



US005838430A

United States Patent [19]
Slater et al.

[11] **Patent Number:** **5,838,430**
[45] **Date of Patent:** **Nov. 17, 1998**

[54] **DUAL BEAM LASER DEVICE FOR LINEAR AND PLANAR ALIGNMENT**

5,408,318 4/1995 Slater .
5,517,023 5/1996 Ohtomo et al. 250/234

[75] Inventors: **Dan Slater**, La Habra Heights; **David M. Kramer**, Palos Verdes, both of Calif.

[73] Assignee: **Nearfield Systems Incorporated**, Carson, Calif.

[21] Appl. No.: **675,655**

[22] Filed: **Jul. 3, 1996**

[51] **Int. Cl.**⁶ **G01B 11/26**

[52] **U.S. Cl.** **356/138**

[58] **Field of Search** 356/138, 73, 150, 356/400, 248, 249, 250, 153, 148, 149, 399, 247, 401, 351, 152.1-152.3, 140, 141.1-141.5; 250/234

OTHER PUBLICATIONS

"A 550 GHz Near-field Antenna Measurement System for the NASA Submillimeter Wave Astronomy Satellite," by Dan Slater, Antenna Measurement Techniques Association Conference, Oct. 3-7, 1994.

"Position Correction On Large Near-field Scanners Using An Optical Tracking System," by Greg Hindman, Antenna Measurement Techniques Association Conference, Oct. 3-7, 1994.

"Antenna Measurements Come in From The Cold," by Greg Hindman, T&MW Communications Test Supplement, Apr. 1992.

Primary Examiner—K. Hantis
Attorney, Agent, or Firm—Graham & James LLP

[57] **ABSTRACT**

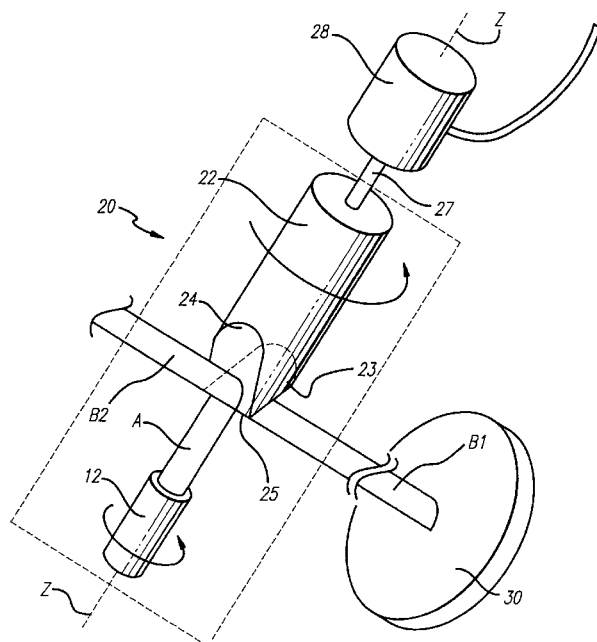
A high precision alignment apparatus is provided that utilizes a semiconductor laser device, such as a laser diode, to provide a source laser beam. The alignment apparatus permits the division of a pair of beam components from the source laser beam useful for either linear or planar alignment. A centroid measurement between the beam components provides a corrected reference point that accounts for the inherent instability of the source laser beam to yield a high level of alignment accuracy. For linear alignment purposes, the beam components are collinearly directed. In the alternative, for planar alignment purposes, the beam components may be either collinear or directed in opposite directions, and rotated to sweep respective planar regions. The laser alignment apparatus is capable of providing a level of accuracy heretofore achievable only with gas lasers, while maintaining the economical attributes of commercial semiconductor laser diodes.

[56] **References Cited**

U.S. PATENT DOCUMENTS

- 3,816,000 6/1974 Fiedler .
- 4,035,084 7/1977 Ramsay .
- 4,062,634 12/1977 Rando et al. .
- 4,154,507 5/1979 Barr .
- 4,170,401 10/1979 Yoder et al. .
- 4,297,031 10/1981 Hamar .
- 4,367,949 1/1983 Lavering .
- 4,382,680 5/1983 Hamar .
- 4,662,707 5/1987 Teach et al. .
- 4,676,598 6/1987 Markley et al. .
- 4,770,480 9/1988 Teach .
- 4,774,405 9/1988 Malin .
- 4,830,489 5/1989 Cain et al. .
- 4,844,618 7/1989 Hamar .
- 4,884,697 12/1989 Takacs et al. .
- 5,295,018 3/1994 Konuma et al. .
- 5,307,368 4/1994 Hamar .

