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12/789,303 27 May 2010 (27.05.2010) US(71) Applicant (for all designated States except US): **SORAA, INC.** [US/US]; 485 Pine Avenue, Goleta, California 93117 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **RARING, James W.** [US/US]; 485 Pine Avenue, Goleta, California 93117 (US). **RUDY, Paul** [US/US]; 485 Pine Avenue, Goleta, California 93117 (US).(74) Agents: **KAO, Dah-Bin** et al.; Townsend and Townsend and Crew LLP, Two Embarcadero Center, 8th Floor, Palo Alto, California 94111 (US).

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(54) Title: LASER BASED DISPLAY METHOD AND SYSTEM

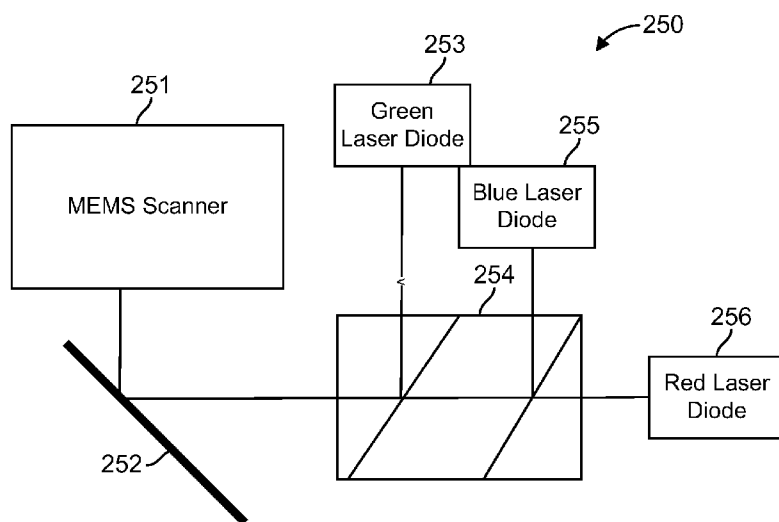


FIG. 2

(57) Abstract: The present invention is directed to display technologies. More specifically, various embodiments of the present invention provide projection display systems where one or more laser diodes are used as light source for illustrating images. In one set of embodiments, the present invention provides projector systems that utilize blue and/or green laser fabricated using gallium nitride containing material. In another set of embodiments, the present invention provides projection systems having digital lighting processing engines illuminated by blue and/or green laser devices. In one embodiment, the present invention provides a 3D display system. There are other embodiments as well.



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LASER BASED DISPLAY METHOD AND SYSTEM**CROSS-REFERENCES TO RELATED APPLICATIONS**

- 5 [0001] The present application claims priority to U.S. Provisional Patent Application No. 61/182,105, filed May 29, 2009. The present application also claims priority to U.S. Application No. 12/789,303, filed May 27, 2010.

**STATEMENT AS TO RIGHTS TO INVENTIONS MADE UNDER
FEDERALLY SPONSORED RESEARCH AND DEVELOPMENT**

10

[0002] NOT APPLICABLE

**REFERENCE TO A "SEQUENCE LISTING," A TABLE, OR A COMPUTER
PROGRAM LISTING APPENDIX SUBMITTED ON A COMPACT DISK**

15

[0003] NOT APPLICABLE

BACKGROUND OF THE INVENTION

- 20 [0004] The present invention is directed to display technologies. More specifically, various embodiments of the present invention provide projection display systems where one or more laser diodes and/or LEDs are used as light source for illustrating images. In one set of embodiments, the present invention provides projector systems that utilize blue and/or green laser fabricated using gallium nitride containing material. In another set of embodiments, the present invention provides projection systems having digital lighting processing engines
- 25 illuminated by blue and/or green laser devices. In a specific embodiment, the present invention provides a 3D display system. There are other embodiments as well.

- [0005] Large displays are becoming increasingly popular and are expected to gain further traction in the coming years as LCD displays get cheaper for television and digital advertising becomes more popular at gas stations, malls, and coffee shops. Substantial growth (e.g., over
- 30 40%) has been seen in the past several years for large format displays (e.g., 40 inch TVs), and consumers have grown accustomed to larger displays for laptops and PCs as well. As more

viewing content is available via hand held device such as TV, internet and video, displays in handheld consumer electronics remain small (<3") with the keyboard, camera, and other features competing for space and power.

[0006] Therefore, improved systems for displaying images and/or videos are desired.

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BRIEF SUMMARY OF THE INVENTION

[0007] The present invention is directed to display technologies. More specifically, various embodiments of the present invention provide projection display systems where one or more laser diodes are used as light source for illustrating images. In one set of embodiments, the present invention provides projector systems that utilize blue and/or green laser fabricated using gallium nitride containing material. In another set of embodiments, the present invention provides projection systems having digital lighting processing engines illuminated by blue and/or green laser devices. There are other embodiments as well.

[0008] According to an embodiment, the present invention provides a projection system. The projection system includes an interface for receiving video. The system also includes an image processor for processing the video. The system includes a light source including a plurality of laser diodes. The plurality of laser diodes includes a blue laser diode. The blue laser diode is fabricated on non-polar oriented gallium nitride material. The system includes a power source electrically coupled to the light source.

[0009] According to another embodiment, the present invention provides a projection system. The system includes an interface for receiving video. The system also includes an image processor for processing the video. The system includes a light source including a plurality of laser diodes. The plurality of laser diodes includes a blue laser diode. The blue laser diode is fabricated on semi-polar oriented gallium nitride material. The system also includes a power source electrically coupled to the light source.

[0010] According to an embodiment, the present invention provides a projection apparatus. The projection apparatus includes a housing having an aperture. The apparatus also includes an input interface for receiving one or more frames of images. The apparatus includes a video processing module. Additionally, the apparatus includes a laser source. The laser source includes a blue laser diode, a green laser diode, and a red laser diode. The blue laser diode is fabricated on a nonpolar or semipolar oriented Ga-containing substrate and has a peak operation wavelength of about 430 to 480nm. The green laser diode is fabricated on a nonpolar or semipolar oriented Ga-containing substrate and has a peak operation wavelength

of about 490nm to 540nm. The red laser could be fabricated from AlInGaP. The laser source is configured produce a laser beam by combining outputs from the blue, green, and red laser diodes. The apparatus also includes a laser driver module coupled to the laser source. The laser driver module generates three drive currents based on a pixel from the one or more frames of images. Each of the three drive currents is adapted to drive a laser diode. The apparatus also includes a microelectromechanical system (MEMS) scanning mirror, or “flying mirror”, configured to project the laser beam to a specific location through the aperture resulting in a single picture. By rastering the pixel in two dimensions a complete image is formed. The apparatus includes an optical member provided within proximity of the laser source, the optical member being adapted to direct the laser beam to the MEMS scanning mirror. The apparatus includes a power source electrically coupled to the laser source and the MEMS scanning mirror.

[0011] According to an embodiment, the present invention provides a projection apparatus. The projection apparatus includes a housing having an aperture. The apparatus also includes an input interface for receiving one or more frames of images. The apparatus includes a video processing module. Additionally, the apparatus includes a laser source. The laser source includes a blue laser diode, a green laser diode, and a red laser diode. The blue laser diode is fabricated on a nonpolar or semipolar oriented Ga-containing substrate and has a peak operation wavelength of about 430 to 480nm. The green laser diode is fabricated on a nonpolar or semipolar oriented Ga-containing substrate and has a peak operation wavelength of about 490nm to 540nm. In this embodiment, the blue and the green laser diode would share the same substrate. The red laser could be fabricated from AlInGaP. The laser source is configured produce a laser beam by combining outputs from the blue, green, and red laser diodes. The apparatus also includes a laser driver module coupled to the laser source. The laser driver module generates three drive currents based on a pixel from the one or more frames of images. Each of the three drive currents is adapted to drive a laser diode. The apparatus also includes a MEMS scanning mirror, or “flying mirror”, configured to project the laser beam to a specific location through the aperture resulting in a single picture. By rastering the pixel in two dimensions a complete image is formed. The apparatus includes an optical member provided within proximity of the laser source, the optical member being adapted to direct the laser beam to the MEMS scanning mirror. The apparatus includes a power source electrically coupled to the laser source and the MEMS scanning mirror.

[0012] According to an embodiment, the present invention provides a projection apparatus. The projection apparatus includes a housing having an aperture. The apparatus also includes

an input interface for receiving one or more frames of images. The apparatus includes a video processing module. Additionally, the apparatus includes a laser source. The laser source includes a blue laser diode, a green laser diode, and a red laser diode. The blue laser diode is fabricated on a nonpolar or semipolar oriented Ga-containing substrate and has a peak operation wavelength of about 430 to 480nm. The green laser diode is fabricated on a nonpolar or semipolar oriented Ga-containing substrate and has a peak operation wavelength of about 490nm to 540nm. The red laser could be fabricated from AlInGaP. In this embodiment, two or more of the different color lasers would be packaged together in the same enclosure. In this copackaging embodiment, the outputs from the blue, green, and red laser diodes would be combined into a single beam. The apparatus also includes a laser driver module coupled to the laser source. The laser driver module generates three drive currents based on a pixel from the one or more frames of images. Each of the three drive currents is adapted to drive a laser diode. The apparatus also includes a microelectromechanical system (MEMS) scanning mirror, or “flying mirror”, configured to project the laser beam to a specific location through the aperture resulting in a single picture. By rastering the pixel in two dimensions a complete image is formed. The apparatus includes an optical member provided within proximity of the laser source, the optical member being adapted to direct the laser beam to the MEMS scanning mirror. The apparatus includes a power source electrically coupled to the laser source and the MEMS scanning mirror.

[0013] According to another embodiment, the present invention provides a projection apparatus. The apparatus includes a housing having an aperture. The apparatus includes an input interface for receiving one or more frames of images. The apparatus includes a laser source. The laser source includes a blue laser diode, a green laser diode, and a red laser diode. The blue laser diode is fabricated on a nonpolar or semipolar oriented Ga-containing substrate and has a peak operation wavelength of about 430 to 480nm. The green laser diode is fabricated on a nonpolar or semipolar oriented Ga-containing substrate and has a peak operation wavelength of about 490nm to 540nm. The red laser could be fabricated from AlInGaP. The laser source is configured produce a laser beam by combining outputs from the blue, green, and red laser diodes. The apparatus includes a digital light processing (DLP) chip comprising a digital mirror device. The digital mirror device including a plurality of mirrors, each of the mirrors corresponding to one or more pixels of the one or more frames of images. The apparatus includes a power source electrically coupled to the laser source and the digital light processing chip. Many variations of this embodiment could exist, such as an embodiment where the green and blue laser diode share the same substrate or two or more of

the different color lasers could housed in the same packaged. In this copackaging embodiment, the outputs from the blue, green, and red laser diodes would be combined into a single beam.

[0014] According to another embodiment, the present invention provides a projection apparatus. The apparatus includes a housing having an aperture. The apparatus includes an input interface for receiving one or more frames of images. The apparatus includes a laser source. The laser source includes a blue laser diode, a green laser diode, and a red laser diode. The blue laser diode is fabricated on a nonpolar or semipolar oriented Ga-containing substrate and has a peak operation wavelength of about 430 to 480nm. The green laser diode is fabricated on a nonpolar or semipolar oriented Ga-containing substrate and has a peak operation wavelength of about 490nm to 540nm. The red laser could be fabricated from AlInGaP. The apparatus includes a digital light processing chip (DLP) comprising three digital mirror devices. Each of the digital mirror devices includes a plurality of mirrors. Each of the mirrors corresponds to one or more pixels of the one or more frames of images. The color beams are respectively projected onto the digital mirror devices. The apparatus includes a power source electrically coupled to the laser sources and the digital light processing chip. Many variations of this embodiment could exist, such as an embodiment where the green and blue laser diode share the same substrate or two or more of the different color lasers could housed in the same packaged. In this copackaging embodiment, the outputs from the blue, green, and red laser diodes would be combined into a single beam.

[0015] As an example, the color wheel may include phosphor material that modifies the color of light emitted from the light source. In a specific embodiment, the color wheel includes multiple regions, each of the regions corresponding to a specific color (e.g., red, green, blue, etc.). In an exemplary embodiment, a projector includes a light source that includes blue and red light sources. The color wheel includes a slot for the blue color light and a phosphor containing region for converting blue light to green light. In operation, the blue light source (e.g., blue laser diode or blue LED) provides blue light through the slot and excites green light from the phosphor containing region; the red light source provides red light separately. The green light from the phosphor may be transmitted through the color wheel, or reflected back from it. In either case the green light is collected by optics and redirected to the microdisplay. The blue light passed through the slot is also directed to the microdisplay. The blue light source may be a laser diode or LED fabricated on non-polar or semi-polar oriented GaN. Alternatively, a green laser diode may be used, instead of a blue

laser diode with phosphor, to emit green light. It is to be appreciated that can be other combinations of colored light sources and color wheels thereof.

[0016] As another example, the color wheel may include multiple phosphor materials. For example, the color wheel may include both green and red phosphors in combination with a blue light source. In a specific embodiment, the color wheel includes multiple regions, each of the regions corresponding to a specific color (e.g., red, green, blue, etc.). In an exemplary embodiment, a projector includes a light source that includes a blue light source. The color wheel includes a slot for the blue laser light and two phosphor containing regions for converting blue light to green light, and blue light and to red light, respectively. In operation, the blue light source (e.g., blue laser diode or blue LED) provides blue light through the slot and excites green light and red light from the phosphor containing regions. The green and red light from the phosphor may be transmitted through the color wheel, or reflected back from it. In either case the green and red light is collected by optics and redirected to the microdisplay. The blue light source may be a laser diode or LED fabricated on non-polar or semi-polar oriented GaN. It is to be appreciated that can be other combinations of colored light sources and color wheels thereof.

[0017] As another example, the color wheel may include blue, green, and red phosphor materials. For example, the color wheel may include blue, green and red phosphors in combination with a ultra-violet (UV) light source. In a specific embodiment, color wheel includes multiple regions, each of the regions corresponding to a specific color (e.g., red, green, blue, etc.). In an exemplary embodiment, a projector includes a light source that includes a UV light source. The color wheel includes three phosphor containing regions for converting UV light to blue light, UV light to green light, and UV light and to red light, respectively. In operation, the color wheel emits blue, green, and red light from the phosphor containing regions in sequence. The blue, green and red light from the phosphor may be transmitted through the color wheel, or reflected back from it. In either case the blue, green, and red light is collected by optics and redirected to the microdisplay. The UV light source may be a laser diode or LED fabricated on non-polar or semi-polar oriented GaN. It is to be appreciated that can be other combinations of colored light sources and color wheels thereof.

[0018] According to yet another embodiment, the present invention provides a projection apparatus. The apparatus includes a housing having an aperture. The apparatus includes an input interface for receiving one or more frames of images. The apparatus includes a laser source. The laser source includes a blue laser diode, a green laser diode, and a red laser diode. The blue laser diode is fabricated on a nonpolar or semipolar oriented Ga-containing

substrate and has a peak operation wavelength of about 430 to 480nm. The green laser diode is fabricated on a nonpolar or semipolar oriented Ga-containing substrate and has a peak operation wavelength of about 490nm to 540nm. The red laser could be fabricated from AlInGaP. The green laser diode has a wavelength of about 490nm to 540nm. The laser

5 source is configured produce a laser beam by coming outputs from the blue, green, and red laser diodes. The apparatus includes a digital light processing chip comprising three digital mirror devices. Each of the digital mirror devices includes a plurality of mirrors. Each of the mirrors corresponds to one or more pixels of the one or more frames of images. The color beams are respectively projected onto the digital mirror devices. The apparatus includes a

10 power source electrically coupled to the laser sources and the digital light processing chip.

Many variations of this embodiment could exist, such as an embodiment where the green and blue laser diode share the same substrate or two or more of the different color lasers could housed in the same packaged. In this copackaging embodiment, the outputs from the blue, green, and red laser diodes would be combined into a single beam.

15 **[0019]** As an example, the color wheel may include phosphor material that modifies the color of light emitted from the light source. In a specific embodiment, the color wheel includes multiple regions, each of the regions corresponding to a specific color (e.g., red, green, blue, etc.). In an exemplary embodiment, a projector includes a light source that includes blue and red light sources. The color wheel includes a slot for the blue color light

20 and a phosphor containing region for converting blue light to green light. In operation, the blue light source (e.g., blue laser diode or blue LED) provides blue light through the slot and excites green light from the phosphor containing region; the red light source provides red light separately. The green light from the phosphor may be transmitted through the color wheel, or reflected back from it. In either case the green light is collected by optics and

25 redirected to the microdisplay. The blue light passed through the slot is also directed to the microdisplay. The blue light source may be a laser diode or LED fabricated on non-polar or semi-polar oriented GaN. Alternatively, a green laser diode may be used, instead of a blue laser diode with phosphor, to emit green light. It is to be appreciated that can be other combinations of colored light sources and color wheels thereof.

