US 20230272893A1

(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2023/0272893 A1
Li et al. (43) Pub. Date: Aug. 31, 2023

(54) INTEGRATED LIDAR WITH SCANNING PHOSPHOR ILLUMINATION SYSTEM AND METHOD

(71) Applicant: **Optonomous Technologies, Inc.**, Agoura Hills, CA (US)

(72) Inventors: **Kenneth Li**, Agoura Hills, CA (US); **Yung Peng Chang**, Hsinchu (TW); **Lion Wang**, Hsinchu (TW); **Andy Chen**, Taichung (TW); **Kirk Huang**, Taichung (TW); **Stark Tsai**, Hsinchu (TW)

(21) Appl. No.: **18/014,138**

(22) PCT Filed: **Jun. 25, 2021**

(86) PCT No.: **PCT/US2021/039266**

§ 371 (c)(1),
(2) Date: **Dec. 30, 2022**

Related U.S. Application Data

(60) Provisional application No. 63/136,312, filed on Jan. 12, 2021, provisional application No. 63/047,905, filed on Jul. 2, 2020.

Publication Classification

(51) **Int. Cl.**

F21S 41/16	(2006.01)
G03B 21/28	(2006.01)
G03B 21/20	(2006.01)
G03B 21/16	(2006.01)
B60Q 1/00	(2006.01)
G01S 7/481	(2006.01)
F21S 41/13	(2006.01)
F21S 41/25	(2006.01)
G01S 17/06	(2006.01)

(52) **U.S. Cl.**

CPC ***F21S 41/16*** (2018.01); ***G03B 21/28*** (2013.01); ***G03B 21/2033*** (2013.01); ***G03B 21/16*** (2013.01); ***B60Q 1/0023*** (2013.01); ***G01S 7/4817*** (2013.01); ***G01S 7/4814*** (2013.01); ***F21S 41/13*** (2018.01); ***F21S 41/25*** (2018.01); ***G01S 17/06*** (2013.01)

(57) **ABSTRACT**

A scanning beam system using a rotating platform driven by a motor, and a prism and/or mirror assembly mounted to the rotating platform. In some embodiments, the prism is a square prism. In some embodiments the prism is of polygon shape other than a square. In some embodiments, the mirror assembly is a square mirror assembly. In some embodiments the mirror assembly is of polygon shape other than a square. In some embodiments the mirror assembly includes a plurality of reflective faces, each at a different angle relative to an axis of rotation of the rotating platform.