21 Claims, 5 Drawing Sheets



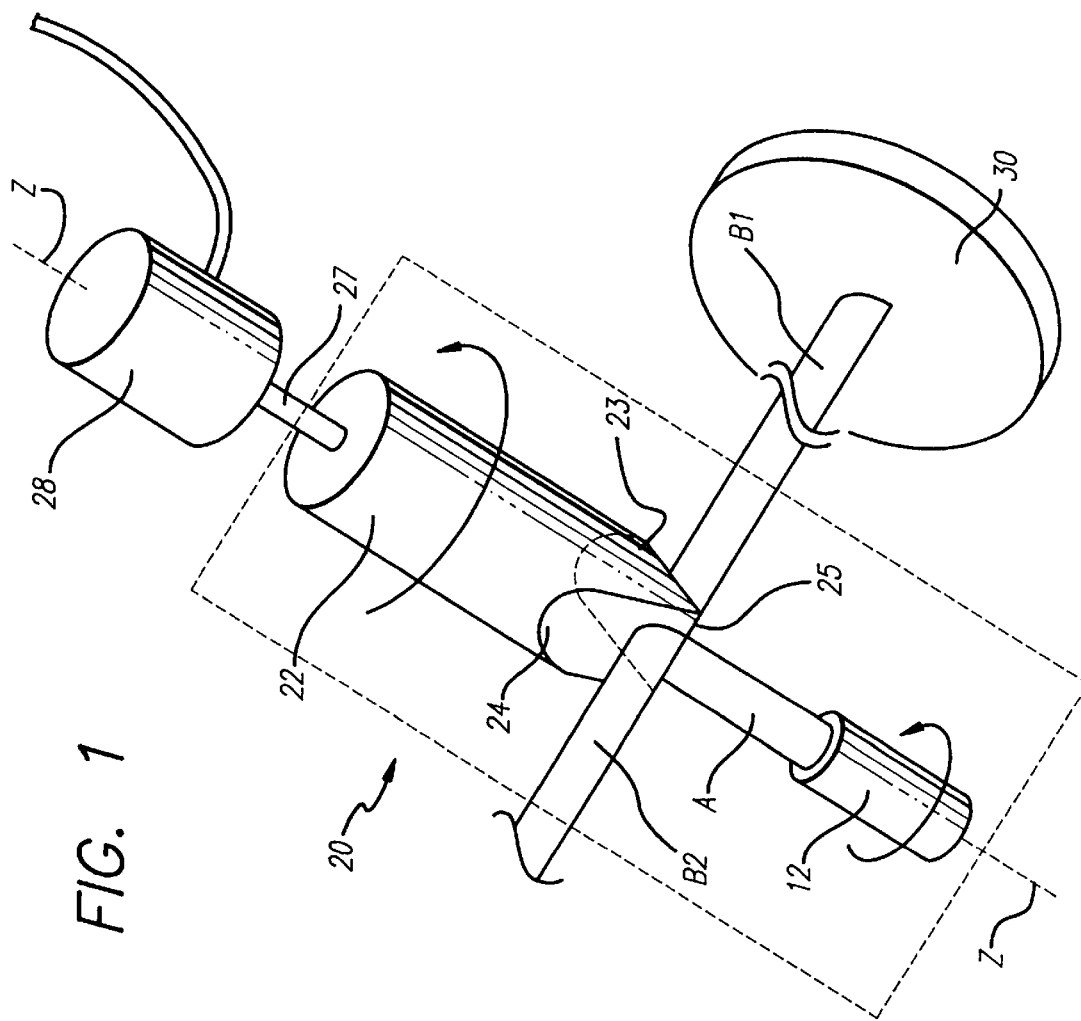


FIG. 1

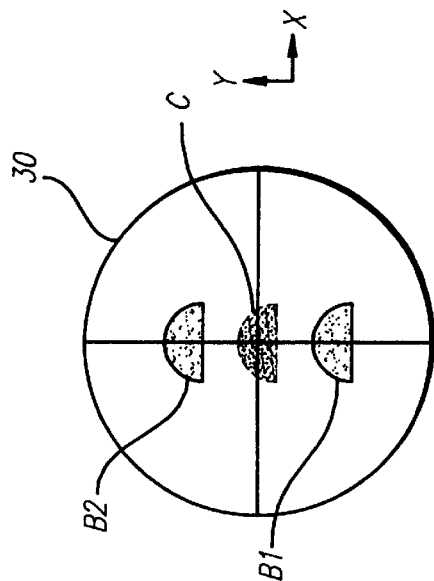
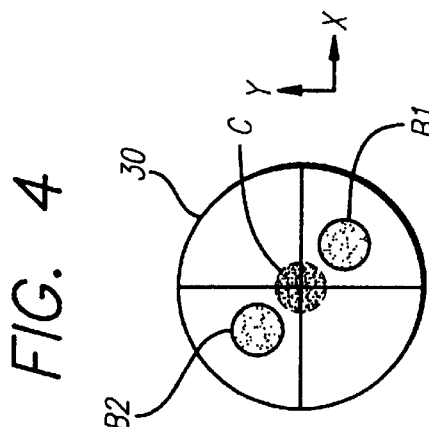
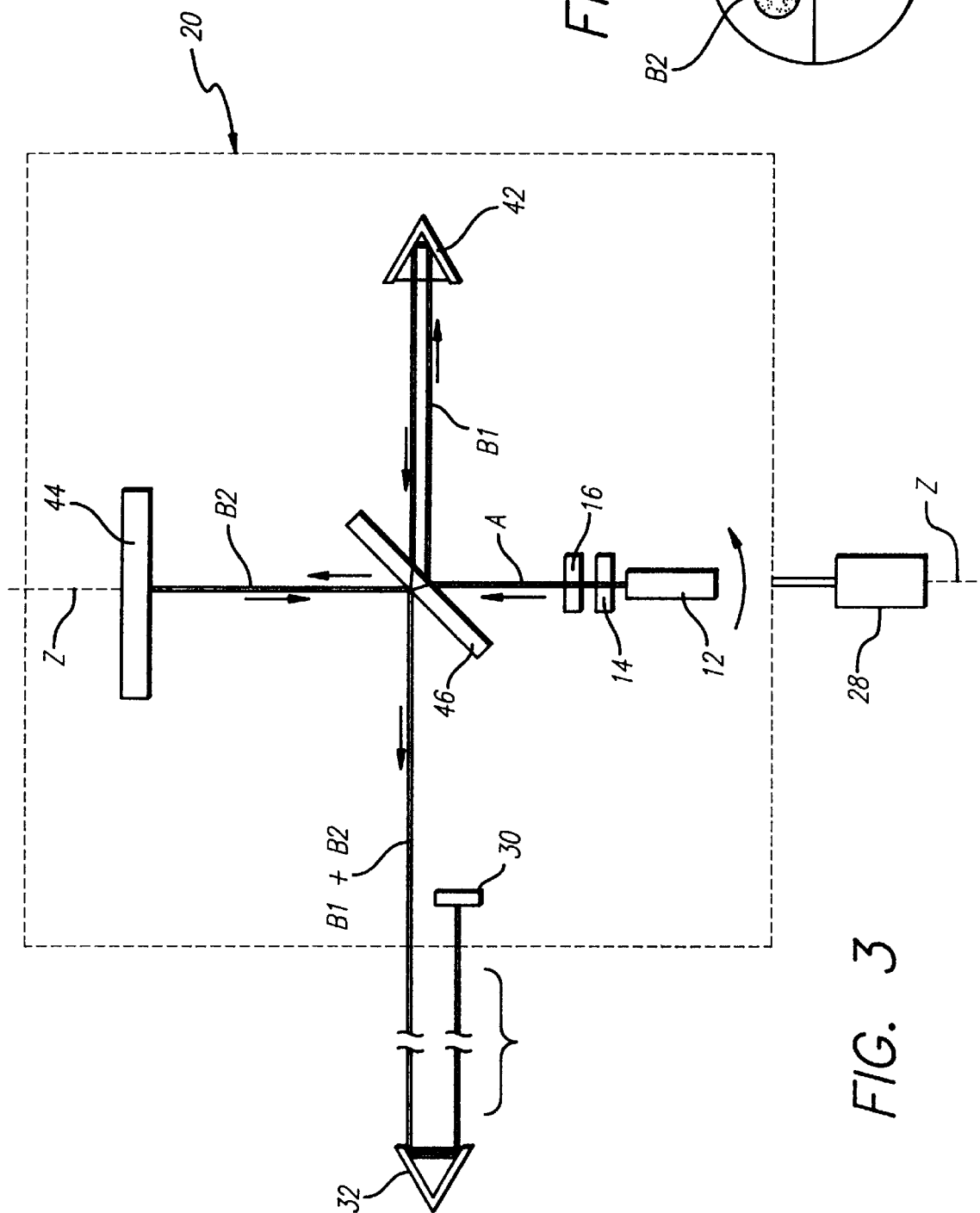
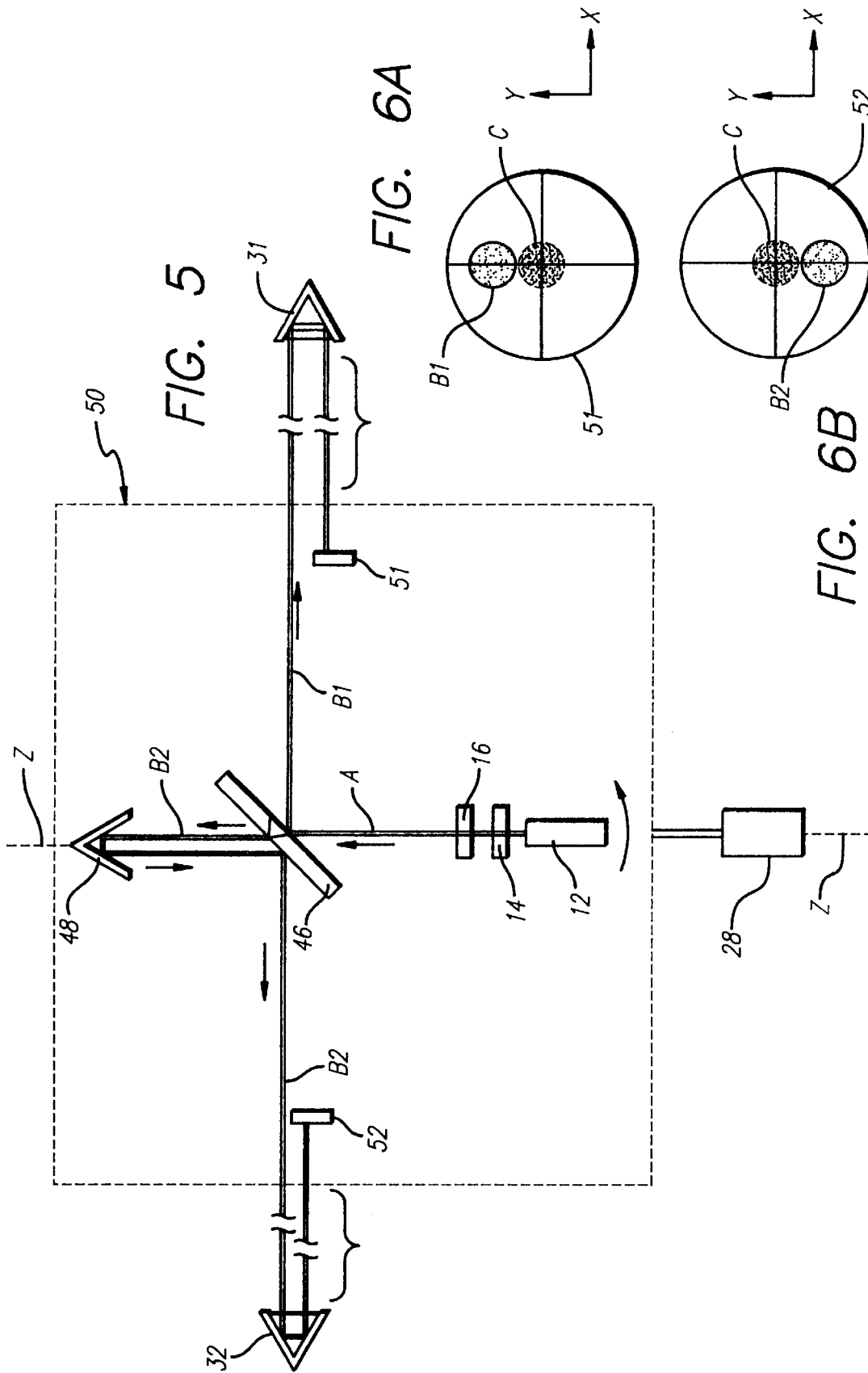