30 **[0020]** As another example, the color wheel may include multiple phosphor materials. For example, the color wheel may include both green and red phosphors in combination with a blue light source. In a specific embodiment, the color wheel includes multiple regions, each of the regions corresponding to a specific color (e.g., red, green, blue, etc.). In an exemplary embodiment, a projector includes a light source that includes a blue light source. The color

wheel includes a slot for the blue laser light and two phosphor containing regions for converting blue light to green light, and blue light and to red light, respectively. In operation, the blue light source (e.g., blue laser diode or blue LED) provides blue light through the slot and excites green light and red light from the phosphor containing regions. The green and red light from the phosphor may be transmitted through the color wheel, or reflected back from it. In either case the green and red light is collected by optics and redirected to the microdisplay. The blue light source may be a laser diode or LED fabricated on non-polar or semi-polar oriented GaN. It is to be appreciated that can be other combinations of colored light sources and color wheels thereof.

10 [0021] As another example, the color wheel may include blue, green, and red phosphor materials. For example, the color wheel may include blue, green and red phosphors in combination with a ultra-violet (UV) light source. In a specific embodiment, color wheel includes multiple regions, each of the regions corresponding to a specific color (e.g., red, green, blue, etc.). In an exemplary embodiment, a projector includes a light source that
15 includes a UV light source. The color wheel includes three phosphor containing regions for converting UV light to blue light, UV light to green light, and UV light and to red light, respectively. In operation, the color wheel emits blue, green, and red light from the phosphor containing regions in sequence. The blue, green and red light from the phosphor may be transmitted through the color wheel, or reflected back from it. In either case the blue, green,
20 and red light is collected by optics and redirected to the microdisplay. The UV light source may be a laser diode or LED fabricated on non-polar or semi-polar oriented GaN. It is to be appreciated that can be other combinations of colored light sources and color wheels thereof.

[0022] Various benefits are achieved over pre-existing techniques using the present invention. In particular, the present invention enables a cost-effective projection systems that
25 utilizes efficient light sources. In a specific embodiment, the light source can be manufactured in a relatively simple and cost effective manner. Depending upon the embodiment, the present apparatus and method can be manufactured using conventional materials and/or methods according to one of ordinary skill in the art. In one or more embodiments, the laser device is capable of multiple wavelengths. Of course, there can be
30 other variations, modifications, and alternatives. Depending upon the embodiment, one or more of these benefits may be achieved. These and other benefits may be described throughout the present specification and more particularly below.

[0023] The present invention achieves these benefits and others in the context of known process technology. However, a further understanding of the nature and advantages of the

present invention may be realized by reference to the latter portions of the specification and attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Figure 1 is a diagram illustrating a conventional projection system.

5 [0025] Figure 2 is a simplified diagram illustrating a projection device according to an embodiment of the present invention.

[0026] Figure 2A is a detailed cross-sectional view of a laser device 200 fabricated on a {20-21} substrate according to an embodiment of the present invention.

[0027] Figure 2B is a simplified diagram illustrating a projector having LED light sources.

10 [0028] Figure 3 is an alternative illustration of a projection device according to an embodiment of the present invention.

[0029] Figure 3A is a simplified diagram illustrating a laser diodes packaged together according to an embodiment of the present invention.

15 [0030] Figure 3B is a diagram illustrating a cross section of active region with graded emission wavelength according to an embodiment of the present invention.

[0031] Figure 3C is a simplified diagram illustrating a cross section of multiple active regions according to an embodiment of the present invention.

[0032] Figure 3D is a simplified diagram illustrating a projector having LED light sources.

20 [0033] Figure 4 is a simplified diagram illustrating a projection device according to an embodiment of the present invention.

[0034] Figure 4A is a simplified diagram illustrating laser diodes integrated into single package according to an embodiment of the present invention.

[0035] Figure 5 is a simplified diagram of a DLP projection device according to an embodiment of the present invention.

25 [0036] Figure 5A is a simplified diagram illustrating a DLP projector according to an embodiment of the present invention.

[0037] Figure 6 is simplified diagram illustrating a 3-chip DLP projection system according to an embodiment of the present invention.

[0038] Figure 7 is a simplified diagram illustrating 3D display involving polarized images filtered by polarized glasses.

[0039] Figure 8 is a simplified diagram illustrating a 3D projection system according to an embodiment of the present invention.

5 [0040] Figure 9 is a simplified diagram illustrating a LCOS projection system 900 according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0041] The present invention is directed to display technologies. More specifically, various embodiments of the present invention provide projection display systems where one or more
10 laser diodes are used as light source for illustrating images. In one set of embodiments, the present invention provides projector systems that utilize blue and/or green laser fabricated using gallium nitride containing material. In another set of embodiments, the present invention provides projection systems having digital lighting processing engines illuminated by blue and/or green laser devices. There are other embodiments as well.

15 [0042] As explained above, conventional display type are often inadequate. Miniature projectors address this problem by projecting large images (up to 60 inch and above) from the hand held device, allowing movies, internet surfing and other images to be shared in a size format consistent with the displays customers are accustomed to. As a result, pocket projectors, standalone companion pico projectors, and embedded pico projectors in mobile
20 devices such as phones are becoming increasingly available.

[0043] Present day commercial InGaN-based lasers and LEDs are grown on the polar c-plane of the GaN crystal. It is well known that InGaN light emitting layers deposited on this conventional GaN orientation suffer from internal polarization-related electric fields. In these structures, spontaneous polarization results from charge asymmetry in the GaN bonding,
25 while piezoelectric polarization is the product of strain. In quantum well structures, these polarization fields spatially separate the electron and hole wave functions, reducing their radiative recombination efficiency. Due to the strain dependence of piezoelectric polarization, these internal fields grow stronger for with increased-indium-content in the emitting layers required for blue and especially for green lasers and LEDs.

30 [0044] In addition to a reduced radiative recombination coefficient to hinder LED brightness, the internal electric fields induce the quantum confined Stark effect (QCSE) within the light emitting quantum well layers. This effect results in a blue-shift of the peak

emission wavelength with increased carrier density in the quantum well layers. Since the carrier density is increased with increased current, a blue or green LED will undergo a shift in peak wavelength as a function of current. Such wavelength dependence on drive current would not be ideal for display applications where the LED is subjected to a current modulation scheme since the color will change with current. In a laser diode the carrier density is increased with increasing current up until the onset of laser threshold where the gain overcomes the loss in the cavity. For achieving lasing wavelengths in the blue and green region, such a blue-shift in the peak wavelength below threshold forces the growth of light emitting layers with increased indium content to compensate the blue-shift. It is well-known that such an increase in indium content can result in degraded material quality due to increased strain and indium-segregation. For the realization of highly efficient blue and green lasers and LEDs, it is therefore desirable to mitigate or completely eliminate polarization-related electric fields.

[0045] It has been long understood that growth of device structures on non-conventional GaN orientations, such as the nonpolar a-plane or m-plane or on semipolar planes between nonpolar planes and the polar c-plane, the polarization fields could be eliminated or mitigated. On these novel crystal planes, unique design freedoms became available to both the epitaxial structure and the device structure. Further, the anisotropic strain of InGaN films grown on nonpolar and semipolar substrates results in a reduced effective hole mass, which can increase the differential gain and reduce the transparency current density in laser diodes. Devices such as blue and green lasers and LEDs fabricated on nonpolar and semipolar planes offer exciting potential for improved performance with higher radiative recombination efficiency, reduced peak wavelength blue-shift with drive current, increased device design flexibility, and favorable epitaxial growth quality

[0046] Typical projectors based on solid-state emitters include:

- a light source (laser or LED),
- optics,
- micro-display such as a liquid crystal on silicon (LCOS) or a digital micro-mirror device (DMD),
- driver boards, and
- power source (i.e., battery or power adapter).

[0047] Depending on the application, projection systems can utilize polarized or unpolarized lights. For example, single scanner based projection systems (e.g., pico

projectors) and DLP based systems typically use unpolarized light source. For certain applications, such as LCOS based projection systems, polarized light source is desirable. Usually, blue and green (maybe red) LEDs used in conventional projectors are unpolarized (or demonstrate low polarization ratio), thereby resulting in excessive optical losses from polarization dependent optical components and exhibit a poor spatial mode quality, which require large LCOS or LCD chips, and are not viable for compact designs because the light is not focusable into a small area. Due to the splitting of the X and Y electronic valence bands on nonpolar and semipolar GaN, the light emission from devices such as LEDs fabricated on these platforms is inherently polarized. By employing semipolar and/or nonpolar GaN based LEDs into projection displays using LCOS technologies or other light-valves requiring polarized light, the optical losses associated with the LEDs would be minimized without having to utilize added components such as polarization recyclers which increase the complexity and cost of the system. Conventional projection system often use laser and/or LED as light sources to illuminate images. Typically, laser light source provides better performance than LED light sources in projection systems.

[0048] Figure 1 is a diagram illustrating a conventional projection system. As shown, blue, green, and red laser lights are combined into a laser beam, which is then projected to an MEMS scanning mirror.

[0049] In a conventional projection system such as the one illustrated in Figure 1, a green second-harmonic generation (SHG) laser is used to provide green laser light. Currently there is no direct diode solution for green laser emission, forcing the use of frequency doubled 1060nm diode lasers which are expensive, bulky, difficult to modulate at high speeds, and emit a narrow spectrum causing speckle in the image. Furthermore, since these devices require generation of a second harmonic using periodically-pulsed lithium niobate (PPLN), there are significant inefficiencies associated with the technology.

[0050] First there is the efficiency of the 1060nm device itself. Second there is the optical coupling losses associated with guiding the light into and out of the PPLN. Third there is the conversion loss within the PPLN. Finally there is the loss associated with cooling the components to a precise temperature.

[0051] In order to manufacture highly efficient display that maximize battery life and minimize cost, size, and weight, optical losses must be minimized from the system. Sources of optical losses in systems include, but are not limited to, losses from optical elements whose transmission is polarization dependent. In many compact projector such as pico

projectors, a micro-display technology is used which is highly polarization sensitive, such as LCOS or LCD. A common LCOS based displays typically need highly polarized light sources based on the nature of the liquid crystal display technology.

5 [0052] In various embodiments, the present invention provides blue and green direct diode GaN based lasers that offers offer highly polarized output, single spatial mode, moderate to large spectral width, high efficiency, and high modulation rates ideal for various types of projection and displays, such as pico projectors, DLP projectors, liquid crystal based displays (e.g., liquid crystal on silicon or "LCOS"), and others.

10 [0053] It is to be appreciated that by using highly polarized light source in projection displays as provided by embodiments of the present invention, the optical efficiency can be maximized with minimal costs and maximum flexibility in the selection on optical components. Conventional illumination sources such as unpolarized LEDs and systems thereof, where complicated optics are required for polarization recycling to increase the efficiency from the non-polarized light source. In contrast, by forming blue and green laser
15 and/or LEDs on nonpolar or semipolar GaN the light output will be highly polarized eliminating the need for additional optics to deal with polarization.

[0054] As described in the present invention, direct diode lasers having GaN based laser are used for blue and green sources. Conventional c-plane GaN lasers emits unpolarized or near-unpolarized light when laser is below threshold. After the laser reaches threshold the
20 output light will become polarized with increased current. In contrast, lasers fabricated on nonpolar or semipolar GaN according to embodiments of the present invention emit polarized light below threshold and will also have an increased polarization ratio with increased current. By using highly polarized light source in projection displays, the optical efficiency can be maximized with minimal costs and maximum flexibility in the selection on optical
25 components.

[0055] In order to manufacturer a highly efficient displays that maximize battery life and minimize cost, size, and weight, optical losses must be minimized from the system. For LCOS systems, convention LCOS is often shrunk to be as small as possible to fit into a tiny volume and also to reduce cost. Therefore, for maximum optical efficiency and minimal
30 power consumption, size, and weight in the display, laser sources are required with high optical spatial brightness.

[0056] Conventional LEDs exhibit a poor spatial mode quality, thus requiring large LCOS or LCD chips, and are not viable for compact designs because the light is not focusable into a

small area. In contrast, blue and green direct diode GaN based lasers according to the present invention exhibit a single spatial mode for maximum throughput.

[0057] Embodiments of the present invention also provides the benefit of reduced speckling. For example, frequency doubled 1060nm diode lasers used in conventional systems produces a narrow spectrum which causes speckle in the image. Direct diode visible lasers (e.g., green laser) used in embodiments of the present invention offer as much as >100 x increase in the spectrum, substantially reducing speckle in the image and reducing the need for additional expensive and bulky components.

[0058] Moreover, frequency doubled 1060nm diode lasers used in conventional system are inefficient because of the second harmonic generation. Direct diode visible lasers used in the present invention offer the potential for substantially higher efficiency with the benefit of reduced optical components and size and weight of the system.

[0059] As explained above, a typical miniature projectors (e.g., pico projector) includes the following components:

- a light source (laser or LED),
- optics,
- micro-display such as a LCOS or a DMD display;
- driver boards
- power source, i.e., battery or power adapter

[0060] Currently, blue and green (maybe red) LEDs are unpolarized leading to excessive optical losses and exhibit a poor spatial mode quality, which require large LCOS or LCD chips, and are not viable for compact designs because the light is not focusable into a small area. Due to the splitting of the X and Y electronic valence bands on nonpolar and semipolar GaN, the light emission from devices such as LEDs fabricated on these platforms is inherently polarized. By employing semipolar and/or nonpolar GaN based LEDs into projection displays or other LCOS technologies, the optical losses associated with unpolarized LEDs would be minimized without having to utilize added components such as polarization recyclers which increase the complexity and cost of the system.

[0061] Currently there is no direct diode solution for green laser emission, forcing the use of frequency doubled 1060nm diode lasers which are expensive, bulky, difficult to modulate at high speeds, and emit a narrow spectrum causing speckle in the image. Furthermore, since these devices require generation of a second harmonic using periodically-pulsed lithium

niobate (PPLN), there are significant inefficiencies associated with the technology. First there is the efficiency of the 1060nm device itself, second there is the optical coupling losses associated with guiding the light into and out of the PPLN, third there is the conversion loss within the PPLN, And finally there is the loss associated with cooling the components to a precise temperature.

[0062] The blue and green direct diode GaN based lasers according to embodiments of the present invention offers highly polarized output, single spatial mode, moderate to large spectral width, high efficiency, and high modulation rates ideal for liquid crystal based displays.

[0063] Conventional approaches for frequency doubling achieves high spatial brightness, but it does not conveniently enable high modulation frequencies and produces image artifacts when attempted. This limits the modulation frequency of the source to ~100MHz where amplitude (analog) modulation must be utilized. With increased frequency capability to ~300MHz, pulsed (digital) modulation could be used which would simplify the system and eliminate the need for look-up tables.

[0064] With a direct diode solution afford by embodiments of the present invention, modulation frequencies beyond 300MHz can be achieved and digital operation can be realized. Nonpolar and/or semipolar based GaN lasers hold great promise for enabling the direct diode green solution, and therefore, digital scanning micro mirror projectors.

[0065] Figure 2 is a simplified diagram illustrating a projection device according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. A projection system 250 includes a MEMS scanning mirror 251, a mirror 252, an optical member 254, green laser diode 253, red laser diode 256, and blue laser diode 255.

[0066] As an example, the projection system 250 is a pico projector. In addition to the components illustrated in Figure 2, the projection system 250 also includes a housing having an aperture and an input interface for receiving one or more frames of images. The projection system 250 also includes a video processing module. In one embodiment, the video processing module is electrically coupled to an ASIC for driving the laser diodes and the MEMS scanning mirrorscanning mirror 251.

[0067] In one embodiment, the laser diodes together with the optical member 254 form a laser source. The green laser diode 253 is characterized by a wavelength of about 490nm to 540nm. The laser source is configured produce a laser beam by combining outputs from the blue, green, and red laser diodes. Depending on the application, various types of optical components may be used to combine the light outputs from the laser diodes. For example, optical components can be dichroic lenses, prisms, converging lenses, etc. In a specific embodiment, the combined laser beam is polarized.

[0068] In one embodiment, a laser driver module is provided. Among other things, the laser driver module is adapted to adjust the amount of power to be provided to the laser diodes. For example, the laser driver module generates three drive currents based one or more pixels from the one or more frames of images, each of the three drive currents being adapted to drive a laser diode. In a specific embodiment, the laser driver module is configured to generate pulse-modulated signal at a frequency range of about 50 to 300 MHz.