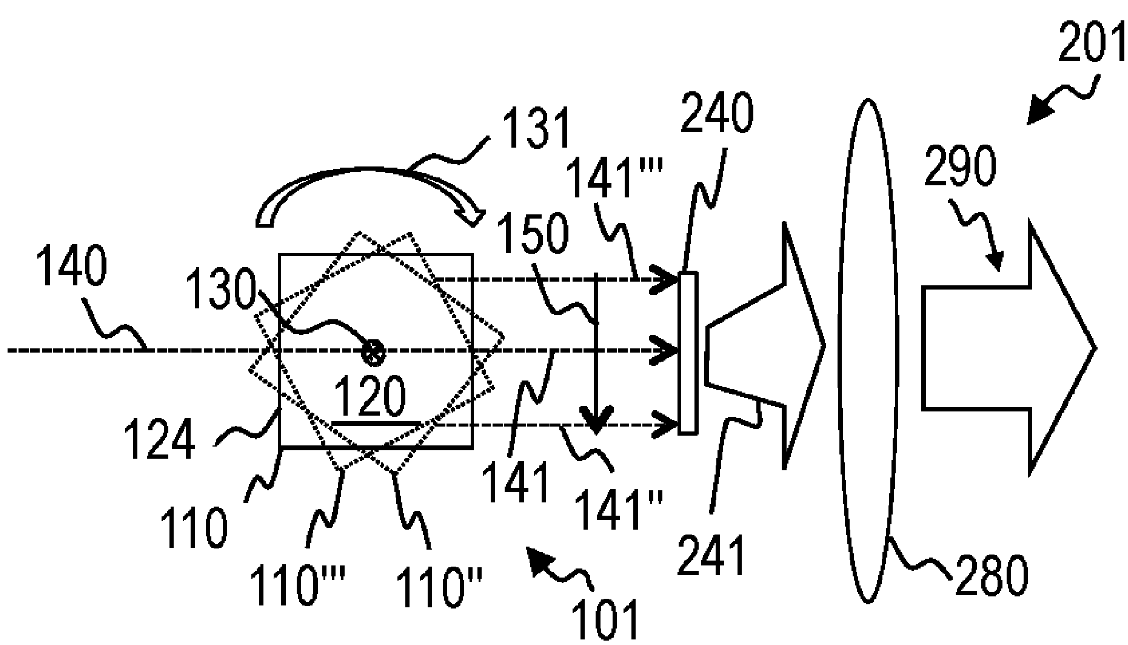


FIG. 1A

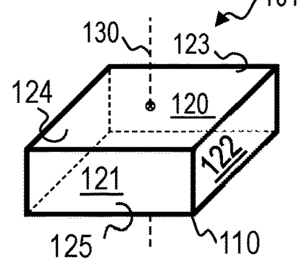


FIG. 1B

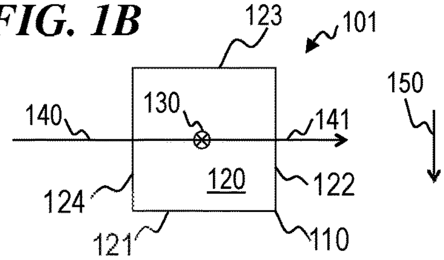


FIG. 1C

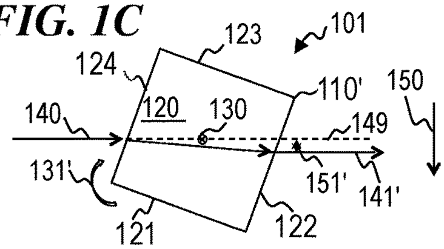


FIG. 1D

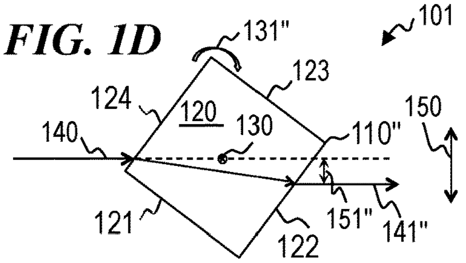


FIG. 1E

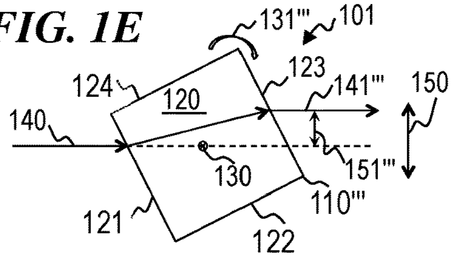


FIG. 2

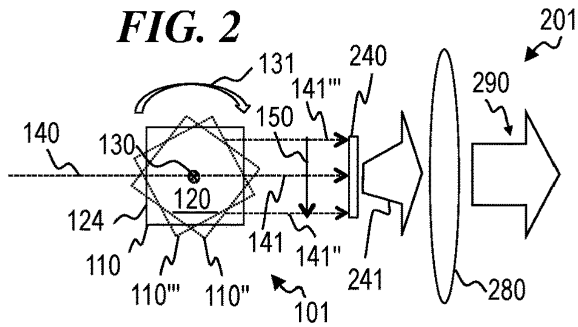


FIG. 3A

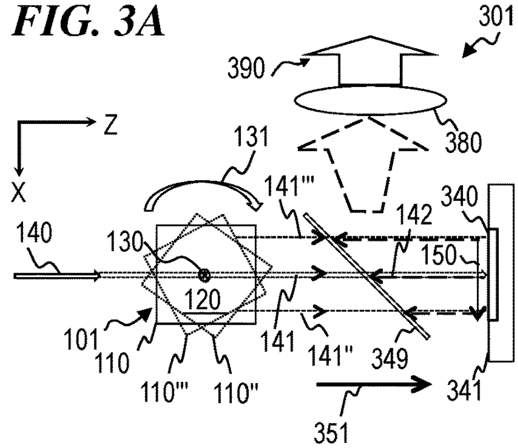


FIG. 3B

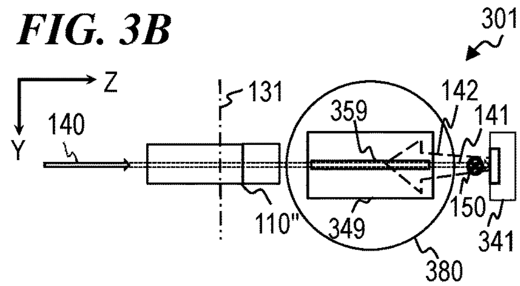


FIG. 3C

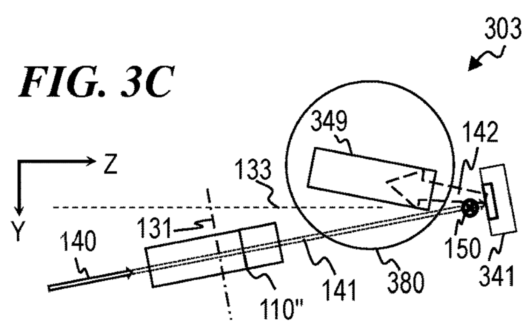


FIG. 4A

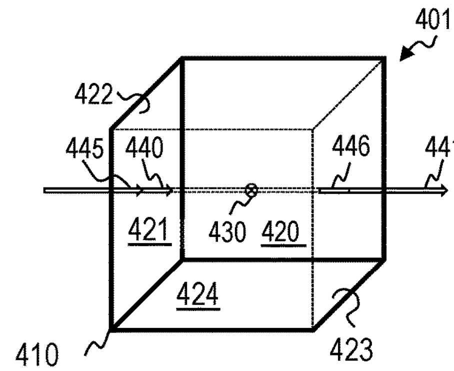


FIG. 4B

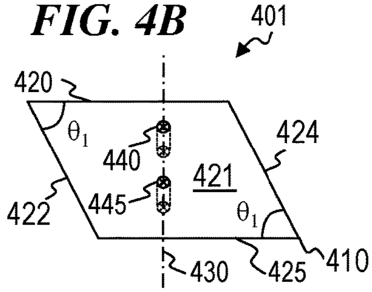


FIG. 4C

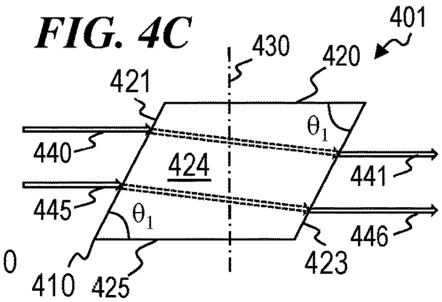


FIG. 4D

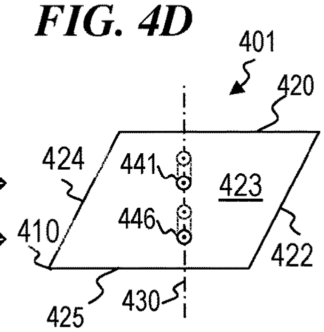


FIG. 5A

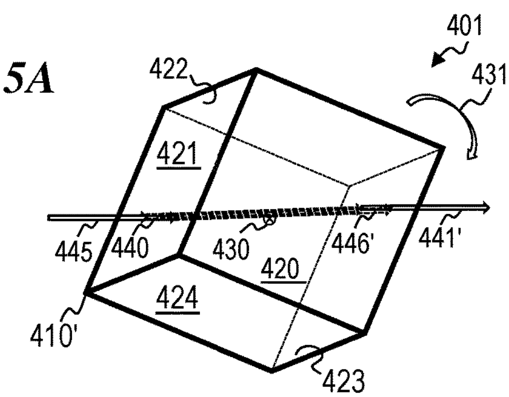


FIG. 5B

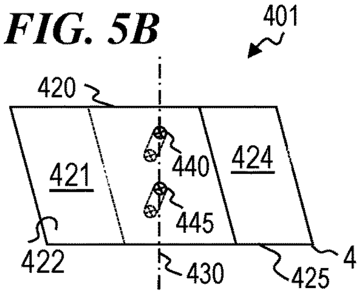


FIG. 5C

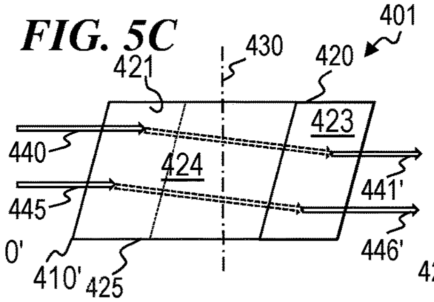


FIG. 5D

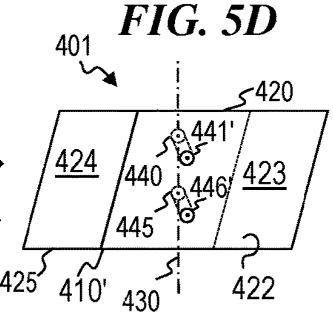


FIG. 6A

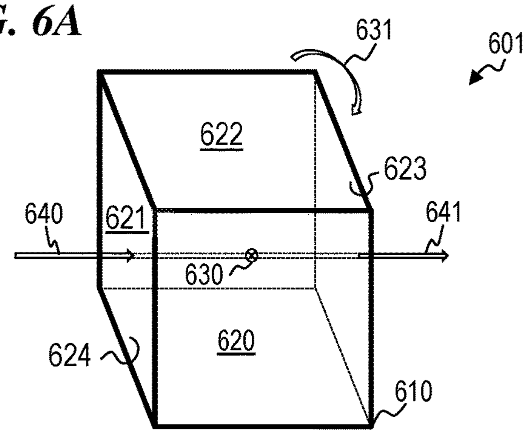


FIG. 6B

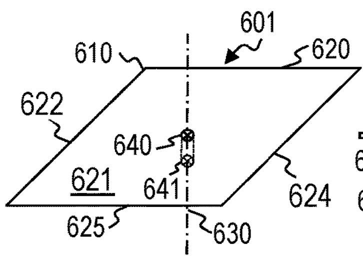


FIG. 6C

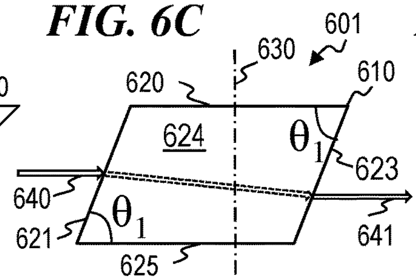


FIG. 6D

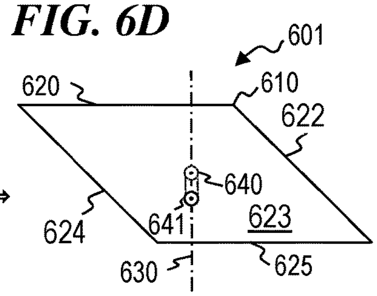


FIG. 6E

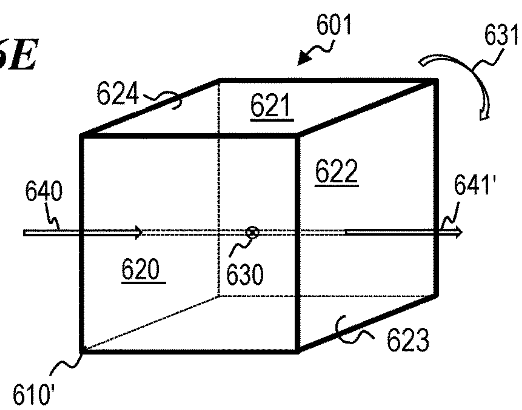


FIG. 6F

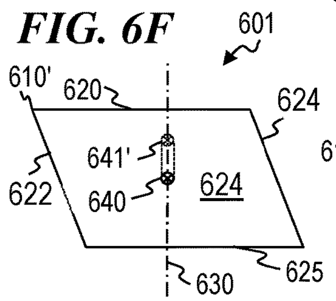


FIG. 6G

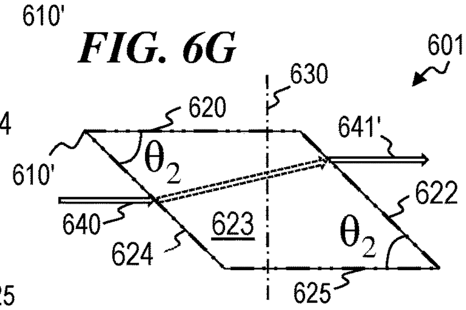


FIG. 6H

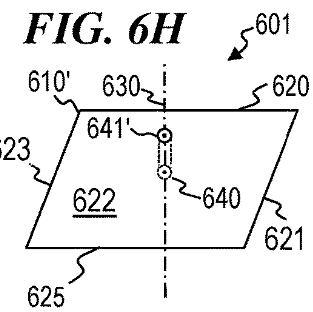


FIG. 7A

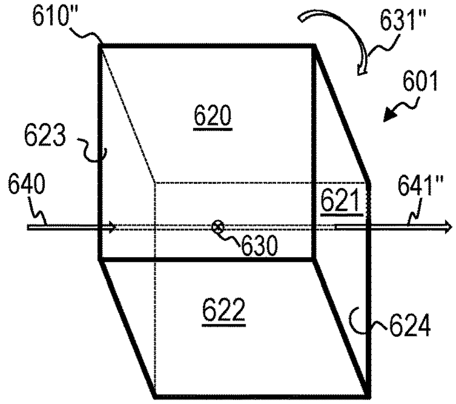


FIG. 7B

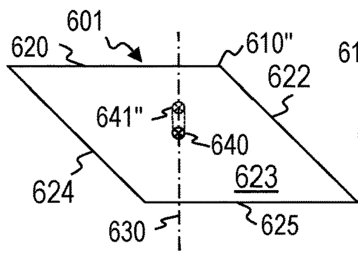


FIG. 7C

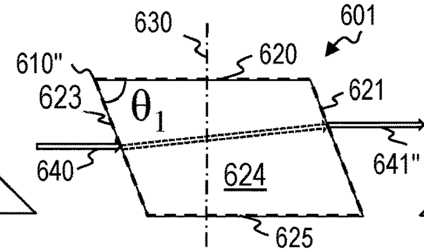


FIG. 7D

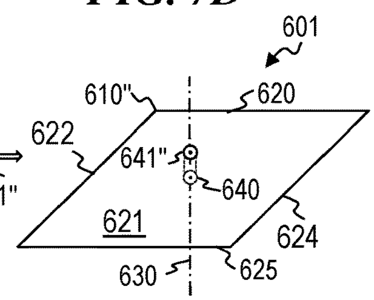


FIG. 7E

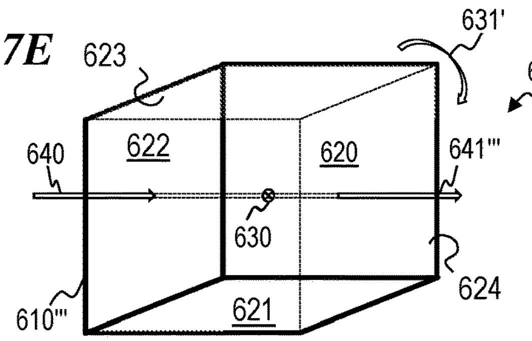


FIG. 7F

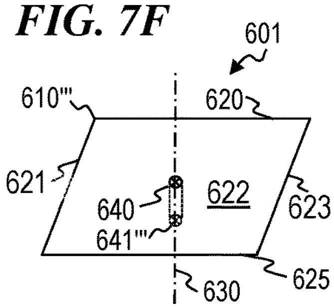


FIG. 7G

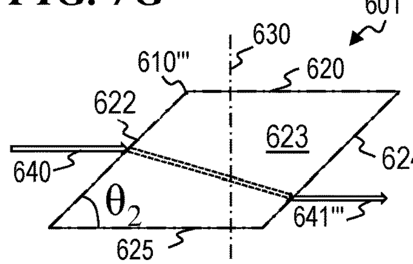


FIG. 7H

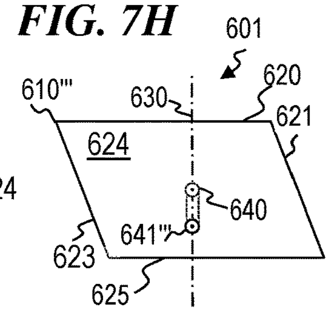


FIG. 8

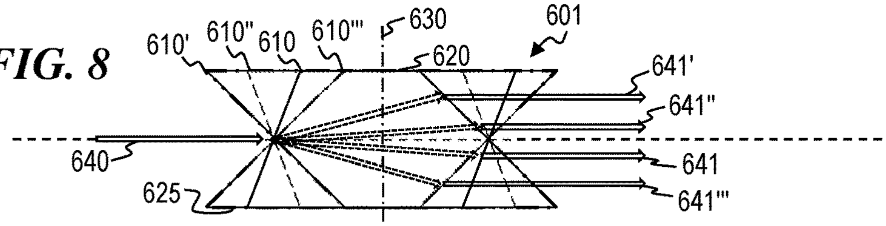


FIG. 9A

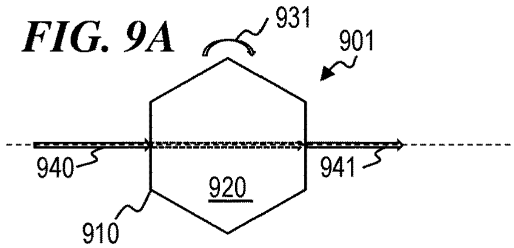


FIG. 9B

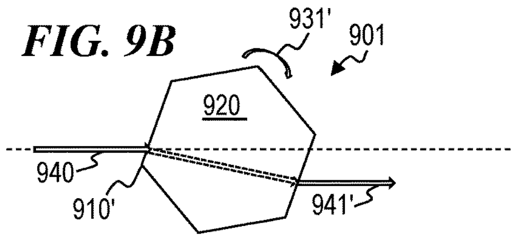


FIG. 9C

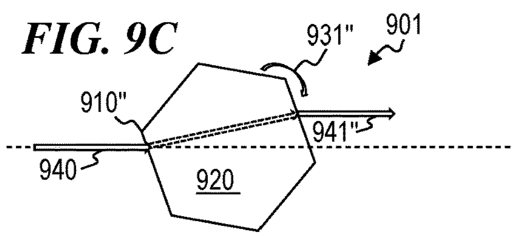


FIG. 10A

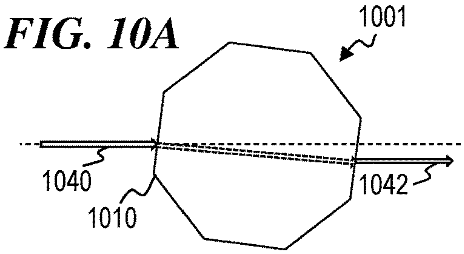


FIG. 10B

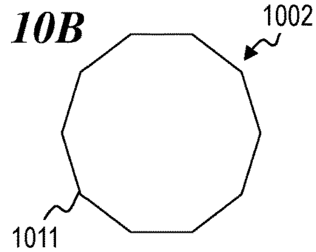


FIG. 10C

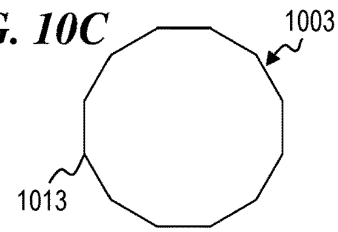


FIG. 11

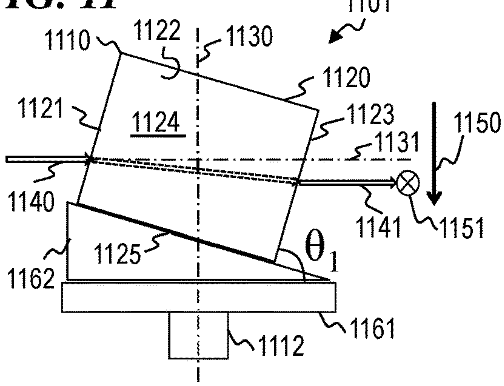


FIG. 13

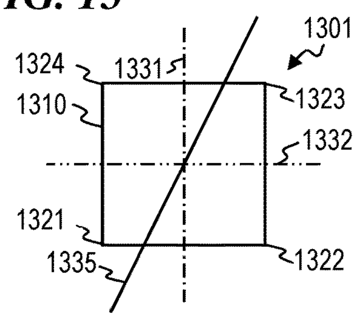


FIG. 12

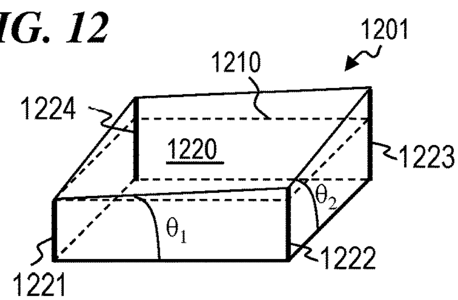


FIG. 14

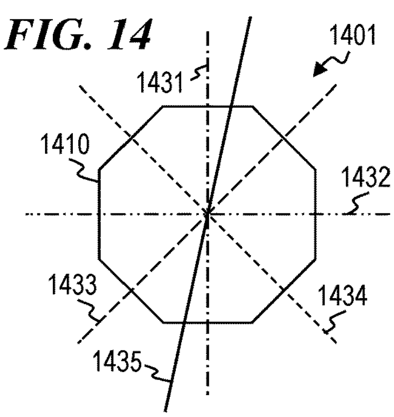


FIG. 15

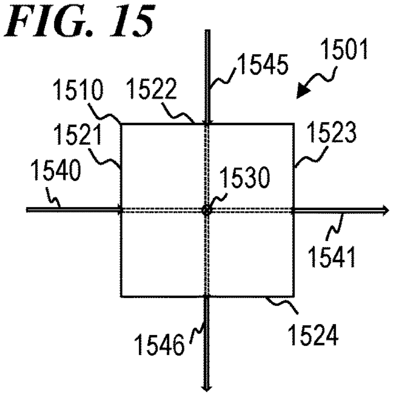


FIG. 18

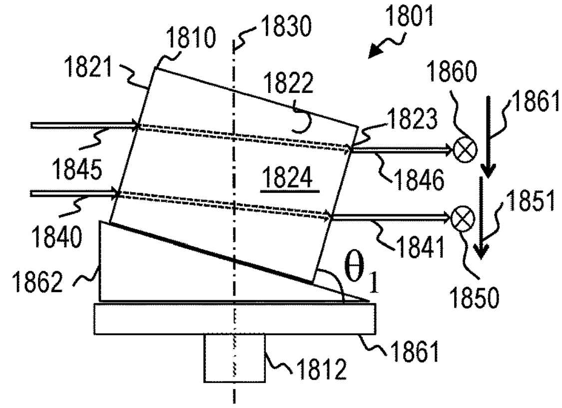


FIG. 16

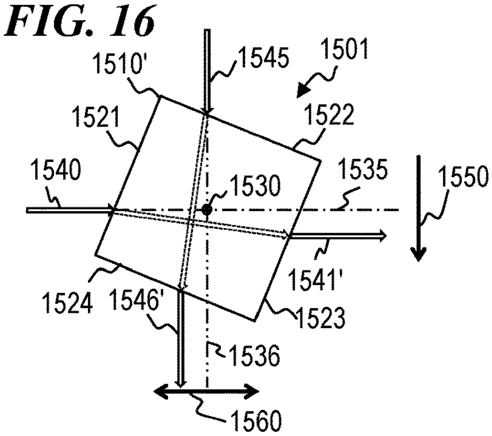


FIG. 19

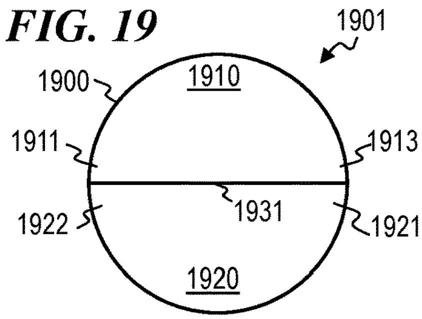


FIG. 20

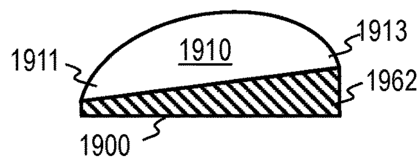


FIG. 17

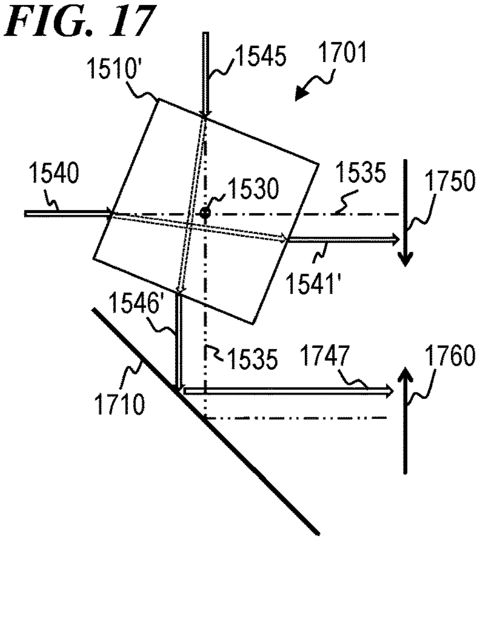


FIG. 21

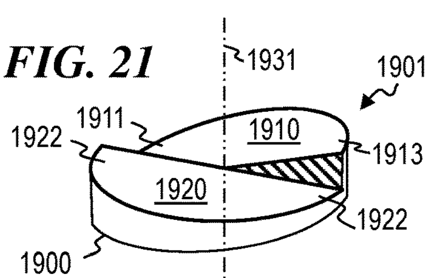


FIG. 22A

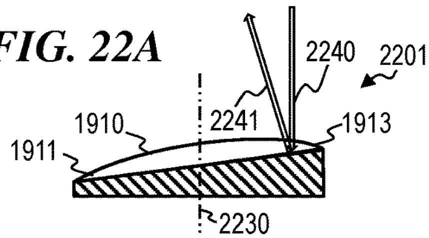


FIG. 22B

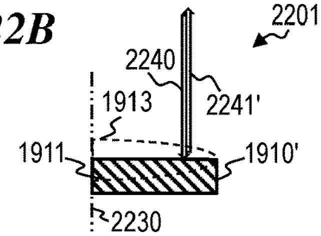


FIG. 22C

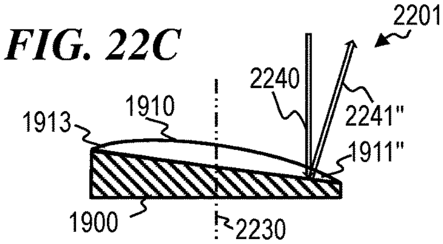


FIG. 24

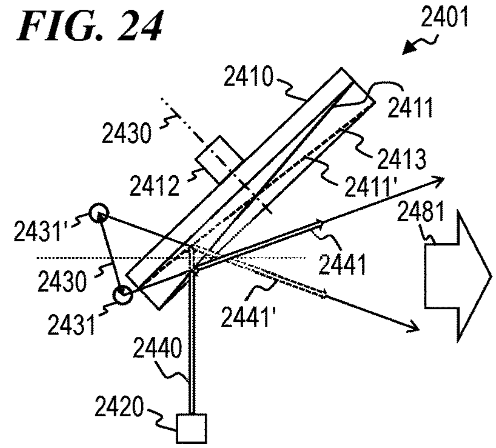


FIG. 25A

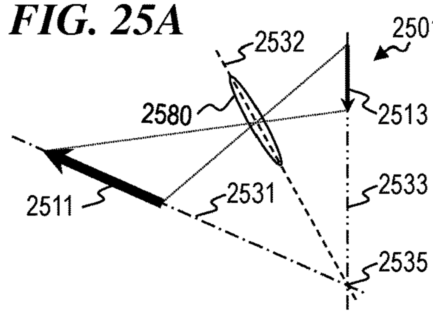


FIG. 25B

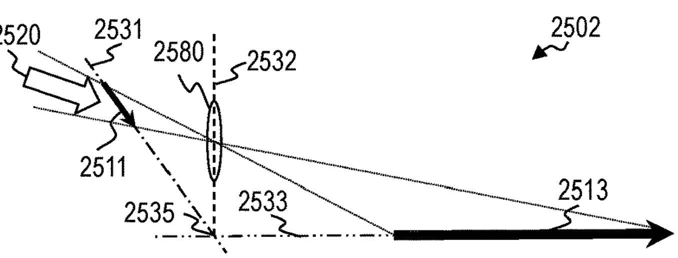


FIG. 23

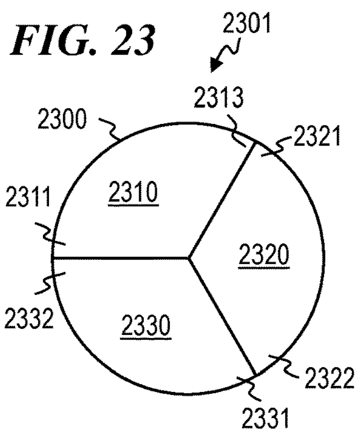


FIG. 26

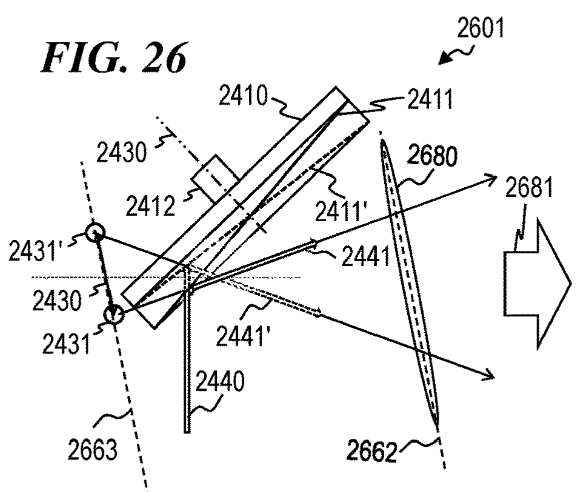


FIG. 27A

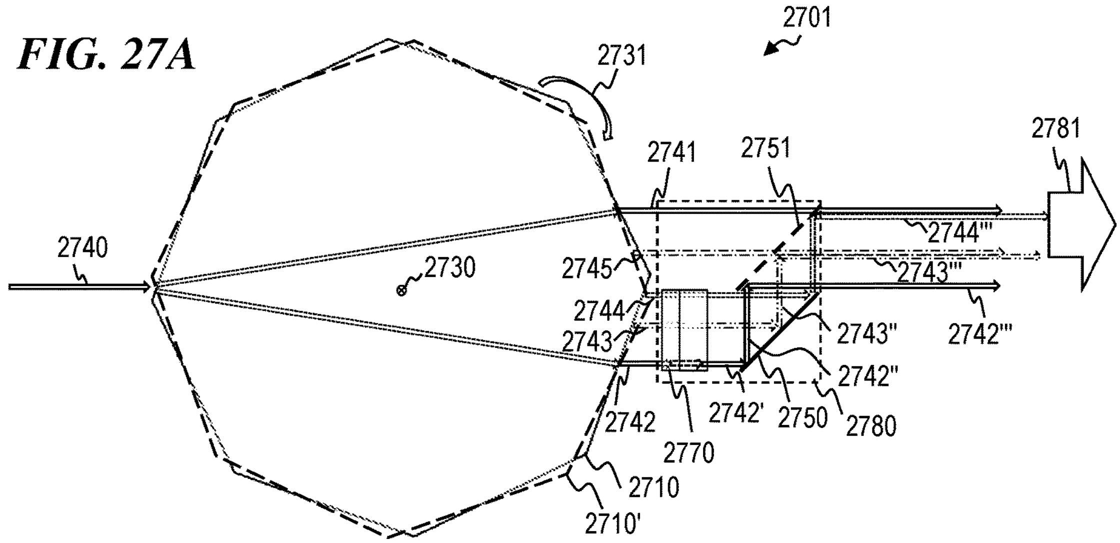


FIG. 27B

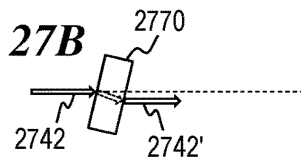


FIG. 28

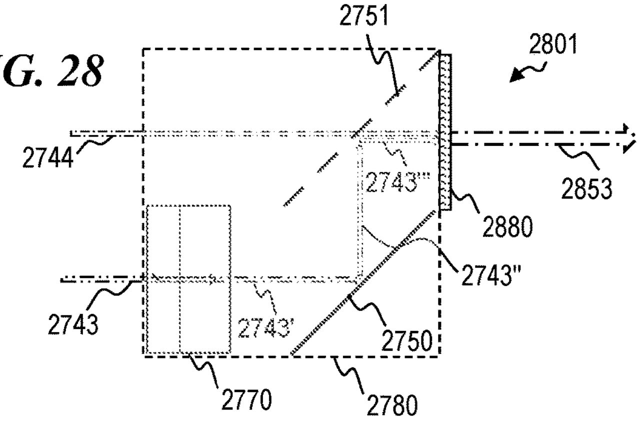


FIG. 29A

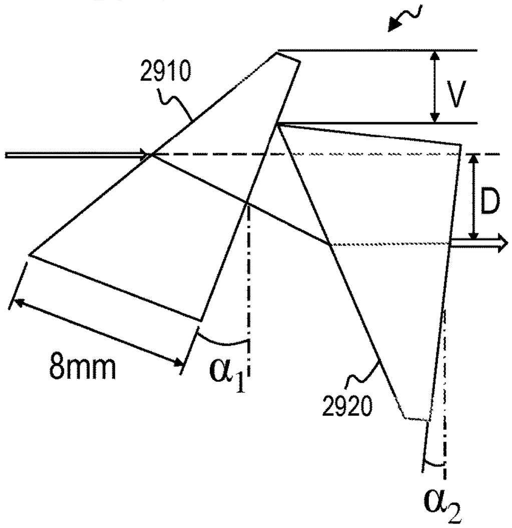


FIG. 29B

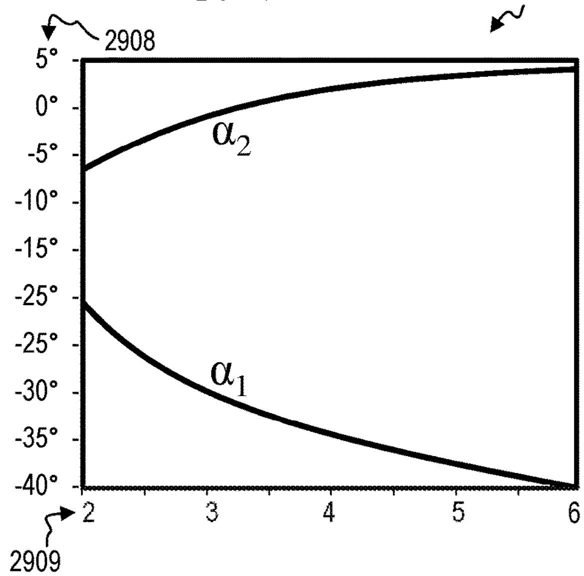


FIG. 30

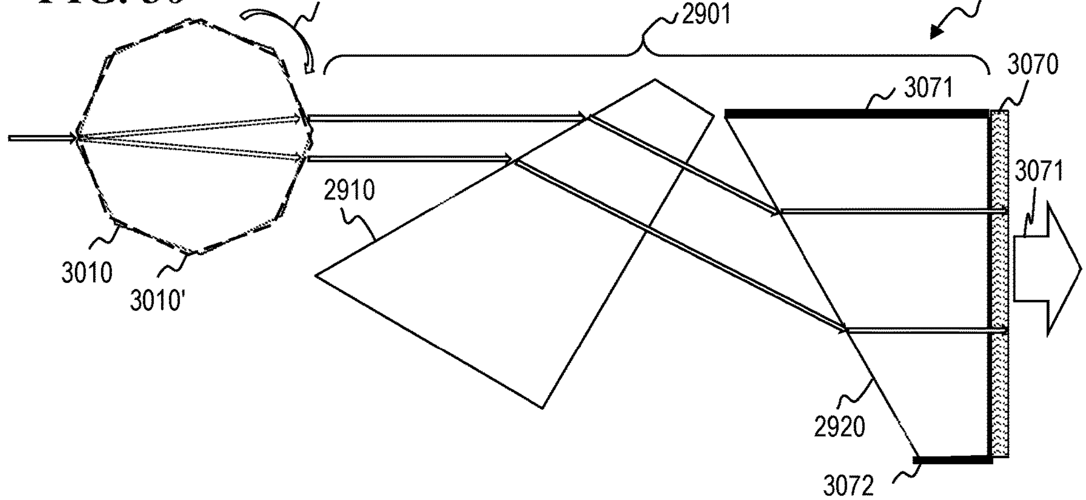


FIG. 31A

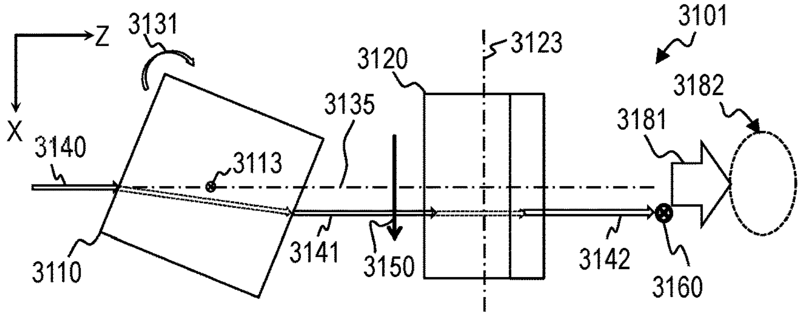


FIG. 31B

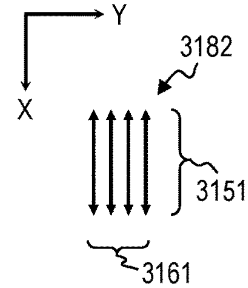


FIG. 31C

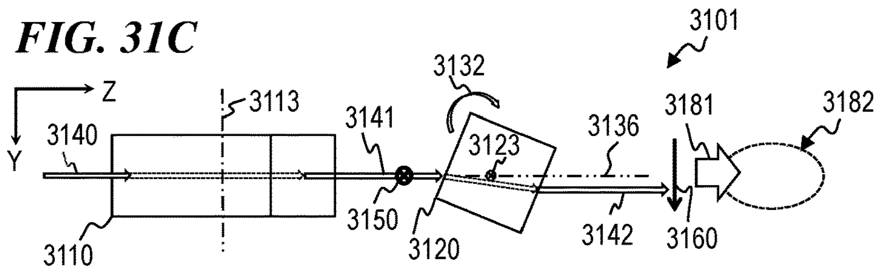


FIG. 32A

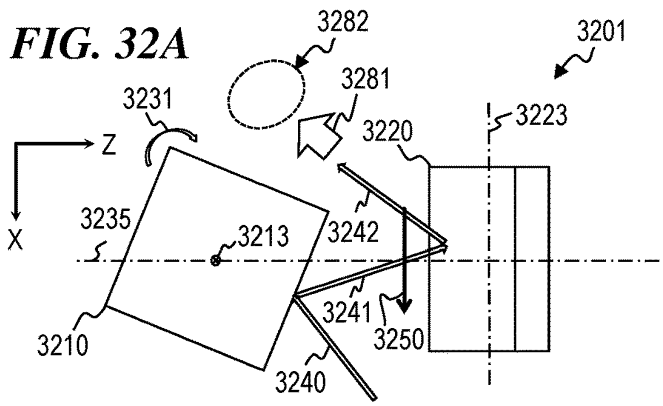


FIG. 32B

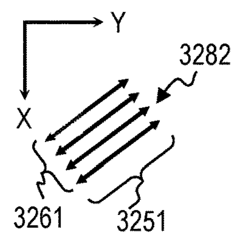


FIG. 32C

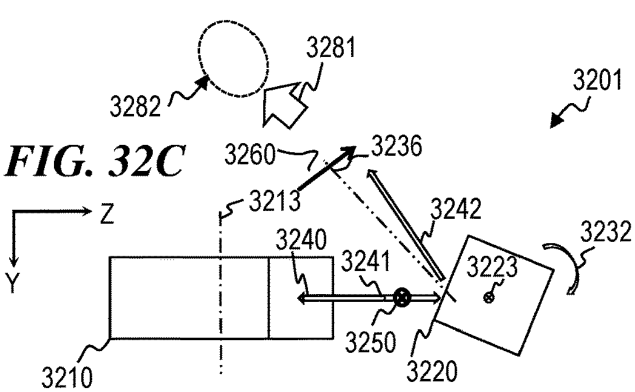


FIG. 33A

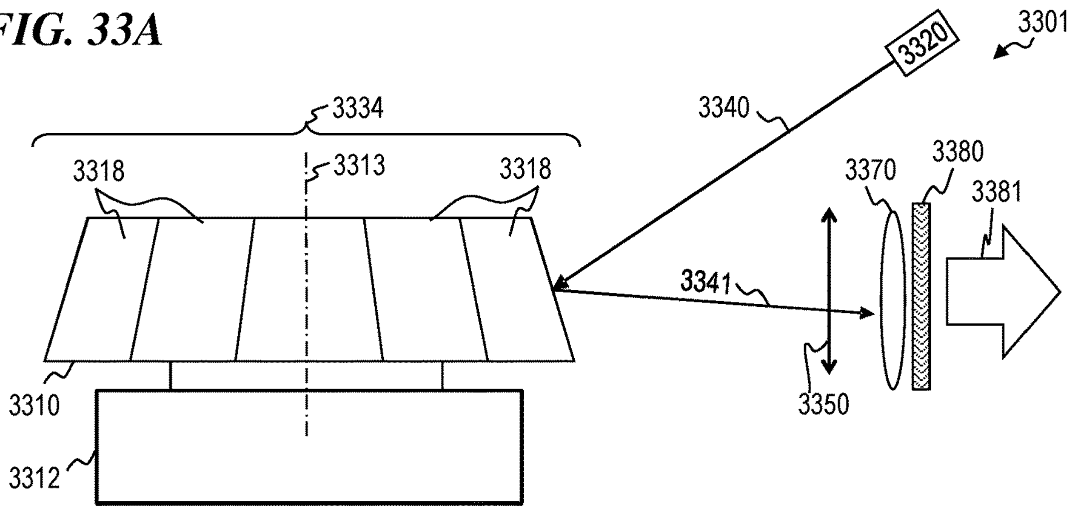


FIG. 33B

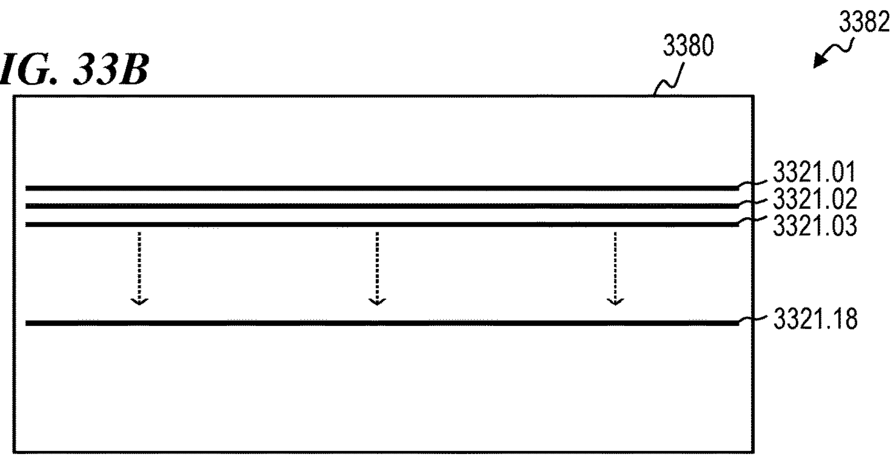


FIG. 34

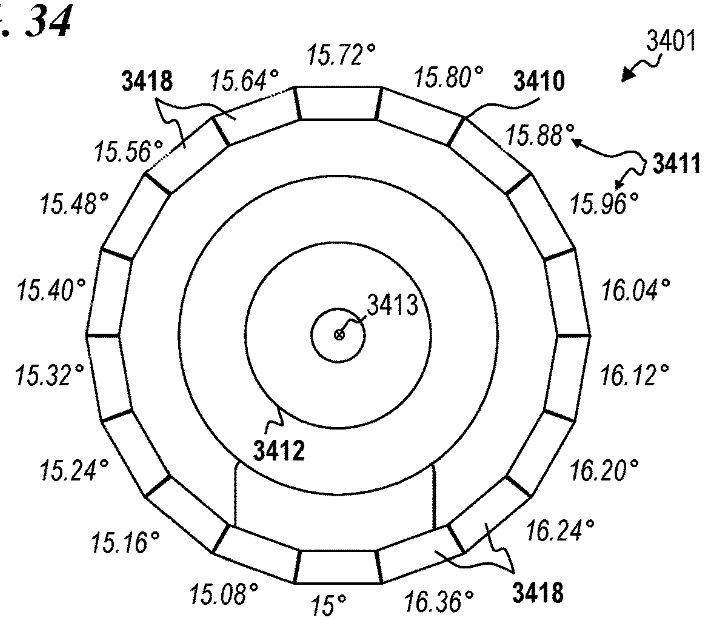


FIG. 35

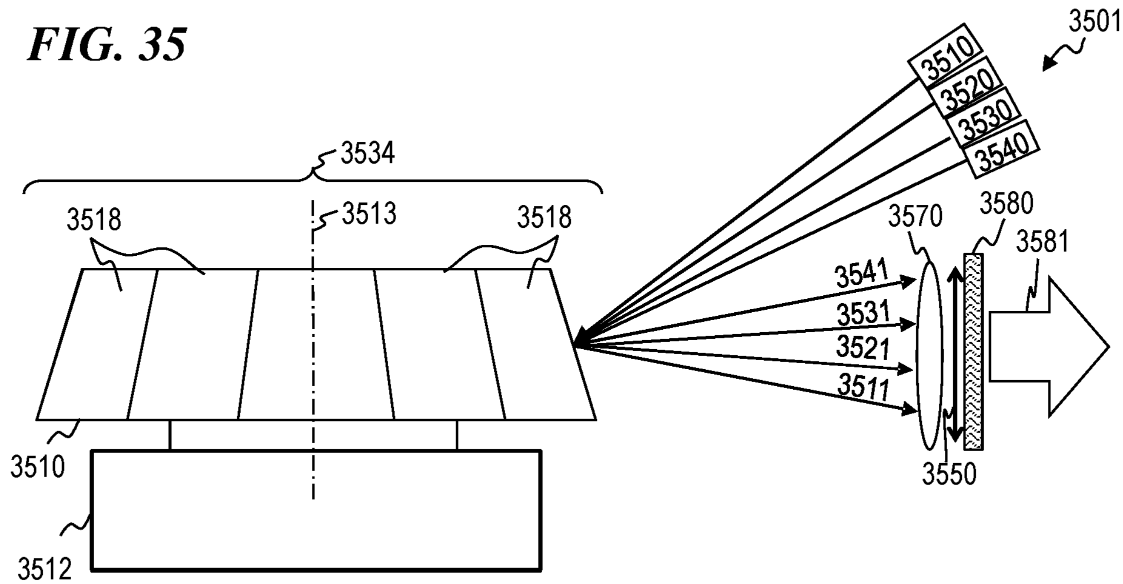

3501
3510
3520
3530
3540
3534
3513
3518
3518
3570
3580
3581
3541
3531
3521
3511
3510
3550
3512