FIG. 2





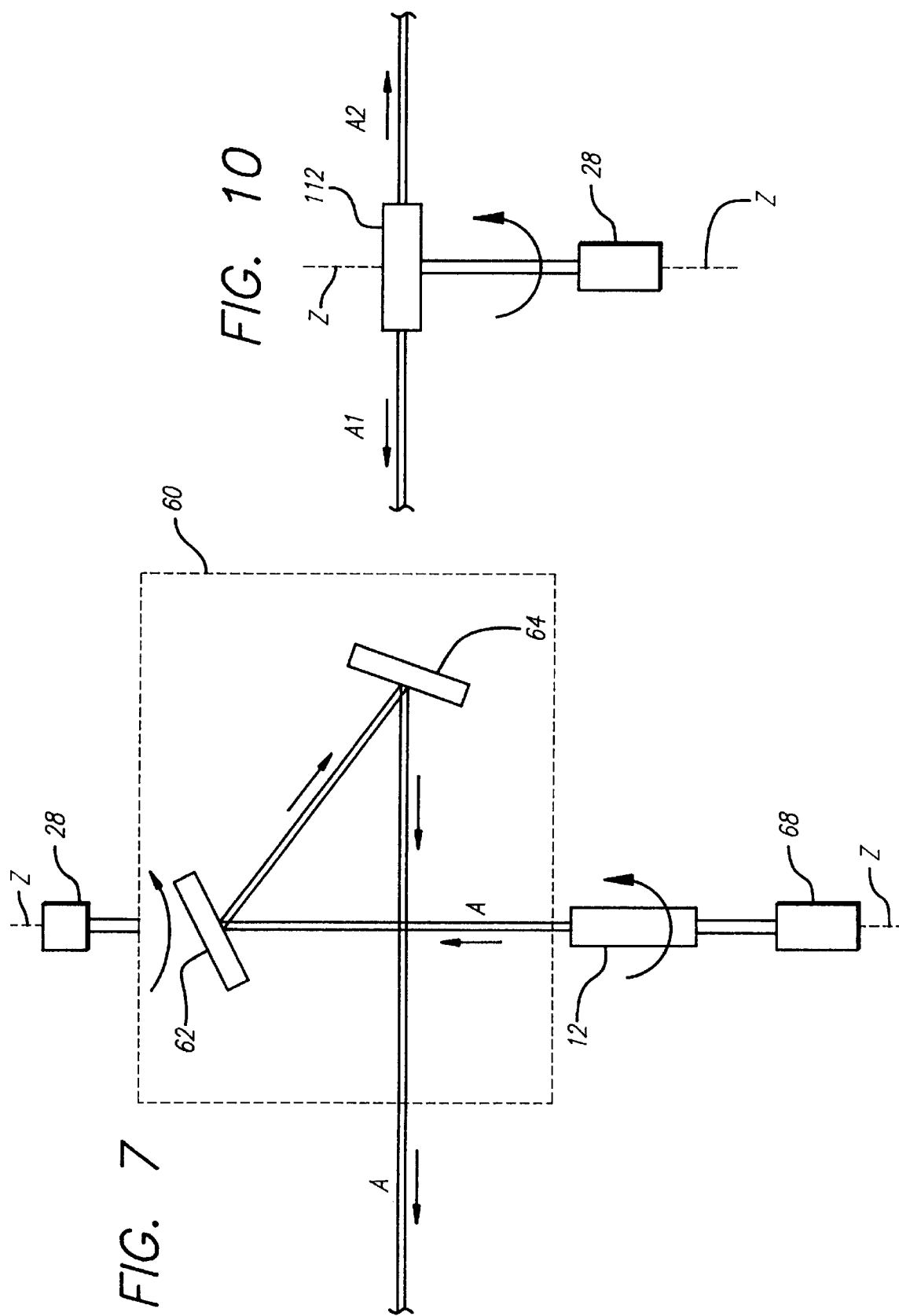
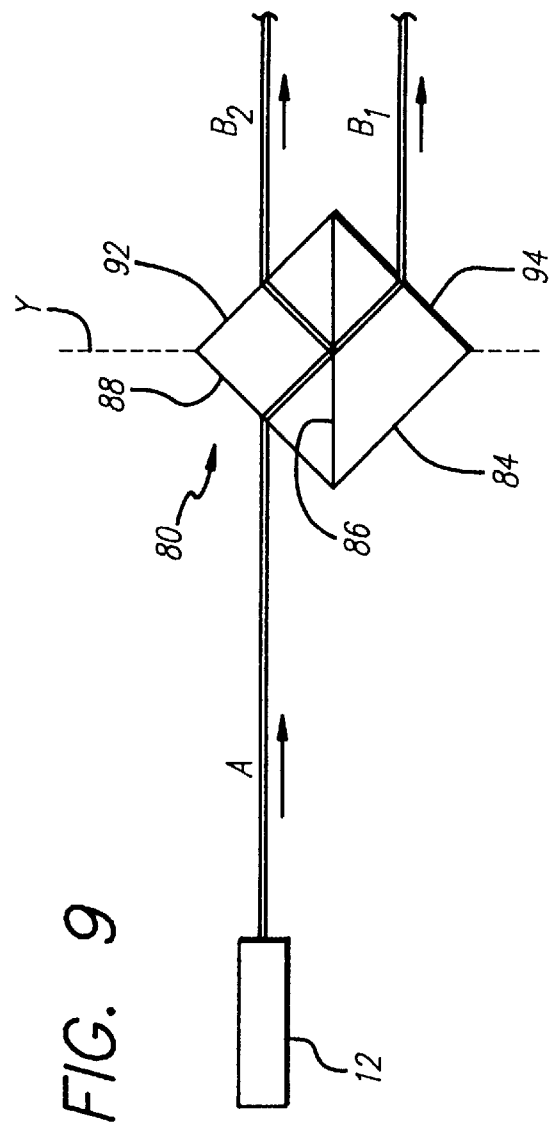
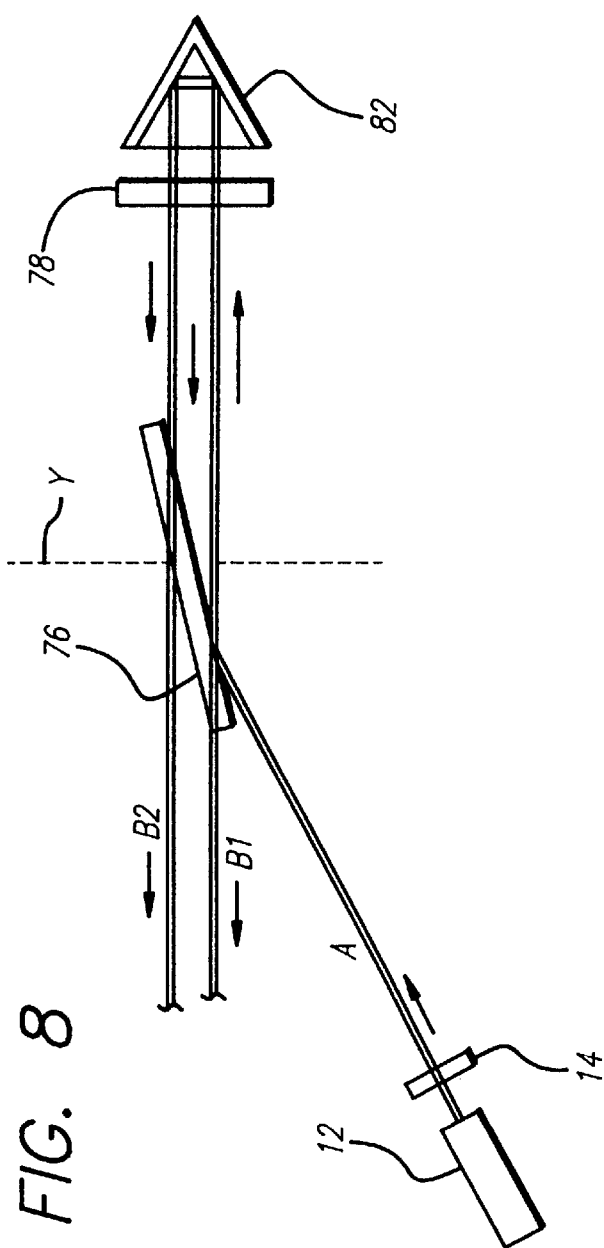