[0069] The MEMS scanning mirror 251 is configured to project the laser beam to a specific location through the aperture. For example, the MEMS scanning mirror 251 process one pixel at a specific time onto a specific location corresponding to an pixel of an image. At a high frequency, pixels projected by the MEMS scanning mirror 251 form images.

[0070] The MEMS scanning mirror 251 receives light from the laser source though mirror 252. As shown, the mirror 252 is provided within proximity of the laser source. Among other things, the optical member is adapted to direct the laser beam to the MEMS scanning mirror 251.

[0071] It is to be appreciated the projection system 250 include other components as well, such as a power source electrically coupled to the laser source and the MEMS scanning mirror 251. Other components can include buffer memory, communication interface, network interface, etc.

[0072] As described above, a key component of the projection system 250 is the laser light source. In contrast to conventional projection systems, embodiments of the present invention use highly efficient laser diodes. In a specific embodiment, the blue laser diode operates in a single lateral mode. For example, the blue laser diode is characterized by a spectral width of about 0.5nm to 2nm. In a specific embodiment, the blue laser diode is designed for integration into portable applications such as embedded and companion pico projectors and features 60 mW of 445 nm single mode output power in a compact TO-38 package. For example, the blue lasers operate with high efficiency and require minimal power

consumption over a broad temperature range, meeting the demanding requirements of consumer projection displays, defense pointers and illuminators, biomedical instrumentation and therapeutics, and industrial imaging applications. According to various embodiments, blue lasers are based on the Indium Gallium Nitride (InGaN) semiconductor technology and are fabricated on GaN substrates.

[0073] In various embodiments, the blue and green laser diodes are fabricated using GaN material. The blue laser diode may be semi-polar or non-polar. Similarly, the green laser diode can be semi-polar or non-polar. For example, the red laser diode can be fabricated using GaAlInP material. For example, following combinations of laser diodes are provided, but there could be others:

- Blue polar + Green nonpolar + Red* AlInGaP
- Blue polar + Green semipolar + Red* AlInGaP
- Blue polar + Green polar + Red* AlInGaP
- Blue semipolar + Green nonpolar + Red* AlInGaP
- Blue semipolar + Green semipolar + Red* AlInGaP
- Blue semipolar + Green polar + Red* AlInGaP
- Blue nonpolar + Green nonpolar + Red* AlInGaP
- Blue nonpolar + Green semipolar + Red* AlInGaP
- Blue nonpolar + Green polar + Red* AlInGaP

[0074] As an example, blue and green laser diodes can be manufactured on m-plane. In a specific embodiment, a blue or green laser diode includes a gallium nitride substrate member having the off-cut m-plane crystalline surface region. In a specific embodiment this offcut angle is between -2.0 and -0.5 degrees toward the c-plane. In a specific embodiment, the gallium nitride substrate member is a bulk GaN substrate characterized by having a semipolar or non-polar crystalline surface region, but can be others. In a specific embodiment, the bulk nitride GaN substrate comprises nitrogen and has a surface dislocation density below 10^5 cm^{-2} . The nitride crystal or wafer may comprise $\text{Al}_x\text{In}_y\text{Ga}_{1-x-y}\text{N}$, where $0 \leq x, y, x+y \leq 1$. In one specific embodiment, the nitride crystal comprises GaN, but can be others. In one or more embodiments, the GaN substrate has threading dislocations, at a concentration between about 10^5 cm^{-2} and about 10^8 cm^{-2} , in a direction that is substantially orthogonal or oblique with respect to the surface. As a consequence of the orthogonal or oblique orientation of the dislocations, the surface dislocation density is below about 10^5 cm^{-2} . In a specific embodiment, the device can be fabricated on a slightly off-cut semipolar substrate.

[0075] In a specific embodiment where the laser is fabricated on the {20-21} semipolar GaN surface orientation, the device has a laser stripe region formed overlying a portion of the off-cut crystalline orientation surface region. In a specific embodiment, the laser stripe region is characterized by a cavity orientation substantially in a projection of a c-direction, which is substantially normal to the a-direction. In a specific embodiment, the laser strip region has a first end and a second end. In a preferred embodiment, the laser cavity is oriented formed in a projection of the c-direction on a {20-21} gallium and nitrogen containing substrate having a pair of cleaved mirror structures, at the end of cavity. Of course, there can be other variations, modifications, and alternatives.

[0076] In a specific embodiment where the laser is fabricated on the nonpolar m-plane GaN surface orientation, the device has a laser stripe region formed overlying a portion of the off-cut crystalline orientation surface region. In a specific embodiment, the laser stripe region is characterized by a cavity orientation substantially in the c-direction, which is substantially normal to the a-direction. In a specific embodiment, the laser strip region has a first end and a second end. In a preferred embodiment, the laser cavity is oriented formed in the the c-direction on an m-plane gallium and nitrogen containing substrate having a pair of cleaved mirror structures, at the end of cavity. Of course, there can be other variations, modifications, and alternatives.

[0077] In a preferred embodiment, the device has a first cleaved facet provided on the first end of the laser stripe region and a second cleaved facet provided on the second end of the laser stripe region. In one or more embodiments, the first cleaved is substantially parallel with the second cleaved facet. Mirror surfaces are formed on each of the cleaved surfaces. The first cleaved facet comprises a first mirror surface. In a preferred embodiment, the first mirror surface is provided by a top-side skip-scribe scribing and breaking process. The scribing process can use any suitable techniques, such as a diamond scribe or laser scribe or combinations. In a specific embodiment, the first mirror surface comprises a reflective coating. The reflective coating is selected from silicon dioxide, hafnia, and titania, tantalum pentoxide, zirconia, including combinations, and the like. Depending upon the embodiment, the first mirror surface can also comprise an anti-reflective coating. Of course, there can be other variations, modifications, and alternatives.

[0078] Also in a preferred embodiment, the second cleaved facet comprises a second mirror surface. The second mirror surface is provided by a top side skip-scribe scribing and breaking process according to a specific embodiment. Preferably, the scribing is diamond scribed or laser scribed or the like. In a specific embodiment, the second mirror surface

comprises a reflective coating, such as silicon dioxide, hafnia, and titania, tantalum pentoxide, zirconia, combinations, and the like. In a specific embodiment, the second mirror surface comprises an anti-reflective coating. Of course, there can be other variations, modifications, and alternatives.

5 [0079] In a specific embodiment, the laser stripe has a length and width. The length ranges from about 50 microns to about 3000 microns. The strip also has a width ranging from about 0.5 microns to about 50 microns, but can be other dimensions. In a specific embodiment, the width is substantially constant in dimension, although there may be slight variations. The width and length are often formed using a masking and etching process, which are commonly
10 used in the art.

[0080] In a specific embodiment, the present invention provides an alternative device structure capable of emitting 501 nm and greater light in a ridge laser embodiment. The device is provided with one or more of the following epitaxially grown elements, but is not limiting:

15 an n-GaN cladding layer with a thickness from 100nm to 5000nm with Si doping level of $5E17$ to $3E18cm^{-3}$

an n-side SCH layer comprised of InGaN with molar fraction of indium of between 3% and 10% and thickness from 20 to 100 nm

multiple quantum well active region layers comprised of at least two 2.0-8.5nm
20 InGaN quantum wells separated by thin 2.5nm and greater, and optionally up to about 8nm, GaN barriers

a p-side SCH layer comprised of InGaN with molar a fraction of indium of between 1% and 10% and a thickness from 15 nm to 100 nm

25 an electron blocking layer comprised of AlGaN with molar fraction of aluminum of between 12% and 22% and thickness from 5nm to 20nm and doped with Mg.

a p-GaN cladding layer with a thickness from 400nm to 1000nm with Mg doping level of $2E17cm^{-3}$ to $2E19cm^{-3}$

a p⁺⁺-GaN contact layer with a thickness from 20nm to 40nm with Mg doping level of $1E19cm^{-3}$ to $1E21cm^{-3}$

[0081] In a specific embodiment, the laser device is fabricated on a {20-21} semipolar Ga-containing substrate. But it is to be understood that the laser device can be fabricated on other types of substrates such as nonpolar oriented Ga-containing substrate as well.

[0082] While light source based on red, green, and blue color sources are widely used, other combinations are possible as well. According to an embodiment of the present invention, the light source used in a projection system combines a yellow light source with the red, green, and blue light sources. For example, the addition of yellow light sources improves the color characteristics (e.g., allowing for wider color gamut) of RGB based projection and display systems. In a specific embodiment, an RGYB light sources is used for a projection system. The yellow light source can be a yellow laser diode manufactured from gallium nitride material or AlInGaP material. In various embodiments, the yellow light source can have a polar, non-polar, or semi-polar orientation. It is to be appreciated that projection systems according to the present invention may use light sources in other colors as well. For example, other colors include cyan, magenta, and others. In a specific embodiment, the laser diodes of the different colors are separately packaged. In another specific embodiment, the laser diodes of two or more of the different colors are copackaged. In yet another specific embodiment, the laser diodes of two or more of the different colors are fabricated on the same substrate. I

[0083] Figure 2A is a detailed cross-sectional view of a laser device 200 fabricated on a {20-21} substrate according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims herein. One of ordinary skill in the art would recognize other variations, modifications, and alternatives. As shown, the laser device includes gallium nitride substrate 203, which has an underlying n-type metal back contact region 201. In a specific embodiment, the metal back contact region is made of a suitable material such as those noted below and others. Further details of the contact region can be found throughout the present specification and more particularly below.

[0084] In a specific embodiment, the device also has an overlying n-type gallium nitride layer 205, an active region 207, and an overlying p-type gallium nitride layer structured as a laser stripe region 209. In a specific embodiment, each of these regions is formed using at least an epitaxial deposition technique of metal organic chemical vapor deposition (MOCVD), molecular beam epitaxy (MBE), or other epitaxial growth techniques suitable for GaN growth. In a specific embodiment, the epitaxial layer is a high quality epitaxial layer overlying the n-type gallium nitride layer. In some embodiments the high quality layer is

doped, for example, with Si or O to form n-type material, with a dopant concentration between about 10^{16} cm^{-3} and 10^{20} cm^{-3} .

5 [0085] In a specific embodiment, an n-type $\text{Al}_u\text{In}_v\text{Ga}_{1-u-v}\text{N}$ layer, where $0 \leq u, v, u+v \leq 1$, is deposited on the substrate. In a specific embodiment, the carrier concentration may lie in the range between about 10^{16} cm^{-3} and 10^{20} cm^{-3} . The deposition may be performed using MOCVD or MBE. Of course, there can be other variations, modifications, and alternatives.

10 [0086] As an example, the bulk GaN substrate is placed on a susceptor in an MOCVD reactor. After closing, evacuating, and back-filling the reactor (or using a load lock configuration) to atmospheric pressure, the susceptor is heated to a temperature between about 900 and about 1200 degrees Celsius in the presence of a nitrogen-containing gas. In one specific embodiment, the susceptor is heated to approximately 1100 degrees Celsius under flowing ammonia. A flow of a gallium-containing metalorganic precursor, such as trimethylgallium (TMG) or triethylgallium (TEG) is initiated, in a carrier gas, at a total rate between approximately 1 and 50 standard cubic centimeters per minute (sccm). The carrier
15 gas may comprise hydrogen, helium, nitrogen, or argon. The ratio of the flow rate of the group V precursor (ammonia) to that of the group III precursor (trimethylgallium, triethylgallium, trimethylindium, trimethylaluminum) during growth is between about 2000 and about 12000. A flow of disilane in a carrier gas, with a total flow rate of between about 0.1 and 10 sccm, is initiated.

20 [0087] In a specific embodiment, the laser stripe region is made of the p-type gallium nitride layer 209. In a specific embodiment, the laser stripe is provided by an etching process selected from dry etching or wet etching. In a preferred embodiment, the etching process is dry, but can be others. As an example, the dry etching process is an inductively coupled process using chlorine bearing species or a reactive ion etching process using similar
25 chemistries. Again as an example, the chlorine bearing species are commonly derived from chlorine gas or the like. The device also has an overlying dielectric region, which exposes 213 contact region. In a specific embodiment, the dielectric region is an oxide such as silicon dioxide or silicon nitride, but can be others. The contact region is coupled to an overlying metal layer 215. The overlying metal layer is a multilayered structure containing palladium and gold (Pd/Au), platinum and gold (Pt/Au), nickel gold (Ni/Au), but can be others. Of
30 course, there can be other variations, modifications, and alternatives.

[0088] In a specific embodiment, the laser device has active region 207. The active region can include one to twenty quantum well regions according to one or more embodiments. As

an example following deposition of the n-type $\text{Al}_u\text{In}_v\text{Ga}_{1-u-v}\text{N}$ layer for a predetermined period of time, so as to achieve a predetermined thickness, an active layer is deposited. The active layer may be comprised of multiple quantum wells, with 2-10 quantum wells. The quantum wells may be comprised of InGaN with GaN barrier layers separating them. In other embodiments, the well layers and barrier layers comprise $\text{Al}_w\text{In}_x\text{Ga}_{1-w-x}\text{N}$ and $\text{Al}_y\text{In}_z\text{Ga}_{1-y-z}\text{N}$, respectively, where $0 \leq w, x, y, z, w+x, y+z \leq 1$, where $w < u, y$ and/or $x > v, z$ so that the bandgap of the well layer(s) is less than that of the barrier layer(s) and the n-type layer. The well layers and barrier layers may each have a thickness between about 1 nm and about 20 nm. The composition and structure of the active layer are chosen to provide light emission at a preselected wavelength. The active layer may be left undoped (or unintentionally doped) or may be doped n-type or p-type. Of course, there can be other variations, modifications, and alternatives.

[0089] In a specific embodiment, the active region can also include an electron blocking region, and a separate confinement heterostructure. In some embodiments, an electron blocking layer is preferably deposited. The electron-blocking layer may comprise $\text{Al}_s\text{In}_t\text{Ga}_{1-s-t}\text{N}$, where $0 \leq s, t, s+t \leq 1$, with a higher bandgap than the active layer, and may be doped p-type. In one specific embodiment, the electron blocking layer comprises AlGaIn . In another embodiment, the electron blocking layer comprises an AlGaIn/GaN super-lattice structure, comprising alternating layers of AlGaIn and GaN , each with a thickness between about 0.2 nm and about 5 nm. In Of course, there can be other variations, modifications, and alternatives.

[0090] As noted, the p-type gallium nitride structure is deposited above the electron blocking layer and active layer(s). The p-type layer may be doped with Mg, to a level between about 10^{16} cm^{-3} and 10^{22} cm^{-3} , and may have a thickness between about 5 nm and about 1000 nm. The outermost 1-50 nm of the p-type layer may be doped more heavily than the rest of the layer, so as to enable an improved electrical contact. In a specific embodiment, the laser stripe is provided by an etching process selected from dry etching or wet etching. In a preferred embodiment, the etching process is dry, but can be others. The device also has an overlying dielectric region, which exposes 213 contact region. In a specific embodiment, the dielectric region is an oxide such as silicon dioxide, but can be others such as silicon nitride. Of course, there can be other variations, modifications, and alternatives.

[0091] It is to be appreciated the light source of the projector 250 may include one or more LED as well. Figure 2B is a simplified diagram illustrating a projector having LED light sources. This diagram is merely an example, which should not unduly limit the scope of the

claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As an example, the blue and green LEDs are manufactured from gallium nitride containing material. In one specific embodiment, the blue LED is characterized by a non-polar orientation. In another embodiment, the blue LED is characterized by a semi-polar orientation.

[0092] Figure 3 is an alternative illustration of a projection device according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. In Figure 3, a projection device includes an MEMS scanning mirror, a mirror, a light conversion member, a red laser diode, a blue diode, and green laser diode. The blue and green laser diodes as shown are integrated as a single package. For example, the blue and green laser shared the same substrate and surface. Output from the blue and green laser diodes are emitted from a common plane of surface. It is to be appreciated that that by having blue and green laser diodes co-packaged, it is possible to substantially reduce the size and cost (e.g., fewer parts) of the projector device.

[0093] In addition, the green and blue laser diodes are characterized by a high efficiency. For example, the blue on the green laser diode are manufactured from bulk gallium nitride material. The blue laser diode can be non-polar or semi-polar oriented. The green laser diodes similarly can be non-polar polar or semipolar. For example, following combinations of laser diodes are provided, but there could be others:

- Blue polar + Green nonpolar + Red* AlInGaP
- Blue polar + Green semipolar + Red* AlInGaP
- Blue polar + Green polar + Red* AlInGaP
- Blue semipolar + Green nonpolar + Red* AlInGaP
- Blue semipolar + Green semipolar + Red* AlInGaP
- Blue semipolar + Green polar + Red* AlInGaP
- Blue nonpolar + Green nonpolar + Red* AlInGaP
- Blue nonpolar + Green semipolar + Red* AlInGaP
- Blue nonpolar + Green polar + Red* AlInGaP

[0094] In one embodiment, the green laser diode is characterized by wavelength of between 480nm to 540nm, which is different from conventional production devices that use an infrared laser diode (i.e., emission wavelength of about 1060nm) and use SHG to double the frequency.