FIG. 36

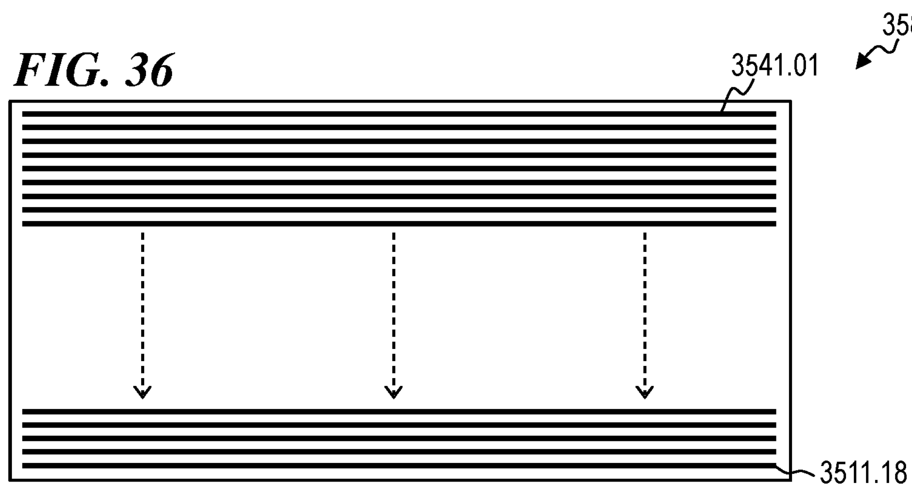

3582
3541.01
3511.18

FIG. 38

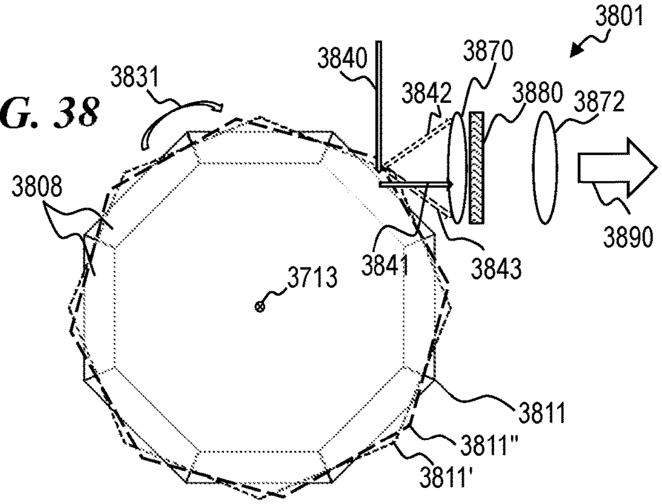


FIG. 37

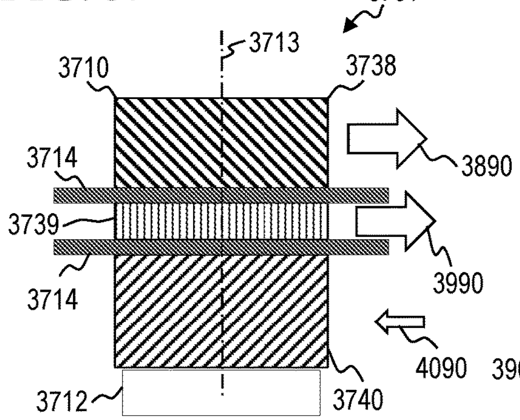


FIG. 39

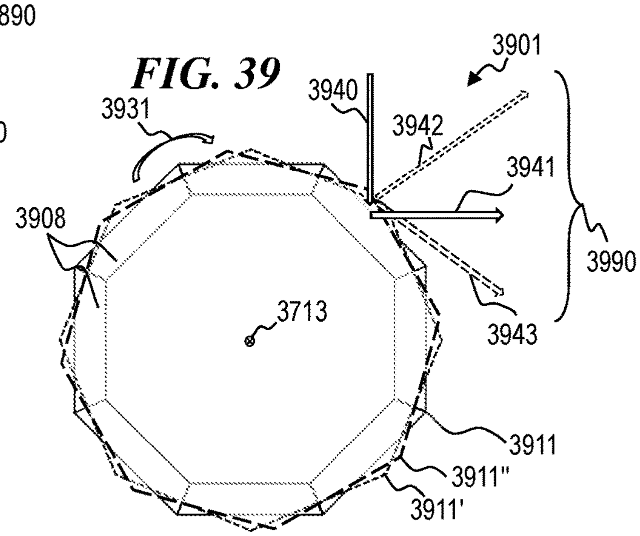


FIG. 40

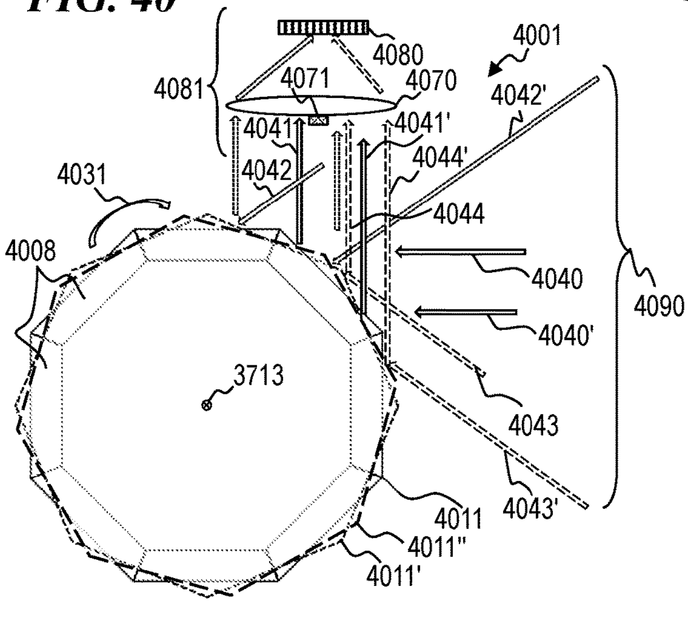


FIG. 41

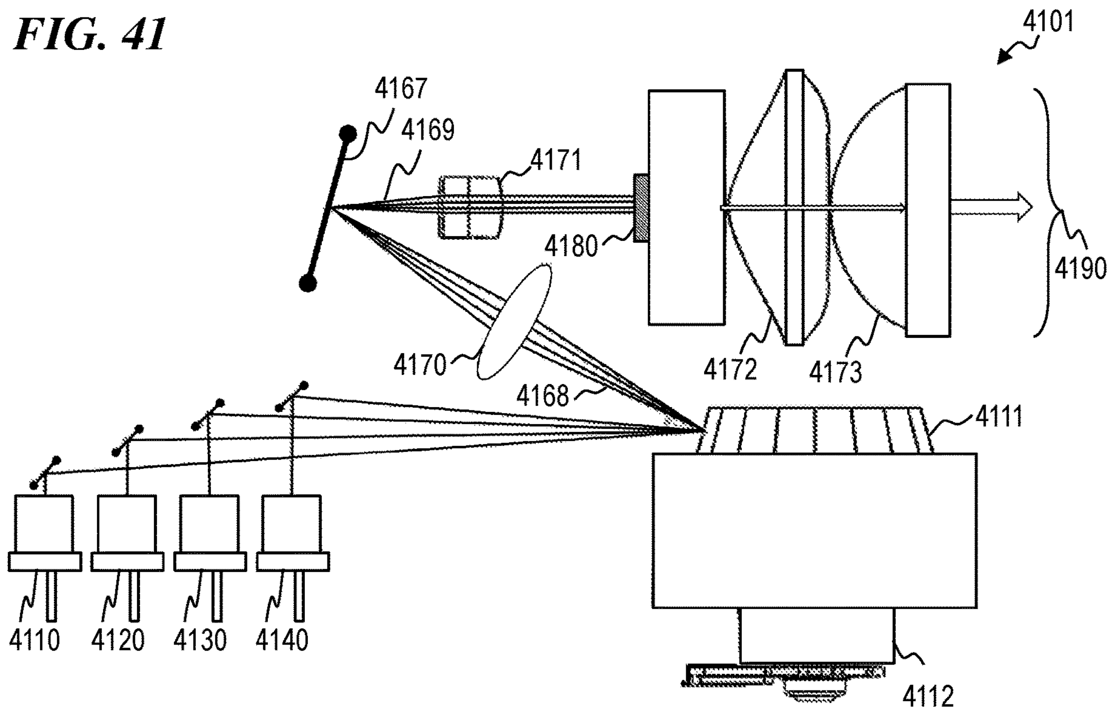

4101
4167
4169
4171
4180
4190
4170
4168
4172
4173
4111
4110
4120
4130
4140
4112

FIG. 42

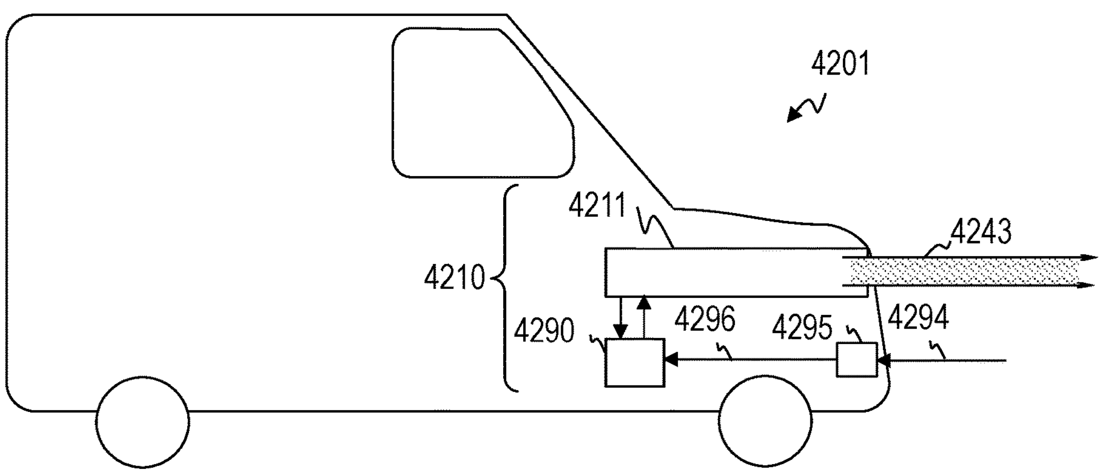

4201
4211
4243
4210
4290
4296
4295
4294

FIG. 43A

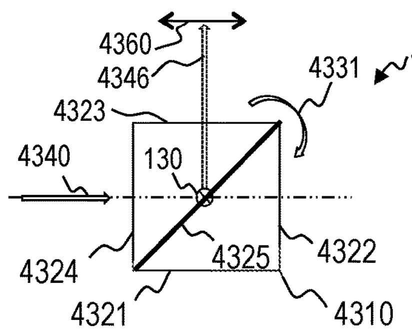


FIG. 43B

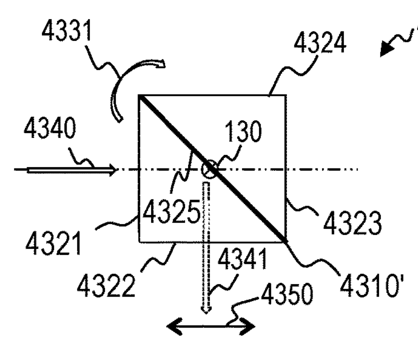
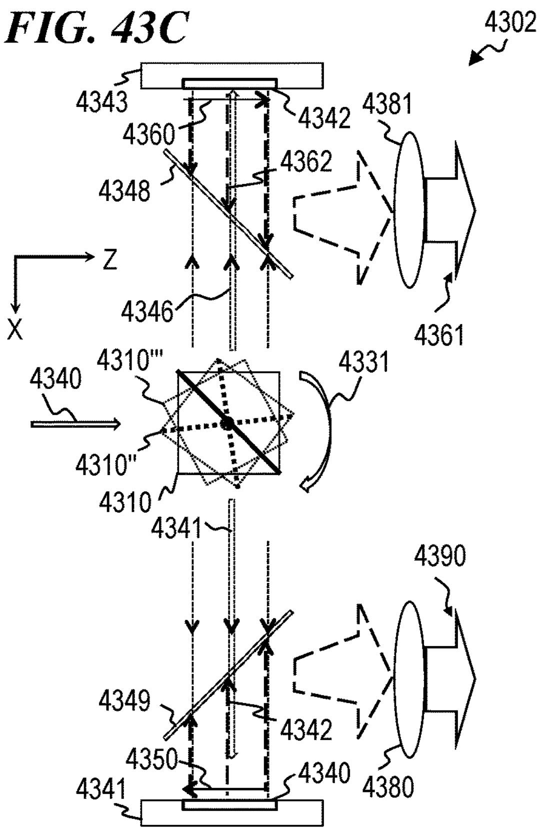


FIG. 43C



INTEGRATED LIDAR WITH SCANNING PHOSPHOR ILLUMINATION SYSTEM AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority benefit, including under 35 U.S.C. § 119(e), of

[0002] U.S. Provisional Patent Application 63/047,905 titled "Scanning phosphor illumination system and method," filed Jul. 2, 2020, by Kenneth Li et al.; and

[0003] U.S. Provisional Patent Application 63/136,312 titled "Scanning phosphor illumination system," filed Jan. 12, 2021 by Kenneth Li; each of which is incorporated herein by reference in its entirety.

[0004] This application is related to:

[0005] U.S. Provisional Patent Application 62/916,580 titled "Recycling Light System using Total Internal Reflection to Increase Brightness of a Light Source," filed Oct. 17, 2019, by Kenneth Li;

[0006] U.S. Provisional Patent Application 62/763,423 titled "Laser Excited Crystal Phosphor Light Module," filed Jun. 14, 2018 by Yung Peng Chang et al.,

[0007] U.S. Provisional Patent Application 62/764,085 titled "Laser Excited Crystal Phosphor Light Source with Side Excitation," filed Jul. 18, 2018 by Yung Peng Chang et al.,

[0008] U.S. Provisional Patent Application 62/764,090 titled "Laser Excited RGB Crystal Phosphor Light Source," filed Jul. 18, 2018 by Yung Peng Chang et al.,

[0009] U.S. Provisional Patent Application 62/766,209 titled "Laser Phosphor Light Source for Intelligent Headlights and Spotlights," filed Oct. 5, 2018 by Yung Peng Chang et al.,

[0010] P.C.T. Patent Application No. PCT/US2020/037669, titled "HYBRID LED/LASER LIGHT SOURCE FOR SMART HEADLIGHT APPLICATIONS," filed Jun. 14, 2020 by Kenneth Li et al. (published Dec. 24, 2020 as WO 2020/257091),

[0011] U.S. Provisional Patent Application 62/862,549 titled "ENHANCEMENT OF LED INTENSITY PROFILE USING LASER EXCITATION," filed Jun. 17, 2019, by Kenneth Li;

[0012] U.S. Provisional Patent Application 62/874,943 titled "ENHANCEMENT OF LED INTENSITY PROFILE USING LASER EXCITATION," filed Jul. 16, 2019, by Kenneth Li;

[0013] U.S. Provisional Patent Application 62/938,863 titled "DUAL LIGHT SOURCE FOR SMART HEADLIGHT APPLICATIONS," filed Nov. 21, 2019, by Y. P. Chang et al.;

[0014] U.S. Provisional Patent Application 62/954,337 titled "HYBRID LED/LASER LIGHT SOURCE FOR SMART HEADLIGHT APPLICATIONS," filed Dec. 27, 2019, by Kenneth Li;

[0015] P.C.T. Patent Application No. PCT/US2020/034447, filed May 24, 2020 by Y. P. Chang et al., titled "LiDAR INTEGRATED WITH SMART HEADLIGHT AND METHOD" (published Dec. 3, 2020 as WO 2020/243038);

[0016] U.S. Provisional Patent Application No. 62/853,538, filed May 28, 2019 by Y. P. Chang et al., titled "LIDAR Integrated With Smart Headlight Using a Single DMD";

[0017] U.S. Provisional Patent Application No. 62/857,662, filed Jun. 5, 2019 by Chun-Nien Liu et al., titled "Scheme of LIDAR-Embedded Smart Laser Headlight for Autonomous Driving";

[0018] U.S. Provisional Patent Application No. 62/950,080, filed Dec. 18, 2019 by Kenneth Li, titled "Integrated LIDAR and Smart Headlight using a Single MEMS Mirror";

[0019] PCT Patent Application PCT/US2019/037231 titled "ILLUMINATION SYSTEM WITH HIGH INTENSITY OUTPUT MECHANISM AND METHOD OF OPERATION THEREOF," filed Jun. 14, 2019, by Y. P. Chang et al. (published Jan. 16, 2020 as WO 2020/013952);

[0020] U.S. patent application Ser. No. 16/509,085 titled "ILLUMINATION SYSTEM WITH CRYSTAL PHOSPHOR MECHANISM AND METHOD OF OPERATION THEREOF," filed Jul. 11, 2019, by Y. P. Chang et al. (published Jan. 23, 2020 as US 2020/0026169);

[0021] U.S. patent application Ser. No. 16/509,196 titled "ILLUMINATION SYSTEM WITH HIGH INTENSITY PROJECTION MECHANISM AND METHOD OF OPERATION THEREOF," filed Jul. 11, 2019, by Y. P. Chang et al. (issued Aug. 25, 2020 as U.S. Pat. No. 10,754,236);

[0022] U.S. Provisional Patent Application 62/837,077 titled "LASER EXCITED CRYSTAL PHOSPHOR SPHERE LIGHT SOURCE," filed Apr. 22, 2019, by Kenneth Li et al.;

[0023] U.S. Provisional Patent Application 62/853,538 titled "LIDAR INTEGRATED WITH SMART HEADLIGHT USING A SINGLE DMD," filed May 28, 2019, by Y. P. Chang et al.;

[0024] U.S. Provisional Patent Application 62/856,518 titled "VERTICAL CAVITY SURFACE EMITTING LASER USING DICHROIC REFLECTORS," filed Jul. 8, 2019, by Kenneth Li et al.;

[0025] U.S. Provisional Patent Application 62/871,498 titled "LASER-EXCITED PHOSPHOR LIGHT SOURCE AND METHOD WITH LIGHT RECYCLING," filed Jul. 8, 2019, by Kenneth Li;

[0026] U.S. Provisional Patent Application 62/857,662 titled "SCHEME OF LIDAR-EMBEDDED SMART LASER HEADLIGHT FOR AUTONOMOUS DRIVING," filed Jun. 5, 2019, by Chun-Nien Liu et al.;

[0027] U.S. Provisional Patent Application 62/873,171 titled "SPECKLE REDUCTION USING MOVING MIRRORS AND RETRO-REFLECTORS," filed Jul. 11, 2019, by Kenneth Li;

[0028] U.S. Provisional Patent Application 62/881,927 titled "SYSTEM AND METHOD TO INCREASE BRIGHTNESS OF DIFFUSED LIGHT WITH FOCUSED RECYCLING," filed Aug. 1, 2019, by Kenneth Li;

[0029] U.S. Provisional Patent Application 62/895,367 titled "INCREASED BRIGHTNESS OF DIFFUSED LIGHT WITH FOCUSED RECYCLING," filed Sep. 3, 2019, by Kenneth Li;

[0030] U.S. Provisional Patent Application 62/903,620 titled "RGB LASER LIGHT SOURCE FOR PROJECTION DISPLAYS," filed Sep. 20, 2019, by Lion Wang et al.; and

[0031] PCT Patent Application No. PCT/US2020/035492, filed Jun. 1, 2020 by Kenneth Li et al., titled "VERTICAL-CAVITY SURFACE-EMITTING LASER USING DICHROIC REFLECTORS" (published Dec. 13, 2020 as WO 22020/247291); each of which is incorporated herein by reference in its entirety.

[0032] U.S. Pat. No. 8,979,308 issued to Kenneth Li on Mar. 17, 2015 with the title "LED illumination system with recycled light", and is incorporated herein by reference. U.S. Pat. No. 8,979,308 describes an LED illumination system includes at least one LED element and a recycling reflector having a transmissive aperture through which emitted light passes. The recycling reflector has a curved surface adapted to reflect the impinging light back to the LED element for improved light output through the transmissive aperture.

[0033] U.S. Pat. No. 8,858,037 issued to Kenneth Li on Oct. 14, 2014 with the title "Light emitting diode array illumination system with recycling", and is incorporated herein by reference. U.S. Pat. No. 8,858,037 describes an LED illumination system includes a plurality of LED modules and a plurality of corresponding collimating lenses to provide increased brightness. Each LED module has at least one LED chip having a light emitting area that emits light and a recycling reflector. The reflector is positioned to reflect the light from the light emitting area back to the LED chip and has a transmissive aperture through which the emitted light exits. The collimating lenses are arranged to receive and collimate the light exiting from the LED modules.

[0034] U.S. Pat. No. 8,602,567 issued to Ouyang et al. on Dec. 10, 2013 with the title "Multiplexing light pipe having enhanced brightness", and is incorporated herein by reference. U.S. Pat. No. 8,602,567 describes multi-color light sources mixed in a recycling housing to achieve high light output. Light from each color light source is multiplexed and a portion of the mixed light passes through an output aperture in the light pipe and a portion light is recycled back, for example, by a shaped reflective surface and/or a reflective coating adjacent the aperture. In one embodiment, the light is directed back from the output side of the housing to an input light source having the same color. In another embodiment, the light is directed back from the output side of the housing to a coating designed to reflect that color. The reflected light is then reflected back toward the output aperture and a portion of that reflected light is again reflected toward the input and impacts the original source for that color light.

[0035] U.S. Pat. No. 8,388,190 issued to Kenneth Li, et al. on Mar. 5, 2013 with the title "Illumination system and method for recycling light to increase the brightness of the light source", and is incorporated herein by reference. U.S. Pat. No. 8,388,190 describes an illumination system for increasing the brightness of a light source that includes an optical recycling device coupled to the light source, preferably light emitting diode (LED), for spatially and/or angularly recycling light. The optical recycling device spatially recycles a portion of rays of light emitted by the LED back to the light source using a reflector or mirror and/or angularly recycles high angle rays of light and transmits small angle rays of light, thereby increasing the brightness of the light source's output.

[0036] U.S. Pat. No. 8,317,331 issued to Li on Nov. 27, 2012 with the title "Recycling system and method for increasing brightness using light pipes with one or more light sources, and a projector incorporating the same", and is incorporated herein by reference. U.S. Pat. No. 8,317,331 describes a recycling system and method for increasing the brightness of light output using at least one recycling light pipe with at least one light source. The output end of the recycling light pipe reflects a first portion of the light back to the light source, a second portion the light to the input end of the recycling light pipe, and transmits the remaining portion of the light as output. The recycling system is incorporated into a projector to provide color projected image with increased brightness. The light source can be white LEDs, color LEDs, and dual paraboloid reflector (DPR) lamp.

[0037] U.S. Pat. No. 7,976,204 issued to Kenneth Li et al. Jul. 12, 2011 with the title "Illumination system and method for recycling light to increase the brightness of the light source", and is incorporated herein by reference. U.S. Pat. No. 7,976,204 describes an illumination system for increasing the brightness of a light source comprises an optical recycling device coupled to the light source, preferably light emitting diode (LED), for spatially and/or angularly recycling light. The optical recycling device spatially recycles a portion of rays of light emitted by the LED back to the light source using a reflector or mirror and/or angularly recycles high angle rays of light and transmits small angle rays of light, thereby increasing the brightness of the light source's output.

[0038] U.S. Pat. No. 7,710,669 issued to Kenneth Li on May 4, 2010 with the title "Etendue efficient combination of multiple light sources", and is incorporated herein by reference. U.S. Pat. No. 7,710,669 describes a multi-colored illumination system including a beam combiner. The beam combiner includes two triangular prisms and a filter for transmitting a first light and reflecting a second light, each light having a different wavelength. The beam combiner combines the transmitted first light and the reflected light to provide a combined beam. The six surfaces of each of the triangular prism of the beam combiner are polished, thereby combining the lights without increasing etendue of the multi-colored illumination system.

[0039] U.S. Pat. No. 7,232,228 issued to Kenneth Li on Jun. 19, 2007 with the title "Light recovery for projection displays", and is incorporated herein by reference. U.S. Pat. No. 7,232,228 describes a light-recovery system for a projection display with a reflector having a first and a second focal points. A source of electro-magnetic radiation is disposed proximate to the first focal point of the reflector to emit rays of radiation that reflect from the reflector and converge substantially at the second focal point. A retroreflector reflects at least a portion of the electromagnetic radiation that does not impinge directly on the reflector toward the reflector through the first focal point of the reflector to increase the flux intensity of the converging rays.