FIG. 7

FIG. 10



DUAL BEAM LASER DEVICE FOR LINEAR AND PLANAR ALIGNMENT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to laser systems useful for precision linear and planar alignment, and more particularly, to an apparatus that performs a light energy centroid measurement between a pair of reference laser beams in order to significantly improve alignment accuracy.

2. Description of Related Art

Laser emitters and detectors are commonly used in industry to perform precision alignment and measurement. In one type of such system, a laser device emits a laser beam that can provide a relatively accurate reference line. A detector operated in conjunction with the laser can measure displacement between the beam and an object requiring alignment to the laser axis. Alternatively, a laser device may be oriented with a rotating pentaprism or penta-mirror assembly that deflects the laser beam through a precise 90° angle and sweeps the beam to provide a flat plane that is perpendicular to the input laser beam. The plane can be used as a reference to which the alignment and/or position of other objects can be compared. Such laser alignment systems have various applications within construction, surveying or manufacturing. In one possible application, a laser beam alignment device could be used in commercial construction to define a plumb line or a planar laser beam alignment device used to build a wall. Examples of such laser beam alignment devices are disclosed in U.S. Pat. No. 4,676,598 to Markley et al. for MULTIPLE REFERENCE LASER BEAM APPARATUS, and in U.S. Pat. No. 4,662,707 to Teach et al. for LIGHTHOUSE STRUCTURE AND COMPENSATING LENS IN REFERENCE LASER BEAM PROJECTING APPARATUS.

Traditionally, the laser beam in such alignment systems is generated by a laser tube containing a suitable active gaseous element, such as helium-neon gas. The gas is excited by an optical or electrical source to emit a low-powered collimated output beam in the red band of the light spectrum. These so-called gas lasers produce a thermally stable beam that is useful for producing highly accurate measurements over relatively long distances (e.g., hundredths of an inch over one hundred feet of distance). Despite the inherent stability of reference beams produced by gas lasers, however, these laser devices are also very energy inefficient, expensive, relatively large and fragile.

In view of the noted deficiencies of gas lasers, laser diodes have increased in commercial popularity as a suitable alternative. A laser diode is a semiconductor device, usually of the gallium-arsenide type, that emits coherent light when a voltage is applied to its terminals. Laser diodes are substantially less expensive than gas lasers, and can be manufactured in a smaller, rugged, more compact package. A significant drawback of laser diodes is that they produce a far less stable beam than gas lasers. In particular, the laser beam does not have uniform intensity over its cross-section and the energy of the beam decreases with distance from the center of the beam. Moreover, the rate of change of the intensity is not uniform, and the center of beam energy will periodically shift in accordance with temperature. As a result of these deficiencies, a linear or planar alignment device using a laser diode cannot be expected to achieve the same degree of accuracy as gas lasers.

Prior art devices have sought to overcome the inadequacy of laser diodes in order to approximate the stability of gas

lasers. In particular, U.S. Pat. No. 5,307,368 to Hamar for LASER APPARATUS FOR SIMULTANEOUSLY GENERATING MUTUALLY PERPENDICULAR PLANES discloses a laser alignment device having a hollow spindle with an aperture that is rotatably mounted within bearings. Laser light from a laser diode floods the aperture so that only the centermost portion of the beam passes entirely through the spindle. The laser alignment device disclosed by Hamar purports to provide a centered beam of uniform density and circular cross-section. In practice, however, the resulting beam still cannot achieve the stability of gas laser beams due to thermal shifts over time within the center of beam energy that passes through the spindle.

Notwithstanding this significant drawback, laser diodes are still acceptable for most alignment applications. In general, commercial construction applications do not require a level of accuracy high enough to justify the additional expense of a gas laser, and, in these applications, a laser beam generated by a laser diode can provide a sufficient level of stability. As a result, demand for laser diodes has totally outstripped demand for gas lasers and, currently, there are few suppliers willing to produce gas lasers to satisfy the particular applications that require greater accuracy than that achievable with laser diodes.

Accordingly, a critical need exists for a laser alignment apparatus capable of providing a highly stable and accurate beam suitable for such critical linear and planar alignment applications. Such a laser alignment apparatus should be capable of providing a level of accuracy heretofore achievable only with gas lasers, while maintaining the economical attributes of commercial laser diodes.

SUMMARY OF THE INVENTION

A high precision alignment apparatus is provided that utilizes a collimated light source, such as a laser diode, to provide a source laser beam. The alignment apparatus permits the division of a pair of beam components from the source laser beam useful for either linear or planar alignment. A centroid measurement between the beam components provides a corrected linear or planar reference point that accounts for the inherent instability of the source laser beam and yields a high level of alignment accuracy.

In a first embodiment of the invention, a planar alignment apparatus is provided. The apparatus comprises a laser diode providing a source laser beam and a wedge having first and second faces that intersect at a 90° angle. The beam is directed at the intersection of the first and second faces of the wedge, which have surfaces that respectively reflect the first and second beam components in opposite directions. The wedge is rotated about a spin axis orthogonal to the reflected beam components and approximately coincident with the source laser beam to cause the first and second beam components to sweep respective planar regions. A stable planar measurement is obtained by detecting a common centroid of the first and second beam components, using a photodetector oriented to permit the first and second beam components to impinge thereon. As the source laser beam deviates due to thermal or angular effects, the first component will shift upward while the second component shifts downward, or vice versa. The centroid measurement of the first and second beam components thus represents a weighted average position of the two beam components that can be used to define a stable planar measurement point for the planar alignment apparatus.