[0095] Figure 3A is a simplified diagram illustrating a laser diodes packaged together according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown in Figure 3A, two laser diodes are provided on a single package. For example, laser 1 as shown in a blue laser diode and laser 2 is a green laser diode. Optics may be used to combine the outputs of lasers.

[0096] The output of the two laser as shown in Figure 3A can be combined in various ways. For example, optical components such as dichroic lens, waveguide, can be used to combine the outputs of the laser 1 and laser 2 as shown.

10 [0097] In other embodiments, blue and green laser diodes are monolithically integrated. Figure 3B is a diagram illustrating a cross section of active region with graded emission wavelength according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As illustrating figure 15 3B, for example, active regions having different emission gradient are used. Ridged waveguides at different portion of the active region are adapted to emit different wavelength.

[0098] Figure 3C is a simplified diagram illustrating a cross section of multiple active regions according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. Among other things, each active region is associated with a specific wavelength.

[0099] It is to be appreciated the light source of the projector 300 may include one or more LED as well. Figure 3D is a simplified diagram illustrating a projector having LED light sources. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As an example, the blue and green LEDs are manufactured from gallium nitride containing material. In one specific embodiment, the blue LED is characterized by a non-polar orientation. In another embodiment, the blue LED is characterized by a semi-polar orientation.

30 [0100] Figure 4 is a simplified diagram illustrating a projection device according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown in Figure 4, blue, green, and red laser

diodes are integrated into a light source 401. The light source 401 is combines outputs of each of the laser diodes. The combined light is projected onto the mirror, which reflects the combined light onto the MEMS scanning mirror. It is to be appreciated that, by providing laser diodes in the same package, both the size and cost of the light source 401 can be reduced. For example, following combinations of laser diodes are provided, but there could be others:

- Blue polar + Green nonpolar + Red* AlInGaP
- Blue polar + Green semipolar + Red* AlInGaP
- Blue polar + Green polar + Red* AlInGaP
- Blue semipolar + Green nonpolar + Red* AlInGaP
- Blue semipolar + Green semipolar + Red* AlInGaP
- Blue semipolar + Green polar + Red* AlInGaP
- Blue nonpolar + Green nonpolar + Red* AlInGaP
- Blue nonpolar + Green semipolar + Red* AlInGaP
- Blue nonpolar + Green polar + Red* AlInGaP

[0101] Figure 4A is a simplified diagram illustrating laser diodes integrated into single package according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. For examples, laser 1 can be a green laser diode, laser 2 can be a red laser diode, and laser 3 can be a blue laser diode. Depending on the application, the green laser diode can be fabricated on a semi-polar, non-polar, or polar gallium containing substrates. Similarly, the blue laser diode can be formed on semi-polar, non-polar, or polar gallium containing substrates.

[0102] It is to be appreciated that various projection systems according to the present invention have wide range of applications. In various embodiments, the projections systems described above are integrated on cellular telephone, camera, personal computer, portable computer, and other electronic devices.

[0103] Figure 5 is a simplified diagram of a DLP projection device according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown in Figure 5, a projection apparatus includes, among other things, a light source, a condensing lens, a color wheel, a shaping lens,

and a digital lighting processor (DLP) board, and a projection lens. The DLP board, among other things, includes a processor, a memory, and a digital micromirror device (DMD).

[0104] As an example, the color wheel may include phosphor material that modifies the color of light emitted from the light source. In a specific embodiment, the color wheel includes multiple regions, each of the regions corresponding to a specific color (e.g., red, green, blue, etc.). In an exemplary embodiment, a projector includes a light source that includes blue and red light sources. The color wheel includes a slot for the blue color light and a phosphor containing region for converting blue light to green light. In operation, the blue light source (e.g., blue laser diode or blue LED) provides blue light through the slot and excites green light from the phosphor containing region; the red light source provides red light separately. The green light from the phosphor may be transmitted through the color wheel, or reflected back from it. In either case the green light is collected by optics and redirected to the microdisplay. The blue light passed through the slot is also directed to the microdisplay. The blue light source may be a laser diode and/or LED fabricated on non-polar or semi-polar oriented GaN. In some cases, by combining both blue lasers and blue LEDs, the color characteristics could be improved. Alternate sources for the green light could include green laser diodes and/or green LEDs, which could be fabricated from nonpolar or semipolar Ga-containing substrates. In some embodiments, it could be beneficial to include some combination of LEDs, lasers, and or phosphor converted green light. It is to be appreciated that can be other combinations of colored light sources and color wheels thereof.

[0105] As another example, the color wheel may include multiple phosphor materials. For example, the color wheel may include both green and red phosphors in combination with a blue light source. In a specific embodiment, the color wheel includes multiple regions, each of the regions corresponding to a specific color (e.g., red, green, blue, etc.). In an exemplary embodiment, a projector includes a light source that includes a blue light source. The color wheel includes a slot for the blue laser light and two phosphor containing regions for converting blue light to green light, and blue light and to red light, respectively. In operation, the blue light source (e.g., blue laser diode or blue LED) provides blue light through the slot and excites green light and red light from the phosphor containing regions. The green and red light from the phosphor may be transmitted through the color wheel, or reflected back from it. In either case the green and red light is collected by optics and redirected to the microdisplay. The blue light source may be a laser diode or LED fabricated on non-polar or semi-polar oriented GaN. It is to be appreciated that can be other combinations of colored light sources and color wheels thereof.

[0106] As another example, the color wheel may include blue, green, and red phosphor materials. For example, the color wheel may include blue, green and red phosphors in combination with a ultra-violet (UV) light source. In a specific embodiment, color wheel includes multiple regions, each of the regions corresponding to a specific color (e.g., red, green, blue, etc.). In an exemplary embodiment, a projector includes a light source that includes a UV light source. The color wheel includes three phosphor containing regions for converting UV light to blue light, UV light to green light, and UV light and to red light, respectively. In operation, the color wheel emits blue, green, and red light from the phosphor containing regions in sequence. The blue, green and red light from the phosphor may be transmitted through the color wheel, or reflected back from it. In either case the blue, green, and red light is collected by optics and redirected to the microdisplay. The UV light source may be a laser diode or LED fabricated on non-polar or semi-polar oriented GaN. It is to be appreciated that can be other combinations of colored light sources and color wheels thereof.

[0107] The light source as shown could be made laser-based. In one embodiment, the output from the light source is laser beam characterized by a substantially white color. In one embodiment, the light source combines light output from blue, green, and red laser diodes. For example, the blue, green, and red laser diode can be integrated into a single package as described above. Other combinations are possible as well. For example, blue and green laser diodes share a single package while the red laser diode is packaged by itself. In this embodiment the lasers can be individually modulated so that color is time-sequenced, and thus there is no need for the color wheel. The blue laser diode can be polar, semipolar, and non-polar. Similarly, green laser diode can be polar, semipolar, and non-polar. For example, blue and/or green diodes are manufactured from bulk substrate containing gallium nitride material. For example, following combinations of laser diodes are provided, but there could be others:

- Blue polar + Green nonpolar + Red* AlInGaP
- Blue polar + Green semipolar + Red* AlInGaP
- Blue polar + Green polar + Red* AlInGaP
- Blue semipolar + Green nonpolar + Red* AlInGaP
- Blue semipolar + Green semipolar + Red* AlInGaP
- Blue semipolar + Green polar + Red* AlInGaP
- Blue nonpolar + Green nonpolar + Red* AlInGaP
- Blue nonpolar + Green semipolar + Red* AlInGaP
- Blue nonpolar + Green polar + Red* AlInGaP

[0108] In Figure 5, the DLP projection system utilizes a color wheel to project one color (e.g., red, green, or blue) of light at a time to the DMD. The color wheel is needed because the light source continuously provide white light. It is to be appreciated that because solid state devices are used as light source in the embodiments of the present invention, a DLP projector according to the present invention does not require the color wheel shown in Figure 5. Figure 5A is a simplified diagram illustrating a DLP projector according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications.

[0109] In an alternative embodiment, the light source comprises a single laser diode. For example, the light source comprises a blue laser diode that outputs blue laser beams. The light source also includes one or more optical members that changes the blue color of the laser beam. For example, the one or more optical members includes phosphor material. The laser beam excites the phosphor material to form a substantially white emission source which becomes the light source for the projection display. In this embodiment, a color wheel is needed in order to sequence the blue, green, and red frames to the DLP.

[0110] A projection system 500 includes a light source 501, a light source controller 502, an optical member 504, and a DLP chip 505. The light source 501 is configured to emit a color light to the DMD 503 through the optical member 504. More specifically, the light source 501 includes colored laser diodes. For example, the laser diodes include red laser diode, blue laser diode, and green laser diode. At a predetermined time interval, a single laser diode is turn on while the other laser diodes are off, thereby emitting a single colored laser beam onto the DMD 503. The light source controller 502 provides control signal to the light source 501 to switch laser diodes on and off based on predetermined frequency and sequence. For example, the switching of laser diodes is similar to the function of the color wheel shown in Figure 5.

[0111] Figure 6 is a simplified diagram illustrating a 3-chip DLP projection system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown in Figure 5, the 3-chip DLP projection system includes a light source, optics, and multiple DMDs, and a color wheel system. As shown, each of the DMDs is associated with a specific color.

[0112] In various embodiment, the white light beam comprises a substantially white laser beam provided by the light source. In one embodiment, the output from the light source is laser beam characterized by a substantially white color. In one embodiment, the light source combines light output from blue, green, and red laser diodes. For example, the blue, green, and red laser diode can be integrated into a single package as described above. Other combinations are possible as well. For example, blue and green laser diodes share a single package while the red laser diode is packaged by itself. The blue laser diode can be polar, semipolar, and non-polar. Similarly, green laser diode can be polar, semipolar, and non-polar. For example, blue and/or green diodes are manufactured from bulk substrate containing gallium nitride material. For example, following combinations of laser diodes are provided, but there could be others:

- Blue polar + Green nonpolar + Red* AlInGaP
- Blue polar + Green semipolar + Red* AlInGaP
- Blue polar + Green polar + Red* AlInGaP
- Blue semipolar + Green nonpolar + Red* AlInGaP
- Blue semipolar + Green semipolar + Red* AlInGaP
- Blue semipolar + Green polar + Red* AlInGaP
- Blue nonpolar + Green nonpolar + Red* AlInGaP
- Blue nonpolar + Green semipolar + Red* AlInGaP
- Blue nonpolar + Green polar + Red* AlInGaP

[0113] In an alternative embodiment, the light source comprises a single laser diode. For example, the light source comprises a blue laser diode that outputs blue laser beams. The light source also includes one or more optical members that change the blue color of the laser beam. For example, the one or more optical members include phosphor material.

[0114] It is to be appreciated that the light source may include laser diodes and/or LEDs. In one embodiment, the light source includes laser diodes in different colors. For example, the light source may additionally include phosphor material for changing the light color emitted from the laser diodes. In another embodiment, the light source includes one or more colored LEDs. In yet another embodiment, light source includes both laser diodes and LEDs. For example, the light source may include phosphor material to change the light color for laser diodes and/or LEDs.

[0115] In various embodiments, laser diodes are utilized in 3D display applications. Typically, 3D display systems rely on the stereopsis principle, where stereoscopic technology

uses a separate device for each person viewing the scene which provides a different image to the person's left and right eyes. Examples of this technology include anaglyph images and polarized glasses. Figure 7 is a simplified diagram illustrating 3D display involving polarized images filtered by polarized glasses. As shown, the left eye and the right eye perceive
5 different images through the polarizing glasses.

[0116] The conventional polarizing glasses, which typically include circular polarization glasses used by RealD Cinema™, have been widely accepted in many theaters. Another type of image separation is provided by interference filter technology. For example, special interference filters in the glasses and in the projector form the main item of technology and
10 have given it this name. The filters divide the visible color spectrum into six narrow bands - two in the red region, two in the green region, and two in the blue region (called R1, R2, G1, G2, B1 and B2 for the purposes of this description). The R1, G1 and B1 bands are used for one eye image, and R2, G2, B2 for the other eye. The human eye is largely insensitive to such fine spectral differences so this technique is able to generate full-color 3D images with only
15 slight colour differences between the two eyes. Sometimes this technique is described as a "super-anaglyph" because it is an advanced form of spectral-multiplexing which is at the heart of the conventional anaglyph technique. In a specific example, the following set of wavelengths are used:

Left eye: Red 629nm, Green 532nm, Blue 446nm

20 Right eye: Red 615nm, Green 518nm, Blue 432nm

[0117] In various embodiments, the present invention provides a projection system for projecting 3D images, wherein laser diodes are used to provide basic RGB colors. Figure 8 is a simplified diagram illustrating a 3D projection system according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the
25 scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown in Figure 8, a projection system includes a projector 801. The projector 801 is configured to project images associated for one eye (e.g., left eye). The projector 801 includes a first light source. The first light source including a first set of laser diodes: a red laser diode, a green laser diode, and a blue laser diode. Each of
30 the laser diode is associated with a specific wavelength. For example, red laser diode is configured to emit a laser beam characterized by a wavelength of 629nm, green laser diode is configured to emit a laser beam characterized by a wavelength of 532nm, and blue laser

diode is configured to emit a laser beam characterized by a wavelength of 446nm. It is to be appreciated that other wavelengths are possible as well.

[0118] In various embodiments, the blue laser diode is characterized by a non-polar or semi-polar orientation. For example, the blue laser diode is fabricated from gallium nitride containing substrate. In one specific embodiment, the blue laser diode is manufactured from
5 bulk substrate material. Similarly, the green laser diode can be manufactured from gallium nitride containing substrate as well. For example, the green laser diode is characterized by a non-polar or semi-polar orientation.

[0119] It is to be appreciated that color LEDs may also be used to provide colored light for
10 the projection elements. For example, a red LED can be used instead of a red laser diode in providing the red light. Similarly LED and/or laser diodes in various colors can be interchangeably used as light sources. Phosphor material may be used to alter light color for light emitted from LED and/or laser diodes.

[0120] The projector 802 is configured to project images associated for the other eye (e.g.,
15 right eye). The second light source including a second set of laser diodes: a red laser diode, a green laser diode, and a blue laser diode. Each of the laser diode is associated with a specific wavelength, and each of the wavelengths is different from that of the corresponding laser diodes of the first light source. For example, the red laser diode is configured to emit a laser beam characterized by a wavelength of 615nm, the green laser diode is configured to emit a
20 laser beam characterized by a wavelength of 518nm, and the blue laser diode is configured to emit a laser beam characterized by a wavelength of 432nm. It is to be appreciated that other wavelengths are possible as well.

[0121] Projectors 801 and 802 shown in Figure 8 are positioned far apart, but it is to be appreciated that the two projectors may be integrally positioned within one housing unit. In
25 addition to light sources and image source, the projectors include optics for focusing images from the two projectors onto the same screen.

[0122] Depending on the specific application, various types of filters can be used to filter projected images for viewers. In one embodiment, bandpass filters are used. For example, a bandpass filter only allows one set of RGB color wavelength to pass to an eye. In another
30 embodiment, notch filters are used, where the notch filters would allow substantially all wavelength except a specific set of RGB color wavelength to pass to an eye. There can be other embodiments as well.

[0123] In certain embodiments, the present invention provides a liquid crystal on silicon (LCOS) projection system. Figure 9 is a simplified diagram illustrating a LCOS projection system 900 according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown in Figure 9, a green laser diode provides green laser light to the green LCOS through splitter 901; a blue laser diode provides blue laser light to the blue LCOS through splitter 903; and a red laser diode provides red laser light to the red LCOS through splitter 904. Each of the LCOS is used to form images in a predetermined single color as provided by its corresponding laser diode, and the single-colored image is combined by the x-cube component 902. The combined color image is projected onto the lens 906.

[0124] In various embodiments, one or more laser diodes used in the projection system 900 are characterized by semi-polar or non-polar orientation. In one embodiment, the laser diodes are manufactured from bulk substrate. In a specific embodiment, the blue and green laser diodes are manufactured from gallium nitride containing substrate. It is to be appreciated that color LEDs may also be used to provide colored light for the projection elements. For example, a red LED can be used instead of a red laser diode in providing the red light. Similarly LED and/or laser diodes in various colors can be interchangeably used as light sources. Phosphor material may be used to alter light color for light emitted from LED and/or laser diodes.