FIELD OF THE INVENTION

[0040] This invention relates to the field of light sources and/or receivers, and more specifically to a method and light-manipulation system that includes a controller that controls one or more scanned light beams and, optionally, a wavelength-converting phosphor plate, wherein the light-manipulation system includes a light source and a rotating faceted optical element that together are usable as an adaptive-driving-beam (ADB) headlight system that generates a selectively controlled ADB headlight output pattern, and optionally includes a LiDAR ("light detection and ranging" or "laser imaging, detection, and ranging") output-signal generator that selectively controls successive output directions of a LiDAR output signal, and a LiDAR receiver that selectively receives return signal from primarily those successive directions corresponding to the successive output directions of the LiDAR output signal. In some embodiments, the ADB headlight system includes a single rotary motor that synchronously rotates three optical elements: a first polygonal mirror system that scans the light for the headlight output pattern, a second polygonal mirror system that scans the successive output directions of the LiDAR output signal, and a third polygonal mirror system that scans the successive input directions for the LiDAR return signal.

BACKGROUND OF THE INVENTION

[0041] In various automotive adaptive-driving-beam (ADB) systems, the modulation of the output headlight-beam pattern can be achieved by using an imaging device, e.g., a DMD (digital micromirror device), or a scanned laser beam exciting a spot moving across a phosphor plate for wavelength-converted emission of a scanned visible spot that is scanned using various means, such as one or more MEMS (micro-electromechanical systems) mirrors, or rotating mirrors. When the scanning visible spot from the phosphor plate is projected by lenses and/or mirrors onto the roadway, various scanned light-output patterns can be obtained by modulating the drive current of the laser. For various scanning systems, a rotating optical element is the preferred method, because reliable motors are readily available and have been well proven in many applications, including beam scanners, projector color wheels, phosphor wheels, etc.

[0042] What is needed is an improved system for a selectively changeable variable-pattern automotive headlight and optionally integrated with a LiDAR system for assisted and/or autonomous vehicles.

SUMMARY OF THE INVENTION

[0043] In some embodiments, the present invention includes a scanning beam system that uses a rotating platform driven by a motor, and a prism or mirror array—in some embodiments, a simple square prism and/or mirrors to scan a laser beam across an area such as a phosphor plate, along with optional optics to project the resulting light pattern. The invention allows laser excitation of such a phosphor plate to move across widespread areas of the phosphor plate, in a manner that prevents overheating of the phosphor plate in any specific location. In some embodiments, the phosphor plate surface is curved such that a scanned beam from a rotating optical beam deflector (such as a prism or polygonal mirror system) remains in focus across the surface of the phosphor plate. In some embodiments, the system includes a LiDAR system sharing part of the scanning mechanism of the lighting system.

[0044] In some embodiments, the present invention provides a first method for scanning a light beam. This first method includes: providing a first faceted optical device; rotating the first faceted optical device around a rotational axis; wherein the first faceted optical device has a plurality of faces, each of which is at one selected angle of a plurality of different angles relative to the rotational axis; generating a first light beam; and deflecting the first light beam toward the rotating first faceted optical device to form a first plurality of spaced-apart scanned light-beam lines. In some embodiments, the deflecting includes refracting the first light beam using a transparent prism. In other embodiments, the deflecting includes refracting the first light beam using a plurality of mirrors on the rotated first faceted optical device.

[0045] In some embodiments, the present invention provides first system having a scanned-light-beam apparatus that includes: a first source of a first light beam; a first rotary motor that has a rotational axis; and a first faceted optical device that is rotated around the rotational axis by the first motor, wherein the first faceted optical device has a plurality of faces, each of which is at one selected angle of a plurality of different angles relative to the rotational axis, and wherein the first light beam is operatively coupled to the rotated first faceted optical device to form a first plurality of spaced-apart scanned light-beam lines.

BRIEF DESCRIPTION OF THE DRAWINGS

[0046] FIG. **1**A is a perspective view of a square transparent prism system **101**, according to some embodiments of the present invention.

[0047] FIG. **1**B is a top view of square transparent prism system **101** with a square-top rectangular rotating prism **110** in a first orientation relative to input beam **140**, according to some embodiments of the present invention.

[0048] FIG. **1**C is a top view of square transparent prism system **101** with rotating prism **110** in a second orientation (indicated as **110'**) relative to input beam **140**.

[0049] FIG. **1**D is a top view of square transparent prism system **101** with rotating prism **110** in a third orientation (indicated as **110"**) relative to input beam **140**.

[0050] FIG. **1**E is a top view of square transparent prism system **101** with rotating prism **110** in a fourth orientation (indicated as **110'"**) relative to input beam **140**.

[0051] FIG. **2** is a top view of a square transparent prism system **201** with rotating prism **110** in three different orientations (indicated as **110**, **110'**, **110"**) relative to input beam **140**, and a transparent phosphor plate **240**, according to some embodiments of the present invention.

[0052] FIG. **3**A is a top view of a square transparent prism system **301** with rotating prism **110** in three different orientations (indicated as **110**, **110'**, **110"**) relative to input beam **140**, and a reflective phosphor plate **340**, according to some embodiments of the present invention.

[0053] FIG. **3**B is a side view of one embodiment of square transparent prism system **301** with rotating prism **110** in the third orientations (indicated **110"**) relative to a horizontal input beam **140**, according to some embodiments of the present invention.

[0054] FIG. **3**C is a side view of an alternative square transparent prism system **303** (which would have a top view substantially similar to FIG. **3**A) with rotating prism **110** in the third orientations (indicated **110"**) relative to tilted-to-horizontal input beam **140**, according to some embodiments of the present invention.

[0055] FIG. **4**A is a top view of a rotating-transparent-prism system **401** with a rotating square-top angle-sided transparent prism **410** in a first orientation (indicated as **410**, in contrast to the orientation **410'** shown in FIGS. **5**A-**5**D) relative to first input beam **440** and second input beam **445** (which are vertically above one another as shown in FIG. **4**B, FIG. **4**C and FIG. **4**D, but here are shown superimposed due to the view), according to some embodiments of the present invention.

[0056] FIG. **4**B is a left-side-elevation view of rotating-transparent-prism system **401** with rotating square-top angle-sided transparent prism **410** in the first orientation (indicated as **410**) relative to first input beam **440** and second input beam **445**.

[0057] FIG. **4**C is a front-side-elevation view of rotating-transparent-prism system **401** with rotating square-top angle-sided transparent prism **410** in the first orientation (indicated as **410**) relative to first input beam **440** and second input beam **445**.

[0058] FIG. **4**D is a right-side-elevation view of rotating-transparent-prism system **401** with rotating square-top angle-sided transparent prism **410** in the first orientation (indicated as **410**) relative to first output beam **441** and second output beam **446**.

[0059] FIG. **5**A is a top view of rotating-transparent-prism system **401** with a rotating square-top angle-sided transparent prism **410** in a second orientation (indicated as **410'**, which is rotated around the center rotational axis **430** about twenty-three degrees (23°) relative to the view of FIG. **4**A) relative to first input beam **440** and second input beam **445** (which are vertically above one another as shown in FIG. **5**B, FIG. **5**C and FIG. **5**D, but here are shown superimposed due to the view), according to some embodiments of the present invention.

[0060] FIG. **5**B is a left-side-elevation view of rotating-transparent-prism system **401** with rotating square-top angle-sided transparent prism **410** in the second orientation (indicated as **410'**) relative to first input beam **440** and second input beam **445**.

[0061] FIG. **5**C is a front-side-elevation view of rotating-transparent-prism system **401** with rotating square-top angle-sided transparent prism **410** in the second orientation (indicated as **410'**) relative to first input beam **440** and second input beam **445** and relative to first exit beam **441'** and second input beam **446'**.

[0062] FIG. **5**D is a right-side-elevation view of rotating-transparent-prism system **401** with rotating square-top angle-sided transparent prism **410** in the second orientation (indicated as **410'**) relative to first exit beam **441'** and second input beam **446'**.

[0063] FIG. **6**A is a top view of a rotating-transparent-prism system **601** with a rotating square-top angle-sided transparent prism **610** in a first orientation (indicated as **610**, in contrast to the orientation **610'** shown in FIGS. **6**E-**6**H) relative to first input beam **640** and first exit beam **641** having a first displacement, according to some embodiments of the present invention.

[0064] FIG. **6**B is a left-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the first orientation (indicated as **610**) relative to first input beam **640** and exit beam **641** having the first displacement.

[0065] FIG. **6**C is a front-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the first orientation (indicated as **610**) relative to first input beam **640** and exit beam **641** having the first displacement.

[0066] FIG. **6**D is a right-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the first orientation (indicated as **610**) relative to first input beam **640** and exit beam **641** having the first displacement.

[0067] FIG. **6**E is a top view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in a second orientation (indicated as **610'**) relative to first input beam **640** and exit beam **641'** having a second displacement (see FIG. **8**).

[0068] FIG. **6**F is a left-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the second orientation (indicated as **610'**) relative to first input beam **640** and exit beam **641'** having the second displacement.

[0069] FIG. **6**G is a front-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the second orientation (indicated as **610'**) relative to first input beam **640** and exit beam **641'** having the second displacement.

[0070] FIG. **6**H is a right-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the second orientation (indicated as **610'**) relative to first input beam **640** and exit beam **641'** having the second displacement.

[0071] FIG. **7**A is a top view of a rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in a third orientation (indicated as **610"**) relative to first input beam **640** and exit beam **641"** having a third displacement (see FIG. **8**), according to some embodiments of the present invention.

[0072] FIG. **7**B is a left-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the third orientation (indicated as **610"**) relative to first input beam **640** and to first input beam **640** and exit beam **641"** having the third displacement.

[0073] FIG. **7**C is a front-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the third orientation (indicated as **610"**) relative to first input beam **640** and exit beam **641"** having the third displacement.

[0074] FIG. **7**D is a right-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the third orientation (indicated as **610"**) relative to first input beam **640** and exit beam **641"** having the third displacement.

[0075] FIG. **7**E is a top view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in a fourth orientation (indicated as **610'"**) relative to first input beam **640** and exit beam **641'"** having a fourth displacement (see FIG. **8**).

[0076] FIG. **7**F is a left-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the fourth orientation (indicated as **610'"**) relative to first input beam **640** and exit beam **641'"** having the fourth displacement.

[0077] FIG. **7**G is a front-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the fourth orientation (indicated as **610'"**) relative to first input beam **640** and exit beam **641'"** having the fourth displacement.

[0078] FIG. **7**H is a right-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the fourth orientation (indicated as **610'"**) relative to exit beam **641'"** having the fourth displacement.

[0079] FIG. **8** is a front-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the four orientations (indicated as **610** as in FIG. **6**C, **610'** as in FIG. **6**G, **610"** as in FIG. **7**C, and **610'"** as in FIG. **7**G) relative to first input beam **640**.

[0080] FIG. **9**A is a top view of a top face **920** of a rotating-transparent-prism system **901** with rotating hexagonal-top rectangular-sided transparent prism **910** in a first orientation (indicated as **910**) relative to first input beam **940**, according to some embodiments of the present invention.

[0081] FIG. **9**B is a top view of top face **920** of rotating-transparent-prism system **901** with rotating hexagonal-top rectangular-sided transparent prism **910** in a second orientation (indicated as **910'**) relative to first input beam **940**.

[0082] FIG. **9**C is a top view of top face **920** of rotating-transparent-prism system **901** with rotating hexagonal-top rectangular-sided transparent prism **910** in a third orientation (indicated as **910"**) relative to first input beam **940**.

[0083] FIG. **10**A is a top view of a rotating-transparent-prism system **1001** with rotating octagonal-top, rectangular-sided-faces transparent prism **1010** in a first orientation relative to first input beam **1040**, according to some embodiments of the present invention.

[0084] FIG. **10**B is a top view of a rotating-transparent-prism system **1002** with rotating ten-sided-top, rectangular-sided-faces transparent prism **1011** in a first orientation relative to first input beam **1040**, according to some embodiments of the present invention.

[0085] FIG. **10**C is a top view of a rotating-transparent-prism system **1003** with rotating twelve-sided-top, rectangular-sided-faces transparent prism **1013** in a first orientation relative to first input beam **1040**, according to some embodiments of the present invention.

[0086] FIG. **11** is a front-elevational view of rotating-transparent-prism system **1101** with rotating square-top angle-sided transparent prism **1110**, mounted on a wedge-spacer **1162** that is rotated by motor **1112**, when in a first orientation relative to first input beam **1140**, according to some embodiments of the present invention.

[0087] FIG. **12** is a perspective view of a spacer **1201** usable in rotating-transparent-prism system **1101**, wherein spacer **1201** includes angular deviations in two directions, according to some embodiments of the present invention.

[0088] FIG. **13** is a top view of a spacer **1301** usable in rotating-transparent-prism system **1101**, wherein spacer **1201** includes angular deviations in two directions such that the tilt axis **1335** does not correspond to axis **1331** or axis **1332** of a square prism, such as prism **1110** of FIG. **11**, according to some embodiments of the present invention.

[0089] FIG. **14** is a top view of a spacer **1401** usable in rotating-transparent-prism system that uses an octagonal spacer **1410** and a prism such as octagonal prism **1310** of FIG. **10**A, wherein spacer **1410** includes angular deviations in two directions such that the tilt axis **1435** does not correspond to any of the four axes of the octagonal prism such as **1010** of FIG. **10**A, according to some embodiments of the present invention.

[0090] FIG. **15** is a top view of a rotating-transparent-prism system **1501** with a rotating square-top rectangular-sided transparent prism **1510** in a first orientation (indicated as **1510**, in contrast to the orientation **1510'** shown in FIG. **16**) relative to first input beam **1540** and second input beam **1545**, each approaching different input faces (e.g., faces **1521** and **1522**, respectively, in this first orientation), according to some embodiments of the present invention.

[0091] FIG. **16** is a top view of a rotating-transparent-prism system **1501** with a rotating square-top rectangular-sided transparent prism **1510** in a second orientation (indicated as **1510'**) relative to first input beam **1540** and second input beam **1545**.

[0092] FIG. **17** is a top view of a rotating-transparent-prism system **1701** with a rotating square-top rectangular-sided transparent prism **1510** in a second orientation (indicated as **1510'**) relative to first input beam **1540** and second input beam **1545**, and further including a flat mirror **1710**, according to some embodiments of the present invention.

[0093] FIG. **18** is a front-elevational view of rotating-transparent-prism system **1801** with rotating square-top angle-sided transparent prism **1810**, mounted on a wedge-spacer **1862** that is rotated by motor **1812**, when in a first orientation relative to first input beam **1840** and second input beam **1845**, both approaching the same input face (e.g., **1821** in this first orientation), according to some embodiments of the present invention.

[0094] FIG. **19** is a top view of a rotating-dual-mirror system **1901** that includes two semi-circular planar mirrors **1910** and **1920** mounted to or formed on a circular double-wedge-shaped substrate **1900**, according to some embodiments of the present invention.

[0095] FIG. **20** is a perspective view of half of rotating-dual-mirror system **1901** (shown in its entirety in FIG. **21**) showing semi-circular planar mirror **1910** mounted to or formed on double-wedge-shaped substrate **1900**.

[0096] FIG. **21** is a perspective cross-section view of rotating-dual-mirror system **1901** that includes two semi-circular planar mirrors **1910** and **1920** mounted to or formed on a circular double-wedge-shaped substrate **1900**.

[0097] FIG. **22**A is a perspective cross-section view of wedged mirror **1910** of rotating-dual-mirror system **2201** in a first rotational orientation.

[0098] FIG. **22**B is a perspective cross-section view of wedged mirror **1910** of rotating-dual-mirror system **2201** in a second rotational orientation.

[0099] FIG. **22**A is a perspective cross-section view of wedged mirror **1910** of rotating-dual-mirror system **2201** in a third rotational orientation.

[0100] FIG. **23** is a top view of a rotating-triple-mirror system **2301** that includes three semi-circular planar mirrors **2310**, **2320**, and **2330** mounted to or formed on a circular triple-wedge-shaped substrate **2300**, according to some embodiments of the present invention.

[0101] FIG. **24** is an elevational side view of a rotating circular double-wedged mirror system **2401** with rotating mirror **2411**, mounted on a wedge-spacer **2410** that is rotated by motor **2412**, when mirror **2411** is in a first orientation (indicated by **2411**) and in a second orientation (indicated by **2411'**) relative to first input beam **2440**, according to some embodiments of the present invention.

[0102] FIG. **25**A is a side view of a system **2501** that obeys the Scheimpflug principle, wherein the object plane **2531**, the lens plane **2532** and the image plane **2533** (only the edges of which show in FIG. **25**A) all intersect at a single line **2535** (only the end of which shows in FIG. **25**A) to the right, according to some embodiments of the present invention.

[0103] FIG. **25**B is a side view of a system **2502** that also obeys the Scheimpflug principle, according to some embodiments of the present invention.

[0104] FIG. **26** is a front-elevational side view of rotating-mirror system **2601** with rotating mirror **2411**, mounted on a wedge-spacer **2410** that is rotated by motor **2412**, when mirror **2411** is in a first orientation (indicated by **2411**) and in a second orientation (indicated by **2411'**) relative to first input beam **1140**, according to some embodiments of the present invention.

[0105] FIG. **27**A is a top view of a rotating octagonal-transparent-prism system **2701** with a rotating octagonal-top rectangular-sided transparent prism **2710** in a first orientation (indicated as **2710**) and in a second orientation (indicated as **2710'**) relative to first input beam **2740**, and further including a rectangular beam-shifting prism **2770** and a mirror-prism-slotted mirror subsystem **2780**, according to some embodiments of the present invention.

[0106] FIG. **27**B a side view of rectangular beam-shifting prism **2770** of system **2701**.

[0107] FIG. **28** is a top view of a mirror-prism-slotted-mirror and phosphor-plate system **2801**, which adds phosphor plate **2880** to mirror-prism-slotted mirror subsystem **2780** (as shown in FIG. **27**A), according to some embodiments of the present invention.

[0108] FIG. **29**A a side view of an anamorphic-prism-pair system **2901** that can increase the width in one direction such that a greater number of lines with wider widths can be obtained simultaneously, according to some embodiments of the present invention.

[0109] FIG. **29**B is a graph of magnification versus prism angels of anamorphic-prism-pair system **2901**, according to some embodiments of the present invention.

[0110] FIG. **30** is a top view of a rotating octagonal-transparent-prism system **3001** with a rotating octagonal-top rectangular-sided transparent prism **3010** in a first orientation (solid-line outline) and a second orientation **3010'** (the slightly angularly offset dashed-line outline) relative to first input beam **3040**, and further including an anamorphic-prism-pair system **2901** and a phosphor plate **3070**, according to some embodiments of the present invention.

[0111] FIG. **31**A is a top view of a dual rotating square-transparent-prism system **3101** with a rotating square-top rectangular-sided transparent prism **3110** in a first orientation relative to first input beam **3140**, and further including a second rotating square-top rectangular-sided transparent prism **3120**, according to some embodiments of the present invention.

[0112] FIG. **31**B is a front view of a resulting pattern of scan lines **3182** generated by dual rotating square-transparent-prism system **3101**, according to some embodiments of the present invention.

[0113] FIG. **31**C is a side view of dual rotating square-transparent-prism system **3101**.

[0114] FIG. **32**A is a top view of a dual rotating polygonal-mirror system **3201** with a rotating square-polygon mirror **3210** in a first orientation relative to first input beam **3240**, and further including a second rotating square-polygon mirror **3220**, according to some embodiments of the present invention.

[0115] FIG. **32**B is a front view of a resulting pattern of scan lines **3382** generated by dual rotating polygonal-mirror system **3201**, according to some embodiments of the present invention.

[0116] FIG. **32**C is a side view of dual rotating polygonal-mirror system **3201**.

[0117] FIG. **33**A is a side view of a rotating multi-faceted-mirror system **3301** with a rotating multi-faceted mirror **3310** in a first orientation relative to first input beam **3340** generated from laser source **3320**, according to some embodiments of the present invention.

[0118] FIG. **33**B is a front view of a resulting pattern of scan lines **3382** generated by dual rotating polygonal-mirror system **3101**, according to some embodiments of the present invention.

[0119] FIG. **34** is a top view of a rotating multi-faceted-mirror system **3401** with a rotating multi-faceted mirror **3410**, according to some embodiments of the present invention.

[0120] FIG. **35** is a side view of a rotating multi-faceted-mirror system **3501** with a rotating multi-faceted mirror **3510** in a first orientation relative to a plurality of input laser beams generated from laser sources **3510**, **3520**, **3530**, and **3540**, according to some embodiments of the present invention.

[0121] FIG. **36** is a front enlarged view of a plurality of scan lines **3582** on phosphor plate **3580** produced by rotating multi-faceted mirror **3510** and the plurality of input beams **3540**, according to some embodiments of the present invention.

[0122] FIG. **37** is a side-view block diagram of a rotating multi-faceted-mirror system **3701** with three systems of rotating multi-faceted mirrors **3738**, **3739**, and **3740** all rotated by the same motor **3712** usable to generate a headlight beam **3890**, a scanning LiDAR beam **3990** and provide for a scanning LiDAR receiver (not shown) for receiving reflected LiDAR signals **4090**, according to some embodiments of the present invention.

[0123] FIG. **38** is a top view of a rotating multi-faceted-mirror system **3801** with rotating multi-faceted mirrors **3811** shown in three positions labeled **3811**, **3811'** and **3811"**, a phosphor plate **3880** and a system of one or more optional collimation and projection lenses **3870**, and **3872**, according to some embodiments of the present invention.

[0124] FIG. **39** is a top view of a rotating multi-faceted-mirror system **3901** with rotating multi-faceted mirrors **3911** shown in three positions labeled **3911**, **3911'** and **3911"**, according to some embodiments of the present invention.

[0125] FIG. **40** is a bottom view of a rotating multi-faceted-mirror system **4001** with rotating multi-faceted mirrors **4011** shown in three positions labeled **4011**, **4011'** and **4011"**, a line sensor **4080** and a system of one or more optional collimation or focussing lenses **4070**, according to some embodiments of the present invention.

[0126] FIG. **41** is a side view of a rotating multi-faceted-mirror system **4101** with a system of rotating multi-faceted mirrors **4141** rotated by motor **4112** usable to generate a headlight beam **4190**, according to some embodiments of the present invention.

[0127] FIG. **42** is a block diagram of a vehicle **4201** that includes a light source **4211**, according to some embodiments of the present invention.

[0128] FIG. **43**A is a top view of a square beam-splitter prism system **4301** with a square-top rectangular beam-splitter rotating prism **4310** in a first orientation relative to input beam **4340**, according to some embodiments of the present invention.

[0129] FIG. **43**B is a top view of square beam-splitter prism system **101** with rotating beam-splitter prism **4310** in a second orientation (indicated as **4310'**) relative to input beam **140**.

[0130] FIG. **43**C is a top view of a square beam-splitter prism system **4302** with rotating beam-splitter prism **4310** in three different orientations (indicated as **4310**, **4310'**, **4310"**) relative to input beam **4340**, and a first reflective phosphor plate **4340** and a second reflective phosphor plate **4360**, according to some embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0131] Although the following detailed description contains many specifics for the purpose of illustration, a person of ordinary skill in the art will appreciate that many variations and alterations to the following details are within the scope of the invention. Specific examples are used to illustrate particular embodiments; however, the invention described in the claims is not intended to be limited to only these examples, but rather includes the full scope of the attached claims. Accordingly, the following preferred embodiments of the invention are set forth without any loss of generality to, and without imposing limitations upon the claimed invention. Further, in the following detailed description of the preferred embodiments, reference is made to the accompanying drawings that form a part hereof, and in which are shown by way of illustration specific embodiments in which the invention may be practiced. It is understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present invention. The embodiments shown in the Figures and described here may include features that are not included in all specific embodiments. A particular embodiment may include only a subset of all of the features described, or a particular embodiment may include all of the features described.

[0132] The leading digit(s) of reference numbers appearing in the Figures generally corresponds to the Figure number in which that component is first introduced, such that the same reference number is used throughout to refer to an identical component which appears in multiple Figures. Signals and connections may be referred to by the same reference number or label, and the actual meaning will be clear from its use in the context of the description.

[0133] FIG. **1**A is a perspective view of a square transparent prism system **101**, according to some embodiments of the present invention, where the four sides (beam-input-and-output rectangular faces **121**, **122**, **123** and **124** that are each perpendicular to the top-side square face **120** and to bottom-side square face **125**) are optically polished and optionally anti-reflection coated. In some embodiments, top-side square face **120** and/or bottom-side square face **125** are used for mounting to a mechanism such as a motor (not shown) used to rotate the prism around rotational axis **130**.

[0134] FIG. **1**B is a top view of square transparent prism system **101** with a square-top rectangular rotating prism **110** in a first orientation, here with input face **124** at ninety degrees (90°) relative to input beam **140**, and thus with output face **122** at ninety degrees (90°) relative to output beam **141**, and the output beam **141** propagation axis has zero displacement (i.e., by a first displacement amount, which is zero) from the propagation axis **149** (see FIG. **1**C) of input beam **140**. Rotating square prism **110** is mounted on a rotating platform (not shown) that continually rotates square prism **110** to different angular orientations relative to input beam **140**.

[0135] FIG. **1**C is a top view of square transparent prism system **101** with rotating prism **110** rotated (see curved arrow **131'**) to a second orientation (indicated as **110'**) of about one-hundred-and-ten degrees (110°) relative to input beam **140**, and thus with output face **122** at seventy degrees (70°) relative to output beam **141'**, which has a propagation axis that is displaced downward by a second amount **142'** in FIG. **1**C.

