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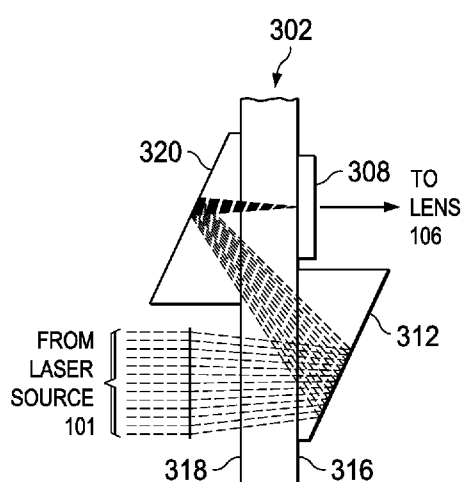
(54) **Title:** PROJECTOR WITH LASER AND PHOSPHOR

FIG. 3B

(57) **Abstract:** A projector includes a laser light source and a glass wheel. The laser source is configured to generate laser light. The glass wheel is optically coupled to the laser source. The glass wheel includes a first surface (318) and a second surface (316). The first surface (318) is configured to receive the laser light and includes a light direction device (320) optically coupled to the laser source. The second surface (316) is opposite the first surface (318) and is configured to emit light. The second surface (316) includes a first arc of a phosphor (308) deposited at a first distance from a center of the glass wheel. The light direction device (320) is configured to direct the laser light to the first arc of the phosphor (308). The second surface (316) also includes a second arc of the phosphor deposited at a second distance from the center of the glass wheel.

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
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- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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PROJECTOR WITH LASER AND PHOSPHOR

BACKGROUND

[0001] Some spatial light modulator (SLM) based projection systems can generate a displayed image having a higher resolution (greater pixel density) than the SLM used to generate the displayed image. For example, an SLM-based projector may include a moving glass plate interposed in the light path after the light has been modulated by the SLM. An actuator moves the plate so that, in one position, the output of the projector shifts by one-half pixel in both the x and y directions. This shift places the center of the shifted pixels at the intersection of four of the unshifted pixels. The output of the SLM alternates between the pixel information for unshifted and shifted pixels rapidly enough that the eye sees the combination of the unshifted and shifted pixels as an image having double the resolution of the SLM. This technique may be extended to further increase the resolution of the displayed image by moving the glass plate to more sub-pixel positions (e.g., four positions).

SUMMARY

[0002] A spatial light modulator (SLM) based projector that provides improved image resolution by generating offset beams using a phosphor wheel is described herein. In one example, a projector includes a laser light source and a glass wheel. The glass wheel is optically coupled to the laser source, and includes a first surface and a second surface. The first surface includes a first arc of a phosphor deposited at a first distance from a center of the glass wheel, and a second arc of the phosphor deposited at a second distance from the center of the glass wheel. The second surface is opposite the first surface, and includes a light direction device optically coupled to the laser source and the first arc of the phosphor.

[0003] In another example, a projector includes a laser light source and a glass wheel. The laser source is configured to generate laser light. The glass wheel is optically coupled to the laser source. The glass wheel includes a first surface and a second surface. The first surface is configured to receive the laser light, and includes a light direction device optically coupled to the laser source. The second surface is opposite the first surface and is configured to emit light. The second surface includes a first arc of a phosphor deposited at a first distance from a center of the

glass wheel. The light direction device is configured to direct the laser light to the first arc of the phosphor. The second surface also includes a second arc of the phosphor deposited at a second distance from the center of the glass wheel.

[0004] In a further example, a method for projection includes generating laser light, and rotating a glass wheel in a path of the laser light. The laser light illuminates a first arc of a phosphor in a first sector of the glass wheel to generate a first beam. The laser light illuminates a second arc of the phosphor, that is offset from the first arc of phosphor, in a second sector of the glass wheel to generate a second beam that is offset from the first beam.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. 1 shows an example light generation path for a spatial light modulator (SLM) based projector in accordance with this description.

[0006] FIG. 2 shows an example projection path for an SLM based projector in accordance with this description.

[0007] FIGS. 3A-3C show an example glass wheel that includes prisms for directing laser light to multiple locations in accordance with this description.

[0008] FIGS. 4A-4C show an example glass wheel that includes diffractive optical elements for directing laser light to multiple locations in accordance with this description.

[0009] FIGS. 5A-5C show an example glass wheel that includes a glass wedge for directing laser light to multiple locations in accordance with this description.

[0010] FIG. 6 shows a flow diagram for a method for using a glass wheel to direct laser light to multiple locations in accordance with this description.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

[0011] In this description, the term “couple” or “couples” means either an indirect or direct wired or wireless connection. Thus, if a first device couples to a second device, that connection may be through a direct connection or through an indirect connection via other devices and connections. Also, in this description, the recitation “based on” means “based at least in part on.” Therefore, if X is based on Y, then X may be a function of Y and any number of other factors.

[0012] The optics and the actuator for using a moving glass pate to increase the resolution of a spatial light modulator (SLM) based projector are not compact, and therefore not suitable for compact applications, such as pico-projectors. In addition, an actuator capable of high speed and

precise operation is costly. To reduce cost and complexity, some SLM-based projectors employ multiple light sources to generate the multiple sub-pixels of an enhanced resolution display. In such systems, the light sources are sequentially enabled to generate the corresponding sub-pixels. Such operation is inefficient when using laser light sources because multiple laser sources are required, and the laser sources are discontinuously enabled.

[0013] The SLM-based projectors described herein direct laser light between two or more positions to provide the appearance of laser light generated by two or more sequentially enabled laser sources. The projectors include a glass wheel with arcs of phosphor at different radial distances from the center of the wheel. As the wheel rotates, optical elements attached to the wheel direct the laser light to the different arcs of phosphor. In various implementations, the optical elements include prisms, diffractive optical elements, or a glass wedge. The diffractive optical elements may include a holographic optical element. Some implementations use a blue laser source to illuminate the arcs of phosphor on the wheel. Light emitted by the phosphor is filtered to produce red light and green light that are combined with the blue light to provide an image.

[0014] FIG. 1 shows an example light generation path 100 for an SLM-based projector in accordance with this description. The light generation path 100 includes a laser source 101, a glass wheel 103, a lens 106, a fly's eye array 108, a fly's eye array 110, a lens 118, and an SLM 112. The laser source 101 may be a laser diode, a vertical cavity surface emitting laser (VCSEL), or other device that emits laser light. In some implementations of the light generation path 100, the laser source 101 emits blue laser light. Laser light emitted by the laser source 101 is projected onto the glass wheel 103.

[0015] The glass wheel 103 receives the laser light projected by the laser source 101 and directs the laser light to form beam 107 or beam 109 emitted from the glass wheel 103. The glass wheel 103 includes an arc of phosphor 104, an arc of phosphor 105, and a light direction device 102. The arc of phosphor 104 and the arc of phosphor 105 may absorb the laser light projected by the laser source 101 and emit yellow or other color of light as the beams 107 and 109. The beams 107 and 109 emitted by the arc of phosphor 104 and the arc of phosphor 105 may be filtered to produce red and green light. For example, the beams 107 and 109 may be filtered with a thin-film dichroic coating deposited on the surface of the phosphor, or on the glass wheel 103 after the phosphor emission, or in a separate color wheel (not shown) in the light

generation path 100 to produce red and green light.

