LEDs **254**, the light emitting surface **208** corresponding the input surface **226**B of the second waveguide **204**B may include an array **256** of three individual LEDs **254**, while the light emitting surface **208** corresponding the input surface **226**C or **226**D of the third waveguide **204**C or **204**D may include an array **256** of three or more individual LEDs **254**. The LED light source **202** further comprises a mounting surface or plate **258** upon which the light emitting surfaces **208** are secured, and apertures **260** disposed therein are configured to receive the pegs **250**A, **250**B, **250**C/**250**D for mounting the waveguides **204**A, **204**B, **204**C/**204**D to the LED light source **202**. More specifically, the apertures **260** may have different diameters or shapes as to allow the first, second and third waveguides, **204**A, **204**B, **204**C/**204**D to be properly indexed, i.e., positioned and oriented, during assembly of the system **200**.

[0063] As shown in FIGS. **12** and **13** the combination of waveguides **204**A, **204**B and **204**C or **204**D may include additional structural components for further altering both the shape and/or intensity of the light emitted from the system **200**. In addition to the protrusions **244**A, **244**B,**244**C the top surface **218**A of the first waveguide **204**A and the bottom surface **220**B of the second waveguide **204**B may exhibit complementary irregular or asymmetrical surfaces that are complementarily configured to mate and/or align when the second waveguide **204**B is positioned above the first waveguide **204**A, as are the top surface **218**B of the second waveguide **204**B and the bottom surface **220**C or **220**D of the third waveguide **240**C or **240**D. Such a complementary or mating configuration ensures that when utilized in combination, i.e., when the high beam lights and extended high beam lights are activated, no void or gap is present within the light output pattern **238**C/D. While FIG. **13** illustrates the third waveguide **204**C as being slightly rotated when positioned on top surface **218**B of second waveguide **204**B, it is understood that the bottom surface of third waveguide **204**C may be modified from the illustrated configuration so as to nest on top surface **218**B of second waveguide **204**B without any such rotation.

[0064] Additionally, in one alternative embodiment not shown, positioning of the waveguides **204**A, **204**B, **204**C or **204**D in such close proximity allows for the LED light source **202** to provide a common printed circuit board (PCB) including both light emitting surfaces **208** corresponding to the input surfaces **226**A of the first waveguide **204**A, the input surfaces **226**B of the second waveguide **204**B, and the input surfaces **226**C/**226**D of the third waveguide **204**C/**204**D, i.e., all LEDs **254** for the system **200** are provided on a common printed circuit board (PCB). Similarly, the relative proximity of the output surfaces **228**A, **228**B, **228**C or **228**D of all waveguides **204**A, **204**B, **204**C or **204**D allows for a single common projection lens **206** to be utilized by all waveguides **204**A, **204**B, **204**C or **204**D in system **200**.

[0065] It should be understood that the invention is not limited in its application to the details of construction and arrangements of the components set forth herein. The invention is capable of other embodiments and of being practiced or carried out in various ways. Variations and modifications of the foregoing are within the scope of the present invention. It also being understood that the invention disclosed and defined herein extends to all alternative combinations of two or more of the individual features mentioned or evident from the text and/or drawings. All of these different combinations constitute various alternative aspects of the present invention. The embodiments described herein explain the best modes known for practicing the invention and will enable others skilled in the art to utilize the invention.

[0066] Various additions, modifications, and rearrangements are contemplated as being within the scope of the following claims, which particularly point out and distinctly claim the subject matter regarding as the invention, and it is intended that the following claims cover all such additions, modifications, and rearrangements.

I claim:

1. A lighting system for a vehicle, comprising:

an at least one LED light source adapted to be mounted to a vehicle, the at least one LED light source configured to emit a light;

a first waveguide configured to receive the light emitted from one of the at least one LED light source at a first end and output a low beam light pattern at an opposing second end;

a second waveguide configured to receive the light emitted from one of the at least one LED light source at a first end and output an intermediate light pattern at an opposing second end;

one or more of the first and second waveguides having a refracting surface array disposed within a body of the waveguide between the first and second ends, the refracting surface array being configured to shape the light received from the LED light source to form the light pattern at the second end of the waveguide;

a third waveguide configured to receive the light emitted from one of the at least one LED light source at a first end and output a high beam at an opposing second end; and

at least one projection lens disposed adjected the second end of the waveguides configured to receive the light pattern and project the same in front of the vehicle.