[0136] FIG. **1**D is a top view of square transparent prism system **101** with rotating prism **110** rotated (see curved arrow **131"**) to a third orientation (indicated as **110"**) of about one-hundred-and-twenty-seven degrees (127°) relative to input beam **140**, and thus with output face **122** at fifty-three degrees (53°) relative to output beam **141"**, which is displaced downward by a third amount **151"** in FIG. **1**D.

[0137] FIG. **1**E is a top view of square transparent prism system **101** with rotating prism **110** (see curved arrow **131'"**) to a fourth orientation (indicated as **110'"**) of about one-hundred-and-fifty-three degrees (153°) relative to input beam **140** such that input beam **140** now enters face **121**, and thus beam **141'"** exits output face **123**, which is displaced upward by a fourth amount **151'"** in FIG. **1**E.

[0138] FIG. **2** is a top view of square transparent prism system **201** with rotating square prism **110** in three different orientations (indicated as **110**, **110'**, **110"**) relative to input beam **140**, and a transparent phosphor plate **240**. Rotating square prism **110** is mounted on a rotating platform (not shown) that continually rotates square prism **110**. The input laser beam **140** is directed towards an input face of square prism **110**, passes through prism **110**, and exits square prism **110** from an opposite face as beam **141** that is parallel to the original laser beam **140**. As square prism **110** is rotated in direction **131** from position **110** (also as shown in FIG. **1**B) to position **110"** (also as shown in FIG. **1**D), the input laser beam **140** is refracted downward by the input surface **124** and directed toward the opposite face **122** (the lower-right side as shown in FIG. **1**D) of the square prism **110** and exits the opposite surface **122** as output beam **141"** at a lower position, while remaining parallel to input laser beam **140** (as a consequence of being refracted in equal degree, but opposite directions, at the input face and output face of square prism **110**). Thus, the output laser beam **141** is moved from the center position labeled **141**, to a lower position labeled **141'** (as shown in FIG. **1**D). As square prism **110** continues to rotate to the position labeled **110"** (also as shown in FIG. **1**D), the output beam **141"** continues to move further in the lower position. As the square prism continues to rotate, when input laser beam **140** passes across the corner position between face **124** and face **121** of square prism **110**, the beam is refracted inside square prism **110** upwards (as shown in FIG. **1**E) in the opposite direction than was the case in FIGS. **1**C and **1**D, above the line of the input-laser-beam position, as shown in FIG. **1**E. As square prism **110** continues to rotate, the output beam **141** will be scanning from the top to the bottom, as shown by arrow **150** in the figures, and will jump from the lowest position **141"** to the highest position **141'"** each time input beam **140** passes by a corner of square prism **110**.

[0139] Continuing, the embodiment shown in FIG. **2** of prism system **201** can be used as a square-transparent prism-adaptive-driving-beam (ADB) headlight system, with rotating square prism **110** shown in three different rotational orientations (indicated as **110**, **110'**, **110"**) relative to input beam **140**. In some embodiments, ADB-headlight system **201** includes a rotating-square-prism beam-scanning system **101**, a transmissive phosphor plate **240**, and a projection lens **290**. As square prism **110** is rotating around its vertical axis **130**, the output laser beam **141** (e.g., in some embodiments, a blue-wavelength laser beam) is scanned in direction **150** across transmissive phosphor plate **240**, forming a line with visible-light emission from the phosphor(s) in the phosphor plate **240**, converting the laser light **141** (e.g., one or more blue wavelengths, indicated by short dashed lines) at least partially into one or more longer wavelengths (e.g., in some embodiments, resulting in white light, wherein the phosphor (s) are chosen to provide a desired wavelength spectrum). In some embodiments, projection lens **280** then transforms the output light **241** (in some embodiments, emitted in a diverging Lambertian pattern) from phosphor plate **240** into the required light pattern of output light beam **290** onto the roadway. In some embodiments, selective dimming and/or ON/OFF functionality imposed on different selected portions of output beam **290** is achieved by controlling the drive current of the laser(s) that generate(s) laser beam **140** in synchronism with the angle of rotating square prism **110** that controls the positions of scanning laser beam **141** on transmissive phosphor plate **240**.

[0140] In some embodiments, laser beam **140** is focused (e.g., by one or more lenses (not shown)) into a round spot onto transmissive phosphor plate **240** such that the output light beam **290** is a scanning spot of light moved across a line (which, in some embodiments, is repeatedly moved across the pattern at high-enough speed that the beam appears constant to the human eye). In other embodiments, the laser beam is focused into a (e.g., vertical) line of light on phosphor plate **240** such that the output beam **290** is a scanning band of light. In addition, in some embodiments, an array of two or more lasers is used to generate a plurality of laser beams **140** such that multiple round spots or lines of light from phosphor plate **240** are projected onto the roadway with another dimension of illumination control because each of the plurality of lasers is independently controlled to be selectively dimmed or turned on and off. For example, if ten (10) laser beams are used, the pattern of output light beam **290** on the roadway can be modulated with ten vertical regions, each selectively dimmed or turned on and off for its own portion of the headlight beam **290**, producing a two-dimensional (2D) light pattern.

[0141] FIG. **3**A is a top view of a rotating square-transparent prism ADB-headlight system **301** with rotating prism **110** shown in three different orientations (indicated as **110**, **110'**, **110"**) relative to input beam **140**, and a reflective phosphor plate **340** mounted on an optional heat sink **341**, such that phosphor plate **340** is heat sunk to remove heat with high effectiveness, thus allowing higher-power operations than possible with the transmissive phosphor plate **240** of system **201** of FIG. **2**. In some embodiments, reflector **349** is highly reflective to all wavelengths on most of the surface facing phosphor plate **340**, but includes an elongated slot aperture (such as slot **359** shown in FIG. **3**B) shaped to allow the focused scanning laser beam **141** to pass through from its lowest extent **141"** to its upper-most extent **141'"**. In other embodiments, reflector **349** has a wavelength-sensitive filter that is highly transmissive to, and passes the wavelengths of, scanning beam **141** and is highly reflective of, and reflects the wavelengths of, light emitted by phosphor plate **340**. In still other embodiments, reflector **349** combines the two approaches just mentioned, and thus is highly reflective to all wavelengths on most of the surface facing phosphor plate **340**, but includes an elongated slot aperture covered by a wavelength-sensitive filter that is highly transmissive to, and passes the wavelengths of, scanning beam **141** and is highly reflective and reflects the wavelengths of light emitted by phosphor plate. Thus, in some embodiments, scanning laser beam **141** passes through the slot aperture in reflector **349**, optionally with a wavelength-sensitive filter that passes blue light (here, of scanning laser beam **141**) and reflects yellow light (here, emitted from laser-excited phosphor plate **340**), and the beam passed by reflector **349** propagates towards reflective phosphor plate **340**. The wavelength-converted emission from phosphor plate **340** then propagates back toward reflector **349** and is reflected upwards towards projection lens **380**. The scanning of the output light is then projected as a scanning beam **390** onto the roadway. Selective dimming or ON/OFF control of various parts of output beam **390** is again achieved by controlling the drive current of the laser(s) in synchronism with the angle of rotating square prism **110** that controls the position of the scanning laser beam **141** on phosphor plate **340**.

[0142] FIG. **3**B is a side view of one embodiment of square transparent prism system **301** with rotating prism **110** in the third orientations (indicated **110"**) relative to a horizontal input beam **140**, according to some embodiments of the present invention.

[0143] FIG. **3**C is a side view of an alternative square transparent prism system **303** (which would have a top view substantially similar to FIG. **3**A) with rotating prism **110** in the third orientations (indicated **110"**) relative to tilted-to-horizontal input beam **140**, according to some embodiments of the present invention. In this embodiment, the tilted-to-horizontal input beam **140** and the rotating prism **110** (shown in a third rotational orientation of top-view FIG. **3**A) are at a tilted angle relative to the horizontal plane **133**, and thus the input scanning beam **141** is incident onto the phosphor plate **340** at an angle from below the horizontal plane **133**, such that the reflector **349** does not interfere with scanning beam **141**. In this case, reflector **349** can be simply a plane mirror without any wavelength-selective or slot features.

[0144] In a manner similar to system **201** in FIG. **2**, in some embodiments of system **301** laser beam **141** is focused into a round spot that is scanned across a line (top to bottom in FIG. **3**A) onto the phosphor plate such that the output beam **390** is a spot of light that is scanned across a line, in some embodiments, repeatedly scanned left-to-right. In other embodiments, laser beam **141** is focused into a line of light (e.g., in some embodiments, a horizontal line) such that the output is a scanning band of light (the horizontal line scanned left-to-right). In addition, in some embodiments, an array of lasers is used such that multiple round spots or lines of lights are projected onto the roadway with another dimension of illumination control, as described above for FIG. **2**. For each rotation of prism **110**, the output beam **141** will scan across the phosphor plate **340** four times (referring to FIGS. **1**B, **1**C and **1**D again, a first scan will occur when the beam **140** enters face **124** and exits face **122** as beam **141**; referring to FIG. **1**E again, a second scan will occur when the beam **140** enters face **121** and exits face **123** as beam **141**, then as prism **110** continued to rotate, a third scan will occur when the beam **140** enters face **122** and exits face **124** as beam **141**, and a fourth scan will occur when the beam **140** enters face **123** and exits face **121** as beam **141**, and then this process repeats).

[0145] As square prism **110** is rotating around its axis **130**, the path lengths change from one position to another; as a result, for scanning beam **141** to be focused at the phosphor plate at all times, in some embodiments, phosphor plate **340** is formed having a curved front surface with a curvature matching the path lengths. Accordingly, in some embodiments, projection lens **380** is also designed to accommodate the curvature of phosphor plate **340**, providing the required patterns on the roadway.

[0146] In other embodiments of FIGS. **3**A, **3**B and **3**C (not shown), still using a single square rotating prism **110** with perpendicular sides **121**, **122**, **123** and **124**, a plurality of two or more parallel input beams **140** are used, one above the other, and thus two or more parallel scanning beams **141** (one scanning beam for each input beam) are produced and projected onto phosphor **340**.

[0147] In other embodiments, such as shown in FIGS. **4**A-**5**D and **5**A-**5**D, the opposite parallel sides of the prism are tilted at the same angle to the rotational axis, and thus two successive scanning output beams per rotation of the prism are produced for each parallel input beam.

[0148] In still other embodiments, such as shown in FIGS. **6**A-**6**H, **7**A-**7**H and **8**, the opposite parallel sides of the prism are tilted at different angles to the rotational axis, and thus four successive scanning output beams per rotation of the prism are produced for each parallel input beam.

[0149] FIG. **4**A is a top view of a rotating-transparent-prism system **401** with a rotating square-top, slanted-angle-sided transparent prism **410** in a first orientation (indicated as **410**, in contrast to the orientation **410'** shown in FIGS. **5**A-**5**E) relative to two parallel input beams (first input beam **440** and second input beam **445**) and two scanned output lines **441** and **446** (which are vertically above one another as shown in FIG. **4**B, FIG. **4**C and FIG. **4**D, but here are shown superimposed due to the top view) per pair of sides of the prism, according to some embodiments of the present invention. In some embodiments, the four polished input/output side faces, **421**, **422**, **423**, and **424**, are slanted relative to top face **420** and bottom face **425** (i.e., the side faces **421** and **423** are parallel to one another and are at an angle θ_1 relative to top face **420** and bottom face **425**, respectively, and side faces **424** and **424** are parallel to one another and are also at an angle θ_1 relative to top face **420** and bottom face **425**, respectively), such that horizontal scanning beam **441** and horizontal scanning beam **446** each have the same vertical positions leaving successive output faces as prism **410** is rotated around its axis **430**, allowing two scanned lines of output-light that each move up and down due to different angles of rotating prism **410**.

[0150] FIG. **4**B is a left-side-elevation view of rotating-transparent-prism system **401** with rotating square-top angle-sided transparent prism **410** in the first orientation (indicated as **410**) relative to first input beam **440** and second input beam **445**.

[0151] FIG. **4**C is a front-side-elevation view of rotating-transparent-prism system **401** with rotating square-top angle-sided transparent prism **410** in the first orientation (indicated as **410**) relative to first input beam **440** and second input beam **445**.

[0152] FIG. **4**D is a right-side-elevation view of rotating-transparent-prism system **401** with rotating square-top angle-sided transparent prism **410** in the first orientation (indicated as **410**) relative to first output beam **441** and second output beam **446**.

[0153] FIG. **5**A is a top view of rotating-transparent-prism system **401** with rotating square-top angle-sided transparent prism **410** in a second angular orientation (indicated as **410'**) relative to first input beam **440** and second input beam **445** (which are vertically above one another as shown in FIG. **5**B, FIG. **5**C and FIG. **5**D, but here are shown superimposed due to the view) and relative to first exit beam **441** and second exit beam **446** (which are also vertically above one another as shown in FIG. **5**B, FIG. **5**C and FIG. **5**D, but here are shown superimposed due to the view), according to some embodiments of the present invention.

[0154] FIG. **5**B is a left-side-elevation view of rotating-transparent-prism system **401** with rotating transparent prism **410** in the second orientation **410'** relative to first input beam **440** and second input beam **445**.

[0155] FIG. **5**C is a front-side-elevation view of rotating-transparent-prism system **401** with rotating prism **410** in the second orientation **410'** relative to first input beam **440** and second input beam **445** and relative to first exit beam **441'** and second input beam **446'**.

[0156] FIG. **5**D is a right-side-elevation view of rotating-transparent-prism system **401** with rotating transparent prism **410** in the second orientation **410'** relative to first exit beam **441'** and second input beam **446'**.

[0157] Note that exit beams **441'** and **446'** are displaced left and right as well as up and down as rotating square-top angle-sided transparent prism **410** is rotated in direction **431** around axis **430**.

[0158] Note also that FIGS. **4**A-**4**D and **5**A-**5**D show two parallel input beam and two parallel output beams, but the two pairs of input/output faces **421**-**423** and **424**-**422** are shown with the same tilt angle to the rotational axis **430**, so there is one output scan beam for each input beam, but each output scan beam is generated twice for each rotation of the prism **401**. Then, as described below, FIGS. **6**A-**6**H and **7**A-**7**H and **8** show the two pairs of input/output faces **621**-**623** and **624**-**622** having different tilt angles to the rotational axis, but only a single input beam. This is for clarity of the Figures. Note that other embodiments of system **601** (not shown) include a plurality of parallel input beams and correspondingly two output scan lines for each input laser beam, but each output scan line is generated once for each rotation of the prism **601**.

[0159] FIG. **6**A is a top view of a rotating-transparent-prism system **601** with a rotating square-top angle-sided transparent prism **610** in a first orientation (indicated as **610**, in contrast to the orientation **610'** shown in FIGS. **6**E-**6**H) relative to first input beam **640** and first exit beam **641** having a first displacement, according to some embodiments of the present invention. In some embodiments, input face **621** is parallel to output face **623**, and both are at the same angle θ_1 relative to the bottom face **625** and top face **620** respectively, as shown in FIG. **6**C. In some embodiments, face **624** is parallel to face **622**, and both are at the same angle θ_2 relative to the top face **620** and bottom face **625**, respectively, as shown in FIG. **6**G. Note that angle θ_1 and angle θ_2 are different from one another, such that the amount of vertical displacement between input laser beam **640** and the parallel output beam **641** (displaced downward by a first amount, indicated by reference number **641** as shown in FIG. **6**C and FIG. **8**, or upward by a first amount, indicated by reference number **641"** as shown in FIG. **7**C and FIG. **8**) is different when passing through faces **621** and **623** as compared to the vertical displacement of the output beam (upward by a second amount, indicated by reference number **641'** as shown in FIG. **6**G and FIG. **8**, or downward by a second amount, indicated by reference number **641'"** as shown in FIG. **7**G and FIG. **8**) when passing through faces **622** and **624**, thus generating two different scan lines for each input laser beam. This provides two different displacement amounts (which in turn depend on the different angles θ_1 and θ_2) for each input laser beam when a plurality of two or more parallel input laser beams are used, such as shown in FIGS. **4**A-**4**D and **5**A-**5**D.

[0160] Note that in some embodiments (not shown combined together), a plurality of two (or more) stacked laser input beams (such as shown in FIGS. **4**A-**4**D and **5**A-**5**D) are used as the laser beam inputs (rather than just a single input beam **640**) into rotating-transparent-prism system **601** shown in FIGS. **6**A-**6**H and **7**A-**7**H, to increase the number of output scan lines.

[0161] FIG. **6**B is a left-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the first orientation (indicated as **610**) relative to first input beam **640** and its parallel exit beam **641** having the first downward displacement that depends on angle θ_1 as shown in FIG. **6**C.

[0162] FIG. **6**C is a front-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the first orientation (indicated as **610**) relative to first input beam **640** and exit beam **641** having the first displacement. Note again, the angle θ_1 between top face **620** and output face **623** is the same as angle θ_1 between bottom face **625** and input face **621**, as shown in FIG. **6**C, and the angle θ_2 between top face **620** and input face **624** is the same as angle θ_2 between bottom face **625** and output face **622**, as shown in FIG. **6**G, and angle θ_1 is different than angle θ_1.

[0163] FIG. **6**D is a right-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the first orientation (indicated as **610**) relative to first input beam **640** and exit beam **641** having the first displacement.

[0164] FIG. **6**E is a top view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the second orientation (indicated as **610'**, which is rotated 90° from the first orientation shown in FIGS. **6**A-**6**D) relative to first input beam **640** and exit beam **641'** having a second displacement (see also FIG. **8**).

[0165] FIG. **6**F is a left-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the second orientation (indicated as **610'**) relative to first input beam **640** and exit beam **641'** having the second displacement.

[0166] FIG. **6**G is a front-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the second orientation (indicated as **610'**) relative to first input beam **640** and exit beam **641'** having the second displacement.

[0167] FIG. **6**H is a right-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the second orientation (indicated as **610'**) relative to first input beam **640** and exit beam **641'** having the second displacement.

[0168] FIG. **7**A is a top view of a rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in a third orientation (indicated as **610"**, which is rotated 180° from the first orientation shown in FIGS. **6**A-**6**D, (and 90° from the second orientation shown in FIGS. **6**E-**6**H) relative to first input beam **640** and exit beam **641"**) having a third displacement (see also FIG. **8**), according to some embodiments of the present invention.

[0169] FIG. **7**B is a left-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the third orientation (indicated as **610"**) relative to first input beam **640** and to first input beam **640** and exit beam **641"** having the third displacement.

[0170] FIG. **7**C is a front-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the third orientation (indicated as **610"**) relative to first input beam **640** and exit beam **641"** having the third displacement.

[0171] FIG. **7**D is a right-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the third orientation (indicated as **610"**) relative to first input beam **640** and exit beam **641"** having the third displacement.

[0172] FIG. **7**E is a top view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in a fourth orientation (indicated as **610'"**, which is rotated 270° from the first orientation shown in FIGS. **6**A-**6**D and 90° from the third orientation shown in FIGS. **7**A-**7**D) relative to first input beam **640** and exit beam **641'"** having a fourth displacement (see also FIG. **8**).

[0173] FIG. **7**F is a left-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the fourth orientation (indicated as **610'"**) relative to first input beam **640** and exit beam **641'"** having the fourth displacement.

[0174] FIG. **7**G is a front-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the fourth orientation (indicated as **610'"**) relative to first input beam **640** and exit beam **641'"** having the fourth displacement.

[0175] FIG. **7**H is a right-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the fourth orientation (indicated as **610'"**) relative to exit beam **641'"** having the fourth displacement.

[0176] FIG. **8** is a front-side-elevation view of rotating-transparent-prism system **601** with rotating square-top angle-sided transparent prism **610** in the four orientations (indicated as **610** in solid lines as in FIG. **6**C, **610'** in wide dash-dot-dot lines over light solid lines as in FIG. **6**G, **610"** in wide dash lines over light solid lines as in FIG. **7**C, and **610'"** in wide dash-dot lines over light solid lines as in FIG. **7**G) relative to first input beam **640**. The amounts of vertical displacement of the exit beams **641**, **641'**, **641"** and **641'"** depend on the angle θ_1 and angle θ_2 between the top and bottom faces **620** and **625** and the respective input/output face pairs **621**-**623** and **622**-**624**, as well as the varied rotational angle **631** as each complete rotation is completed.

[0177] In total, in some embodiments, such as shown in FIGS. **6**A-**6**H, **7**A-**7**H and **8**, there are four successive-in-time scan lines generated per full rotation of this angledsided prism **610** that has two different pairs of parallel sides of different tilt angles relative to the rotational axis **630** using a single input laser beam **640**. In other embodiments, when two or more parallel input laser beams are used, a total of eight or more scan lines are produced (four scan lines for each parallel input beam). When the horizontal input beam **640** passes through each input face **621**, **622**, **623** and **624**, the beam is refracted downwards or upwards towards the respective output face **623**, **624**, **621** and **622**, below or above the centerline propagation axis of input beam **640**, and exits as output beam **641** in the horizontal direction parallel to input beam **640** at a variable distance above or below the centerline. As the prism is rotated around its vertical axis **630**, the first displacement distance downward for exit beam **641** shown in FIG. **8** and FIG. **6**C is equal to the third displacement distance upward for exit beam **641"** shown in FIG. **8** and FIG. **7**C, and the third displacement distance upward for exit beam **641'** shown in FIG. **8** and FIG. **6**G is equal to the fourth displacement distance downward for exit beam **641'''** shown in FIG. **8** and FIG. **7**G. As the square-top prism **610** with its two pairs of slanted side surfaces (parallel pair **621** and **623** and parallel pair **624** and **622**) at two different angles rotates (for example, initially the beam enters face **621** and exits face **623** as in FIG. **6**C, and next enters face **624** and exits face **622** as in FIG. **6**G), four horizontal scanning lines as shown in FIG. **8** are successively produced (at four successive periods of time on each rotation of prism **610**), allowing the scanning of the headlight beam at four different vertical positions onto the roadway. In some embodiments, when prism **610** is rotated at sufficiently high speeds, the four different vertical positions of the headlight beam will be perceived as “constantly on” to a human viewer (when the input laser is “on” for that portion of the headlight pattern), rather than being seen as successively generated, or flickering.

[0178] FIG. **9**A is a top view of a top face **920** of a rotating-transparent-prism system **901** with rotating hexagonal-top rectangular-sided transparent prism **910** in a first orientation (indicated as **910**) relative to first input beam **940**, according to some embodiments of the present invention.

[0179] FIG. **9**B is a top view top face **920** of rotating-transparent-prism system **901** with rotating hexagonal-top rectangular-sided transparent prism **910** in a second orientation (indicated as **910'**) relative to first input beam **940**.

[0180] FIG. **9**C is a top view of top face **920** rotating-transparent-prism system **901** with rotating hexagonal-top rectangular-sided transparent prism **910** in a third orientation (indicated as **910"**) relative to first input beam **940**.

[0181] FIGS. **9**A, **9**B and **9**C show three positions of angular rotation of an embodiment of the invention that uses hexagonal prism **910** with three pairs of parallel side surfaces (not shown), which, in some embodiments, are slanted at three different angles relative to the horizontal top face **920** of the prism **910**, such that output beam **941** scanning at three different levels above and three different levels below an input-beam propagation axis of each of one or more parallel input beams (two or more such input beams, such as shown in FIGS. **4**A-**4**D, and **5**A-**5**D) is produced, with a total of six successive-in-time lines of output light having six vertical positions for each input beam **940**, allowing more flexibility in the output light pattern.

[0182] FIG. **10**A is a top view of a rotating-transparent-prism system **1001** with rotating octagonal-top, rectangular-sided-faces transparent prism **1010** in a first orientation relative to first input beam **1040**, according to some embodiments of the present invention.

[0183] FIG. **10**B is a top view of a rotating-transparent-prism system **1002** with rotating ten-sided-top, rectangular-sided-faces transparent prism **1011** in a first orientation relative to first input beam **1040**, according to some embodiments of the present invention.

[0184] FIG. **10**C is a top view of a rotating-transparent-prism system **1003** with rotating twelve-sided-top, rectangular-sided-faces transparent prism **1013** in a first orientation relative to first input beam **1040**, according to some embodiments of the present invention.

[0185] FIGS. **10**A, **10**B and **10**C further extend the design to eight-sided, ten-sided, and twelve-sided polygons, with correspondingly more pairs of parallel faces at different slanted angles relative to the top and bottom faces (four different slant angles for the four pairs for FIG. **10**A, five different slant angles for the five pairs for FIG. **10**B, or six different slant angles for the six pairs for FIG. **10**C, respectively) for the sides, for even more scanning output lines. Similarly, fourteen-sided or more-sided polygons can be made, to produce even more lines at the output for each parallel input beam.

[0186] FIG. **11** is a front-elevational view of rotating-transparent-prism system **1101** with rotating square-top angle-sided transparent prism **1110**, mounted on a wedge-spacer **1162** that is rotated by motor **1112**, when in a first orientation relative to first input beam **1140**, according to some embodiments of the present invention. FIG. **11** shows one of the embodiments where the slanting of the prism sides is achieved by tilting a square prism (e.g., a square prism with four sides that are perpendicular to the top and bottom square faces), wherein the prism is oriented at an angle to the horizontal using a tilter spacer, as shown. If the spacer is tilted in one direction (shown by angle θ_1 in FIG. **11**), the output beam deviation will occur in downward direction **1150** only when the light beam **1140** enters face **1121** or **1123**, and output beam **1141** scans in a direction **1151** (whether the beam moves toward the sheet and away from the viewer, as shown here, depends on the direction of rotation of prism **1110** around its rotational axis **1139**) perpendicular to the sheet of FIG. **11**. When the prism is turned for the input beam **1140** to enter the other faces **1122** and **1124**, the scanned output beam **1141** will not be deviated vertically from the propagation axis **1131** of the input beam **1140**.