In a second embodiment of the invention, a linear or axial alignment apparatus is provided. A source laser beam from

a semiconductor device is divided into first and second beam components that may be partially overlapping. A first optical element disposed at a predetermined angle with respect to an optical axis reflects the first beam component therefrom in a direction normal to the axis and transmits the second beam component therethrough. The optical axis is approximately coincident with the source laser beam. A second optical element collinearly reflects the reflected first beam component back to the first optical element, the first beam component being thereby transmitted through the first optical element. A third optical element disposed normal to the axis coaxially reflects the second beam component back to the first optical element. The reflected second beam component thereby reflects off of the first optical element in a partially overlapping manner with the first beam component.

A linear or planar alignment measurement is made by detecting a common centroid of the first and second beam components. A photodetector is oriented to permit the first and second beam components to impinge thereon and provide the common centroid measurement therefrom. Thereby, the collinear and overlapping beams provide a reference for a linear alignment system. Alternatively, by rotating the overlapping beam components about the optical axis, the beam components sweep a planar region to provide a planar alignment system.

In a third embodiment of the invention, a planar alignment apparatus is provided. A semiconductor laser source provides a laser beam that is divided into a first and second beam component directed in opposite directions. A first optical element disposed at a predetermined angle with respect to an optical axis approximately coincident with the laser beam reflects the first beam component therefrom in a direction normal to the optical axis and transmits the second beam component therethrough. A second optical element collinearly reflects the transmitted second beam component back to the first optical element, with the first beam component being thereby reflected therefrom in a direction normal to the optical axis and opposite to the direction of the first beam component. The first and second beam components are rotated about the optical axis to sweep respective planar regions, and a common centroid measurement of the first and second beam components is made to provide a planar alignment system.

In a fourth embodiment of the invention, a planar alignment apparatus is provided. A semiconductor laser emitting source provides a laser beam and the laser emitting source is rotated about a spin axis approximately coincident with the laser beam at a first rotational rate. The laser beam is reflected in a direction normal to the spin axis by an optical element having a plurality of reflecting surfaces, which is rotated about the spin axis at a second rotational rate to cause the reflected laser beam to sweep through a substantially planar region. The first rotational rate is half that of the second rotational rate. A centroid measurement of the reflected laser beam provides planar alignment information.

In a fifth embodiment of the invention, a planar or linear alignment apparatus is provided. A semiconductor laser source provides a laser beam that is divided into collinear first and second beam polarization components. A first optical element disposed at a predetermined angle with respect to the laser beam reflects the laser beam therefrom. A second optical element reflects the first beam polarization component therefrom back to the first optical element, the first beam polarization component being thereby transmitted through the first optical element in a reference direction. The second optical element further transmits the second beam polarization component therethrough. A third optical ele-

ment coaxially reflects the second beam polarization component back to the first optical element, the reflected second beam polarization component being thereby transmitted through the first optical element in a collinear manner with the first beam polarization component in the reference direction. A common centroid of the first and second beam polarization components provides linear alignment information. Alternatively, the first and second beam polarization components may be rotated about an axis orthogonal to the reference direction to sweep respective planar regions. A common centroid measurement of the first and second beam polarization components is made to provide planar alignment information.

In a sixth embodiment of the invention, a linear or planar alignment apparatus is provided. A collimated light source provides a laser beam that is divided by an optical element into collinear first and second beam components. The optical element comprises a plurality of surfaces and a partially reflective boundary. The laser beam impinges upon a first surface thereof and is internally deflected into the optical element. A first beam component is reflected from the partially reflective boundary and passes through a second surface of the optical element in a reference direction. A second beam component is thereby transmitted through the partially reflective boundary and passes through a third surface of the optical element in the reference direction. A common centroid of the first and second beam components provides linear or planar alignment information.

In a seventh embodiment of the invention, a planar alignment apparatus is provided. A collimated light source provides a first and a second laser beam that are directed in opposite directions. The collimated light source is rotated about an axis to cause the first and second laser beams to sweep respective planar regions. A common centroid of the first and second laser beams provides planar alignment information. The collimated light source further comprises a gas laser.

A more complete understanding of the dual beam laser device for linear and planar alignment will be afforded to those skilled in the art, as well as a realization of additional advantages and objects thereof, by a consideration of the following detailed description of the preferred embodiment. Reference will be made to the appended sheets of drawings which will first be described briefly.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a first embodiment of the laser alignment apparatus of the present invention;

FIG. 2 is a front view of a centroid measurement device of the first embodiment having a first and second beam component impinging thereon;

FIG. 3 is a block diagram of a second embodiment of the laser alignment apparatus useful for planar or linear alignment;

FIG. 4 is a front view of a centroid measurement device of the second embodiment having a first and second beam component impinging thereon;

FIG. 5 is a block diagram of a third embodiment of the laser alignment apparatus useful for planar alignment;

FIGS. 6a and 6b are front views of centroid measurement devices of the third embodiment having a first and second beam component impinging thereon, respectively;

FIG. 7 is a block diagram of a fourth embodiment of the laser alignment apparatus;

FIG. 8 is a block diagram of a fifth embodiment of the laser alignment apparatus;

5

FIG. 9 is a block diagram of a sixth embodiment of the laser alignment apparatus; and

FIG. 10 is a block diagram of a seventh embodiment of the laser alignment apparatus.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention satisfies the critical need for a laser alignment apparatus capable of providing a highly stable and accurate beam suitable for critical linear and planar alignment applications. The laser alignment apparatus provides a level of accuracy heretofore achievable only with gas lasers, while maintaining the economical attributes of commercial laser diodes. In the detailed description that follows, like reference numerals are used to describe like elements illustrated in one or more of the figures.

Referring first to FIG. 1, a first embodiment of a planar laser alignment apparatus is illustrated. The laser alignment apparatus comprises a collimated light source 12 and a rotating wedge 22. The laser device 12 may be a conventional semiconductor device, such as a laser diode, which provides a laser beam A. The wedge 22 has a central axis Z aligned approximately coincident with the laser device 12. Since the laser beam A provided by the laser device 12 is inherently unstable, it should be apparent that the central axis Z does not precisely coincide with the laser beam. The wedge 22 has first and second reflective surfaces 23, 24 disposed at an end thereof that intersect at a 90° angle to form an edge 25. Each of the first and second reflective surfaces 23, 24 are respectively disposed at a 45° angle with respect to the central axis Z of the wedge 22 and laser device 12.

A motor 28 is coupled to the wedge 22 by a shaft 27 which enables the wedge to rotate about the central axis Z. The wedge 22 may be comprised of a thermally stable material, such as glass or quartz, and may be provided with a reflective coating on the surfaces 23, 24. As known in the art, the laser source 12 and wedge 22 may be further disposed within a housing 20 that provides a mechanical structure to control and permit adjustment to the relative alignment of the operative elements. The laser source 12 is coupled mechanically to the wedge 22 via the housing 20 so that the laser device and wedge rotate in unison. The laser source 12 emits a beam A directed along the central axis to the intersection 25 of surfaces 23, 24 of the wedge 22. Upon uniformly striking the surfaces 23, 24, the beam A divides into respective beam components B1, B2. Rotation of the wedge 22 causes the beam components B1, B2 to sweep respective planar regions useful for planar alignment. The housing 20 may further include windows or other openings that permit the beam components B1, B2 to project there-through.