2. The vehicle lighting system of claim **1**, wherein the third waveguide has a refracting surface array disposed within a body of the waveguide between the first and second ends, the refracting surface array being configured to shape the light received from the LED light source to form the light pattern at the second end of the third waveguide.

3. The vehicle lighting system of claim **1**, wherein the third waveguide defines a solid body, devoid of any openings therein, between the first and second ends.

4. The vehicle lighting system of claim **1**, wherein the first end of each of the first, second and third waveguides is mounted to a common mounting member that includes the LED light source.

5. The vehicle lighting system of claim **4**, wherein each of the first, second and third waveguides is secured to the common mounting member via an aperture and opening mounting arrangement interposed between the common mounting member and the respective mounting member.

6. The vehicle lighting system of claim **5**, wherein the aperture and opening mounting arrangement of each of the first, second and third mounting members is differently configured relative to each other.

7. The vehicle lighting system of claim **4**, wherein the first waveguide is oriented at a first angle relative to the common mounting member, the second waveguide is mounted to the common mounting member above the first mounting member at its first end and rests on the first mounting member at its second end, and the third waveguide is mounted to the common mounting member above the second mounting member at its first end and rests on the second mounting member at its second end.

8. The vehicle lighting system of claim **7**, wherein lighting system is adapted to be mounted to a vehicle at an elevated location above an implement associated with the vehicle so as to enable light patterns emitted by the first, second and third waveguides to illuminate areas in front of the implement.

9. A lighting system mounted to a vehicle at an elevated location above an implement associated with the vehicle, comprising:

an at least one LED light source adapted to be mounted to a vehicle, the at least one LED light source configured to emit a light;

a first waveguide configured to receive the light emitted from one of the at least one LED light source at a first end and output a low beam light pattern at an opposing second end;

a second waveguide configured to receive the light emitted from one of the at least one LED light source at a first end and output an intermediate light pattern at an opposing second end;

a third waveguide configured to receive the light emitted from one of the at least one LED light source at a first end and output a high beam at an opposing second end; and

at least one projection lens disposed adjected the second end of the waveguides configured to receive the light pattern and project the same in front of the vehicle;

wherein the elevated location of the lighting system enables light patterns emitted by the first, second and third waveguides to illuminate areas in front of the implement.

10. The vehicle lighting system of claim **9**, wherein one or more of the first and second waveguides includes a refracting surface array disposed within a body of the waveguide between the first and second ends, the refracting surface array being configured to shape the light received from the LED light source to form the light pattern at the second end of the waveguide.

11. The vehicle lighting system of claim **10**, wherein the third waveguide has a refracting surface array disposed within a body of the waveguide between the first and second ends, the refracting surface array being configured to shape the light received from the LED light source to form the light pattern at the second end of the third waveguide.

12. The vehicle lighting system of claim **10**, wherein the third waveguide defines a solid body, devoid of any openings therein, between the first and second ends.

13. The vehicle lighting system of claim **9**, wherein the first end of each of the first, second and third waveguides is mounted to a common mounting member that includes the LED light source.

14. The vehicle lighting system of claim **13**, wherein each of the first, second and third waveguides is secured to the common mounting member via an aperture and opening mounting arrangement interposed between the common mounting member and the respective mounting member.

15. The vehicle lighting system of claim **14**, wherein the aperture and opening mounting arrangement of each of the first, second and third mounting members is differently configured relative to each other.

16. The vehicle lighting system of claim **13**, wherein the first waveguide is oriented at a first angle relative to the common mounting member, the second waveguide is mounted to the common mounting member above the first mounting member at its first end and rests on the first mounting member at its second end, and the third waveguide is mounted to the common mounting member above the second mounting member at its first end and rests on the second mounting member at its second end.

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