[0016] The arc of phosphor 104 is disposed at a first offset from the center of the glass wheel 103. The arc of phosphor 105 is concentric with the arc of phosphor 104 and is disposed at a second offset from the center of the glass wheel 103. The second offset is different from the first offset. The light direction device 102 receives the laser light projected by the laser source 101, and directs the received laser light to one of the arc of phosphor 104 or the arc of phosphor 105. For example, in a first sector of the laser source 101, a first instance of the light direction device 102 directs the laser light to the arc of phosphor 104, and in a second sector of the laser source 101, a second instance of the light direction device 102 directs the laser light to the arc of phosphor 105. Thus, the glass wheel 103 is rotated (e.g., by an electric motor), and produces offset beams 107 and 109, at different positions of rotation, from the laser light generated by the laser source 101.

[0017] The beams 107 and 109 pass through the lens 106. The lens 106 may be a single lens or a system of lenses. Light projection lines in the figures are schematic and do not show the complete path of the light but show the general path of the light. The lens 106 focuses the beam 107 and the beam 109 onto the fly's eye array 108 and the fly's eye array 110, respectively. The fly's eye array 108 and the fly's eye array 110 include many small lenses. These arrays may include dozens or thousands of small lenses. The purpose of these lenses is to homogenize or "even out" the light to provide uniform light. In the light generation path 100, two fly's eye arrays enhance the geometric separation of the two light paths from the glass wheel 103. However, one fly's eye array may be used for both paths in some implementations of the light generation path 100. The light output by the fly's eye array 108 and the fly's eye array 110 passes through the lens 118 to the SLM 112. The lens 118 may be a single lens or a group of lenses.

[0018] The SLM 112 is a digital micromirror device (DMD) in some implementations of the light generation path 100. In some implementations of the light generation path 100, the SLM 112 may be a liquid crystal on silicon (LCOS) SLM or other device. The lens 106, the fly's eye array 108, the fly's eye array 110 and the lens 118 preserve an angular difference to the light beams provided by glass wheel 103 so that the light from the glass wheel 103 is incident on the SLM 112 at different angles.

[0019] FIG. 2 shows an example projection path 200 for an SLM based projector in accordance

with this description. The projection path 200 includes an SLM 212, a lens 206, a glass plate 208, a glass plate 210, and a lens 213. The SLM 212 may be the SLM 112 of the light generation path 100. The lens 206 focuses modulated light 202 onto the glass plate 208. The lens 206 also focuses modulated light 204 onto the glass plate 210. The glass plate 208 and the glass plate 210 provide an image direction device 209. In this example, the glass plate 208 is a flat glass plate that does not significantly modify the modulated light 202, and the glass plate 210 is a trapezoidal plate (also known as a wedge prism) that shifts the pixel position of the modulated light 204 one-half pixel in the horizontal direction (x direction) and one-half pixel in the vertical direction (y direction). The lens 213 projects the modulated light 202 from the glass plate 208 and the modulated light 204 from the glass plate 210 onto a target 214. In this example, the target 214 is a projection screen.

[0020] FIGS. 3A-3C show views of an example glass wheel 300 that includes prisms for directing laser light to multiple locations in accordance with this description. The glass wheel 300 is an implementation of the glass wheel 103. FIG. 3A shows a view of a side 316 the glass wheel 300. The glass wheel 300 includes a sector 302, a sector 304, and a sector 306. More than one of the sector 302, the sector 304, and the sector 306 may be provided on the glass wheel 300. The sector 302 includes an arc of phosphor 308 and a prism 312. The prism 312 is a light direction device. The sector 304 includes an arc of phosphor 310 and a prism 314. The arc of phosphor 310 is concentric with the arc of phosphor 308, and offset from the arc of phosphor 308 with respect to the center of the glass wheel 300. The sector 306 lacks the arc of phosphor 308 and the arc of phosphor 310, and may include an instance of the prism 312 or the prism 314. For example, a first instance of the sector 306 includes the prism 312, and a second instance of the sector 306 includes the prism 314.

[0021] FIG. 3B shows a cross-sectional view of the glass wheel 300 taken through the sector 302. As shown in FIG. 3B, the glass wheel 300 includes a side 318 opposite the side 316. A prism 320 is disposed on the side 318 opposite the arc of phosphor 308. FIG. 3B shows a path of laser light in the sector 302. The laser light passes through the glass wheel 300 and is reflected by the prism 312 to the prism 320. The outside surfaces of prisms 312, 320, 314, and 322 are coated with a reflective material or thin film stack that is highly reflective. The prism 320 reflects the laser light received via the prism 312 to the arc of phosphor 308. The arc of phosphor 308 absorbs the laser light reflected by the prism 320, and emits a beam of light directed to the lens 106. The prisms 312 and 320 may be formed as arcs that follow the arc of phosphor 308, and may be

attached to the glass wheel 300 by adhesive or molded into the glass wheel 300 in various implementations.

[0022] FIG. 3C shows a cross-sectional view of the glass wheel 300 taken through the sector 304. A prism 322 is disposed on the side 318 opposite the arc of phosphor 310. FIG. 3C shows a path of laser light in the sector 304. The laser light passes through the glass wheel 300 and is reflected by the prism 314 to the prism 322. The prism 322 reflects the laser light received via the prism 314 to the arc of phosphor 310. The arc of phosphor 310 absorbs the laser light reflected by the prism 322, and emits a beam of light directed to the lens 106. The prisms 314 and 323 may be formed as arcs that follow the arc of phosphor 310, and may be attached to the glass wheel 300 by adhesive or molded into the glass wheel 300 in various implementations. Because the arc of phosphor 308 and the arc of phosphor 310 are disposed at different offsets from the center of the glass wheel 300, the light beams produced by the arc of phosphor 308 and the arc of phosphor 310 are offset.

[0023] FIGS. 4A-4C show an example glass wheel 400 that includes diffractive optical elements for directing laser light to multiple locations in accordance with this description. The glass wheel 400 is an implementation of the glass wheel 103. FIG. 4A shows a view of a side 416 of the glass wheel 400. The glass wheel 400 includes a sector 402, a sector 404, and a sector 406. More than one of the sector 402, the sector 404, and the sector 406 may be provided on the glass wheel 400. The sector 402 includes an arc of phosphor 408 and a diffractive optical element 412. The diffractive optical element 412 is a light direction device which may be a surface diffraction grating or a volume Bragg grating. The sector 404 includes an arc of phosphor 410 and a diffractive optical element 414. The arc of phosphor 410 is concentric with the arc of phosphor 408, and offset from the arc of phosphor 408 with respect to the center of the glass wheel 400. The sector 406 lacks the arc of phosphor 408 and the arc of phosphor 410, and may include an instance of the diffractive optical element 412 or the diffractive optical element 414. For example, a first instance of the sector 406 includes the diffractive optical element 412, and a second instance of the sector 406 includes the diffractive optical element 414.