[0187] FIG. **12** is a perspective view of a spacer **1201** usable in rotating-transparent-prism system **1101**, wherein spacer **1201** includes angular deviations in two directions, according to some embodiments of the present invention. As a result, deviations in two different amounts up and down are provided, since spacer **1201** is tilted in different amounts in the X and Y directions, as shown in FIG. **12**. In this case, the heights **1222**, **1223**, and **1224** relative to height **1221** are determined by the amount of slant angle θ_1 and slant angle θ_2 in the two X and Y directions. The height **1224** will be a dependent variable calculated from **1221**, **1222**, and **1223** to make top surface **1220** a single plane.

[0188] FIG. **13** is a top view of a spacer **1301** usable in rotating-transparent-prism system **1101** of FIG. **11**, wherein spacer **1301** includes angular deviations in two directions such that the tilt axis **1335** does not correspond to axis **1331** or axis **1332** of a square prism to be mounted on spacer

1301, such as prism **1110** of FIG. **11**, according to some embodiments of the present invention. In this case, the heights of the corners **1322**, **1323**, and **1324** relative to height **1321** are determined by the amount of slant angle θ_1 and slant angle θ_2 (see FIG. **12**) in the two X and Y directions. In order to provide the two slant angles θ_1 and θ_2, the tilting axis **1335** has to be different from the prism axes **1331** and **1332**, as shown in FIG. **13**. In this case, the prism axis **1331** and prism axis **1332** are perpendicular to the respective faces of the square prism **1310**. In some embodiments, spacer tilt axis **1335** is chosen (e.g., as shown) as determined by the desired amount of tilt in both X and Y directions.

[0189] FIG. **14** is a top view of a spacer **1401** usable in rotating-transparent-prism system that uses an octagonal spacer **1410** and a prism such as octagonal prism **1310** of FIG. **10**A, wherein spacer **1410** includes angular deviations in two directions such that the tilt axis **1435** does not correspond to any of the four axes **1431**. **1432**, **1433** and **1434** of the octagonal prism such as **1010** of FIG. **10**A, according to some embodiments of the present invention. In general, as shown in the example in FIG. **14**, which is for an eight-sided prism having faces that are perpendicular to the top and bottom faces, the spacer tilt axis **1435** is chosen such that it is not any one of the four prism axes **1431**. **1432**, **1433** and **1434**. In some embodiments, the exact spacer-tilt axis **1435** is determined by the four slant angles required by the scanning system.

[0190] In general, the spacer-tilt axis can fall in any direction, as required by the design of the output pattern; in particular, in one of the embodiments, the spacer-tilt axis passes through the opposite corners of the prism such that the output beams have a highest number of different or independent scanning lines of light.

[0191] FIG. **15** is a top view of a rotating-transparent-prism system **1501** with a rotating square-top rectangular-sided transparent prism **1510** in a first orientation (indicated as **1510**, in contrast to the orientation **1510'** shown in FIG. **16**) relative to first input beam **1540** and second input beam **1545**, each approaching different input faces (e.g., **1521** and **1522**, respectively, in this first orientation). In some embodiments, rotating square prism **1510** is a square-top rectangular-sided prism (such as shown in FIG. **1**A), but here the square prism **1510** receives two input beams **1540** and **1545** propagating towards the square transparent prism **1510** from two directions (e.g., in this FIG. **15**, input beam **1540** from the left of the drawing and input beam **1545** from the top of the drawing), such that two independent output beams **1541** (scanned in direction **1550**) and **1546** (scanned in direction **1560**) are scanned simultaneously by the same square prism **1510** when the square prism **1510** is rotating. In some embodiments, the two scanned output beams **1541** and **1546** are used independently.

[0192] FIG. **16** is a top view of a rotating-transparent-prism system **1501** with a rotating square-top rectangular-sided transparent prism **1510** in a second orientation (indicated as **1510'**) relative to first input beam **1540** and second input beam **1545**, such that both output beams **1541'** and **1546'** are deviated from their respective centerlines **1535** and **1536**.

[0193] FIG. **17** is a top view of a rotating-transparent-prism system **1701** with a rotating square-top rectangular-sided transparent prism **1510** in a second orientation (indicated as **1510'**) relative to first input beam **1540** and second input beam **1545**, and further including a flat mirror **1710** to reflect the second scanning beam **1546** (shown here as deflected to position **1546'**) to be scanning beam **1747**, which is parallel to scanning beam **1541** in some embodiments of the present invention. FIG. **17** shows an embodiment where reflector **1710** has been added, to reflect the output of output scanning beam **1747** to a perpendicular path to the direction of the intermediate scanning beam **1546**. In other embodiments (not shown), both scanning beams **1541** and **1747** can be redirected to their respective desired directions using the appropriate optical components.

[0194] When the same method is applied to a hexagonal prism (such as shown in FIGS. **9**A, **9**B and **9**C), three independent input beams impinge on three different faces of the hexagonal prism **910** simultaneously and are scanned to three scanning output beams (in three different directions each parallel to the three respective input beam, since the hexagonal prism can accept input beams propagating towards the hexagonal transparent prism from three directions such that three independent output beams are scanned simultaneously by the same hexagonal prism when the hexagonal prism is rotating. Following the same approach, in embodiments with prisms having a greater number of sides in the prism, more independent input beams can be used to generate additional scanned output beams.

[0195] FIG. **18** is a front-elevational view of rotating-transparent-prism system **1801** with rotating square-top angle-sided transparent prism **1810**, mounted on a wedge-spacer **1862** that is rotated by motor **1812**, when in a first orientation relative to first input beam **1840** and second input beam **1845**, both approaching the same input face (e.g., **1821** in this first orientation), according to some embodiments of the present invention. FIG. **18** shows an embodiment where two input beams are placed one on top of another (e.g., in some embodiments, the two input beams are parallel to one another), such that both beams are scanned, producing two output beams (e.g., two parallel scanned beams) when the square prism **1810** is rotating (e.g., beam **1841** scanning in direction **1850** (into the sheet depending on the rotational direction of prism **1810** around axis **1830**) while deflected in downward direction **1851**, and beam **1846** scanning in the same direction **1860** (into the sheet depending on the rotational direction of prism **1810** around axis **1830**) while deflected in downward direction **1861**). In some embodiments, spacer **1862** is tilted to different slant angle θ_1 and slant angle θ_2 such as shown in FIGS. **12** and **13**, to provide two different tilt angles for the two pairs of parallel input/output faces **1821-1823** and **1822-1824**. In general, and as implemented in various embodiments, more than two parallel beams can be stacked on top of, and/or beside each other and/or additional stacked beams approach different input faces such as shown in FIGS. **16-17**, producing even more scanning output beams. Combining the approach of having beams impinging from different directions on multiple faces of a prism and stacked on top of each other (e.g., a plurality of parallel beams stacked on one another directed to each of a plurality of faces of the prism), a single rotating prism can produce multiple scanning beams for various applications.

[0196] As an example, in some embodiments, the scanning beams, combined with the appropriate wavelength converters (such as transmissive or reflective phosphor plates), and a controller such as controller **4290** shown in FIG. **42**, are used for generating a light profile that includes one or more automotive-headlight output beams, including low beam, high beam, or ultra-high beam only, or a desired combination, etc. With such a light profile, having a variably controlled shape and brightness, projected onto the roadway together with the intensity-modulation capability of the laser(s) under the control of a controller (such as shown in FIG. **42**, described below), the desired output shape-and-intensity profile is produced, such as lighting various portions or subsets of low beam only, high beam only, or ultra-high beam only, or a desired combination. In addition, in some embodiments other scanning beams include one or more pulsed infrared laser (IR) beams used for LiDAR application targeting, with one or more output beams targeting at one or more directions (such as described in FIGS. **37**, **39**, **40** and **42**, for example).

[0197] FIG. **19** is a top view of a rotating-dual-mirror system **1901** that includes two semi-circular planar mirrors **1910** and **1920** mounted to or formed on a circular double-wedge-shaped substrate **1900**, according to some embodiments of the present invention. In some embodiments, headlight applications using light sources such as light-emitting diodes (LEDs), or laser-excited phosphors, use a tilted-mirror embodiment such as shown in FIG. **19**. FIG. **19** uses two semi-circular planar mirrors **1910** and **1920** mounted or formed on a circular double-wedge-shaped substrate **1900** (alternatively, substrate **1900** may be other shapes, such as using two different wedge angles). The mirrors **1910** and **1920** are tilted in the opposite direction such that there are high levels **1913** and **1922**, and low levels **1911** and **1921**, as shown more clearly in FIG. **21**. The dual-mirror system **1901** is rotated around the central rotation axis **1931**.

[0198] FIG. **20** is a perspective view of half of rotating-dual-wedged-mirror system **1901** (shown in its entirety in FIG. **21**), showing semi-circular planar mirror **1910** mounted to or formed on double-wedge-shaped substrate **1900**, wherein the cross-section **1962** is a wedge.

[0199] FIG. **21** is a perspective cross-section view of rotating-dual-mirror system **1901** that includes two semi-circular planar mirrors **1910** and **1920** mounted to or formed on a circular double-wedge-shaped substrate **1900**. In some embodiments, two sections of the same mirror shape are placed facing and opposite to each other, forming a single circular double-wedged mirror, as shown in FIG. **21**. The dual-mirror system **1901** is rotated around the central axis **1931** of rotation. In some embodiments, the complete rotating dual-mirror system **1901** is made as a single unit, or as an assembly of two units. In some embodiments dual-mirror system **1901** is made using glass, metal, or other suitable material, and with the reflective surfaces polished and coated to be highly reflective. In some embodiments dual-mirror system **1901** is made using die casting, or electro-forming, such that dual-mirror system **1901** is made as a single unit with mounting features included.

[0200] FIG. **22**A is a perspective cross-section view of wedged mirror **1910** of rotating-dual-mirror system **2201** in a first rotational orientation.

[0201] FIG. **22**B is a perspective cross-section view of wedged mirror **1910** of rotating-dual-mirror system **2201** in a second rotational orientation.

[0202] FIG. **22**A is a perspective cross-section view of wedged mirror **1910** of rotating-dual-mirror system **2201** in a third rotational orientation.

[0203] FIGS. **22**A, **22**B and **22**C show three cross-sectional views of wedged mirror half **1910** of circular double-wedged mirror **1901** in three positions of the wedge mirror **1910**—in the 0°, 90°, and 180° positions. At the 0° position of FIG. **22**A, a vertical-angle input beam **2240**, which in various embodiments includes one or more laser beams, and/or one or more white-light LED beams, will be reflected upward as output beam **2241** toward the left side of system **2201**, as shown. When the wedged mirror **1910** is rotated to the 90° position of FIG. **22**B, vertical-angle input beam **2240** will be reflected vertically upward as output beam **2241'**, since mirror **1910** at the 90° position is perpendicular to input beam **2240**. As the wedged prism is rotated to the 180° position of FIG. **22**C, vertical-angle input beam **2240** will be reflected vertically upward as output beam **2241"**, reflected upward to the right. As the wedge mirror **1901** is rotating, output beam **2241** will be reflected from one side to the other, and as the input beam jumps from one wedge **1910** to the other wedge **1920**, the output beam **2241** will also jump from the end of the scan line back to the start of the scan-line scanning position. The circular double-wedged mirror system **1901** as shown in FIG. **21** will produce two scans for each revolution.

[0204] FIG. **23** is a top view of a rotating-triple-mirror system **2301** that includes three semi-circular planar mirrors **2310**, **2320**, and **2330** mounted to or formed on a circular triple-wedge-shaped substrate **2300**, according to some embodiments of the present invention. In some embodiments, rotating-triple-mirror system **2301** includes three wedged mirrors, each of which occupies 120°, allowing three sets of wedged mirrors to be combined into a single circular mirror. This will produce three scans in one revolution, allowing a slower rotation speed to achieve a given scanning rate. In general, and as implemented in various embodiments, three or more segments of wedged mirrors are used, producing three or more scans per revolution.

[0205] FIG. **24** is an elevational side view of a rotating circular double-wedged mirror system **2401** with rotating mirror **2411**, mounted on a wedge-spacer **2410** that is rotated by motor **2412**, when the first wedged mirror **2411** is in a first orientation (indicated by **2411**) and in a second orientation (indicated by dashed-line **2411'**, which also represents the second wedged mirror **2412**) relative to first input beam **2440**, according to some embodiments of the present invention. FIG. **24** shows a circular double-wedged mirror scanning system **2410**, such as system **1901** of FIG. **21**, used with a light source **2420**, such as an LED source, a laser-excited-phosphor source, or the like, such that the output **2481** can be scanned by the rotating wedge mirrors. In the embodiment shown, the rotation axis **2430** is placed at 45 degrees from propagation direction of beam **2440** from single input light source **2420** such that, nominally, the scanning output beam **2441** will be reflected by 90 degrees to be output light **2481**. The input beam **2440** from light source **2420** is directed to both wedged mirror **2411** and wedged mirror **2413** as the double-wedged mirrors are rotating. When light beam **2440** is reflected by the high-level sides of the two mirrors **2411** and **2413** (which is shown superimposed on the line labeled **2411'**, representing a position of mirror **2411** when rotated) 180°, the output is in the direction of reflection **2441**. When light beam **2440** is reflected by the respective low-level sides of the two mirrors **2411** and **2413** as they rotate to successive positions, the output is in the direction of reflection **2441'**. As mirrors **2411** and **2413** are rotating, output beam **2481** will be scanned between angular directions **2441** and **2441'**. In some embodiments, output beam **2481** is then projected to the roadway or screen using a projection lens (not shown here, but see lens **2580** of FIG. **25**B). Considering the reflections from both the high-level and low-level sides of the mirrors, the images of the light source have different optical distances and would not produce a focused image using a traditional projection system using a projection lens perpendicular to the horizontal position.

[0206] In general, and as implemented in various embodiments, two or more input light sources **2440** can be stacked (e.g., such as using two or more parallel input laser beams impinging on the circular double-wedged mirror scanning system of FIG. **21**), producing even more scanning output beams. In some embodiments, this approach of using a plurality of parallel input laser beams impinging on a rotating wedged mirror system is also applied to rotating wedged-mirror systems using three or more wedged mirror segments.

[0207] FIG. **25**A is a side view of a system **2501** that obeys the Scheimpflug principle (e.g., see Wikipedia en.wikipedia.org/wiki/Scheimpflug_principle), wherein the object plane **2531**, the lens plane **2532** and the image plane **2533** all intersect at a single line **2535** (only the end of which shows in FIG. **25**A), according to some embodiments of the present invention. In some embodiments, as shown in FIG. **25**A, when the object or subject **2511** (which is to be projected to image **2513**, which, in some embodiments, represents scanning light source **2430** between **2431** and **2431"** as shown in FIG. **24**) is tilted to plane **2531**, projection lens **2580** is tilted to plane **2532** that is oriented to correct the focusing disparities introduced by the tilt of the subject **2511** relative to the image plane **2533**. Considering the planes **2531**, **2532**, and **2533** of the subject **2511**, the lens **2580**, and the image **2513**, respectively, all these planes should intersect at the same line **2535** in space, as shown. Under this "Scheimpflug" condition, the image **2513** will be focused.

[0208] FIG. **25**B is a side view of a system **2502** that also obeys the Scheimpflug principle, according to some embodiments of the present invention. In this configuration, system **2502** includes a source of illumination **2520** characterized by the source-illumination object or subject **2511** being in plane **2531**, the lens **2580** is in the vertical plane **2532**, and the image **2513** (e.g., in some embodiments, the headlight beam on a roadway) is on the horizontal plane **2533**. This configuration is designed for automotive uses such that the intersection of the three planes **2531**, **2532** and **2533** all at line **2535** (again, only the end of which shows in FIG. **25**B) provides that image **2513** (the headlight beam) is in focus from its near-to-vehicle left end to its furthest-from-vehicle right-hand end in FIG. **25**B.

[0209] FIG. **26** is a front-elevational side view of rotating-mirror system **2601** with rotating mirror **2411**, mounted on a wedge-spacer **2410** that is rotated by motor **2412**, when mirror **2411** is in a first orientation (indicated by **2411**) and in a second orientation (indicated by **2411'**) relative to first input beam **1140**, according to some embodiments of the present invention. Applying the same "Scheimpflug" principle, when applied in FIG. **26**, assuming that the image of the light source will be projected to a long distance, the image plane can be considered as vertical for the entire scan to be in focus at that plane (not shown in FIG. **26**, since it would be far to the right of FIG. **26**). In this case, the three planes will meet at a considerable distance (e.g., infinity). As a result, in some embodiments, the plane **2662** of projection lens **2680** and the light-source plane **2663** will be parallel, and meet the image plane (not shown) at infinity downward. If one considers imaging the light at a plane closer than infinity, such as 25 meters for a standard-system test, the angles of the light-source plane **2663** and lens plane **2662** are angled accordingly such that they both intersect the image plane at the same single line (e.g., see FIG. **25**B described above).

[0210] In some embodiments, the light source includes an array of LEDs in one dimension (along a line) or in two dimensions (in a plane), such that the output beam **2681** will have more than one output component, with the plurality of scanning-beam components from the multiple beams, increasing the brightness and pattern capabilities of the system.

[0211] FIGS. **27**A and **27**B show a rotating octagonal-transparent-prism system **2701**. FIG. **27**A is a top view of rotating octagonal-transparent-prism system **2701** with a rotating octagonal-top rectangular-sided transparent prism **2710** in a first orientation (indicated as **2710**) and in a second orientation (indicated as **2710'**) relative to first input beam **2740**, and further including a rectangular beam-shifting prism (such as a glass plate **2770** having parallel faces) and a mirror-prism-slotted mirror subsystem **2780**, according to some embodiments of the present invention.

[0212] FIG. **27**B a side view of rectangular beam-shifting prism **2770** of system **2701**. FIG. **27**A shows an embodiment where the full extent of the scanned line can be folded, producing twice as many lines at half the scanned width. As shown in FIGS. **27**A and **27**B, half of the scan line is shifted vertically in position using a glass plate **2770**. The amount of shift can be determined by the thickness and tilt angle of the glass plate **2770**, and is preferably adjusted such that the shifted lines (**2742'**, and the like, in FIG. **27**A) are in between the original lines **2741**, **2745** and the like), interlacing between them. The shifted set of lines **2744'''**, **2743'''**, and **2742'''** will then be reflected by a flat mirror **2750** towards the other half of the lines. These two sets of lines are then combined using a slotted mirror **2751** in which the shifted line will be reflected again towards the direction of output beam **2781** and the unshifted lines **2741**, **2745** etc., will pass through the slots in the slotted mirror **2751** towards the output beam **2781**. The resulting output beam **2781** has twice the number of lines with half the scanned width.

[0213] FIG. **28** is a top view of a mirror-prism-slotted-mirror and phosphor-plate system **2801**, which adds phosphor plate **2880** to mirror-prism-slotted mirror subsystem **2780** (as shown in FIG. **27**A), according to some embodiments of the present invention. FIG. **28** shows an arrangement where the complete assembly is integrated into a single component system **2801** with the tilted glass plate **2770**, the flat mirror **2750**, the slotted mirror **2751**, and the phosphor plate **2880** mounted together. In some embodiments, this single component **2801** is placed at the output of a rotating prism system (such as those described above) or a rotating mirror system (such as those described below), producing a scanned phosphor wavelength-converted light output. For certain desired light-output patterns, the laser is modulated with a digitally transformed mapping of the output pattern back to the input pattern with the folding considered.

[0214] In general, and as implemented in various embodiments, the output can be folded three times or more such that successive scan lines from a single rotation of the prism lie on top of one another. For example, when folded three times, by dividing the scanning line in thirds, shifting them between the original lines also in thirds, and reflecting and combining them in two separate flat mirrors and two separate slotted mirrors. In addition, in some embodiments one or more units of these systems are used in a cascade arrangement, producing more lines—such as two times, three times, 2×2 times, 2×3 times, etc.—with corresponding reductions in line widths. This allows the use of a single rotation prism with a smaller number of sides and produces a greater number of scanned lines for higher-resolution systems.

[0215] FIG. **29**A a side view of an anamorphic-prism-pair system **2901** that can increase the width in one direction such that a greater number of lines with wider widths can be obtained simultaneously, according to some embodiments of the present invention. In some embodiments, anamorphic-prism-pair system **2901** includes a first prism **2910** at a first angle α_1 that refracts the light downward and spreads the beam, and a second prism **2920** at a second angle α_2, that refracts the light back and stops the spreading at a desired width.

[0216] FIG. **29**B is a graph **2902** of the amount of vertical magnification versus prism angles of anamorphic-prism-pair system **2901**, according to some embodiments of the present invention. After the number of lines is increased with the reduction of line width (such as described above for FIGS. **27**A and **28**, the embodiment of FIG. **29**A shows an anamorphic prism pair that can increase the width in one direction such that a greater number of lines with wider widths can be obtained simultaneously. In this embodiment, system **2901** includes two triangular prisms **2910** and **2920**, placed as shown, such that the amount of width increase is controlled by the positioning of the prisms and determined by the two angles α_1 and α_2. The graph **2902** shows the combinations of these two angles, the lower graph line representing α_1 and the upper graph line representing α_2, producing a magnification in a range of two to six.

[0217] FIG. **30** is a top view of a rotating octagonal-transparent-prism system **3001** with a rotating octagonal-top rectangular-sided transparent prism **3010** in a first orientation (solid-line outline) and a second orientation **3010'** (the slightly angularly offset dashed-line outline) relative to first input beam **3040**, and further including an anamorphic-prism-pair system **2901** and a phosphor plate **3070**, according to some embodiments of the present invention. FIG. **30** shows the embodiment of integrating the rotating prism **3010**, together with the anamorphic-prism pair **2901**, widening the scanned phosphor-emission output lines **3071** of the system **3001**. In another embodiment, not shown, the systems as described in FIG. **27**A and FIG. **28** are inserted between the rotation prism **3010** and the anamorphic-prism pair **2901**, as a complete system for increasing the number of scanned lines and the width of the lines.

[0218] FIG. **31**A is a top view of a dual rotating square-transparent-prism system **3101** with a rotating square-top rectangular-sided transparent prism **3110** in a first orientation relative to first input beam **3140**, and further including a second rotating square-top rectangular-sided transparent prism **3120**, according to some embodiments of the present invention.

[0219] FIG. **31**B is a front view of a resulting pattern of scan lines **3182** generated by dual rotating square-transparent-prism system **3101**, according to some embodiments of the present invention.

[0220] FIG. **31**C is a side view of dual rotating square-transparent-prism system **3101**.

[0221] In some other embodiments (not shown), prism **3110** and/or prism **3120** are tilted (as shown in FIG. **11** and/or FIG. **18**) such that additional scan lines are formed.

[0222] FIGS. **31**A and **31**C show another scanning laser system **3101** that scans in two dimensions **3150** and **3160** using two rotation prisms **3110** and **3120**. In some embodiments, two square prisms **3110** and **3120** are used. In other embodiments (not shown), prisms with more sides are used, as may be required. The X-rotating prism **3110** rotates around axis **3113**, as shown, to produce a scan line **3150** in the X-direction. The output beam **3141** is directed toward Y-rotating prism **3120** in which the scanned lines are shifted in the Y-direction (in the **3160** direction), producing a raster scanned pattern **3182** (see FIG. **31**B) at the output beam **3181**. The different relative rotating speeds of prisms **3110** and **3120** determines the number of lines in pattern **3182**. For example, if the X-rotating prism **3110** has a rotational speed of 20,000 rotations per second and the Y-rotating prism **3120** has a rotational speed of 100 rotations per second, the number of lines will be 20,000/100=200 lines with 100 frames per second. As a result, the number of lines and frames per second can be controlled by the rotation speeds of the motors that rotate prisms **3110** and **3120**, providing flexibility for the system.

[0223] FIG. **32**A is a top view of a dual rotating polygonal-mirror system **3201** with a rotating square-polygon mirror **3210** in a first orientation relative to first input beam **3240**, and further including a second rotating square-polygon mirror **3220**, according to some embodiments of the present invention.

[0224] FIG. **32**B is a front view of a resulting pattern of scan lines **3382** generated by dual rotating polygonal-mirror system **3201**, according to some embodiments of the present invention.

[0225] FIG. **32**C is a side view of dual rotating polygonal-mirror system **3201**. In some embodiments, laser beam **3240** is scanned using polygon mirror scanners, as shown in FIGS. **32**A and **32**C, wherein two rotating polygon mirror scanners **3210** and **3220** are placed with their rotational axes orthogonal to each other, producing raster-scan pattern **3282** as shown in the FIG. **32**B. In this example, four-mirror polygons are used. Similar to that as shown in FIG. **31**, the number of lines and frames per second can be controlled by the speed of the motors that rotate mirror systems **3210** and **3220**.

[0226] FIG. **33**A is a side view block diagram of a rotating multi-faceted-mirror system **3301** with a rotating multi-faceted-mirror system **3334** (which, in some embodiments, uses rotating multi-faceted-mirror system **3401** as shown in FIG. **34**) with a rotating multi-faceted mirror **3310** in a first orientation relative to first input beam **3340** generated from laser source **3320**, according to some embodiments of the present invention. In some embodiments, multi-faceted mirror **3310** has a plurality of mirrors **3318** (e.g., in some embodiments, eighteen (18) mirrors), each tilted at a different angle to rotational axis **3313** so as to produce a plurality of different reflection angles for the scan lines when motor **3312** rotates multi-faceted mirror **3310**.