[0125] The LCOS projection system 900 comprises three panels. In an alternative embodiment, the present invention provides a projection system with a single LCOS panel. Red, green, and blue laser diodes are aligned where red, green, and blue laser beams are collimated onto a single LCOS. The laser diodes are pulse-modulated so that only one laser diode is power at a given time and the LCOS is lit by a single color. It is to be appreciated that since colored laser diodes are used, LCOS projection systems according to the present invention do not need beam splitter that split a single white light source into color beams as used in conventional LCOS projection systems. In various embodiments, one or more laser diodes used in the single LCOS projection system are characterized by semi-polar or non-polar orientation. In one embodiment, the laser diodes are manufactured from bulk substrate. In a specific embodiment, the blue and green laser diodes are manufactured from gallium nitride containing substrate. In various embodiments, the configuration illustrated in Figure 9 is also used in ferroelectric liquid crystal on silicon (FLCOS) systems. For example, the panels illustrated Figure 9 can be FLCOS panels.

[0126] While the above is a full description of the specific embodiments, various modifications, alternative constructions and equivalents may be used. Therefore, the above description and illustrations should not be taken as limiting the scope of the present invention which is defined by the appended claims.

WHAT IS CLAIMED IS:

1. A projection system comprising:
an interface for receiving images or video signal;
a light source including a plurality of laser diodes, the plurality of laser diodes including a first laser diode, the first laser diode being non-polar or semi-polar and fabricated from gallium nitride material; and
a power source electrically coupled to the light source.
2. The system of claim 1 wherein the first diode is a blue diode characterized by a non-polar orientation.
3. The system of claim 1 wherein the first diode is a blue diode characterized by a semi-polar orientation.
4. The system of claim 1 wherein the first diode is a green laser diode characterized by a non-polar orientation.
5. The system of claim 1 wherein the first diode is a green laser diode characterized by a semi-polar orientation.
6. A projection system comprising:
an interface for receiving images or video signal;
a light source including one or more LEDs, the one or more LEDs including a first LED, the first LED being non-polar or semi-polar and fabricated from gallium nitride material; and
a power source electrically coupled to the light source.
7. A light engine comprising:
a communication interface for receiving drive signals;
a light source including one or more LEDs, the one or more LEDs including a first LED, the first LED being non-polar or semi-polar and fabricated from gallium nitride material; and
a power source electrically coupled to the light source.

8. A light engine comprising:
a communication interface for receiving drive signals;
a light source including a plurality of laser diodes, the plurality of laser diodes including a first laser diode, the first laser diode being non-polar or semi-polar and fabricated from gallium nitride material; and
a power source electrically coupled to the light source.

9. The light engine of claim 8 further comprising a control module for selectively switching the plurality of laser diodes.

10. The light engine of claim 8 further comprising an optical member for combining outputs from at least two of the plurality of laser diodes.

11. A light engine comprising:
a communication interface for receiving drive signals;
a light source including a plurality of light emitting diodes (LED), the plurality of LEDs including a first LED, the LED being non-polar or semi-polar and fabricated from gallium nitride material; and
a power source electrically coupled to the light source.

12. A projection apparatus comprising:
a housing having an aperture;
an input interface for receiving one or more frames of images;
a video processing module;
a laser source, the laser source including a blue laser diode, a green laser diode, and a red laser diode, the blue laser diode and the green laser diode sharing a first mounting surface, the green laser diode having a wavelength of about 490nm to 540nm, the laser source being configured to produce a laser beam by combining outputs from the blue, green, and red laser diodes;
a laser driver module coupled to the laser source, the laser driver module being configured to generate three drive currents based on a pixel from the one or more frames of images, each of the three drive currents being adapted to drive a laser diode;

an MEMS scanning module configured to project the laser beam to a specific location through the aperture;

an optical member provided within proximity of the laser source, the optical member being adapted to direct the laser beam to the MEMS scanning module; and

a power source electrically coupled to the laser source.

13. The apparatus of claim 12 wherein the MEMS scanning module comprises a flying mirror scanner.

14. The apparatus of claim 12 wherein the MEMS scanning module comprises a single mirror scanner.

15. The apparatus of claim 12 wherein the laser beam is polarized.

16. The apparatus of claim 12 wherein the blue laser diode operates in a single spatial mode.

17. The apparatus of claim 12 wherein the blue laser diode is characterized by a spectral width of about 0.8nm to 2nm.

18. The apparatus of claim 12 wherein the blue laser diode and the green laser diode are fabricated from a same GaN substrate.

19. The apparatus of claim 12 wherein the MEMS scanning module comprises one or more drive coils.

20. The apparatus of claim 12 wherein the optical member comprises a mirror.

21. The apparatus of claim 12 wherein the green laser diode characterized by a non-polar orientation.

22. The apparatus of claim 12 wherein the green laser diode is characterized by a semi-polar orientation.

23. The apparatus of claim 12 wherein the blue laser diode is characterized by a semi-polar orientation.

24. The apparatus of claim 12 wherein the blue laser diode is characterized by a non-polar orientation.

25. The apparatus of claim 12 wherein the red laser diode comprises GaAlInP material.

26. The apparatus of claim 12 wherein the laser source comprises a waveguide for combining outputs from the green and blue laser diodes.

27. The apparatus of claim 12 wherein the laser source comprises one or more dichroic filters.

28. A projection apparatus comprising:

a housing having an aperture;

an input interface for receiving one or more frames of images;

a laser source, the laser source including a blue laser diode, a green laser diode, and a red laser diode, the blue laser diode and the green laser diode sharing a first mountain surface, the green laser diode having a wavelength of about 490nm to 540nm, the laser source being configured produce a laser beam by combining outputs from the blue, green, and red laser diodes;

a digital light processing chip comprising a digital mirror device, the digital mirror device including a plurality of mirrors, each of the mirror corresponding to one or more pixels of the one or more frames of images;

a power source electrically coupled to the laser source.

29. The apparatus of claim 28 further comprising a condensing lens.

30. The apparatus of claim 28 further comprising a projection lens.

31. The apparatus of claim 28 wherein the digital light processing chip comprises a buffer memory.

32. The apparatus of claim 28 wherein the green laser diode is characterized by a non-polar orientation.

33. The apparatus of claim 28 wherein the blue laser diode is characterized by a non-polar orientation.

34. The apparatus of claim 28 wherein the green laser diode is characterized by a semi-polar orientation.

35. The apparatus of claim 28 wherein the blue laser diode is characterized by a semi-polar orientation.

36. The apparatus of claim 28 comprising more than one digital mirror device.

37. A projection apparatus comprising:

a housing having an aperture;

an input interface for receiving one or more frames of images;

a laser source including a blue laser diode and a wavelength modifying module, the blue laser diode being a non-polar diode, the wavelength modifying module comprising phosphor material, the laser exciting the phosphor material to form a colored emission source;

a digital light processing chip comprising a digital mirror device, the digital mirror device including a plurality of mirrors, each of the mirror corresponding to one or more pixels of the one or more frames of images;

means for directing light from the blue laser diode and the colored emission sources to the digital mirror device; and

a power source electrically coupled to the laser source and the digital light processing chip.

38. A projection apparatus comprising:

a housing having an aperture;

an input interface for receiving one or more frames of images;

a laser source including a blue laser diode and a wavelength modifying module, the blue laser diode being a semi-polar diode, the wavelength modifying comprising phosphor material, the laser exciting the phosphor material to form a colored emission source;

a digital light processing chip comprising a digital mirror device, the digital mirror device including a plurality of mirrors, each of the mirror corresponding to one or more pixels of the one or more frames of images;

means for directing light from the blue laser diode and the colored emission sources to the digital mirror device; and

a power source electrically coupled to the laser source and the digital light processing chip.

39. A projection apparatus comprising:

a first video source, the first video source being associated with a first display, the first video source including a first light source, the first light source including a first blue laser diode characterized by a predetermined first wavelength, the first blue laser diode being manufactured from gallium nitride containing material;

a second video source, the second video source being associated with a second display, the first video source and the second video source being temporally synchronized, the second video source including a second light source, the second light source including a second blue laser diode characterized by a predetermined second wavelength, the second blue laser diode being manufactured gallium nitride material; and

a power source electrically coupled to the first video source.

40. The apparatus of claim 39 wherein:

the first light source further includes a first green laser diode and a first red laser diode, the first green laser diode being characterized by a predetermined third wavelength, the first red laser diode being associated with a predetermined by a predetermined fourth wavelength;

the second light source further includes a second green laser diode and second red laser diode, the second green laser diode being characterized by a predetermined fifth wavelength, the second red laser diode being characterized by a predetermined sixth wavelength; and

the predetermined first wavelength is different from the predetermined second wavelength by 10nm to 30nm.

41. The apparatus of claim 39 further comprising a video driver module for driving the first video source.

42. The apparatus of claim 39 wherein the first blue laser diode is characterized by a semi-polar orientation.

43. The apparatus of claim 39 wherein the first blue laser diode is characterized by a non-polar orientation.

44. The apparatus of claim 39 further comprising optics for projecting the first display and the second display onto a screen.

45. The apparatus of claim 39 wherein the first light source further comprises a green laser diode, the green laser diode being characterized by a non-polar orientation.

46. The apparatus of claim 39 wherein the first light source further comprises a green laser diode, the green laser diode being characterized by a semi-polar orientation.

47. The apparatus of claim 39 further comprising a sound module, the sound module being synchronized with the first video source.

48. The apparatus of claim 39 wherein:
the first display is visible through a first filter and substantially invisible through a second filter;

the second display is visible through the second filter and substantially invisible through the first filter;

the first filter being a notch filter blocking at least the second wavelength;

the second filter being a notch filter blocking at least the first wavelength.

49. The apparatus of claim 39 wherein:
the first display is visible through a first filter and substantially invisible through a second filter;

the second display is visible through the second filter and substantially invisible through the first filter;

the first filter being a bandpass filter blocking at least the second wavelength;

the second filter being a bandpass filter blocking at least the first wavelength.

50. A projection system comprising:
one or more LCOS panels;

a plurality of laser diodes configured to emit laser light onto the one or more LCOS panels, the plurality of laser diodes including a first laser diode, the first laser diode being characterized by a non-polar or semi-polar orientation; and

a power source electrically coupled to the plurality of laser diodes.

51. A projection system comprising:

one or more LCOS panels;

a plurality of LEDs configured to emit light onto the one or more LCOS panels, the plurality of LEDs including a first LED, the first LED being characterized by a non-polar or semi-polar orientation; and

a power source electrically coupled to the plurality of laser diodes.

52. A projection apparatus comprising:

a housing having an aperture;

an input interface for receiving one or more frames of images;

a light source, the light source including a blue laser diode, the blue laser diode being characterized by a semi-polar or non-polar orientation and manufactured from gallium containing material;

a digital light processing chip comprising a digital mirror device, the digital mirror device including a plurality of mirrors, each of the mirror corresponding to one or more pixels of the one or more frames of images;

a color wheel comprising a plurality of wavelength-modifying components, a plurality of wavelength-modifying components including a first component, the first component including phosphor material and corresponding to a predetermined time sequence; and

a power source electrically coupled to the light source and the digital light processing chip.

53. The apparatus of claim 52 wherein the light source further comprises phosphor material.

54. The apparatus of claim 52 wherein the light source further includes one or more LEDs.

55. The apparatus of claim 52 wherein the light source comprises a red LED.

56. The apparatus of claim 52 wherein the light source comprises a yellow emitting laser diode.

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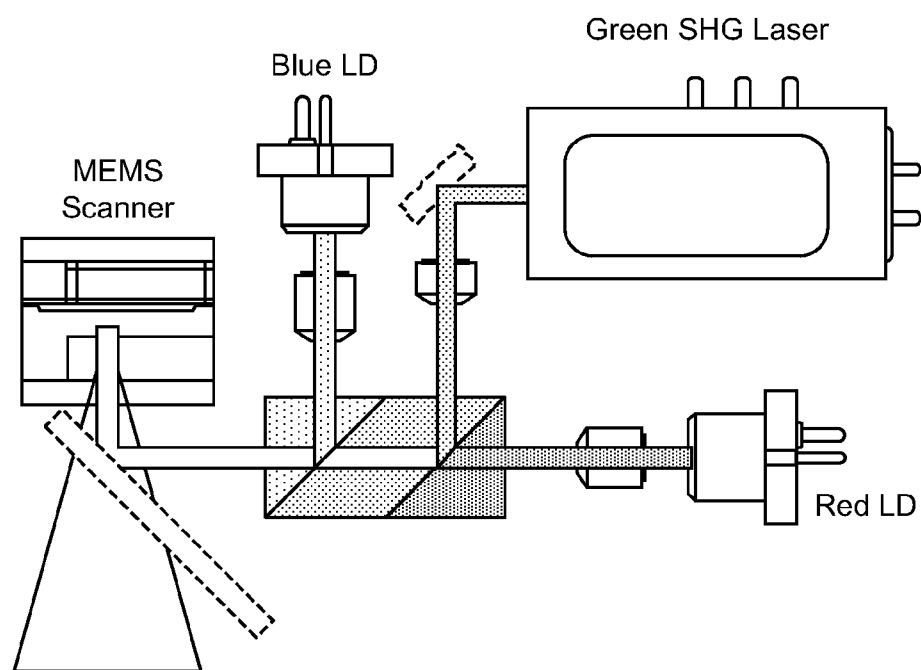


FIG. 1
Prior Art

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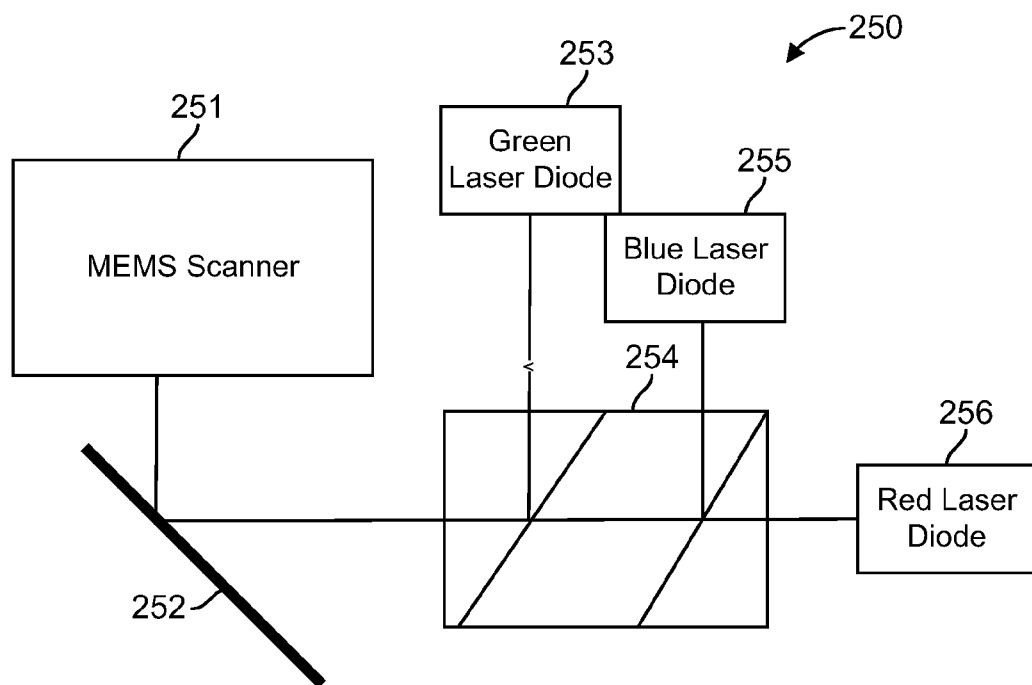