[0024] FIG. 4B shows a cross-sectional view of the glass wheel 400 taken through the sector 402. As shown in FIG. 4B, the glass wheel 400 includes a side 418 opposite the side 416. A diffractive optical element 420 is disposed on the side 418. FIG. 4B shows a path of laser light in the sector 402. The laser light is incident on and is diffracted by the diffractive optical element 420

into the glass wheel 400. The laser light propagates in the glass wheel 400 by total internal reflection until the laser light reaches the diffractive optical element 412. The diffractive optical element 412 is disposed beneath the arc of phosphor 408. The diffractive optical element 412 diffracts the laser light to the arc of phosphor 408. The arc of phosphor 408 absorbs the laser light diffracted by the diffractive optical element 412, and emits a beam of light directed to the lens 106. The diffractive optical element 412 and 420 may be formed as arcs that follow the arc of phosphor 408, and may be attached to the glass wheel 400 by adhesive or molded into the glass wheel 400 in various implementations.

[0025] FIG. 4C shows a cross-sectional view of the glass wheel 400 taken through the sector 404. A diffractive optical element 422 is disposed on the side 418. FIG. 4C show a path of laser light in the sector 404. The laser light is incident on and is diffracted by the diffractive optical element 422 into the glass wheel 400. The laser light propagates in the glass wheel 400 by total internal reflection until the laser light reaches the diffractive optical element 414. The diffractive optical element 414 is disposed beneath the arc of phosphor 410. The diffractive optical element 414 diffracts the laser light to the arc of phosphor 410. The arc of phosphor 410 absorbs the laser light diffracted by the diffractive optical element 414, and emits a beam of light directed to the lens 106. The diffractive optical element 414 and 422 may be formed as arcs that follow the arc of phosphor 410, and may be attached to the glass wheel 400 by adhesive or molded into the glass wheel 400 in various implementations. Because the arc of phosphor 408 and the arc of phosphor 410 are disposed at different offsets from the center of the glass wheel 400, the light beams produced by the arc of phosphor 408 and the arc of phosphor 410 are offset.

[0026] The diffractive optical element 412, the diffractive optical element 414, the diffractive optical element 420, and/or the diffractive optical element 422 may be holographic optical elements in some implementations of the glass wheel 400.

[0027] FIGS. 5A-5C show an example glass wheel 500 that includes a glass wedge for directing laser light to multiple locations in accordance with this description. The glass wheel 500 is an implementation of the glass wheel 103. FIG. 5A shows a view of a side 516 the glass wheel 500. The glass wheel 500 includes a sector 502, a sector 504, and a sector 506. More than one of the sector 502, the sector 504, and the sector 506 may be provided on the glass wheel 500. The sector 502 includes an arc of phosphor 508 disposed on the side 516, and a glass wedge 512 disposed on a side 518 of the glass wheel 500. The side 518 (see FIG. 5B) is opposite the side 516 on which

the arc of phosphor 508 is disposed. The glass wedge 512 is a light direction device. The sector 504 includes an arc of phosphor 510. The arc of phosphor 510 is concentric with the arc of phosphor 508, and offset from the arc of phosphor 508 with respect to the center of the glass wheel 500. The sector 506 lacks the arc of phosphor 508 and the arc of phosphor 510, and may include an instance of the glass wedge 512. For example, a first instance of the sector 506 includes the glass wedge 512, and a second instance of the sector 506 lacks the glass wedge 512.

[0028] FIG. 5B shows a cross-sectional view of the glass wheel 500 taken through the sector 502. As shown in FIG. 5B, the glass wheel 500 includes a side 518 opposite the side 516. The glass wedge 512 is disposed on the side 518 opposite the arc of phosphor 508. FIG. 5B shows a path of laser light in the sector 502. The laser light passes through and is refracted by the glass wedge 512 to the arc of phosphor 508. The arc of phosphor 508 absorbs the laser light refracted by the glass wedge 512, and emits a beam of light directed to the lens 106. The glass wedge 512 may be formed as an arc that follows the arc of phosphor 508, and may be attached to the glass wheel 500 by adhesive or molded into the glass wheel 500 in various implementations.

[0029] FIG. 5C shows a cross-sectional view of the glass wheel 500 taken through the sector 504. The sector 504 lacks the glass wedge 512 or any light direction device. FIG. 5C shows a path of laser light in the sector 504. The laser light is incident on and passes directly through the glass wheel 500 to the arc of phosphor 510. The arc of phosphor 510 absorbs the laser light, and emits a beam of light directed to the lens 106. Because the arc of phosphor 508 and the arc of phosphor 510 are disposed at different offsets from the center of the glass wheel 500, the light beams produced by the arc of phosphor 508 and the arc of phosphor 510 are offset.

[0030] FIG. 6 shows a flow diagram for a method 600 for using a glass wheel to direct laser light to multiple locations in accordance with this description. Though depicted sequentially as a matter of convenience, at least some of the actions shown can be performed in a different order and/or performed in parallel. Additionally, some implementations may perform only some of the actions shown. Operations of the method 600 may be performed by a projector that includes an implementation of the light generation path 100.

[0031] In block 602, the laser source 101 generates laser light. For example, the laser source 101 generates blue laser light.

[0032] In block 604, the glass wheel 103 is rotated in the path of the laser light generated by the laser source 101. For example, an electric motor is energized to rotate the glass wheel 103.

[0033] In block 606, a first arc of phosphor 104 disposed in a first sector of the glass wheel 103 is illuminated by the laser light. The phosphor arc of phosphor 104 absorbs the laser light and emits a first beam. The laser light is received at a first radial offset of the glass wheel 103, and emitted from the glass wheel 103 at a second radial offset of the glass wheel 103. The second radial offset is different from the first radial offset. The laser light may be radially propagated in the glass wheel 103 by reflecting the laser light in the prism 312 and the prism 320 to the first arc of phosphor 104, by diffracting the laser light in a first diffractive optical element 420 and a second diffractive optical element 412 to the first arc of phosphor 104, or by refracting the laser light in a glass wedge 512 to the first arc of phosphor 104.

[0034] In block 608, glass wheel 103 is rotated such the laser light is incident on a second sector of the glass wheel 103. A second arc of phosphor 105 disposed in the second sector of the glass wheel 103 is illuminated by the laser light. The arc of phosphor 105 absorbs the laser light and emits a second beam that is spatially offset from the first beam produced in block 606. In some implementations, the laser light is received at a first radial offset of the glass wheel 103, and emitted from the glass wheel 103 at a second radial offset of the glass wheel 103, where the second radial offset is different from the first radial offset. In some implementations, the laser light may pass directly through the glass wheel 103 to the arc of phosphor 105. In some implementations, the laser light may be radially propagated in the glass wheel 103 by reflecting the laser light in the prism 314 and the prism 322 to the second arc of phosphor 105, or by diffracting the laser light in a first diffractive optical element 422 and a second diffractive optical element 414 to the second arc of phosphor arc of phosphor 105.