A beam target 30 is disposed remotely from the wedge 22 and is oriented so that the beam components B1, B2 will impinge thereon in an alternating manner as the wedge 22 rotates. The target 30 provides a centroid measurement of the beam components B1, B2, and can be provided by conventional one or two-axis lateral-effect photodiodes formed from a semiconductor material. The photodiodes produce electrical current based upon the energy centroid of the respective laser beam components. The photodiodes produce an output that corresponds to a weighted sum of the combined light energy of the beam components B1, B2 to define a single center point of the combined light energy. Alternatively, the target 30 could be provided by a charge coupled device (CCD) type device which could be config-

6

ured to provide similar energy centroid data. In either embodiment, the centroid measurement is read out using conventional electronic systems. A rotational rate would be selected for the motor 28 that is high enough to permit the beam components B1, B2 to appear as a uniform planar surface, while low enough to not overly complicate the beam target 30 electronics.

As illustrated in FIG. 2, the beam target 30 has spots projected thereon that correspond to the beam components B1, B2. It should be apparent that the beam components B1, B2 do not simultaneously impinge upon the target 30, but the beam components can be made to appear to impinge simultaneously by defining the image persistence of the target to be greater than the rotational rate. Ideally, the spots formed by the beam components B1, B2 would overlap each other precisely if the source beam A were thermally stable. In practice, however, the instability of the source beam A causes the spots formed by the beam components B1, B2 to diverge in a symmetrical manner along the Y-axis dimension on the target 30. As a result, the impinging beam components appear on the target 30 as separate spots disposed above and below the X-axis, respectively, with the distance between the spots varying with the thermal instability of the laser 12. The centroid measurement of the beam components B1, B2 is illustrated in phantom at spot C, which remains constant and represents a thermally stable reference point for the planar alignment apparatus.

FIGS. 3 and 4 illustrate a second embodiment of a laser alignment apparatus configured to provide either linear or planar alignment. The laser alignment apparatus may be included within a single housing illustrated in phantom at 20. As in the first embodiment, the laser alignment apparatus comprises a collimated light source 12 provided by a semiconductor device, such as a laser diode. The light source 12 provides a laser beam A that travels in a direction approximately along a central axis Z. As noted above, the inherent instability of the laser beam A results in the beam not precisely coinciding with the central axis Z.

The laser beam A passes first through a polarizing device 14 to enhance the polarization of the laser beam A, and then through a retardation plate 16. The retardation plate 16 isolates the light source 12, and may comprise a quarter-wavelength ($\lambda/4$) optical plate. Alternatively, the retardation plate 16 may be used to match the power of the two beam components (described below), and for that purpose may comprise a half-wavelength ($\lambda/2$) optical plate. Further, the polarizing device 14 and/or retardation plate 16 may also include anti-reflective coatings that prevent stray reflections of the laser beam A back toward the laser beam source 12. Such reflections could cause undesirable oscillation of the laser beam source 12 that would result in temporal instability of the laser beam A. In this regard, the polarizing device 14 and retardation plate 16 act as an optical isolator or diode to protect the laser beam source 12.

The laser beam A is divided into two beam components B1, B2 by a beamsplitter 46, a retroreflector 42 and a reference mirror 44. The beamsplitter 46 may comprise a glass plate having a coating on a lower surface thereof that causes a portion of the laser beam A to reflect therefrom to provide the beam component B1. The beamsplitter 46 is disposed at a 45° angle with respect to the central axis Z to produce an approximately 50% reflection of the beam component B1 in a direction normal to the central axis. In the preferred embodiment, the beamsplitter 46 is formed from optical quality glass having a high degree of smoothness. Alternatively, a pellicle-type beamsplitter comprising a thin mylar sheet may be advantageously utilized. The beam

component **B1** reflects collinearly off of the retroreflector **42**, returning the beam component **B1** back to the beamsplitter **46**. The reflected beam component **B1** then passes partially through the beamsplitter **46** in a direction normal to the central axis **Z**.

The portion of the laser beam **A** that has not reflected off of the beamsplitter **46** passes through the beamsplitter as beam component **B2**. The beam component **B2** follows a path along the central axis **Y** and reflects off of the surface of the reference mirror **44**. The reflected beam component **B2** then returns to the beamsplitter **46**, and reflects off the beamsplitter in a partially overlapping manner with the beam component **B1**. The overlapping beam components **B1**, **B2** (illustrated in FIG. 3 as beams **B1+B2**) provide a reference beam for the linear alignment apparatus. The beamsplitter **46** may additionally be provided with an anti-reflective coating on an upper surface thereof to improve beam transmittance therethrough and mitigate any internal reflections. Accordingly, the lower surface of the beamsplitter **46** is operative to provide the above described reflections of the beam components **B1**, **B2**.

A retroreflector **32** disposed remotely from the laser alignment apparatus receives the overlapping beam components **B1**, **B2**, and reflects them collinearly back toward the laser alignment apparatus. As in the first embodiment, a beam target **30** is oriented so that the collinearly reflected beam components impinge thereon. As illustrated in FIG. 3, the beam target **30** may be collocated with the laser alignment apparatus housing **20**. Alternatively, the beam target **30** may be disposed remotely from the laser alignment apparatus housing **20** and instead may be oriented to receive the overlapping beam components **B1**, **B2** directly from the laser alignment apparatus without a retroreflector **32**, or may be disposed with the retroreflector as part of a remote sensing unit. Moreover, a plurality of beam targets **30** may be disposed at different locations in order to measure relative alignment therebetween.

The beam target **30** has spots projected thereon that correspond to the beam components **B1**, **B2**. In the absence of instability of the source laser beam **A**, the beam components **B1**, **B2** would overlap precisely. As can be seen in FIG. 4, however, the instability of the source beam **A** causes the beam components **B1**, **B2** to diverge symmetrically in both the **X** and **Y**-axis dimensions. As a result, the impinging beam components appear on the target **30** as separate spots disposed uniformly like mirror-images about the origin of the **X** and **Y**-axes, with the distance between the spots and their relative orientation varying with the angular instability of the laser device **12**. The centroid measurement of the beam components **B1**, **B2** illustrated in phantom at spot **C** remains constant and represents a thermally stable reference point for the linear alignment apparatus.

In order to provide a planar alignment system, the alignment apparatus further comprises a motor **28**. The housing **20** containing the laser beam source **12**, polarization device **14**, beamsplitter **46**, retroreflector **42**, reference mirror **44** and target **30** may be rotatable while maintaining these elements in a proper relative orientation. The motor **28** is coupled to the housing **20** in a manner that enables the housing to rotate about the central axis **Z**. Rotation of the housing **20** causes the overlapping beam components **B1**, **B2** to sweep respective planar regions, similar to the first embodiment described above. The beam target **30** will continue to collect centroid information in the same manner described above to provide planar alignment information. Accordingly, it should be apparent that the same alignment apparatus can be used to provide either linear or planar alignment information.

In FIGS. 5, 6a and 6b, a third embodiment of a laser alignment apparatus configured to provide planar alignment is illustrated. The laser alignment apparatus is contained within a housing illustrated in phantom at **50**. As in the previous two embodiments, the laser alignment apparatus includes a collimated light source **12** provided by a semiconductor device, such as a laser diode. The light source **12** provides a moderately polarized laser beam **A** that travels in a direction along a central axis **Z**, which is ideally coincident with the laser beam **A**. The laser beam **A** passes through a polarization device **14** and a retardation plate **16** in order to improve the polarization of the laser beam **A**, preclude stray reflection, and/or match beam component power, as described above.

The beamsplitter **46** of FIG. 5 operates in a similar manner to that of FIG. 3 by dividing the laser beam **A** into two beam components **B1**, **B2**. As in FIG. 3, the beamsplitter **46** has a coating on a lower surface thereof that causes a portion of the laser beam **A** to reflect therefrom to provide the beam component **B1**. The beamsplitter **46** is disposed at a 45° angle with respect to the central axis **Z** to produce a reflection of the beam component **B1** in a direction normal to the central axis **Z**. Unlike the second embodiment of FIG. 3, however, the beam component **B1** is transmitted outwardly from the laser alignment apparatus to provide a first planar reference beam.