FIG. 2

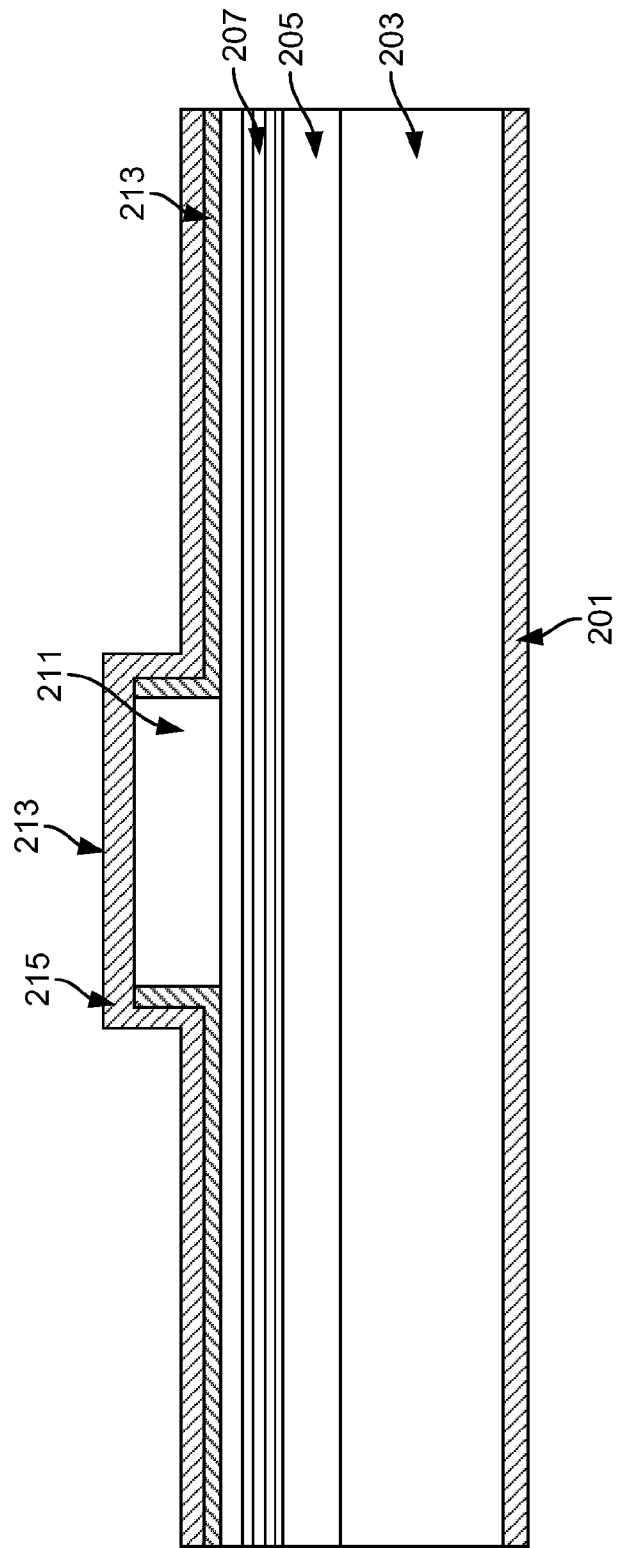


FIG. 2A

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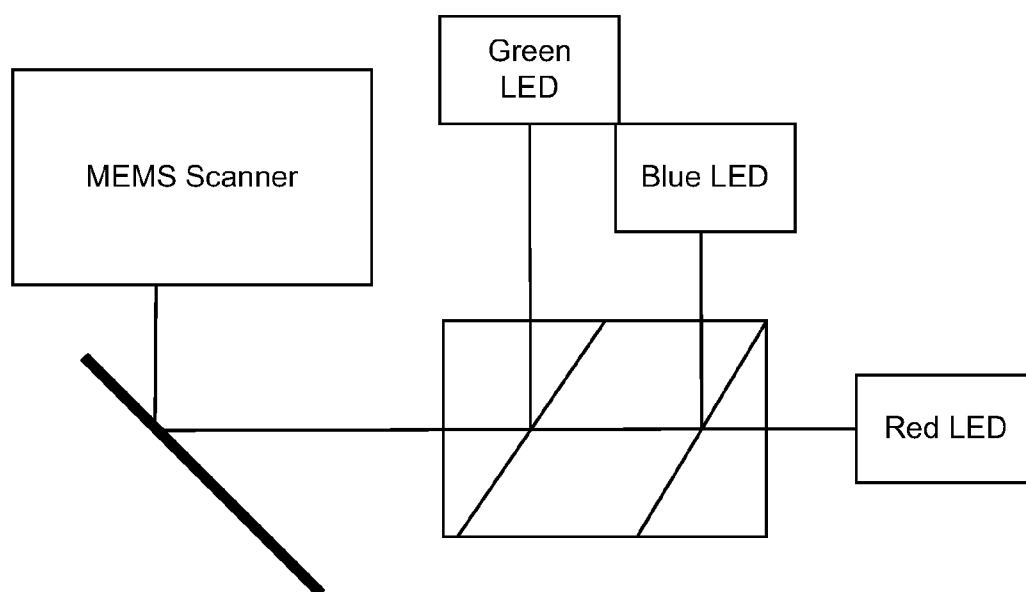


FIG. 2B

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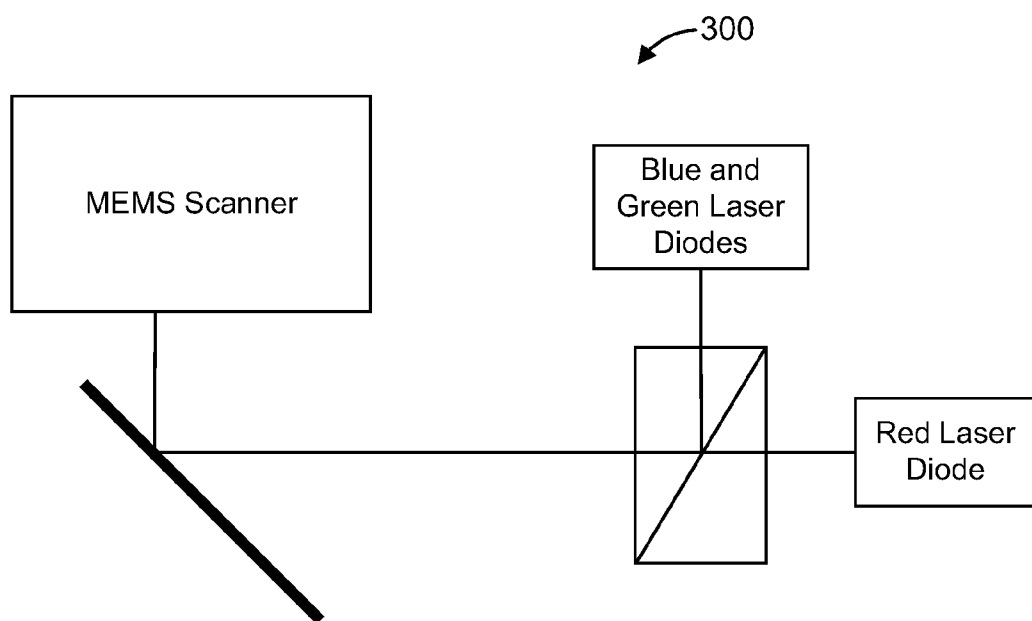


FIG. 3

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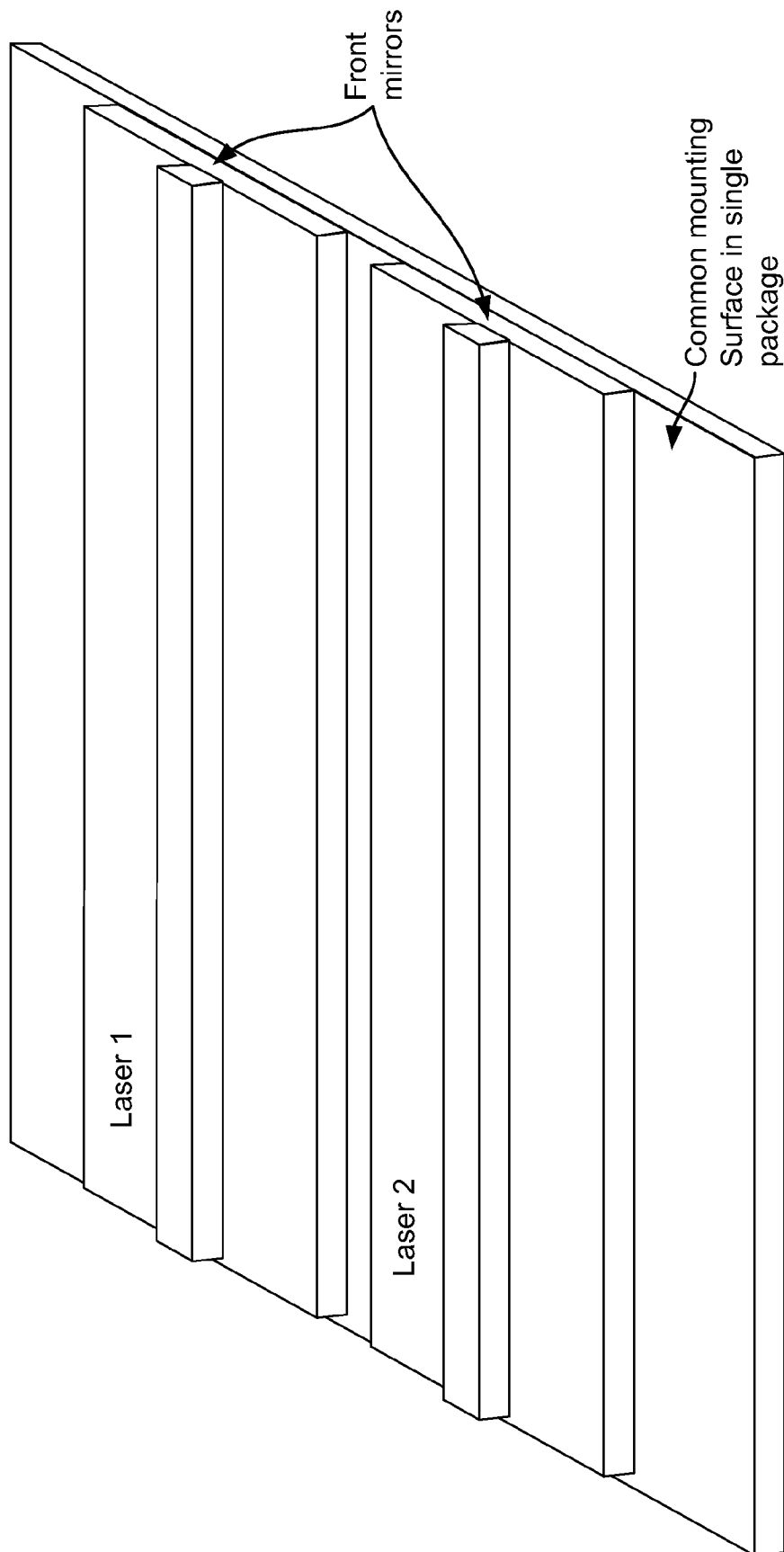
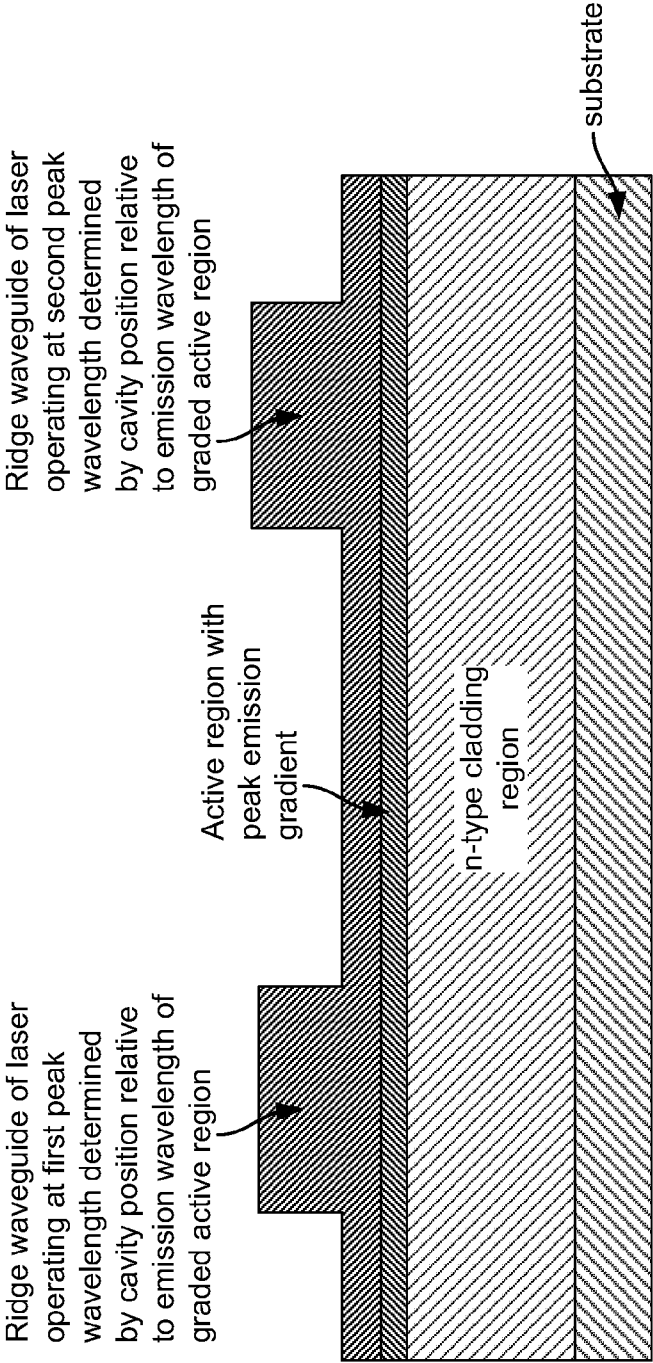


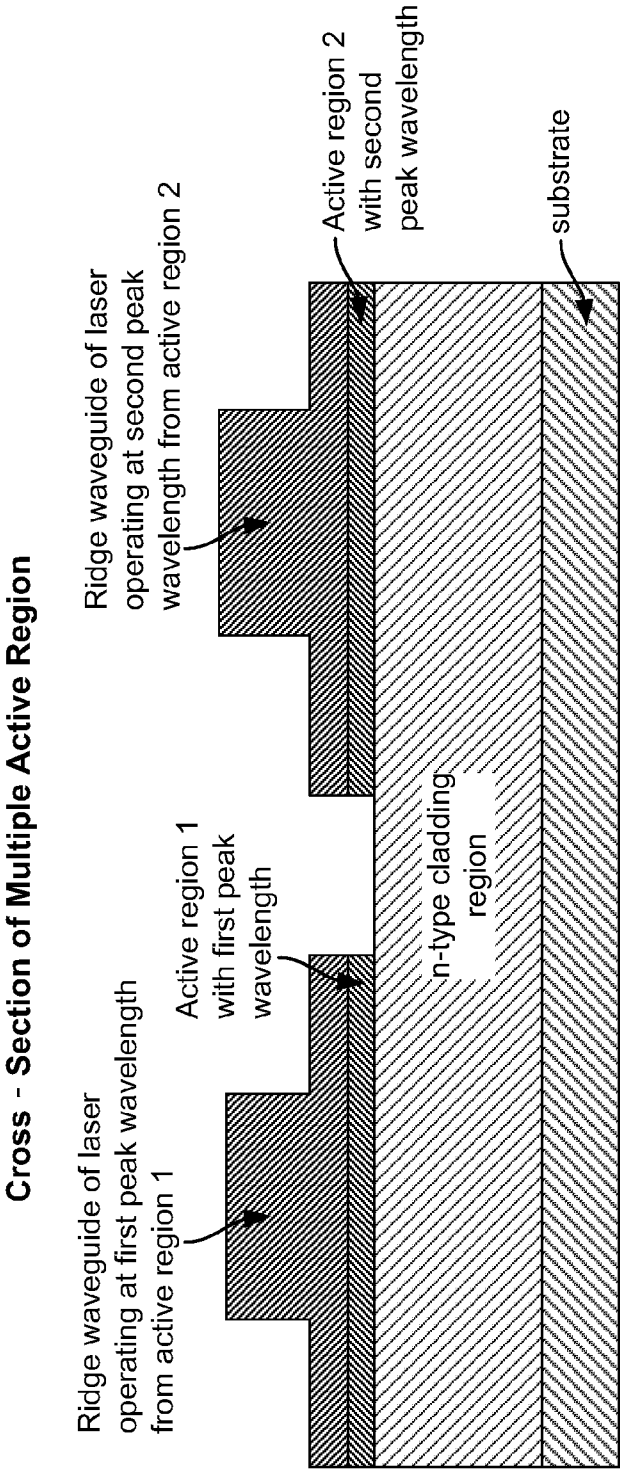
FIG. 3A

Cross-Section of Active Region with Graded Emission Wavelength



An example of graded emission wavelength active region configuration where adjacent lasers are operating at different wavelengths as a result of lasing off being positioned in areas where the active region possesses different peak emission wavelengths

FIG. 3B



An example of a multiple active region configuration where adjacent lasers are operating at different wavelengths as a result of lasing off of two different active regions with different peak wavelengths