[0227] FIG. **33**B is a front view of a resulting pattern of scan lines **3382** generated by dual rotating polygonal-mirror system **3101**, according to some embodiments of the present invention. FIGS. **33**A and **33**B show an embodiment where a multi-faceted polygon-mirror scanner **3310** rotated by motor **3312** reflects an input laser beam **3340** as scanning beam **3341** to produce a pattern **3382** having multiple scan lines **3321.01**, **3321.02**, **3321.03** . . . through **3321.18**. In some embodiments, the laser beam **3340** with its focus adjusted (by laser **3320**'s internal optics and/or lens **3370**) at the phosphor plate is directed towards the polygon scanner. Each facet **3318** of the scanner **3334** with its multi-faceted-mirror **3310** and motor **3312** is designed to have a different tilt angle for each mirror **3318** relative to rotational axis **3313** such that the scanned laser line **3341** produced by each facet **3318** will have a different output angle (tilted up/down as shown by double arrow **3350**), thus scanning the full area of the phosphor plate **3380**. In some embodiments an optional collimating lens **3370** is placed before the phosphor plate **3380**, such that the output beam direction from lens **3370** is made perpendicular to the front surface of phosphor plate **3380**.

[0228] FIG. **34** is a top view of a rotating multi-faceted-mirror system **3401** with a rotating multi-faceted polygon mirror **3410**, according to some embodiments of the present invention. As shown in FIG. **34**, in some embodiments, multi-faceted polygon mirror **3410** has eighteen (18) facets **3418**, each having a respective tilted mirror face oriented at eighteen different angles relative to rotational axis **3413**. In some embodiments, the eighteen different angles are 15°, 15.08°, 15.16°, 15.24°, 15.32°, 15.4°, 15.48°, 15.56°, 15.64°, 15.72°, 15.8°, 15.88°, 15.96°, 16.04°, 16.12°, 16.2°, 16.28°, and 16.36°. Other embodiments can use different angles. In some embodiments, multi-faceted polygon mirror system **3401** is used for rotating optical system **3334** in system **3301** of FIG. **33**A, and the output pattern shown in FIG. **33**B will have eighteen scanned lines. In some embodiments, to produce a larger number of lines, a plurality of lasers is used. In some embodiments, multi-faceted polygon mirror system **3401** is used for rotating optical system **3534** in system **3501** of FIG. **35**A, four lasers **3510**, **3520**, **3530** and **3540** are used, and the output pattern **3582** shown in FIG. **36** will have seventy-two scanned lines.

[0229] FIG. **35** is a side view block diagram of a rotating multi-faceted-mirror system **3501** with a rotating multi-faceted-mirror system **3534** (which, in some embodiments, uses rotating multi-faceted-mirror system **3401**) that includes rotating multi-faceted mirror system **3510** (which is rotated around rotational axis **3513** by motor **3512**). Multi-faceted-mirror system **3534** is shown in a first orientation relative to a plurality of input laser beams generated from laser sources **3510**, **3520**, **3530**, and **3540**, according to some embodiments of the present invention. In some embodiments, multi-faceted mirror **3510** includes eighteen mirrored facets **3518**, each at a different angle to the rotational axis **3513**. In some embodiments, multi-faceted-mirror system **3501** includes four lasers, **3510**, **3520**, **3530**, and **3540** as shown. In some embodiments, each of the lasers **3510**, **3520**, **3539**, and **3540** includes a laser diode and a focusing lens. Lasers **3510**, **3520**, **3530** and **3540** have their beams directed towards the polygon mirrored facets **3518** at different angles such that four scanned lines **3541**, **3531**, **3521** and **3511** are reflected at different angles by each mirrored facet **3518** of the polygon multi-faceted mirror **3510**. In some embodiments, the angles between the laser beam propagation-axes lasers, **3510**, **3520**, **3530**, and **3540** and the different tilting angles of each mirrored facet **3518** of the polygon multi-faceted mirror **3510** are adjusted such that the lines on the phosphor plate **3550** are equally spaced or spaced to form a certain pattern, as desired.

[0230] FIG. **36** is a front enlarged view of a plurality of scan lines **3582** on phosphor plate **3580** produced by rotating multi-faceted mirror **3510** and reflecting the plurality of input beams from lasers **3510**, **3520**, **3530** and **3540**. FIG. **36** shows the output of example system **3501** with four lasers **3510**, **3520**, **3530** and **3540** and eighteen-facet mirror **3510**. In some embodiments a larger number of scanned lines (e.g., scan line **3541.01** for the uppermost reflection of the uppermost scanning laser beam **3541**, through scan line **3511.18** for the lowermost reflection of the lowermost scanning laser beam **3511**) is produced using a greater number of lasers and/or a greater number of facets **3518** of the polygon multi-faceted mirror **3510**.

[0231] FIG. **37** is a side-view block diagram of a rotating multi-faceted-mirror system **3701** with three rotating multi-faceted mirror systems **3738**, **3739**, and **3740**, all rotated by the same motor **3712**, and usable to simultaneously generate a headlight beam **3890**, a scanning LiDAR beam **3990** and provide input for a scanning LiDAR receiver (such as detector **4080** shown in FIG. **40** and associated controller and calculation hardware **4295** and **4290** such as shown in block diagram form in FIG. **42**) for receiving reflected LiDAR signals **4090**, according to some embodiments of the present invention. FIG. **37** shows an embodiment where the smart headlight and the LiDAR output and LiDAR sensor are integrated into a single unit using the same motor **3712**. As shown in FIG. **37**, some embodiments include the headlight scanner using mirror system **3738** placed on the top, the LiDAR laser output scanner using mirror system **3739** is placed in the middle layer, and the LiDAR detector scanner using mirror system **3740** is placed at the bottom. Each pair **3738-3739** and **3739-3740** is separated from one another by a light shield **3714**, so that they do not interfere with each other. In various other embodiments (not shown), the three scanners **3738**, **3739**, and **3740** can also be rearranged per system requirements. For example, in some embodiments the laser output scanner **3739** is on the top and the headlight scanner **3738** is at the bottom.

[0232] FIG. **38** is a top view of a rotating multi-faceted-mirror headlight system **3801** with a rotating multi-faceted mirror system **3811** shown in three positions labeled **3811**, **3811'** and **3811"**, a phosphor plate **3880** and a system of one or more optional collimation and projection lenses **3870**, and **3872**, according to some embodiments of the present invention. FIG. **38** shows an embodiment where the scanner is an eight-sided polygon, with eight tilted mirrors **3808** at eight different angles. The tilting angle of each mirror facet **3808**, and the number of mirror facets **3808**, can be designed such that multiple scan lines can be produced from the plurality of mirror facets at different angles. In this case, a total of eight scan lines are produced from the input laser beam **3840** for each full rotation of rotating multi-faceted mirror system **3811**, if the eight mirrors **3808** are tilted at eight different angles. In some embodiments the output is then used to excite the phosphor plate **3880** through a field lens **3870** with the desired illumination pattern, and the output visible light **3890** is projected onto the roadway using projection lens **3872**. In various embodiments, polygons with different numbers of sides are used, for generating different numbers of lines. In some embodiments, a plurality of scan lines on top of one another are scanned using a subset of the plurality of mirrors **3808** that have the same tilt angle, for increased intensity at certain lines of the output beam **3890**, as required.

[0233] FIG. **39** is a top view of a rotating multi-faceted-mirror system **3901** with rotating multi-faceted mirrors **3911** shown in three positions labeled **3911**, **3911'** and **3911"**, according to some embodiments of the present invention. FIG. **39** shows an embodiment of the IR laser-beam scanner usable for outputting a scanning pulsed LiDAR signal. An example embodiment is shown in FIG. **39**, with eight tilted mirrors **3908** at eight different angles, one of which is on each side. Similarly, depending on the number of IR-laser-beam LiDAR scan lines required in various embodiments, the number of mirrors is changed and the mirrors are tilted accordingly. According to the angle of rotation of the polygon and the tilting of the mirror, the direction of the laser beam target can be determined in terms of vertical angle and horizontal angle. The LiDAR signal will then be reflected by the target and be detected by the detection system, as shown in FIG. **40**. In some embodiments, laser beam **3990** is from a pulsed laser, where the return pulse **4090** is detected and the distance is calculated by the time-of-flight (ToF) between the sending of the outgoing pulse and the receiving of the reflected pulse. With the output scanning laser beam **3990** and multiple pulses, a three-dimensional (3D) image or picture of the scanned area can be constructed digitally. In other embodiments, the laser beam **3990** is a continuous-wave (CW) laser beam, wherein the beam is frequency modulated (FMCW). The reflected received beam **4090** is optically combined with a portion of the output beam where the phase difference between the two beams is measured. In some embodiments, the distance is calculated by the phase difference between the output beam and the reflected received beam. Again, the 3D image or picture of the scanned area is constructed digitally. The lasers used to generate beam **3940** can be an Edge Emitting Laser (EEL), DFB Laser, Vertical Cavity Surface Emitting Laser (VCSEL), Photonic Crystal Surface Emitting Laser (PCSEL), etc. For higher power operations, multiple units of these lasers can be configured in one-dimensional or two-dimensional arrays. Appropriate lenses are used to collimate the output beams as required. The wavelength of the lasers can be selected from a range of about 900 nm to about 1,550 nm. The longer wavelengths lasers are considered to be more eye-safe and are preferred for some embodiments, but perhaps at higher cost.

[0234] FIG. **40** is a bottom view of a rotating multi-faceted-mirror system **4001** with rotating multi-faceted mirrors **4011** shown in three positions labeled **4011**, **4011'** and **4011"**, a line sensor (or detector) **4080** and a system of one or more optional collimation or focussing lenses **4070**, according to some embodiments of the present invention. FIG. **40** shows the embodiment of a detection system with an eight-sided polygon scanner with eight tilted mirrors **4008** at eight different angles, one of which is on each side of the polygon. The tilting of the mirrors **4008** has the same angles as the laser scanner polygon **3901** of FIG. **39** and is synchronized such that the reflected signal **4090** from the laser-beam target is reflected into detector system **4081**, by one of the tilted mirrors **4008**, and focused onto the detector **4080**. Since the laser-scanning and the detector-scanning polygons are synchronized, the reflected laser light from each point on the target will be reflected back and focused back into a single point where the detector **4080** is located (thus the spot of interest will have a relatively higher intensity), while light from other directions is not focused on detector **4080** (thus having relatively lower intensity). When the incoming beam **4090** includes the scanned beam coming from solid-line-arrow directions **4040** to **4040'**, the rotating multi-faceted mirrors will be in the position marked **4011**, and thus will be reflected as solid-line-arrow vertical beams **4041** to **4041'**. Similarly, when the incoming beam **4090** includes the scanned beam coming from long-dashed-line-arrow directions **4043** to **4043'**, the rotating multi-faceted mirrors will be in the position marked **4011'**, and thus will be reflected as long-dashed-line-arrow vertical beams **4044** to **4044'**, and when the incoming beam **4090** includes the scanned beam coming from short-dashed-line-arrow vertical directions **4042** to **4042'**, the rotating multi-faceted mirrors will be in the position marked **4011"**, and thus will be reflected as short-dashed-line-arrow vertical beams (not labeled). In some embodiments, a lens **4070** is used to focus the vertical beams **4041-4041'** through **4044-4044'** to detector array **4080**, and optionally includes a shade **4071**. In a LiDAR system operation, the location of the target is determined by the vertical and horizontal angles of the outgoing laser beam and its reflected signal, and the time delay between the output pulse from rotating multi-faceted-mirror system **3901** and the detected light pulse received by rotating multi-faceted-mirror system **4001**. The distance to each target object is determined by the out-and-back time-of-flight—the time between the generated laser pulse and the received reflected laser pulse. In some embodiments, using such distances and vertical and horizontal angles, a three-dimensional (3D) map with the field of view is generated or determined.

[0235] FIG. **41** is a side view of a rotating multi-faceted-mirror system **4101** with a system of rotating multi-faceted mirrors **4111** rotated by motor **4112** usable to generate a headlight beam **4190**, according to some embodiments of the present invention. FIG. **41** shows an embodiment of this invention in which the right-hand edge of the projection lens **4173** of the headlight is made nearly flush with the IR-laser-beam-scanning polygon **4111** and the detector-scanning polygon (not shown here), such that the complete assembly can be package as a complete assembly and placed at the location of the headlight (e.g., such as headlight system **4211** of FIG. **42**). In this case, the headlight laser diodes **4110**, **4120**, **4130** and **4140** are placed at the back of the assembly (the left-hand side of FIG. **41**) with their beams incident at the reflective polygon **4111** (which, in some embodiments, has a plurality of reflective faces at different reflecting angles to form scan lines from the laser beam(s)). The output scanning beam **4168** is directed towards the transmissive phosphor plate **4180** through a relay lens **4170**, a mirror **4168** (to form scanning beam **4169**), and a focusing lens **4171**. The scanning focused spots produce scan lines on the phosphor plate **4180** as moving light spots. The output from phosphor plate **4180** is then projected using lenses **4172** and **4173** onto the roadway. The laser diodes **4110**, **4120**, **4130** and **4140** are digitally controlled and are synchronized with the rotating polygon reflective set of mirrors **4111** such that the desired light patterns are produced.

[0236] FIG. **42** is a block diagram of a vehicle **4201** that includes a light source **4211** (such as, in some embodiments, rotating multi-faceted-mirror system **3701** (as shown in FIG. **37**) with rotating multi-faceted mirror systems **3801** (as shown in FIG. **38**) and **3901** (as shown in FIG. **39**), all rotated by the same motor **3712**, and usable to simultaneously generate a headlight beam **3890**, a scanning LiDAR beam **3990** and/or provide input for a scanning LiDAR receiver for receiving reflected LiDAR signals **4090**, according to some embodiments of the present invention. In some embodiments, a scene sensor **4295** is configured to actively (e.g., using a received LiDAR signal such as **4090** described for FIG. **37** and FIG. **40** above) and/or passively (using a camera or the like) receive light signals **4294** (such as reflections of LiDAR signals **3940**) to sense the environment around the vehicle **4201** in which sensor **4295** and light source **4211** are housed, and the received signals or data **4294** received by sensor **4295** are processed into sensed data **4296** and operatively coupled to processor **4290**, which then optionally generates a 3D map of the surrounding environment, which can be used to control operation of vehicle **4201** (such as a self-driving car or truck), detect pedestrians, other vehicles or other objects around vehicle **4201**, and/or to adjust the shape, direction and/or intensity of various low-beam, high-beam and/or extreme-high-beam portions of headlight beam **4243** as described above. In some embodiments, this sensing/controlling function is optionally activatable and deactivatable by the human driver (analogous to automobile "cruise control").

[0237] FIG. **43**A is a top view of a square beam-splitter prism system **4301** with a square-top rectangular-face rotating beam-splitter prism **4310** in a first orientation relative to input beam **4340**, according to some embodiments of the present invention. As shown, input beam **4340** enters face **4324** and is reflected upward by internal beam splitter **4325** for 90° of rotation of beam-splitter prism **4310**, producing scan beam **4346** scanning in direction **4360** (while input beam **4340** enters face **4324** and exits face **4323**).

[0238] Then, as shown in FIG. **43**B, input beam **4340** enters face **4321** and is reflected downward by internal beam splitter **4325** for 90° of rotation of beam-splitter prism **4310** producing scan beam **4341** scanning in direction **4350** (while input beam **4340** enters face **4321** and exits face **4322**).

[0239] FIG. **43**B is a top view of square beam-splitter prism system **4301** with rotating beam-splitter prism **4310** in a second orientation (indicated as **4310'** since it is rotated 90° from the orientation of FIG. **43**A) relative to input beam **4340**.

[0240] Then, for the following 90° of rotation of beam-splitter prism **4310** (not shown) input beam **4340** enters face **4322** and is reflected upward by internal beam splitter **4325** for 90° of rotation of beam-splitter prism **4310**, again producing scan beam **4346** scanning in direction **4360** (while input beam **4340** enters face **4322** and exits face **4321**).

[0241] Then, for the following 90° of rotation of beam-splitter prism **4310** (again, not shown) input beam **4340** enters face **4323** and is reflected downward by internal beam splitter **4325** for 90° of rotation of beam-splitter prism **4310** producing scan beam **4341** scanning in direction **4350** (while input beam **4340** enters face **4323** and exits face **4324**), directions again as shown in FIG. **43**B. Then the whole process repeats for the next full rotation of prism **4310**.

[0242] FIG. **43**C is a top view of a square beam-splitter prism system **4302** with rotating beam-splitter prism **4310** in three different orientations (indicated as **4310**, **4310'**, **4310"**) relative to input beam **4340**, and a first reflective phosphor plate **4340** (with its heat sink **4341**) and a second reflective phosphor plate **4342** (with its heat sink **4343**), according to some embodiments of the present invention. In this embodiment, first reflective phosphor plate **4340** (which is mounted on heatsink **4341**) receives the downward scanning beam **4341** scanning in the **4350** direction, and the resulting emitted light **4342** in the upward direction is reflected rightward by reflector **4349** (which can be any of the embodiments described above for reflector **349** of FIG. **3**) and projected as output beam **4390** by lens **4380**. Similarly, second reflective phosphor plate **4342** (which is mounted on heatsink **4343**) receives the upward scan beam **4346** scanning in the **4360** direction, and the resulting emitted light **4362** in the downward direction is reflected rightward by reflector **4348** (which can be any of the embodiments described above for reflector **349** of FIG. **3**) and projected as output beam **4361** by lens **4381**.

[0243] In various embodiments, the beam splitter **4325** is highly reflective (to create two scanning patterns—one scanning pattern upward and one scanning pattern downward), partially reflective (to create three patterns—one straight through as in FIGS. **1**B-**1**E) plus one scanning pattern upward and one scanning pattern downward), wavelength-selective, and/or polarized, in order to create different scanning patterns, a desired.

[0244] In some embodiments (not shown, but similar to that of FIG. **43**C), beam splitter **4325** is partially reflective (as described above) to create three patterns—one straight through as in FIGS. **1**B-**1**E and this not-shown embodiment, including a third phosphor plate such as plate **340** of FIGS. **3**A, **3**B and **3**C and a third set of associated reflector(s) and lens(es)), plus one scanning pattern **4360** upward and one scanning pattern downward **4350** as shown here).

[0245] In some embodiments (not shown, but similar to FIGS. **11**, **12**, **13**, **14** and **18**), beam splitter **4310** is mounted on a tilted wedge and/or a plurality of parallel input beams are used to obtain a plurality of output scan lines spaced apart from one another on the scan surfaces (such as phosphor plates **4340** and **4342**).

[0246] In some embodiments, the present invention provides first system having a scanned-light-beam apparatus that includes: a first source of a first light beam; a first rotary motor that has a rotational axis; and a first faceted optical device that is rotated around the rotational axis by the first motor, wherein the first faceted optical device has a plurality of faces, each of which is at one selected angle of a plurality of different angles relative to the rotational axis, and wherein the first light beam is operatively coupled to the rotated first faceted optical device to form a first plurality of spaced-apart scanned light-beam lines.

[0247] In some embodiments of the first system, the first faceted optical device includes a first multi-faceted mirror system that includes a first plurality of mirrors wherein each one of the first plurality of mirrors is tilted at a different angle relative to the rotational axis; the first light beam is a first input laser beam that is directed toward the first faceted optical device to form a first plurality of scanned laser-beam lines spaced apart from one another. This first system further includes: a phosphor plate operatively coupled to receive the first plurality of scanned laser-beam lines and to emit wavelength-converted light when stimulated by the first plurality of scanned laser-beam lines; a projection lens optically coupled to receive light emitted by the phosphor plate and to project an output headlight beam that includes the wavelength-converted light; a second multi-faceted mirror system that includes a second plurality of mirrors, wherein each one of the second plurality of mirrors is tilted at a different angle relative to the rotational axis, and wherein the second multi-faceted mirror system is rotated by the first motor; a second laser that emits a pulsed infrared (IR) laser beam that is directed toward the second multi-faceted mirror system to form a pattern of output light across a pattern of scanned directions spaced apart from one another to form a scanned pulsed output LiDAR beam; a third multi-faceted mirror system that includes a third plurality of mirrors, wherein each one of the third plurality of mirrors is tilted at a different angle relative to the rotational axis, wherein the second multi-faceted mirror system is rotated by the first motor, and wherein the third multi-faceted mirror system is configured to receive a LiDAR signal reflected from the pattern of directions of the scanned pulsed output LiDAR beam toward the third multi-faceted mirror system; a LiDAR receiver operatively coupled to receive light reflected by the third multi-faceted mirror system from the pattern of scanned directions; and a vehicle, wherein the first motor, the first laser, the first multi-faceted mirror system, the phosphor plate, the second laser, the second multi-faceted mirror system, the third multi-faceted mirror system and the LiDAR receiver are mounted to the vehicle and are used to form a headlight beam and the scanned pulsed LiDAR output beam for the vehicle. In some such embodiments, the IR laser beam includes at least one wavelength in a range of 700 nm to 1600 nm (or, in various other embodiments, in a range of 700 nm to 800 nm, in a range of 800 nm to 900 nm, in a range of 900 nm to 1000 nm, in a range of 1000 nm to 1100 nm, in a range of 1100 nm to 1200 nm, in a range of 1200 nm to 1300 nm, in a range of 1300 nm to 1400 nm, in a range of 1400 nm to 1500 nm, and/or in a range of 1500 nm to 1600 nm, or two or more of such ranges) from a pulsed IR laser and the first laser beam includes blue light having at least one wavelength in a range of 390 nm to 500 nm (or, in various other embodiments, a violet wavelength of about 405 nm, a blue wavelength of about 450 nm, or wavelengths in a range of 390 nm to 400 nm, in a range of 400 nm to 420 nm, in a range of 420 nm to 440 nm, in a range of 440 nm to 460 nm, in a range of 460 nm to 480 nm, in a range of 480 nm to 500 nm, or two or more of such ranges).

[0248] In some embodiments of the first system, the first faceted optical device includes a square prism that is tilted relative to the rotational axis such that a first pair of opposite faces is at a first angle to the rotational axis, and a second pair of opposite faces is at a second angle to the rotational axis, and the first angle is not equal to the second angle.

[0249] In some embodiments of the first system, the first faceted optical device includes a prism that has a plurality of pairs of parallel faces opposite each other relative to the rotational axis, wherein each pair of parallel faces is oriented at a different angle relative to the rotational axis.

[0250] In some embodiments of the first system, the first faceted optical device includes a multi-faceted mirror that includes a first plurality of mirrors, wherein each one of the first plurality of mirrors is tilted at a different angle relative to the rotational axis.

[0251] In some embodiments of the first system, the first light beam is a first input laser beam directed toward the first faceted optical device to form a first plurality of scanned laser-beam lines spaced apart from one another, wherein the apparatus further comprises a second source of a second input laser beam directed toward the first faceted optical device, and wherein the second laser beam is coupled to the first faceted optical device to form a second plurality of scanned laser-beam lines spaced apart from one another and from the first plurality of scanned laser-beam lines.

[0252] In some embodiments of the first system, the first light beam is a first input blue-light laser beam directed toward the first faceted optical device to form a first plurality of scanned blue-light laser-beam lines spaced apart from one another, wherein the apparatus further includes: a phosphor plate operatively coupled to receive the first plurality of scanned blue-light laser-beam lines and to emit wavelength-converted light when stimulated by the first plurality of scanned blue-light laser-beam lines; and a projection lens optically coupled to receive light emitted by the phosphor plate and to project an output beam that includes the wavelength-converted light.

[0253] In some embodiments of the first system, the first light beam is a first input laser beam that includes at least one wavelength in a range of 390 nm to 500 nm from a first laser and that is directed toward the first faceted optical device to form a first plurality of scanned laser-beam lines spaced apart from one another, and wherein the apparatus further comprises: a phosphor plate operatively coupled to receive the first plurality of scanned laser-beam lines and to emit wavelength-converted light when stimulated by the first plurality of scanned laser-beam lines; a projection lens optically coupled to receive light emitted by the phosphor plate and to project an output beam that includes the wavelength-converted light; and a vehicle, wherein the first motor, the first laser, the rotated first faceted optical device, the phosphor plate and the projection lens mounted to the vehicle and are used to form a headlight beam for the vehicle.

[0254] In some embodiments of the first system, the first faceted optical device includes a first multi-faceted mirror system that includes a first plurality of mirrors, wherein each one of the first plurality of mirrors is tilted at a different angle relative to the rotational axis; the first light beam is a first input laser beam that includes at least one wavelength in a range of 390 nm to 500 nm from a first laser and that is directed toward the first faceted optical device to form a first plurality of scanned laser-beam lines spaced apart from one another, and the apparatus further includes: a phosphor plate operatively coupled to receive the first plurality of scanned laser-beam lines and to emit wavelength-converted light when stimulated by the first plurality of scanned laser-beam lines; a projection lens optically coupled to receive light emitted by the phosphor plate and to project an output beam that includes the wavelength-converted light; and a vehicle, wherein the first motor, the first laser, the rotated first multi-faceted mirror system, the phosphor plate and the projection lens mounted to the vehicle and are used to form a headlight beam for the vehicle.