[0035] Modifications are possible in the described embodiments, and other embodiments are possible, within the scope of the claims.

CLAIMS

What is claimed is:

1. A projector comprising:
a laser source; and
a glass wheel optically coupled to the laser source, the glass wheel including:
a first surface including: a first arc of a phosphor deposited at a first distance from a center of the glass wheel; and a second arc of the phosphor deposited at a second distance from the center of the glass wheel; and
a second surface opposite the first surface, the second surface including a light direction device optically coupled to the laser source and the first arc of the phosphor.
2. The projector of claim 1, wherein:
the light direction device is a first light direction device; and
the second surface of the glass wheel includes a second light direction device optically coupled to the laser source and the second arc of the phosphor.
3. The projector of claim 2, wherein the second light direction device includes:
a first prism disposed on the second surface opposite the first arc of the phosphor; and
a second prism optically coupled to the first prism and disposed on the first surface.
4. The projector of claim 2, wherein the second light direction device includes:
a first diffractive optical element disposed on the second surface; and
a second diffractive optical element optically coupled to the first diffractive optical element and disposed on the first surface of the glass wheel between the first surface and the second arc of the phosphor.
5. The projector of claim 1, wherein the light direction device includes:
a first prism disposed on the second surface opposite the first arc of the phosphor; and
a second prism optically coupled to the first prism and disposed on the first surface.
6. The projector of claim 1, wherein the light direction device includes:
a first diffractive optical element disposed on the second surface; and
a second diffractive optical element optically coupled to the first diffractive optical element and disposed on the first surface of the glass wheel between the first surface and the first arc of the phosphor.

7. The projector of claim 1, wherein the light direction device includes a glass wedge disposed on the second surface of the glass wheel opposite the first arc of the phosphor.
8. The projector of claim 1, wherein the glass wheel includes a sector lacking the first arc of the phosphor and the second arc of the phosphor.
9. A projector, comprising:
 - a laser source configured to generate laser light; and
 - a glass wheel optically coupled to the laser source, the glass wheel including:
 - a first surface configured to receive the laser light, the first surface including a light direction device optically coupled to the laser source; and
 - a second surface opposite the first surface and configured to emit light, the second surface including: a first arc of a phosphor deposited at a first distance from a center of the glass wheel, in which the light direction device is configured to direct the laser light to the first arc of the phosphor; and a second arc of the phosphor deposited at a second distance from the center of the glass wheel.
10. The projector of claim 9, wherein:
 - the light direction device is a first light direction device; and
 - the second surface of the glass wheel includes a second light direction device optically coupled to the laser source, in which the second light direction device is configured to direct the laser light to the second arc of the phosphor.
11. The projector of claim 10, wherein the second light direction device includes:
 - a first prism disposed on the second surface of the glass wheel; and
 - a second prism disposed on the first surface of the glass wheel;in which the second prism is configured to direct the laser light to the first prism, and the first prism is configured to direct the laser light received from the first prism to the second arc of the phosphor.
12. The projector of claim 10, wherein the second light direction device includes:
 - a first diffractive optical element disposed on the second surface of the glass wheel; and
 - a second diffractive optical element disposed on the first surface of the glass wheel;in which the second diffractive optical element is configured direct the laser light to the first diffractive optical element, and the first diffractive element is configured to direct the laser

light received from the second diffractive element to the second arc of the phosphor.

13. The projector of claim 9, wherein the light direction device includes:

a first prism disposed on the second surface of the glass wheel; and

a second prism disposed on the first surface of the glass wheel;

in which the second prism is configured to direct the laser light to the first prism, and the first prism is configured to direct the laser light received from the first prism to the first arc of the phosphor.

14. The projector of claim 9, wherein the light direction device includes:

a first diffractive optical element disposed on the second surface of the glass wheel; and

a second diffractive optical element disposed on the first surface of the glass wheel;

in which the second diffractive optical element is configured direct the laser light to the first diffractive optical element, and the first diffractive element is configured to direct the laser light received from the second diffractive element to the first arc of the phosphor.

15. The projector of claim 9, wherein the light direction device includes a glass wedge disposed on the first surface of the glass wheel opposite the first arc of the phosphor, and configured to direct the laser light to the first arc of the phosphor.

16. The projector of claim 9, wherein the glass wheel includes a sector lacking the first arc of the phosphor and the second arc of the phosphor.

17. A method for projection, comprising:

generating laser light;

rotating a glass wheel in a path of the laser light;

illuminating, by the laser light, a first arc of a phosphor in a first sector of the glass wheel to generate a first beam; and

illuminating, by the laser light, a second arc of the phosphor, that is offset from the first arc of the phosphor, in a second sector of the glass wheel to generate a second beam that is offset from the first beam.

18. The method of claim 17, further comprising:

reflecting the laser light in a first prism and a second prism to the first arc of the phosphor;

and

reflecting the laser light in a third prism and a fourth prism to the second arc of the phosphor.

19. The method of claim 17, further comprising:

 diffracting the laser light in a diffractive optical element and a second diffractive optical element to the first arc of the phosphor; and

 diffracting the laser light in a third diffractive optical element and a fourth diffractive optical element to the second arc of the phosphor.

20. The method of claim 17, further comprising:

 refracting the laser light in a glass wedge to the first arc of the phosphor; and

 passing the laser light through the glass wheel with no change in direction to the second arc of the phosphor.