FIG. 3C

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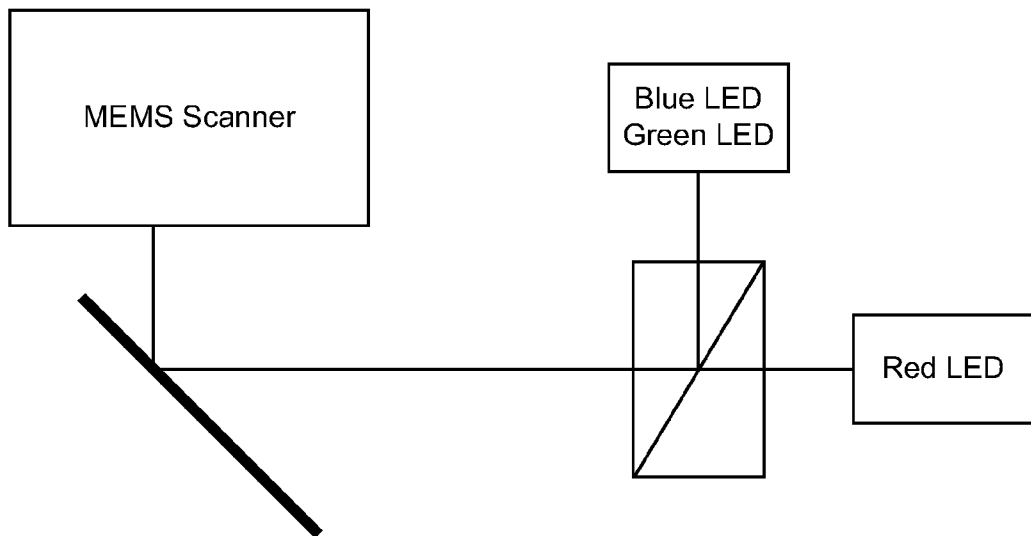


FIG. 3D

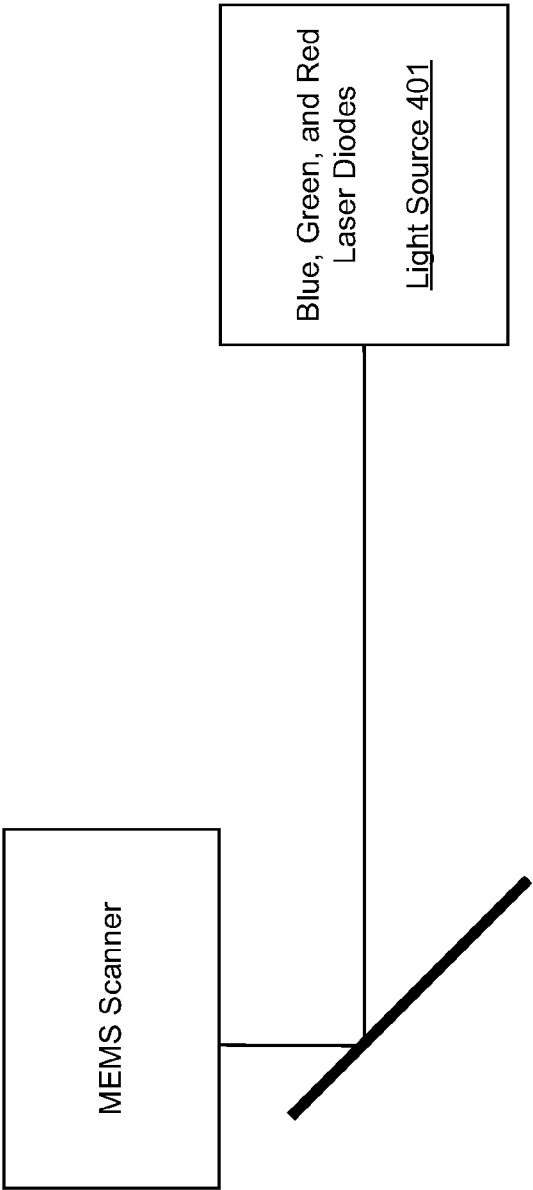


FIG. 4

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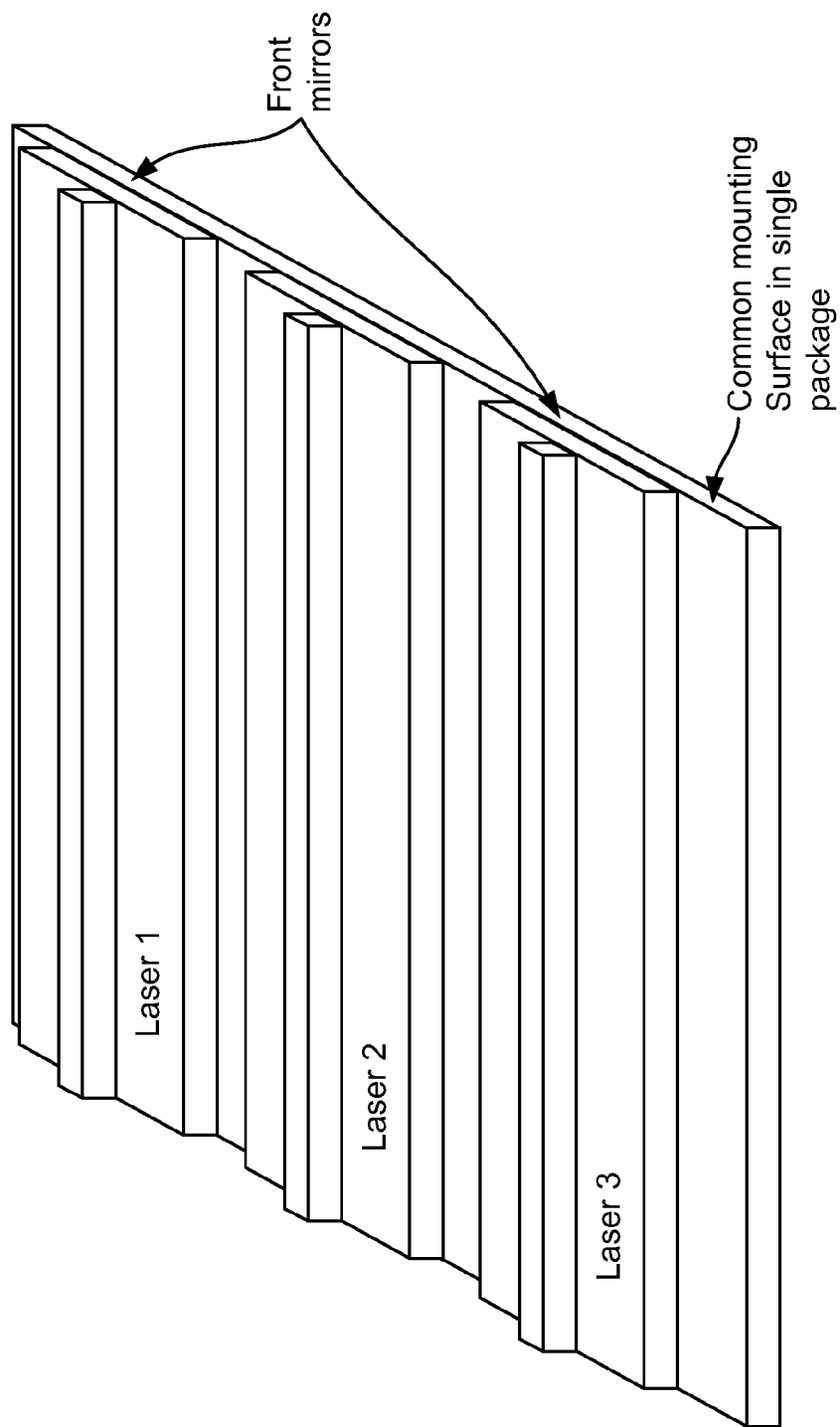