[0255] In some embodiments of the first system, the first faceted optical device includes a first multi-faceted mirror system that includes a first plurality of mirrors, wherein each one of the first plurality of mirrors is tilted at a different angle relative to the rotational axis; the first light beam is a first input infrared (IR) laser beam that optionally includes at least one wavelength in a range of 700 nm to 1500 nm from a first pulsed IR laser and that is directed toward the first faceted optical device to form a pattern of output light across a first plurality of scanned lines spaced apart from one another, and the apparatus further includes: a vehicle, wherein the first motor, the IR laser and the rotated first multi-faceted mirror system are mounted to the vehicle and are used to form a scanned pulsed LiDAR output beam for the vehicle.

[0256] In some embodiments of the first system, the first faceted optical device includes a first multi-faceted mirror system that includes a first plurality of mirrors, wherein each one of the first plurality of mirrors is tilted at a different angle relative to the rotational axis; the first light beam is a received LiDAR signal reflected from a LiDAR beam that optionally includes at least one wavelength in a range of 700 nm to 1500 nm from a pulsed IR laser and that is received toward the first faceted optical device from a pattern of scanned-line directions spaced apart from one another, and the apparatus further includes: a LiDAR receiver operatively coupled to receive light reflected by the first faceted optical device from the pattern of scanned-line directions; and a vehicle, wherein the first motor, the IR laser and the rotated first multi-faceted mirror system are mounted to the vehicle and are used to form a scanned pulsed LiDAR output beam for the vehicle.

[0257] In some embodiments of the first system, the first faceted optical device includes a square prism.

[0258] In some embodiments of the first system, the first faceted optical device includes a first square prism, the first light beam is a first laser beam and the apparatus further includes: a second motor; and a second square prism that is rotated by the second motor, wherein the first plurality of spaced-apart scanned light-beam lines from the first square prism are directed through the second prism to form a second plurality of spaced-apart scanned laser-beam lines.

[0259] In some embodiments of the first system, the first faceted optical device includes a square polygon having four mirror faces.

[0260] In some embodiments of the first system, the first faceted optical device includes a square polygon having four mirror faces, the first light beam is a first laser beam and the apparatus further includes a second motor; and a second square polygon having four mirror faces that is rotated by the second motor, wherein the first plurality of spaced-apart scanned light-beam lines reflected from the first square polygon are directed towards the second prism and reflected to form a second plurality of spaced-apart scanned laser-beam lines.

[0261] In some embodiments, the present invention provides second system having a scanned-light-beam apparatus that includes: a laser that outputs a first input laser beam; a first rotary motor; a first rotating prism driven by the first motor, wherein the first rotating prism has a plurality of pairs of input/output faces, and wherein the input laser beam is coupled through the first rotating prism to form a first scanned laser-beam line; a second rotary motor; and a second rotating prism driven by the second motor, wherein the second rotating prism has a plurality of pairs of input/output faces, and wherein the first scanned laser-beam line is coupled through the second rotating prism to form a plurality of scanned laser-beam lines parallel to one another.

[0262] In some embodiments, the present invention provides third system having a scanned-light-beam apparatus that includes: a laser that outputs a first input laser beam; a first rotating mirror assembly driven by a first motor, wherein the first rotating mirror assembly has a plurality of faces, and wherein the input laser beam is reflected by the first rotating mirror assembly to form a first scanned laser-beam line; and a second rotating mirror assembly driven by a second motor, wherein the second rotating mirror assembly has a plurality of faces, and wherein the first scanned laser-beam line is reflected by the second rotating mirror assembly to form a plurality of scanned laser-beam lines parallel to one another.

[0263] In some embodiments, the present invention provides fourth system having a scanned-light-beam apparatus that includes: a first laser that generates a first input laser beam; a first motor that has an axis of rotation; a first mirror assembly rotated by the first motor around the axis of rotation, wherein the first rotating mirror assembly has a plurality of faces each at a different angle to the axis of rotation, and wherein the first input laser beam is coupled to the first rotating mirror assembly to form a plurality of scanned laser-beam lines parallel to one another.

[0264] Some embodiments of the fourth system further include a phosphor plate, wherein the plurality of scanned laser-beam lines is projected onto the phosphor plate. In some such embodiments, the phosphor plate has a curved face configured such that the scanned laser-beam lines remain in focus across the curved face of the phosphor plate, and the phosphor plate is a reflective phosphor plate mounted to a heatsink.

[0265] In some embodiments, the present invention provides fifth system having a scanned-light-beam apparatus that includes: a first laser that generates a first input laser beam; a first motor that has an axis of rotation; and a rotating mirror assembly driven by the first motor, wherein the rotating mirror assembly has a plurality of faces, each of which is at one selected angle of a plurality of different angles relative to the input laser beam, and wherein the first input laser beam is coupled to reflect from the rotating mirror assembly to form a plurality of scanned laser-beam lines parallel to one another.

[0266] In some embodiments of the fifth system, the rotating mirror assembly is a square mirror assembly.

[0267] In some embodiments of the fifth system, the rotating mirror assembly is of polygon shape other than a square.

[0268] Some embodiments of the fifth system further include a phosphor plate and a projection lens optically coupled such that the plurality of scanned laser-beam lines is directed toward the phosphor plate, and such that light emitted by the phosphor plate is projected by the projection lens. Some embodiments of the fifth system further include a vehicle, wherein the first laser emits a blue wavelength of light, wherein the first laser, the rotating mirror assembly, the phosphor plate and the projection lens are used to form a headlight beam for the vehicle.

[0269] In some embodiments, the present invention provides a first method for scanning a light beam. This first method includes: providing a first faceted optical device; rotating the first faceted optical device around a rotational axis; wherein the first faceted optical device has a plurality of faces, each of which is at one selected angle of a plurality of different angles relative to the rotational axis; generating a first light beam; and deflecting the first light beam toward the rotating first faceted optical device to form a first plurality of spaced-apart scanned light-beam lines. In some embodiments, the deflecting includes refracting the first light beam using a transparent prism. In other embodiments, the deflecting includes refracting the first light beam using a plurality of mirrors on the rotated first faceted optical device.

[0270] Some embodiments of the first method further include: providing a second multi-faceted mirror system that includes a second plurality of mirrors, wherein each one of the second plurality of mirrors is tilted at a different angle relative to the rotational axis; providing a third multi-faceted mirror system that includes a third plurality of mirrors, wherein each one of the third plurality of mirrors is tilted at a different angle relative to the rotational axis; providing a LiDAR receiver; providing a phosphor plate, wherein the first faceted optical device includes a first multi-faceted mirror system that includes a first plurality of mirrors, wherein each one of the first plurality of mirrors is tilted at a different angle relative to the rotational axis, and wherein the first light beam is a first input laser beam; directing the first input laser beam toward the first multi-faceted mirror system to form a first plurality of scanned laser-beam lines spaced apart from one another, and directing the first plurality of scanned laser-beam lines onto the phosphor plate such that the phosphor plate emits wavelength-converted light when stimulated by the first plurality of scanned laser-beam lines; projecting light emitted by the phosphor plate as an output vehicle headlight beam that includes the wavelength-converted light; rotating the second multi-faceted mirror system in synchrony with the first multi-faceted mirror system; directing a pulsed infrared (IR) laser beam toward the second multi-faceted mirror system to form a pattern of output light across a pattern of scanned directions spaced apart from one another to form a scanned pulsed output LiDAR beam; rotating the third multi-faceted mirror system in synchrony with the first multi-faceted mirror system; reflecting, with the third multi-faceted mirror system, a LiDAR light signal from the pattern of directions of the scanned pulsed output LiDAR beam into the LiDAR receiver; generating a LiDAR map based on the LiDAR light signal; and using the headlight beam, the pulsed LiDAR output beam and the LiDAR map for controlling a vehicle. In some such embodiments, the first input laser beam includes at least one wavelength in a range of 390 nm to 500 nm from a first laser and/or the pulsed infrared (IR) laser beam includes at least one wavelength in a range of 700 nm to 1500 nm from a pulsed IR laser.

[0271] In some embodiments of the first method, the first faceted optical device includes a square prism, and the first method further includes: tilting the square prism relative to the rotational axis such that a first pair of opposite faces is at a first angle to the rotational axis, and a second pair of opposite faces is at a second angle to the rotational axis, and the first angle is not equal to the second angle.

[0272] In some embodiments of the first method, the first faceted optical device includes a prism that has a plurality of pairs of parallel faces opposite each other relative to the rotational axis, wherein each pair of parallel faces is oriented at a different angle relative to the rotational axis.

[0273] In some embodiments of the first method, the first faceted optical device includes a multi-faceted mirror that includes a first plurality of mirrors, and the first method further includes: tilting each one of the first plurality of mirrors at a different angle relative to the rotational axis.

[0274] In some embodiments of the first method, the first light beam is a first input laser beam, and the first method further includes: deflecting the first input laser beam by the first faceted optical device to form a first plurality of scanned laser-beam lines spaced apart from one another; deflecting a second input laser beam by the first faceted optical device to form a second plurality of scanned laser-beam lines spaced apart from one another and from the first plurality of scanned laser-beam lines.

[0275] In some embodiments of the first method, the first light beam is a first input blue-light laser beam, and the first method further includes: deflecting the first input blue-light laser beam with first faceted optical device to form a first plurality of scanned blue-light laser-beam lines spaced apart from one another; providing a phosphor plate; directing the first plurality of scanned blue-light laser-beam lines onto the phosphor plate that emits wavelength-converted light when stimulated by the first plurality of scanned blue-light laser-beam lines; and projecting light emitted by the phosphor plate to form an output beam that includes the wavelength-converted light.

[0276] Some embodiments of the first method further include: providing a phosphor plate, wherein the first light beam is a first input laser beam that includes at least one wavelength (optionally in a range of 390 nm to 500 nm); deflecting the first input laser beam with the first faceted optical device to form a first plurality of scanned laser-beam lines spaced apart from one another onto the phosphor plate to emit wavelength-converted light when the phosphor plate is stimulated by the first plurality of scanned laser-beam lines; and projecting light emitted by the phosphor plate as an output headlight beam that includes the wavelength-converted light, wherein the headlight beam is for a vehicle.

[0277] In some embodiments of the first method, the first faceted optical device includes a first multi-faceted mirror system that includes a first plurality of mirrors, wherein each one of the first plurality of mirrors is tilted at a different angle relative to the rotational axis, and wherein the first light beam is a first input laser beam that includes at least one wavelength (optionally in a range of 390 nm to 500 nm), and the first method further includes: providing a phosphor plate; reflecting the first input laser beam using the first faceted optical device to form a first plurality of scanned laser-beam lines spaced apart from one another onto the phosphor plate such that the phosphor plate emits wavelength-converted light when stimulated by the first plurality of scanned laser-beam lines; and projecting light emitted by the phosphor plate as an output headlight beam for a vehicle.

[0278] In some embodiments of the first method, the first faceted optical device includes a first multi-faceted mirror system that includes a first plurality of mirrors, wherein each one of the first plurality of mirrors is tilted at a different angle relative to the rotational axis, wherein the first light beam is a first input infrared (IR) pulsed laser beam that includes at least one wavelength in a range of 700 nm to 1500 nm, wherein the method further includes reflecting the IR pulsed laser beam by the first faceted optical device to form a pattern of output light across a first plurality of scanned lines spaced apart from one another to form a scanned pulsed LiDAR output beam for a vehicle.

[0279] In some embodiments of the first method, the first faceted optical device includes a first multi-faceted mirror system that includes a first plurality of mirrors, wherein each one of the first plurality of mirrors is tilted at a different angle relative to the rotational axis, wherein the first light beam is a received LiDAR signal reflected, by an object, from a LiDAR beam that includes at least one wavelength in a range of 700 nm to 1500 nm, wherein the first method further includes reflecting light by the first faceted optical device from a pattern of scanned-line directions spaced apart from one another onto a LiDAR receiver from the pattern of scanned-line directions; and generating a LiDAR map for a vehicle based on signals from the LiDAR receiver.

[0280] In some embodiments of the first method, the first faceted optical device includes a square prism.

[0281] In some embodiments of the first method, the first faceted optical device includes a first square prism, wherein the first light beam is a first laser beam and the first method further includes: providing a second square prism; rotating the second square prism; and deflecting the first plurality of spaced-apart scanned light-beam lines from the first square prism by the second prism to form a second plurality of spaced-apart scanned laser-beam lines.

[0282] In some embodiments of the first method, the first faceted optical device includes a square polygon having four mirror faces.

[0283] In some embodiments of the first method, the first faceted optical device includes a square mirrored polygon having four mirror faces, wherein the first light beam is a first laser beam and the first method further includes: providing a second square mirrored polygon having four mirror faces; rotating the second square mirrored polygon; directing the first plurality of spaced-apart scanned light-beam lines reflected from the first square polygon towards the second square mirrored polygon; and reflecting the first plurality of spaced-apart scanned laser-beam lines with the second square mirrored polygon to form a second plurality of spaced-apart scanned laser-beam lines.

[0284] In some embodiments, the present invention provides a beam-splitter-based apparatus that forms two or more scanning beams per rotation, wherein the apparatus: a laser that generates a first laser beam; a first motor; a first rotating beam-splitter prism driven by the first motor, wherein the first rotating beam-splitter prism has a plurality of pairs of input/output faces and a first internal beam splitter structure, and wherein the input laser beam is coupled through the first rotating beam-splitter prism to form a first scanned laser-beam line when the first internal beam splitter structure is in a first orientation to the first laser beam, and to form a second scanned laser-beam line when the first internal beam splitter structure is in a second orientation to the first laser beam to form the two or more scanning beams per each rotation of the rotating beam-splitter prism.

[0285] In some embodiments of the beam-splitter-based apparatus, the first rotating beam-splitter prism has a square cross section, and wherein the first internal beam splitter structure extends diagonally between opposite corners of the square cross section. In some such embodiments, the first internal beam splitter structure is highly reflective to a wavelength of the first laser beam. In some such embodiments, the first internal beam splitter structure is partially reflective to a wavelength of the first laser beam. In some such embodiments, the first internal beam splitter structure is selectively reflective to a first polarization direction of the first laser beam. In some such embodiments, the first internal beam splitter structure is wavelength-selectively highly reflective to a wavelength of the first laser beam.

[0286] It is to be understood that the above description is intended to be illustrative, and not restrictive. Although numerous characteristics and advantages of various embodiments as described herein have been set forth in the foregoing description, together with details of the structure and function of various embodiments, many other embodiments and changes to details will be apparent to those of skill in the art upon reviewing the above description. The scope of the invention should be, therefore, determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein," respectively. Moreover, the terms "first, " "second," and "third," etc., are used merely as labels, and are not intended to impose numerical requirements on their objects.

1. (canceled)

2. The apparatus of claim **7**,

wherein the first faceted optical device includes a first multi-faceted mirror system that includes a first plurality of mirrors, wherein each one of the first plurality of mirrors is tilted at a different angle relative to the rotational axis;

wherein the first light beam is a first input laser beam that is directed toward the first faceted optical device to form a first plurality of scanned laser-beam lines spaced apart from one another, and

wherein the apparatus further comprises:

a second multi-faceted mirror system that includes a second plurality of mirrors, wherein each one of the second plurality of mirrors is tilted at a different angle relative to the rotational axis, and wherein the second multi-faceted mirror system is rotated by the first motor;

a second laser that emits a pulsed infrared (IR) laser beam that is directed toward the second multi-faceted mirror system to form a pattern of output light across a pattern of scanned directions spaced apart from one another to form a scanned pulsed output LiDAR beam;

a third multi-faceted mirror system that includes a third plurality of mirrors, wherein each one of the third plurality of mirrors is tilted at a different angle relative to the rotational axis, wherein the third multi-faceted mirror system is rotated by the first motor, and wherein the third multi-faceted mirror system is configured to receive a LiDAR signal reflected from the pattern of directions of the scanned pulsed output LiDAR beam toward the third multi-faceted mirror system;

a LiDAR receiver operatively coupled to receive light reflected by the third multi-faceted mirror system from the pattern of scanned directions; and

a vehicle, wherein the first motor, the first laser, the first multi-faceted mirror system, the phosphor plate, the second laser, the second multi-faceted mirror system, the third multi-faceted mirror system and the LiDAR receiver are mounted to the vehicle and are used to form a headlight beam and the scanned pulsed LiDAR output beam for the vehicle.

3. The apparatus of claim **7**, wherein the first faceted optical device includes a square prism that is tilted relative to the rotational axis such that a first pair of opposite faces is at a first angle to the rotational axis, and a second pair of opposite faces is at a second angle to the rotational axis, and the first angle is not equal to the second angle.

4. The apparatus of claim **7**, wherein the first faceted optical device includes a prism that has a plurality of pairs of parallel faces opposite each other relative to the rotational axis, wherein each pair of parallel faces is oriented at a different angle relative to the rotational axis.

5. The apparatus of claim **7**, wherein the first faceted optical device includes a multi-faceted mirror that includes a first plurality of mirrors, wherein each one of the first plurality of mirrors is tilted at a different angle relative to the rotational axis.

6. The apparatus of claim **7**, wherein the first light beam is a first input laser beam directed toward the first faceted optical device to form a first plurality of scanned laser-beam lines spaced apart from one another, wherein the apparatus further comprises a second source of a second input laser beam directed toward the first faceted optical device, and wherein the second laser beam is coupled to the first faceted optical device to form a second plurality of scanned laser-beam lines spaced apart from one another and from the first plurality of scanned laser-beam lines.

7. A scanned-light-beam apparatus comprising:

a first source of a first light beam;

a first rotary motor that has a rotational axis; and

a first faceted optical device that is rotated around the rotational axis by the first motor,

wherein the first faceted optical device has a plurality of faces, each of which is at one selected angle of a plurality of different angles relative to the rotational axis,

wherein the first light beam is operatively coupled to the rotated first faceted optical device to form a first plurality of spaced-apart scanned light-beam lines, wherein the first light beam is a first input blue-light laser beam directed toward the first faceted optical device to form a first plurality of scanned blue-light laser-beam lines spaced apart from one another, and wherein the apparatus further comprises:

a phosphor plate operatively coupled to receive the first plurality of scanned blue-light laser-beam lines and to emit wavelength-converted light when stimulated by the first plurality of scanned blue-light laser-beam lines; and

a projection lens optically coupled to receive light emitted by the phosphor plate and to project an output beam that includes the wavelength-converted light.

8. The apparatus of claim **7**, wherein the apparatus further comprises:

a vehicle, wherein the first motor, the first laser, the rotated first faceted optical device, the phosphor plate and the projection lens mounted to the vehicle and are used to form a headlight beam for the vehicle.

9. The apparatus of claim **7**,

wherein the first faceted optical device includes a first multi-faceted mirror system that includes a first plurality of mirrors, wherein each one of the first plurality of mirrors is tilted at a different angle relative to the rotational axis, and

wherein the first light beam is a first input laser beam that includes at least one wavelength in a range of 390 nm to 500 nm from a first laser and that is directed toward the first faceted optical device to form a first plurality of scanned laser-beam lines spaced apart from one another.

10.-**19**. (canceled)

20. The apparatus of claim **40**,

wherein the phosphor plate has a curved face configured such that the scanned laser-beam lines remain in focus across the curved face of the phosphor plate, and wherein the phosphor plate is a reflective phosphor plate mounted to a heatsink.

21. (canceled)

22. The method of claim **27**, further comprising:

providing a second multi-faceted mirror system that includes a second plurality of mirrors, wherein each one of the second plurality of mirrors is tilted at a different angle relative to the rotational axis;

providing a third multi-faceted mirror system that includes a third plurality of mirrors, wherein each one of the third plurality of mirrors is tilted at a different angle relative to the rotational axis;

providing a LiDAR receiver;

providing a phosphor plate, wherein the first faceted optical device includes a first multi-faceted mirror system that includes a first plurality of mirrors, wherein each one of the first plurality of mirrors is tilted at a different angle relative to the rotational axis, and wherein the first light beam is a first input laser;

directing the first input laser beam toward the first multi-faceted mirror system to form a first plurality of scanned laser-beam lines spaced apart from one another, and directing the first plurality of scanned laser-beam lines onto the phosphor plate such that the phosphor plate emits wavelength-converted light when stimulated by the first plurality of scanned laser-beam lines;

projecting light emitted by the phosphor plate as an output vehicle headlight beam that includes the wavelength-converted light;

rotating the second multi-faceted mirror system in synchrony with the first multi-faceted mirror system;

directing a pulsed infrared (IR) laser beam toward the second multi-faceted mirror system to form a pattern of output light across a pattern of scanned directions spaced apart from one another to form a scanned pulsed output LiDAR beam;

rotating the third multi-faceted mirror system in synchrony with the first multi-faceted mirror system;

reflecting, with the third multi-faceted mirror system, a LiDAR light signal from the pattern of directions of the scanned pulsed output LiDAR beam into the LiDAR receiver;

generating a LiDAR map based on the LiDAR light signal; and

using the headlight beam, the pulsed LiDAR output beam and the LiDAR map for controlling a vehicle.

23. (canceled)

24. The method of claim **27**, wherein the first faceted optical device includes a prism that has a plurality of pairs of parallel faces opposite each other relative to the rotational axis, wherein each pair of parallel faces is oriented at a different angle relative to the rotational axis.

25. The method of claim **27**, wherein the first faceted optical device includes a multi-faceted mirror that includes a first plurality of mirrors, the method further comprising:

tilting each one of the first plurality of mirrors at a different angle relative to the rotational axis.

26. The method of claim **27**, wherein the first light beam is a first input laser beam, the method further comprising:

deflecting the first input laser beam by the first faceted optical device to form a first plurality of scanned laser-beam lines spaced apart from one another;

deflecting a second input laser beam by the first faceted optical device to form a second plurality of scanned laser-beam lines spaced apart from one another and from the first plurality of scanned laser-beam lines.

27. A method for scanning a light beam, the method comprising:

providing a first faceted optical device;

rotating the first faceted optical device around a rotational axis; wherein the first faceted optical device has a plurality of faces, each of which is at one selected angle of a plurality of different angles relative to the rotational axis;

generating a first light beam; and

deflecting the first light beam with the rotating first faceted optical device to form a first plurality of spaced-apart scanned light-beam lines, wherein the first light beam is a first input blue-light laser beam;

deflecting the first input blue-light laser beam with first faceted optical device to form a first plurality of scanned blue-light laser-beam lines spaced apart from one another;

providing a phosphor plate;

directing the first plurality of scanned blue-light laser-beam lines onto the phosphor plate that emits wavelength-converted light when stimulated by the first plurality of scanned blue-light laser-beam lines; and

projecting light emitted by the phosphor plate to form an output beam that includes the wavelength-converted light.

28. The method of claim **27**, further comprising:

providing a phosphor plate, wherein the first light beam is a first input laser beam that includes at least one wavelength in a range of 390 nm to 500 nm;

deflecting the first input laser beam with the first faceted optical device to form a first plurality of scanned laser-beam lines spaced apart from one another onto the phosphor plate to emit wavelength-converted light when the phosphor plate is stimulated by the first plurality of scanned laser-beam lines; and

projecting light emitted by the phosphor plate as an output headlight beam that includes the wavelength-converted light, wherein the headlight beam is for a vehicle.

29. The method of claim **27**, wherein the first faceted optical device includes a first multi-faceted mirror system that includes a first plurality of mirrors, wherein each one of the first plurality of mirrors is tilted at a different angle relative to the rotational axis, and wherein the first light beam is a first input laser beam that includes at least one wavelength in a range of 390 nm to 500 nm, the method further comprising:

providing a phosphor plate;

reflecting the first input laser beam using the first faceted optical device to form a first plurality of scanned laser-beam lines spaced apart from one another onto the phosphor plate such that the phosphor plate emits wavelength-converted light when stimulated by the first plurality of scanned laser-beam lines; and

projecting light emitted by the phosphor plate as an output headlight beam for a vehicle.

30. The method of claim **27**, wherein the first faceted optical device includes a first multi-faceted mirror system that includes a first plurality of mirrors, wherein each one of the first plurality of mirrors is tilted at a different angle relative to the rotational axis, wherein the first light beam is a first input infrared (IR) pulsed laser beam, wherein the method further includes:

reflecting the IR pulsed laser beam by the first faceted optical device to form a pattern of output light across a first plurality of scanned lines spaced apart from one another to form a scanned pulsed LiDAR output beam for a vehicle.

31. The method of claim **27**, wherein the first faceted optical device includes a first multi-faceted mirror system that includes a first plurality of mirrors, wherein each one of the first plurality of mirrors is tilted at a different angle relative to the rotational axis, wherein the first light beam is a received LiDAR signal reflected, by an object, from a LiDAR beam, wherein the method further includes:

reflecting light by the first faceted optical device from a pattern of scanned-line directions spaced apart from one another onto a LiDAR receiver from the pattern of scanned-line directions; and

generating a LiDAR map for a vehicle based on signals from the LiDAR receiver.

32.-**39**. (canceled)

40. A scanning-beam apparatus comprising:

a first laser that generates a first input laser beam;

a first motor that has an axis of rotation; and

a rotating mirror assembly driven by the first motor, wherein the rotating mirror assembly has a plurality of faces, each of which is at one selected angle of a plurality of different angles relative to the input laser beam, and wherein the first input laser beam is coupled to reflect from the rotating mirror assembly to form a plurality of scanned laser-beam lines parallel to one another;

a phosphor plate and a projection lens optically coupled such that the plurality of scanned laser-beam lines is directed toward the phosphor plate, and such that light emitted by the phosphor plate is projected by the projection lens; and

a vehicle, wherein the first laser emits a blue wavelength of light, wherein the first laser, the rotating mirror assembly, the phosphor plate and the projection lens are used to form a headlight beam for the vehicle.

41.-**46**. (canceled)

* * * * *