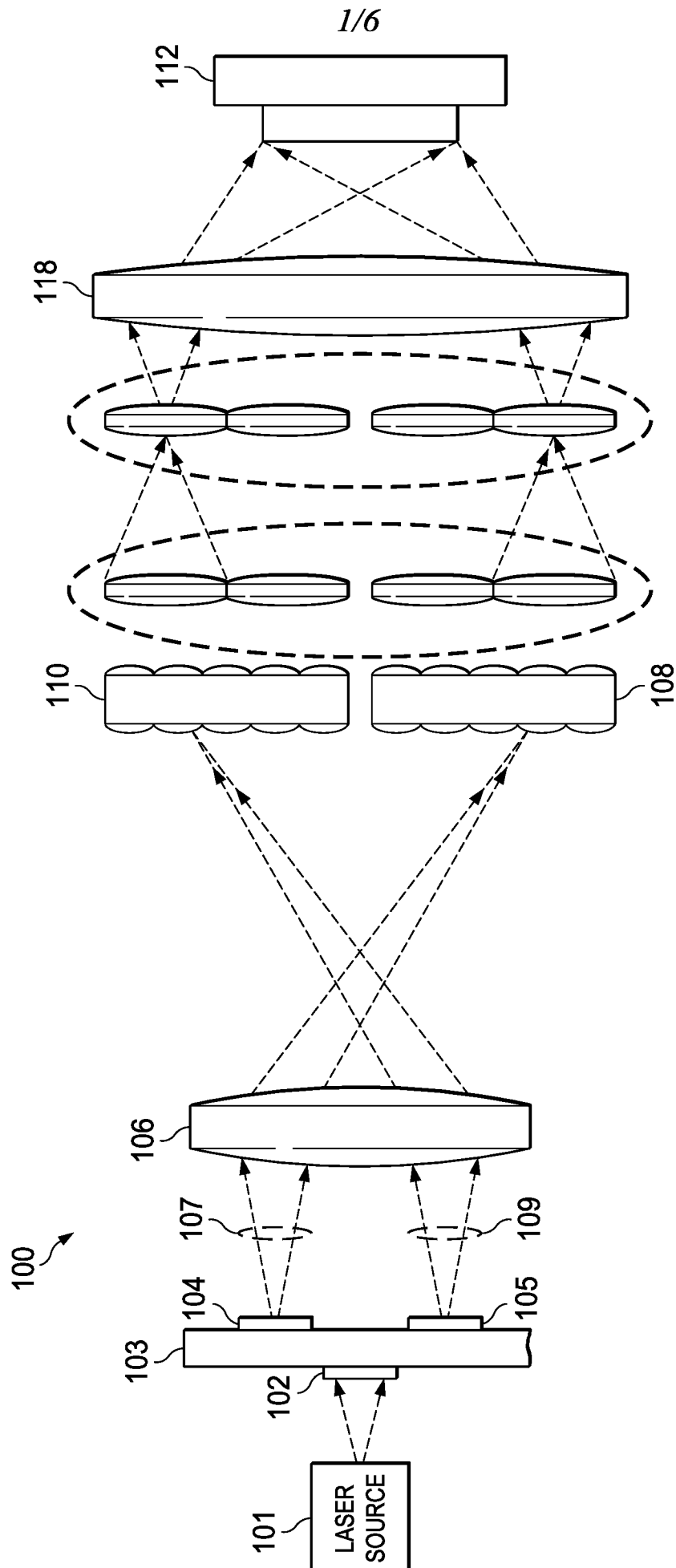
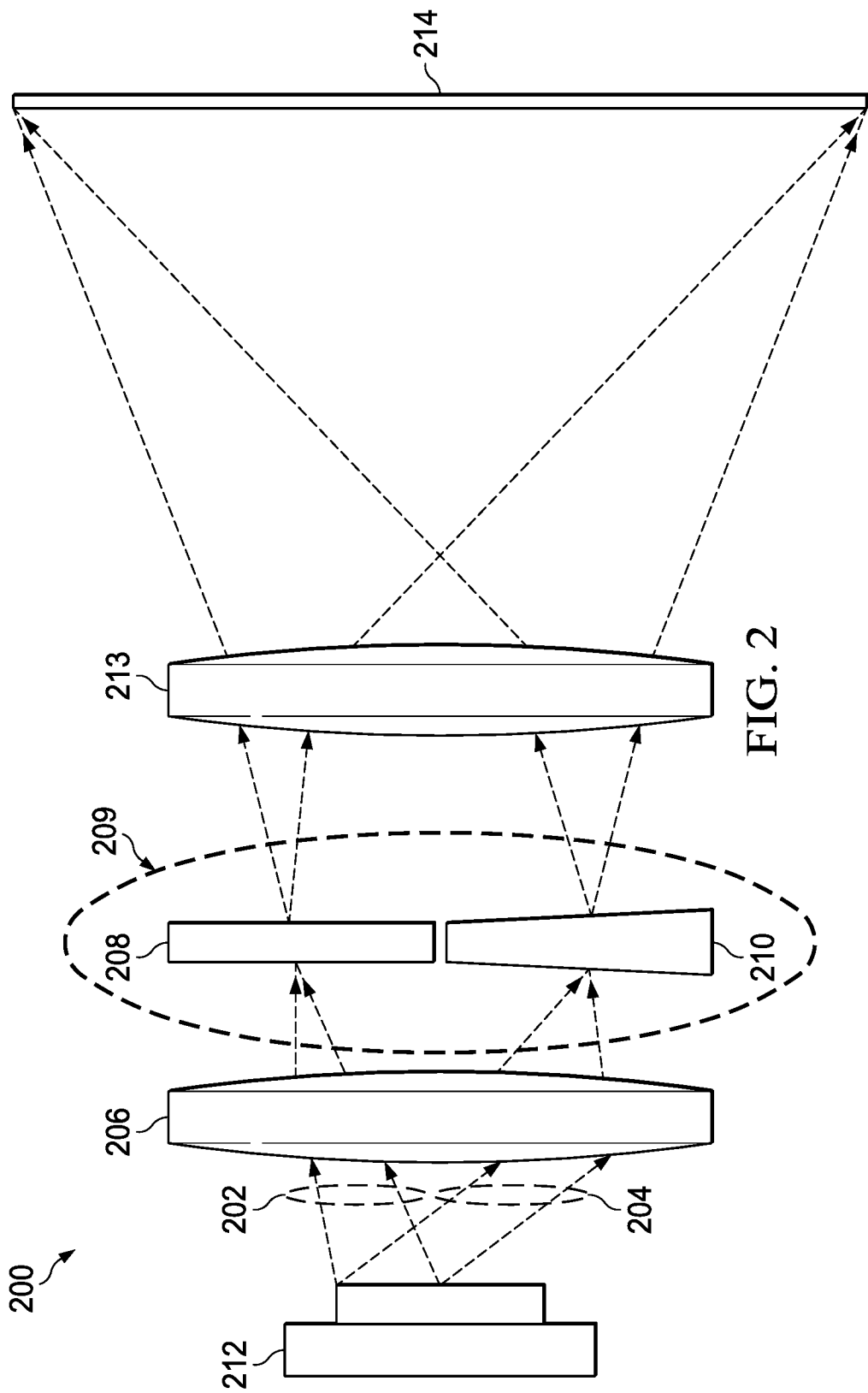