FIG. 4A

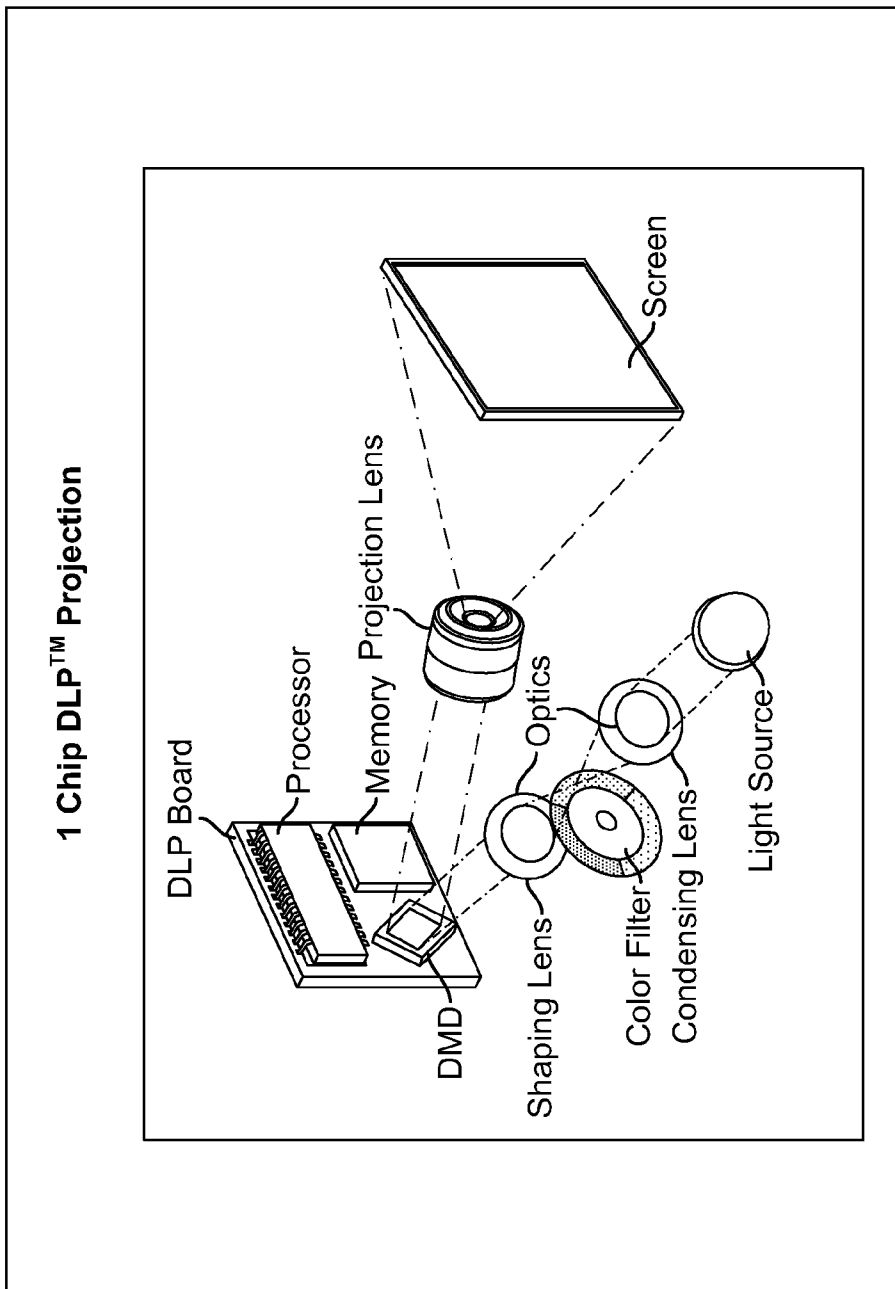


FIG. 5

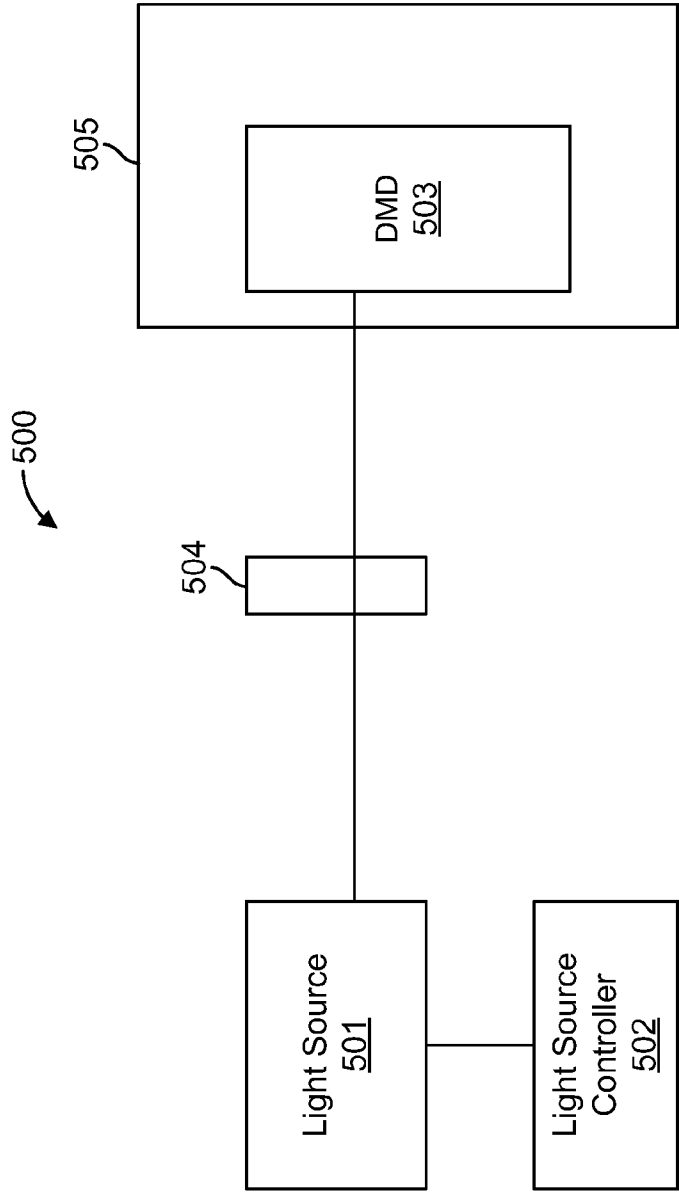


FIG. 5A

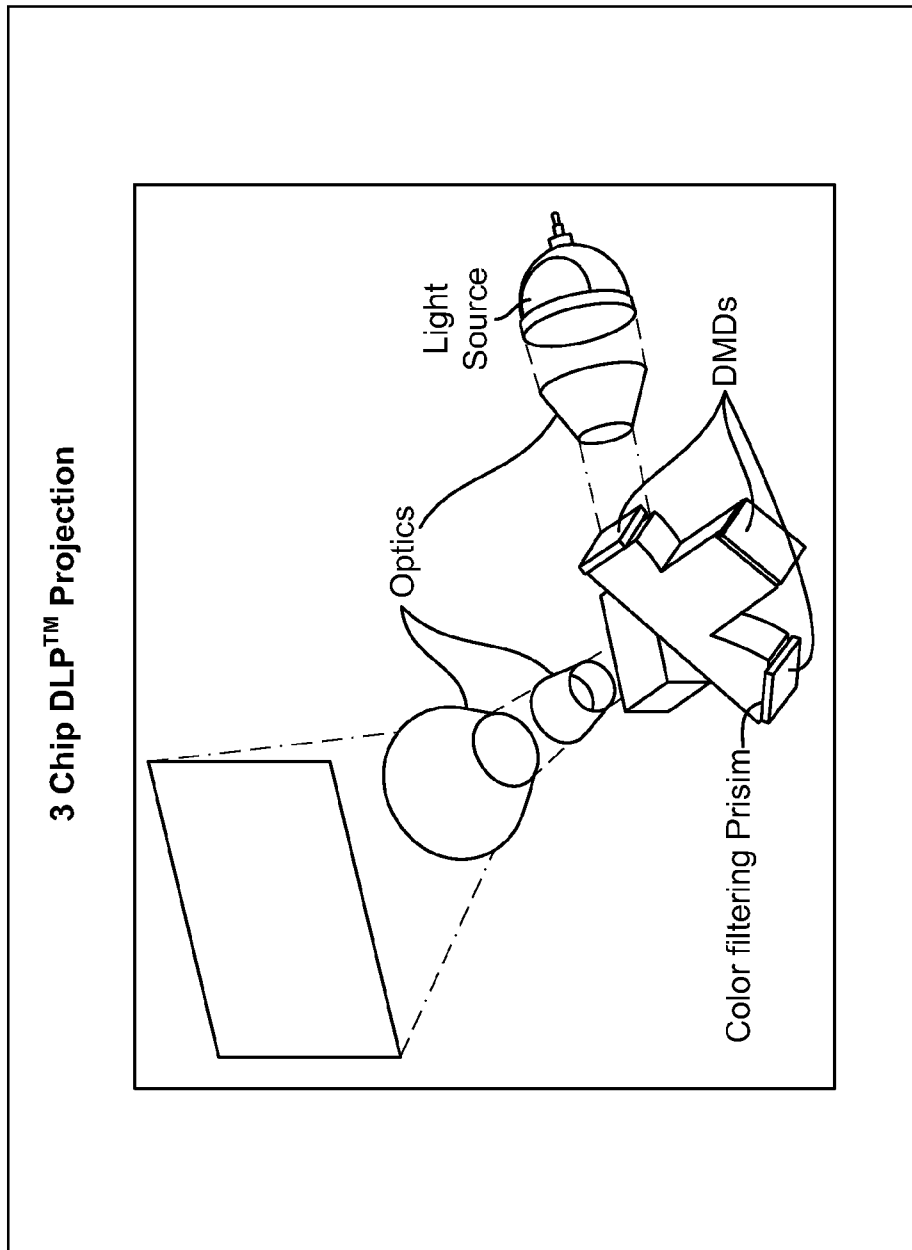


FIG. 6

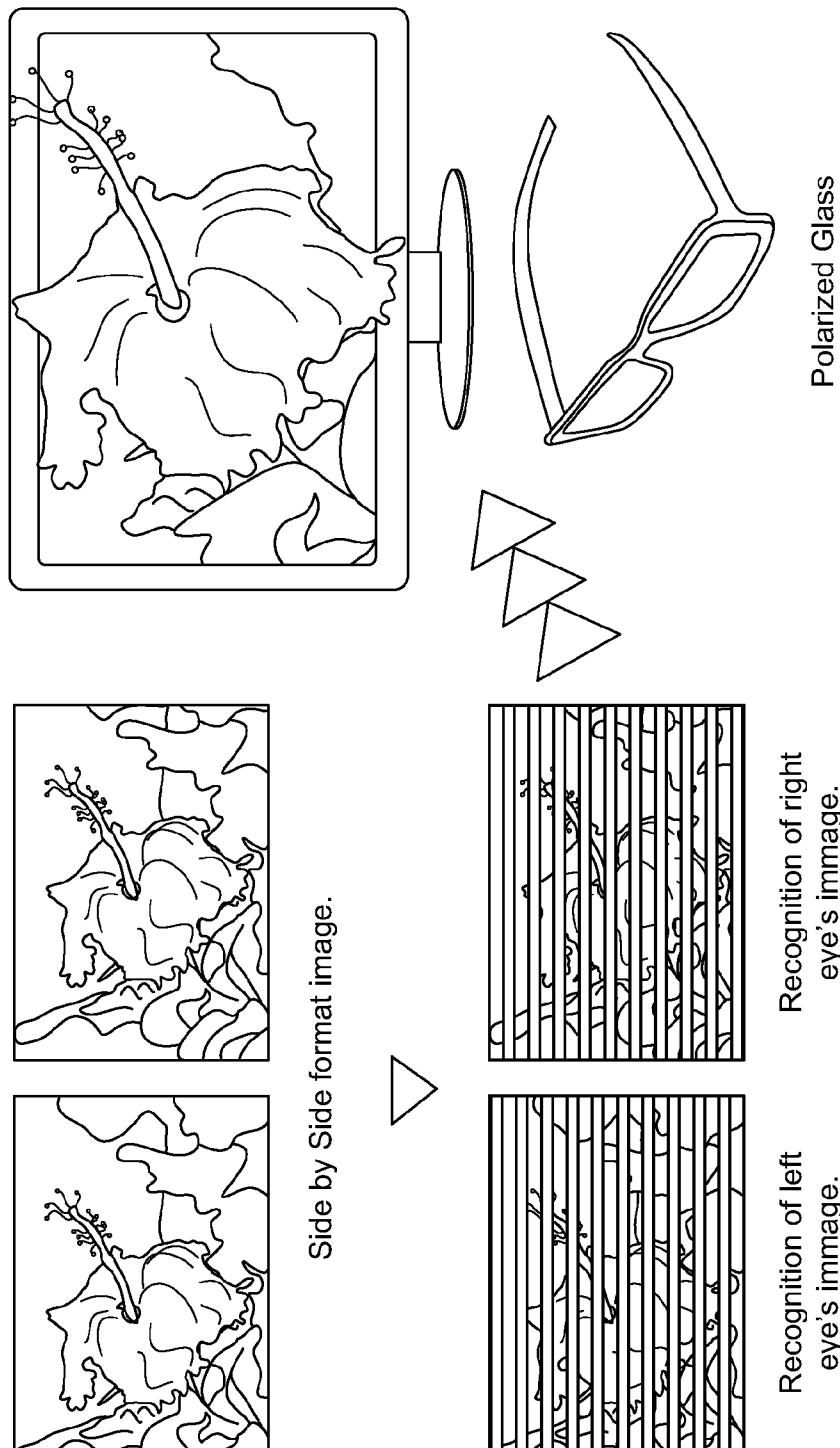


FIG. 7
Prior Art

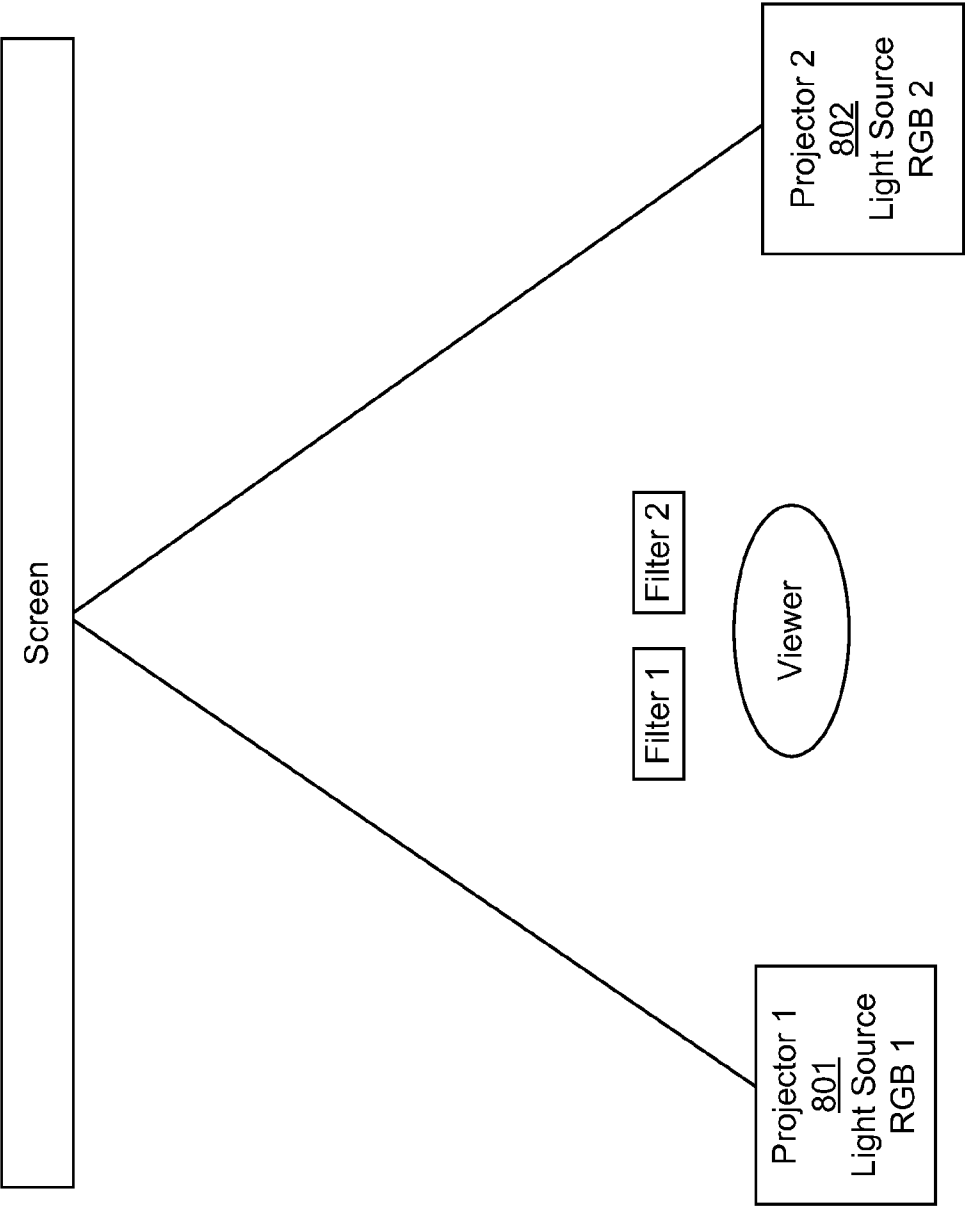


FIG. 8

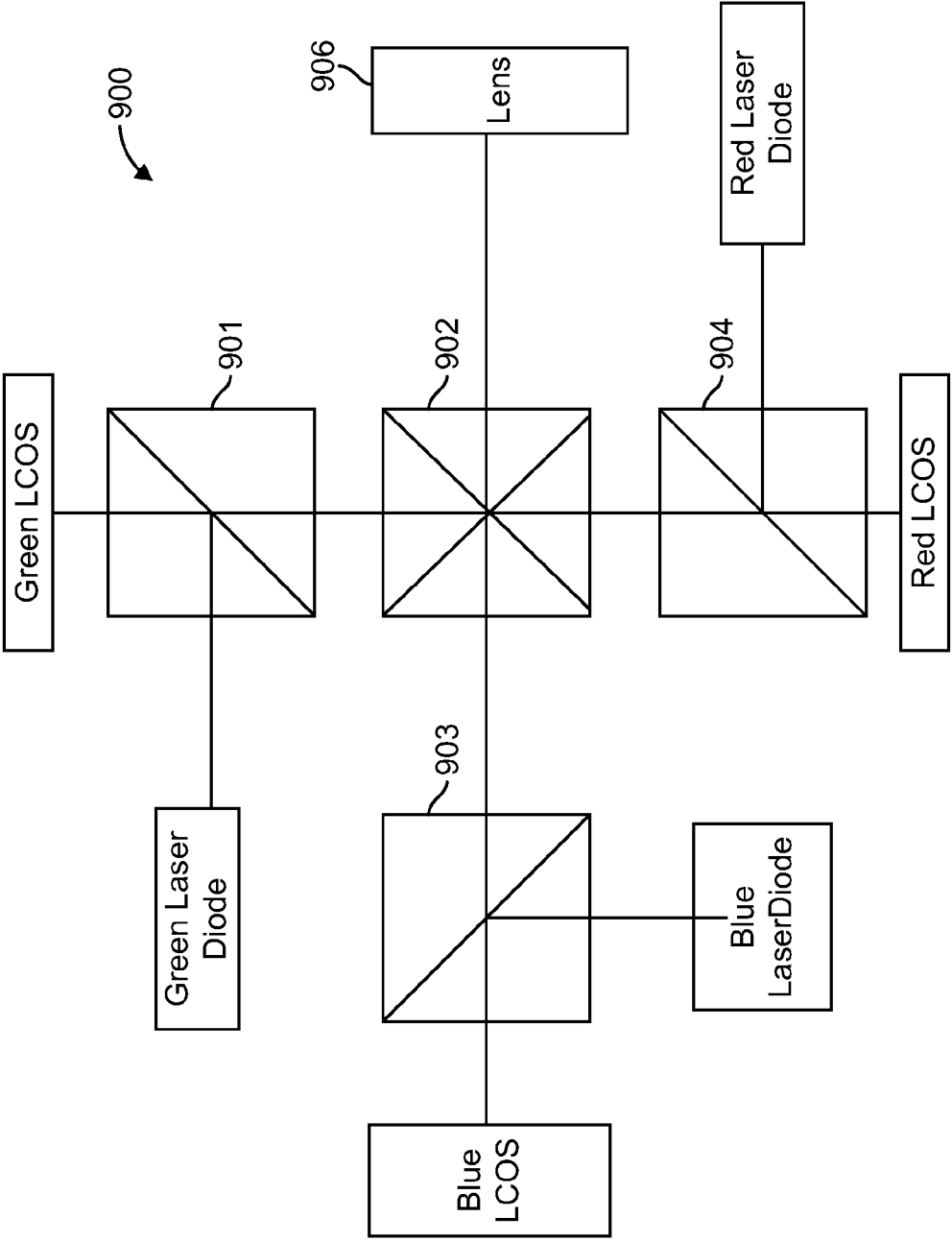


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2010/036739

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G03B 21/14 (2010.01)

USPC - 348/744

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)

IPC(8) - G02B 26/10, 27/18; G03B 21/14; G02F 1/31; H01S 5/323 (2010.01)

USPC - 348/744; 353/99; 359/223.1; 362/230, 241, 259

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)

PatBase, Google Patents

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2006/0279662 A1 (KAPELLNER et al) 14 December 2006 (14.12.2006) entire document	1-11
Y	US 2008/0259431 A1 (WEICHMANN et al) 23 October 2008 (23.10.2008) entire document	1-5, 8-10
Y	US 2008/0143970 A1 (HARBERS et al) 19 June 2008 (19.06.2008) entire document	6, 7, 11
A	US 2007/0109504 A1 (MIYAZAWA) 17 May 2007 (17.05.2007) entire document	1-11
A	US 2007/0280320 A1 (FEEZELL et al) 06 December 2007 (06.12.2007) entire document	1-11
A	WO 2008/109296 A1 (HAASE) 12 September 2008 (12.09.2008) entire document	1-11

☐ Further documents are listed in the continuation of Box C.


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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

16 September 2010

Date of mailing of the international search report

08 NOV 2010

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P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer:

Blaine R. Copenheaver

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2010/036739

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See extra sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-11

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Continuation of Box III.

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claims 1-11, drawn to a projection system or light engine comprising a light source including a plurality of laser diodes or LEDs, including a first laser diode or LED being non-polar or semi-polar and fabricated from gallium nitride material.

Group II, claims 12-36, drawn to a projection apparatus comprising a video processing module and a laser driver module coupled to a laser source, the laser source comprising a blue, green and red laser diode, the blue and a green laser diode sharing a first mounting surface, the laser driver module configured to generate three drive currents based on one or more frames of images; a MEMs scanning module configured to project a laser beam to a specific location through the aperture and an optical member provided to direct the laser beam to the MEMS scanning module.

Group III, claims 37-38, 52-56, drawn to a projection apparatus comprising a laser source including a wavelength modifying module or color wheel comprising a plurality of wavelength modifying modules, the wavelength modifying module comprising phosphor material, the laser exciting the phosphor material to form a colored emission source.

Group IV, claims 39-49, drawn to a projection apparatus comprising a first and a second video source being temporally synchronized.

Group V, claims 50-51, drawn to a projection system comprising one or more LCOS panels.

The inventions listed as Groups I, II, III, IV and V do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the special technical feature of the Group I invention: a first laser diode or LED being non-polar or semi-polar and fabricated from gallium nitride material as claimed therein is not present in the invention of Groups II, III, IV or V. The special technical feature of the Group II invention: a video processing module and a laser driver module coupled to a laser source, the laser source comprising a blue, green and red laser diode, the blue and a green laser diode sharing a first mounting surface, the laser driver module configured to generate three drive currents based on one or more frames of images; a MEMs scanning module configured to project a laser beam to a specific location through the aperture and an optical member provided to direct the laser beam to the MEMS scanning module as claimed therein is not present in the invention of Groups I, III, IV or V. The special technical feature of the Group III invention: a laser source including a wavelength modifying module or color wheel comprising a plurality of wavelength modifying modules, the wavelength modifying module comprising phosphor material, the laser exciting the phosphor material to form a colored emission source as claimed therein is not present in the invention of Groups I, II, IV or V. The special technical feature of the Group IV invention: comprising a first and a second video source being temporally synchronized as claimed therein is not present in the invention of Groups I, II, III or V. The special technical feature of the Group V invention: one or more LCOS panels as claimed therein is not present in the invention of Groups I, II, III or IV.

Groups I, II, III, IV and V lack unity of invention because even though the inventions of these groups require the technical feature of a projection system capable of receiving images and including an LED or laser diode having a wavelength of 490-540 nm, a power source; a control system and a digital light processing chip comprising a digital mirror device including a plurality of mirrors, each of the mirrors corresponding to one or more pixels of one or more frames of images, this technical feature is not a special technical feature as it does not make a contribution over the prior art in view of US 2006/0279662 A2 (KAPELLNER et al) 14 December 2006 (14.12.2006) paragraphs [0009, 0011-0014, 0022-0025, 0063, 0098-0099].

Groups I, IV and V lack unity of invention because even though the inventions of these groups require the technical feature of lasers cells or LEDs which are non-polar or semi-polar or fabricated from gallium nitride or gallium containing material, this technical feature is not a special technical feature as it does not make a contribution over the prior art in view of US 2007/0280320 A1 (FEEZELL et al) 06 December 2007 (06.12.2007) paragraph [0069].

Since none of the special technical features of the Group I, II, III, IV or V inventions are found in more than one of the inventions, unity of invention is lacking.