Instead of the reference mirror **44**, a retroreflector **48** receives the beam component **B2** as it follows a path along the central axis **Z**. The retroreflector **48** reflects the beam component **B2** collinearly back to the beamsplitter **46**. The reflected beam component **B2** then reflects off the beamsplitter **46** in a direction normal to the central axis **Z** and directly opposite from the direction of the beam component **B1**. The beam component **B2** is then transmitted outwardly from the laser alignment apparatus to provide a second planar reference beam. The alignment apparatus further comprises a motor **28** coupled to the housing **50** in a manner that enables the housing to rotate about the central axis **Z**. Rotation of the housing **50** causes the beam components **B1**, **B2** to sweep respective planar regions, similar to the first embodiment described above.

A retroreflector **31** disposed remotely from the laser alignment apparatus receives the beam component **B1** and reflects it collinearly back towards the laser alignment apparatus. Similarly, a retroreflector **32** disposed remotely from the laser alignment apparatus receives the beam component **B2**, and reflects it collinearly back towards the laser alignment apparatus. A pair of beam targets **51**, **52** are oriented so that the respective reflected beam components **B1**, **B2** impinge thereon. As in the previous embodiment, the beam targets **51**, **52** may be co-located with the laser alignment apparatus housing **50**. Alternatively, the beam targets **51**, **52** may be disposed remotely from the laser alignment apparatus housing **50** and instead may be oriented to receive the respective beam components **B1**, **B2** directly from the laser alignment apparatus without the respective retroreflectors **31**, **32**, or may be disposed with the retroreflectors **31**, **32** as part of respective remote sensing units.

The beam targets **51**, **52** have spots projected thereon that correspond to the beam components **B1**, **B2**. As shown in FIGS. 6a and 6b, the impinging beam components **B1**, **B2** appear on the targets **51**, **52** as spots disposed symmetrically above and below the **X**-axis. The targets **51**, **52** operate together as a single target to provide a centroid measurement of the beam components **B1**, **B2** illustrated in phantom at spot **C** in each target. The phantom image at spot **C** remains constant and represents a thermally stable planar reference point for the alignment apparatus.

It should be apparent to those skilled in the art that a single laser alignment apparatus could be constructed to operate in accordance with both the second and third embodiments described above. The retroreflector **42** of FIG. **3** could be disposed within the housing **20** in a manner that permits it to be manipulated into a position in front of the reference mirror **44**. This way, the retroreflector **42** would then be in the position of the retroreflector **48** of FIG. **5**. The beam component **B1** would then project outwardly in a direction opposite from the beam component **B2** as in the embodiment of FIG. **5**, rather than partially overlapping the beam component **B2** as in the embodiment of FIG. **3**. Such a construction would yield substantial additional utility and flexibility to a single laser alignment apparatus.

FIG. **7** illustrates a fourth embodiment of a laser alignment apparatus configured to provide planar alignment. As in the previous embodiments, the laser alignment apparatus includes a collimated light source **12** provided by a semiconductor device, such as a laser diode. The light source **12** provides a laser beam **A** that travels roughly in a direction along a central axis **Z**. As in the previous embodiments, a polarizer may be utilized to improve the polarization of the laser beam **A**.

The laser beam **A** reflects successively off of a pair of reflective surfaces **62**, **64** to redirect the laser beam **A** in a direction normal to the central axis **Z**. The reflective surfaces **62**, **64** may comprise separate optical elements, or alternatively, may comprise separate surfaces of a single optical element, such as a pentaprism or penta-mirror. The reflective surfaces **62**, **64** are further disposed within a single housing **60**. The housing **60** is rotatable independently of the light source **12** about the central axis **Z**. A motor **68** coupled to the housing **60** rotates the housing about the central axis **Z**, causing the laser beam **A** to sweep a planar region. At the same time, the light source **12** is also coupled to a motor **28** that causes the laser beam **A** to rotate about the axis. The motors **28**, **68** may be controlled separately so that they rotate at distinct rotational rates, as will be described below.

As in the previous embodiments, a beam target (not shown in FIG. **7**) is oriented so that the laser beam **A** will impinge thereon. The beam target may be co-located with the laser alignment apparatus housing **60**, or alternatively, the beam target may be disposed remotely from the laser alignment apparatus housing. The beam target may also be oriented to receive the beam **A** from the laser alignment apparatus with or without a retroreflector as part of a remote sensing unit.

In this embodiment, the single laser beam **A** is utilized to provide the planar alignment information, rather than the pair of beam components in the previous embodiments. By rotating the housing **60** at a different rate than the laser beam source **12**, thermal fluctuations in the laser beam **A** will appear as shifts in position of the laser spot impinging on the beam target. As described previously, the beam target will average the laser spot positions from successive passes of the laser beam **A**, i.e., detect a centroid position from the successive laser spots. The rotational rate of the housing **60** may be selected to be half the rotational rate of the laser beam source **12**, or alternatively, a harmonic relationship between the rotational rates may be advantageously utilized.

In FIG. **8**, a fifth embodiment of a laser alignment apparatus is illustrated which is configured to provide linear or planar alignment. As in the previous embodiments, the laser alignment apparatus includes a collimated light source **12** provided by a semiconductor device, such as a laser diode. The light source **12** provides a laser beam **A**, and a

polarizer **14** may be utilized to polarize the laser beam **A**. Unlike the previous embodiments, however, the direction of the laser beam **A** upon emission from the light source **12** is not normal to its ultimate direction.

Instead, the laser beam **A** is directed to a polarization beamsplitter comprising a glass plate **76**, a second polarizing device **78** and a retroreflector **82**. The glass plate **76** has a surface coating that reflects a portion of the laser beam **A** having a particular polarization. The angle in which the glass plate **76** is disposed with respect to the laser beam source **12** is known as the Brewster angle, and is dependent upon the surface coating applied to the glass plate. Preferably, the glass plate **76** is formed from optical quality glass having a high degree of smoothness and is disposed at a roughly 57° angle with respect to the central axis of the light source **12**. The second polarizing device **78** may be a conventional polarization beamsplitter.

The reflected portion of the laser beam **A** impinges perpendicularly onto the surface of the second polarizing device **78**. A first beam component **B1** reflects directly off of the second polarizing device **78**, and a second beam component **B2** passes through the second polarizing device. A retardation plate may additionally be utilized to isolate the light source **12** or to match the power of the beam components, as described above. The retroreflector **82** reflects the second beam component **B2** back collinearly toward the glass plate **76**. Thereafter, both the first beam component **B1** and the second beam component **B2** pass through the glass plate **76** in a collinear manner to provide a linear alignment reference beam. As in the previous embodiments, a beam target may be utilized to determine a centroid of the two beam components **B1**, **B2** in order to provide a thermally stable reference point. Also, the entire apparatus may be rotated to provide a planar reference beam, as substantially described above.

In FIG. **9**, a sixth embodiment of a laser alignment apparatus is illustrated which is configured to provide linear or planar alignment. As in the previous embodiments, the laser alignment apparatus includes a collimated light source **12** provided by a semiconductor device, such as a laser diode. As in the previous embodiment, the direction of the laser beam **A** upon emission from the light source **12** is not normal to its ultimate direction.