FIG. 1

1/6



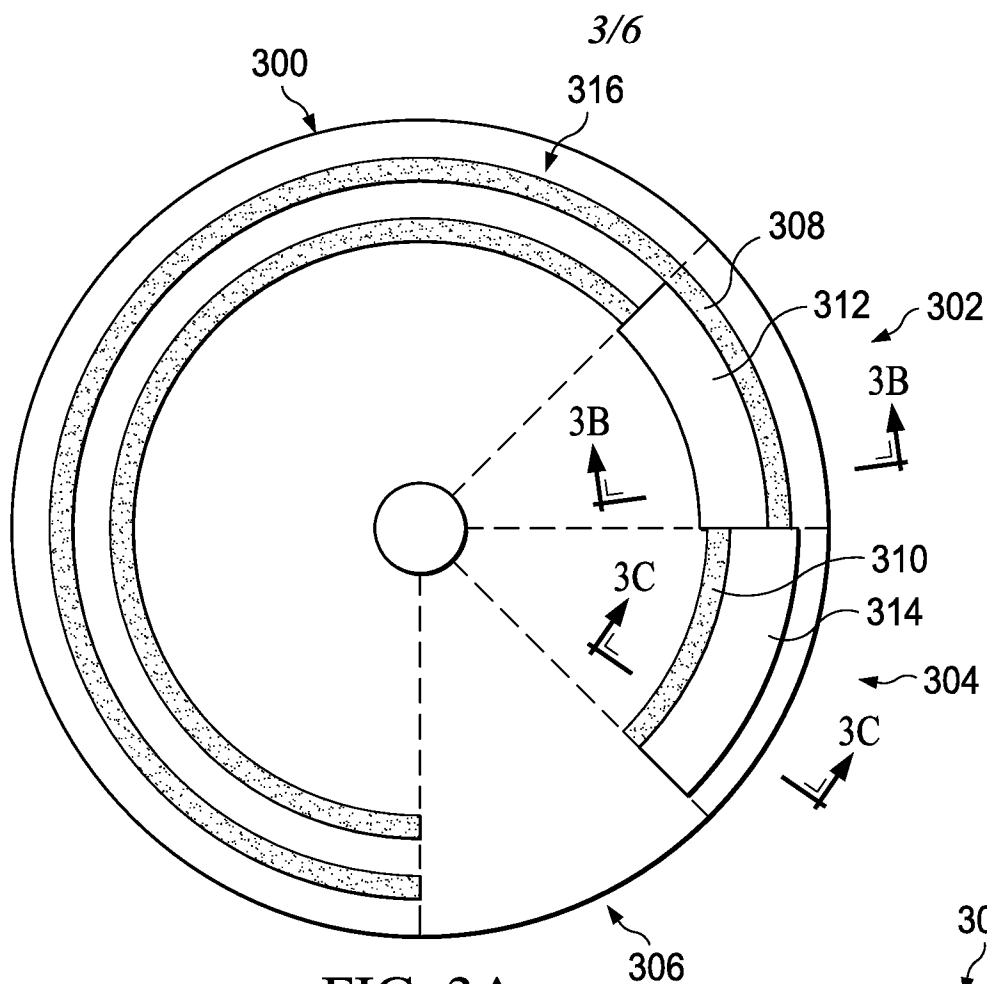


FIG. 3A

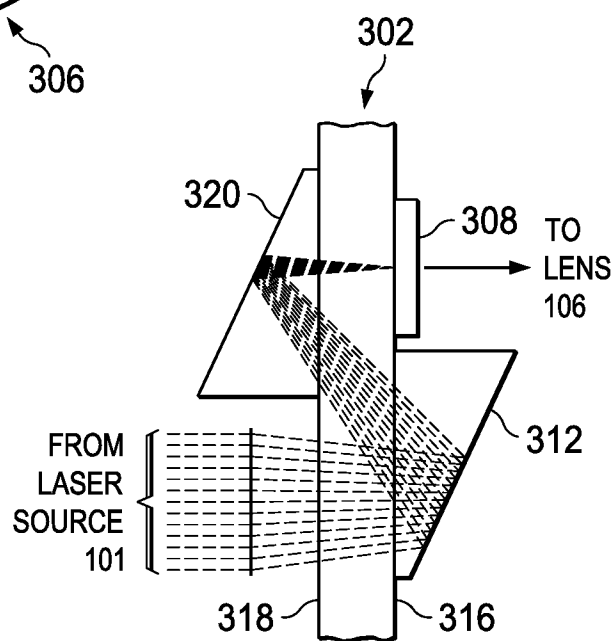


FIG. 3B

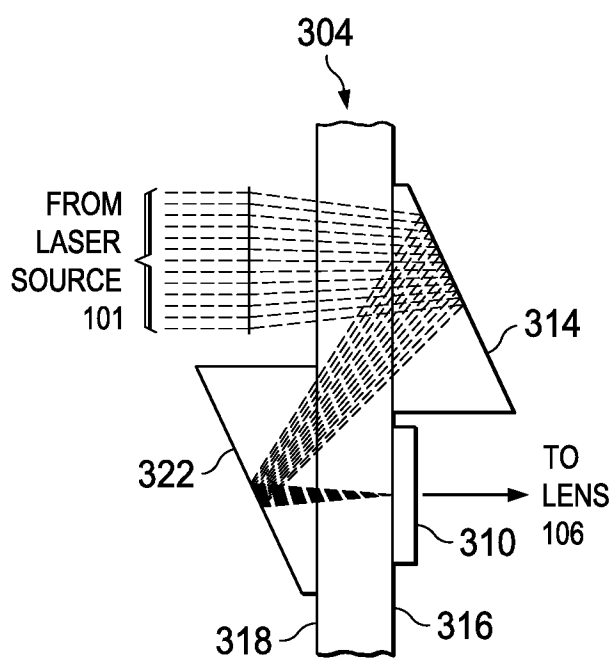


FIG. 3C

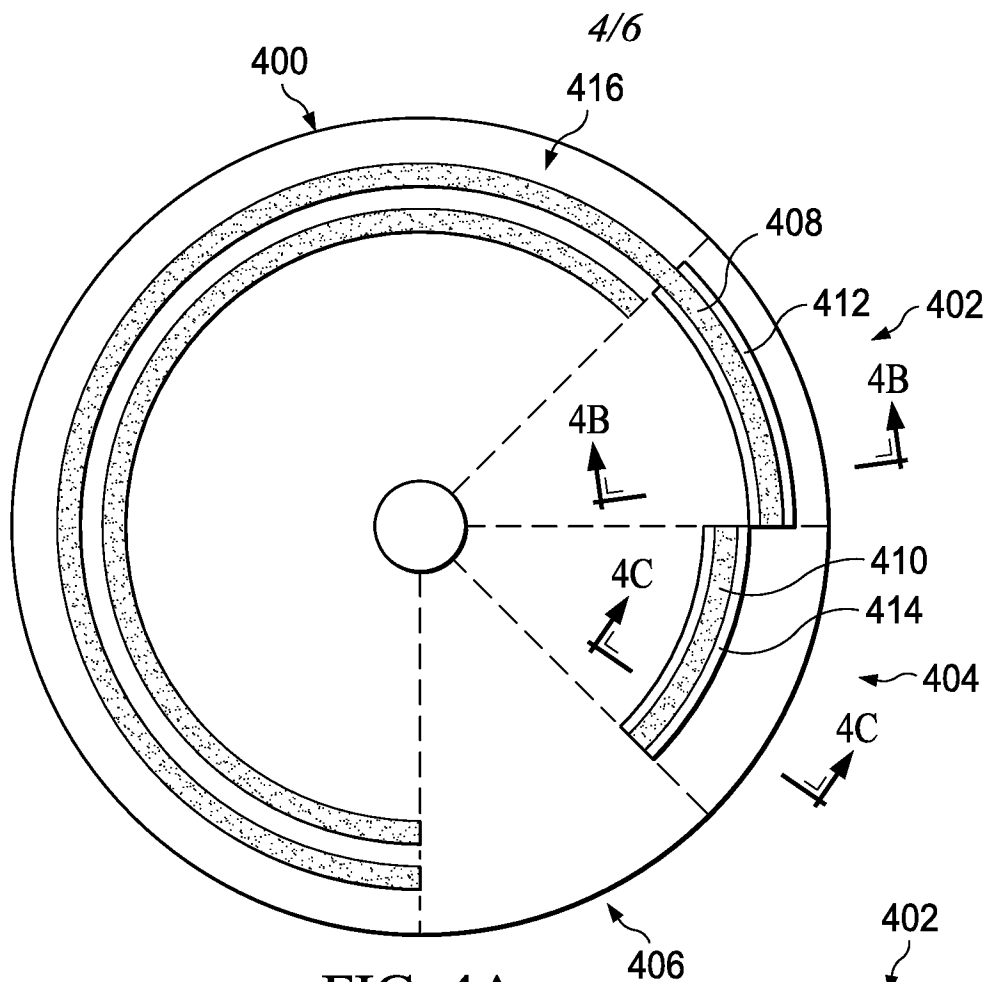


FIG. 4A

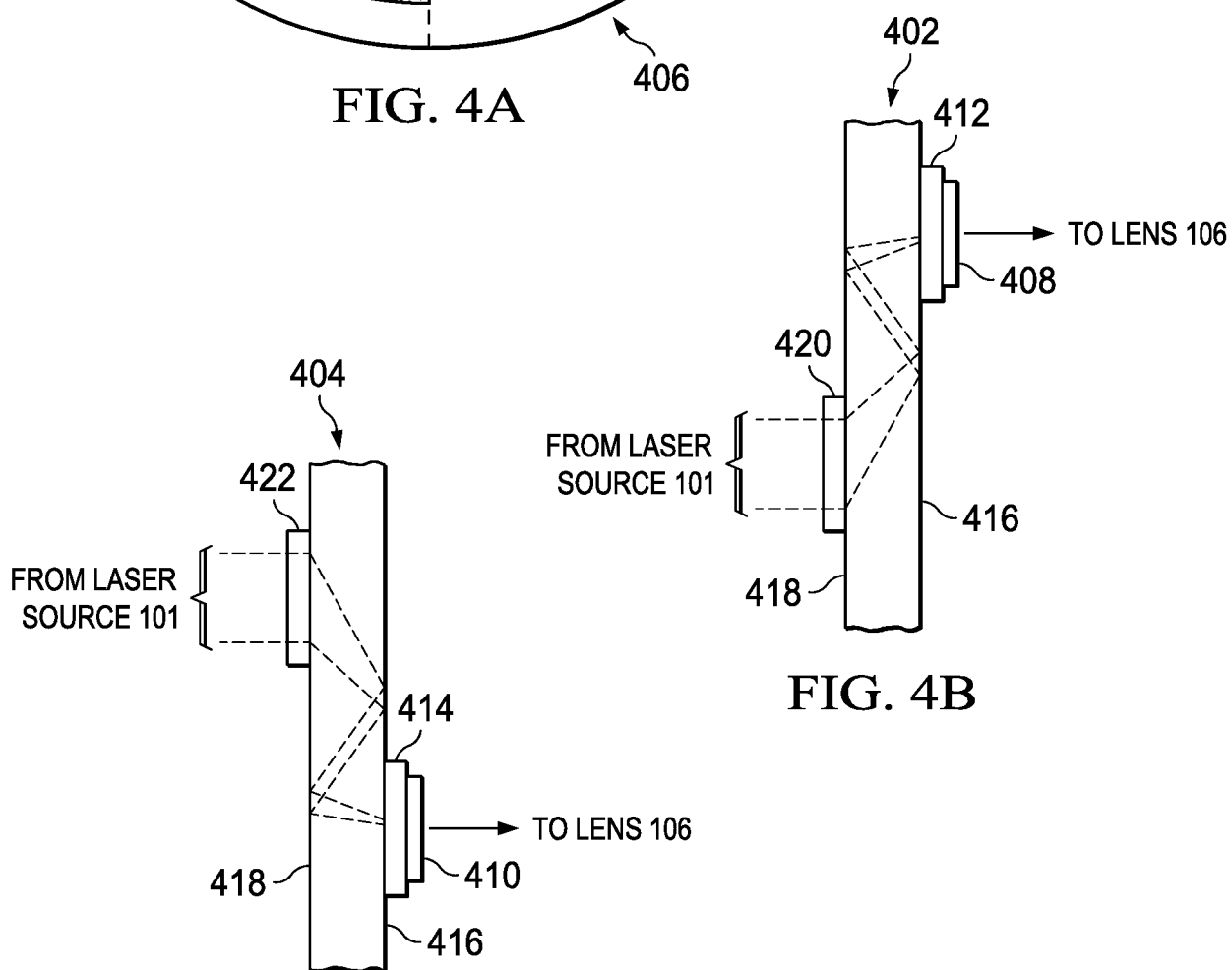


FIG. 4B

FIG. 4C

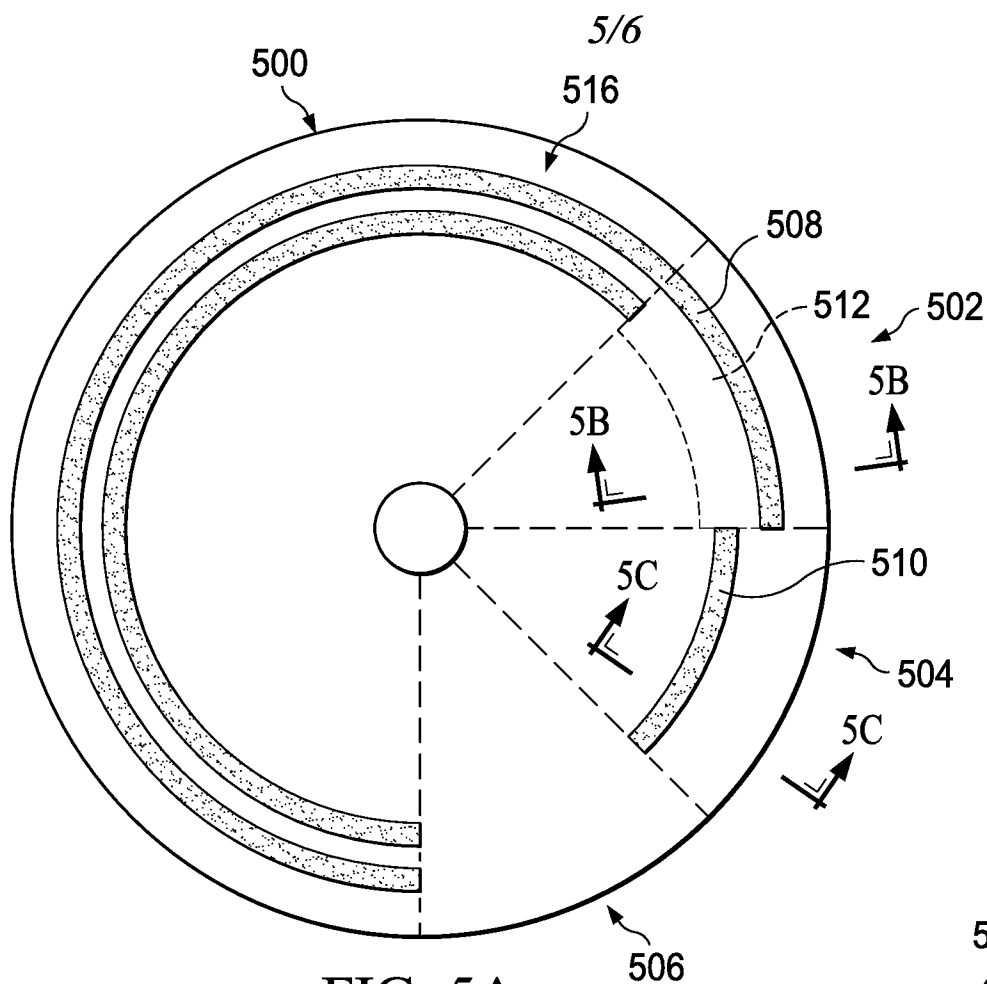


FIG. 5A

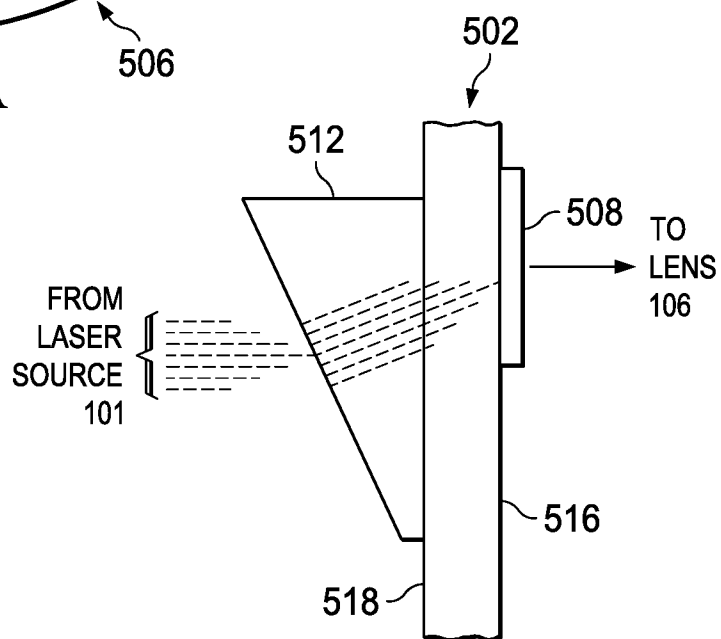


FIG. 5B

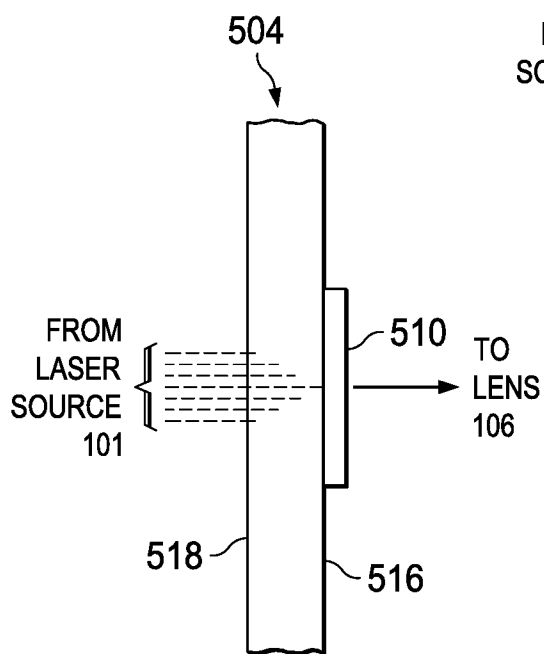


FIG. 5C

6/6

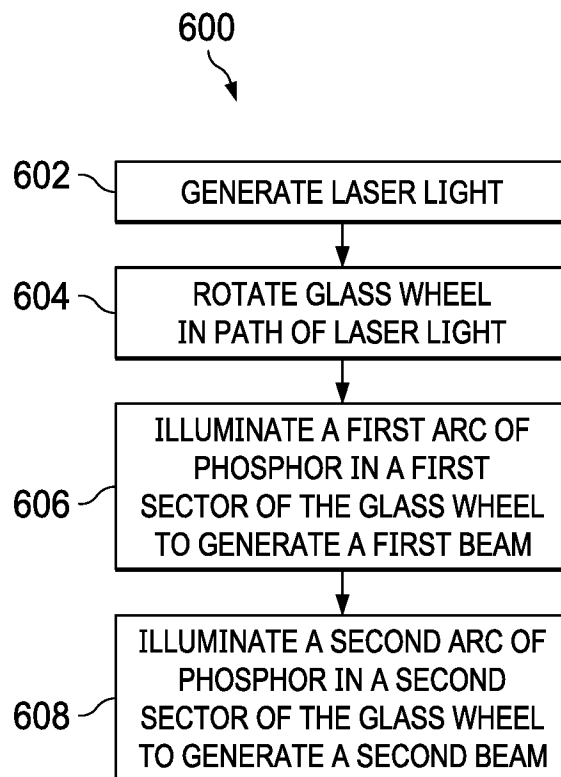


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2020/017514

A. CLASSIFICATION OF SUBJECT MATTER <i>G02B 26/08 (2006.01)</i> <i>G03B 21/14 (2006.01)</i>		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
G02B 26/00, 26/08 G03B 21/00, 21/14		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, DWPI, EAPATIS, PATENTSCOPE, Information Retrieval System of FIPS		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2014/0253882 A1 (TEXAS INSTRUMENTS INCORPORATED) 11.09.2014	1-20
A	US 2015/0036106 A1 (NICHIA CORPORATION) 05.02.2015	1-20
A	CN 207601490 U (QINMEI PHOTOELECTRIC CO LTD) 10.07.2018	1-20
A	JP 2011170363 (CASIO COMPUTER CO LTD) 01.09.2011	1-20
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
*	Special categories of cited documents:	“T” “X” “Y” “&” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art document member of the same patent family
“A”	document defining the general state of the art which is not considered to be of particular relevance	
“E”	earlier document but published on or after the international filing date	
“L”	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	
“O”	document referring to an oral disclosure, use, exhibition or other means	
“P”	document published prior to the international filing date but later than the priority date claimed	
Date of the actual completion of the international search		Date of mailing of the international search report
25 May 2020 (25.05.2020)		28 May 2020 (28.05.2020)
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37		Authorized officer M. Koltsova Telephone No. (499) 240-25-91