The laser beam **A** is directed onto a beamsplitter cube **80**, which divides the beam into a first beam component **B1** and a second beam component **B2**. As known in the art, the beamsplitter cube **80** has four exposed outer surfaces **84**, **88**, **92**, and **94**. A partially reflective boundary **86** is defined through the center of the cube **80** that effectively joins the intersection of surfaces **84**, **88** with the intersection of surfaces **92**, **94**. As illustrated in FIG. **9**, the laser beam **A** impinges onto the surface **88**, and is refracted inward toward the boundary **86**. The refracted laser beam **A** is divided at the boundary **86** into the first beam component **B1** that passes through the boundary and the second beam component **B2** that reflects off of the boundary. The first beam component **B1** emerges from the cube **80** at surface **94**, and the second beam component **B2** emerges from the cube **80** at surface **92**. The two beam components **B1**, **B2** are then projected outwardly in a collinear manner to provide a linear alignment reference beam. As in the previous embodiments, a beam target may be utilized to determine a centroid of the two beam components **B1**, **B2** in order to provide a thermally stable axial reference point. Also, the entire apparatus may be rotated to provide a planar reference beam, as substantially described above.

In FIG. **10**, a seventh embodiment of a laser alignment apparatus is illustrated which is configured to provide planar

alignment. Unlike the previous embodiments, the laser alignment apparatus includes a collimated light source **112** provided by a gas laser device containing a suitable active gaseous element, such as helium-neon gas. The light source **112** comprises a tubular shaped element that is capable of emitting laser beams **A1**, **A2** from opposite ends, respectively. The laser beams **A1**, **A2** are directed along a common axis of the light source **112** in opposing directions.

A motor **28** is coupled to the light source **112** in a manner perpendicular to a central axis **Z** of the light source. Rotation of the laser beam source **112** by the motor **28** causes the beams **A1**, **A2** to sweep respective planar regions. As in the previous embodiments, a beam target may be utilized to determine a centroid of the two beams **A1**, **A2** in order to provide a planar reference point. It should be apparent that the laser beams **A1**, **A2** have much greater thermal stability than the laser diodes described in the preceding embodiments of the invention; nevertheless, the centroid measurement would permit even greater planar alignment accuracy than that achievable with either laser diodes or conventional gas laser alignment systems.

Having thus described a preferred embodiment of dual beam laser device for linear and planar alignment, it should be apparent to those skilled in the art that certain advantages of the within system have been achieved. It should also be appreciated that various modifications, adaptations, and alternative embodiments thereof may be made within the scope and spirit of the present invention. For example, holographic and/or diffractive optic elements may be utilized to split a source laser beam into beam components, rather than the more conventional optical components described above. Further, beam components may be caused to sweep planar regions through an oscillatory movement in which the optical systems are rotated through less than a full 360° of motion, then returned in an opposite direction through an equivalent range of motion, as opposed to a continuous rotation in a single direction. The invention is defined by the following claims.

What is claimed is:

1. An apparatus for providing a reference beam for use in an alignment system, comprising:

a collimated light source providing a light beam;

means for dividing said light beam into a first and second beam component, wherein said first and second beam components are projected outwardly from said dividing means in opposite directions;

means for detecting a common centroid of said first and second beam components that is independent of drift of said light beam; and

means for rotating said dividing means about an axis to cause the first and second beam components to sweep respective planar regions.

2. An apparatus for providing a reference beam for use in an alignment system, comprising:

a collimated light source providing a light beam;

means for dividing said light beam into a first and second beam component, wherein said first and second beam components are projected outwardly from said dividing means in opposite directions, wherein said dividing means further comprises a housing and a beamsplitter disposed within said housing at a predetermined angle, said beamsplitter having a reflective coating which reflects said first beam component therefrom, said second beam component being transmitted through said beamsplitter;

means for detecting a common centroid of said first and second beam components that is independent of drift of said light beam; and

means for rotating said housing about an axis to cause said first and second beam components to sweep a planar region.

3. An apparatus for providing a planar reference beam for use in an alignment system, comprising:

a collimated light source providing a light beam;

a wedge having first and second faces that respectively reflect first and second beam components of said light beam in opposite directions;

means for rotating said wedge about an axis to cause the first and second beam components to sweep respective planar regions; and

means for detecting a common centroid of said first and second beam components.

4. The apparatus of claim 3, wherein said detecting means further comprises a photodetector oriented remotely from said wedge to permit said first and second beam components to impinge thereon and provide said common centroid measurement therefrom.

5. The apparatus of claim 3, wherein said rotating means further comprises a motor.

6. An apparatus for providing a reference beam for use in an alignment system comprising:

a collimated light source providing a light beam;

means for dividing said light beam into first and second beam components, said dividing means comprising:

first optical means disposed at a predetermined angle with respect to said light beam for reflecting said first beam component therefrom and for transmitting said second beam component therethrough;

second optical means for collinearly reflecting said reflected first beam component back to said first optical means, said first beam component being thereby transmitted through said first optical means; and

third optical means for coaxially reflecting said second beam component back to said first optical means, said reflected second beam component being thereby reflected off of said first optical means in an overlapping manner with said first beam component;

means for detecting a common centroid of said first and second beam components; and

means for rotating said dividing means about an axis to cause said first and second beam components to sweep a planar region.

7. An apparatus for providing a planar reference beam for use in an alignment system, comprising:

a light source providing a light beam;

means for dividing said light beam into a first and second beam component directed in opposite directions, said dividing means comprising:

first optical means for reflecting said first beam component therefrom in a first direction and for transmitting said second beam component therethrough; and

second optical means for collinearly reflecting said transmitted second beam component back to said first optical means, said first beam component being thereby reflected therefrom in a second direction opposite to said first direction of said first beam component;

means for rotating said dividing means about a central axis to cause said first and second beam components to sweep respective planar regions; and

means for detecting a common centroid of said first and second beam components.

13

8. The apparatus of claim 7, wherein said first optical means is disposed at a predetermined angle with respect to said central axis.

9. The apparatus of claim 7, wherein said first optical means further comprises a beamsplitter having a reflective coating on at least a first surface thereof. 5

10. The apparatus of claim 7, wherein said second optical means further comprises a retroreflector.

11. The apparatus of claim 7, wherein said detecting means further comprises: 10
at least one photodetector oriented to permit said first and second beam components to impinge thereon and provide said common centroid measurement therefrom.

12. The apparatus of claim 7, wherein said detecting means further comprises: 15

a first photodetector oriented to permit said first beam component to impinge thereon;

a second photodetector oriented to permit said second beam component to impinge thereon; and

means associated with said first and second photodetectors for providing said common centroid measurement therefrom. 20

13. The apparatus of claim 7, wherein said light source further comprises a laser diode. 25

14. The apparatus of claim 7, wherein said rotating means further comprises a motor.

15. An apparatus for providing a planar reference beam for use in an alignment system, comprising:

a collimated light emitting source providing a light beam and means for rotating said light emitting source at a first rotational rate; 30

reflecting means having at least first and second surfaces for reflecting said light beam in a normal direction and

14

means for rotating said reflecting means at a second rotational rate to cause said reflected light beam to sweep through a substantially planar region, said second rotational rate being less than said first rotational rate; and

means oriented to permit said reflected light beam to impinge thereon for detecting a centroid of said reflected light beam.

16. The apparatus of claim 15, wherein said detecting means further comprises a photodetector oriented remotely from said reflecting means.

17. The apparatus of claim 15, wherein said second rotational rate is half said first rotational rate.

18. The apparatus of claim 15, wherein said second rotational rate is harmonically related to said first rotational rate.

19. The apparatus of claim 15, wherein said reflecting means further comprises a pentaprism.

20. An apparatus for providing a reference beam for an alignment system, comprising:

a collimated light source providing a first and a second laser beam directed in opposite directions;

means for rotating said collimated light source about an axis to cause said first and second laser beams to sweep respective planar regions; and

means for detecting a common centroid of said first and second beam laser beams.

21. The apparatus of claim 20, wherein said collimated light source further comprises a gas laser.

* * * * *