US 20180173027A1

(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2018/0173027 A1**

(43) **Pub. Date: Jun. 21, 2018**

MORSE et al.

(54) **CONTROL SYSTEM INCLUDING A BEAM STABILIZER AND A PHASE MODULATION CAPABLE ACOUSTO-OPTIC MODULATOR FOR DIVERTING LASER OUTPUT INTENSITY NOISE TO A FIRST ORDER LASER LIGHT BEAM AND RELATED METHODS**

(71) Applicant: **Harris Corporation**, Melbourne, FL (US)

(72) Inventors: **RANDALL K. MORSE**, Palm Bay, FL (US); **Peter A. Wasilousky**, Indialantic, FL (US); **Lee M. Burberry**, West Melbourne, FL (US); **Michael R. Lange**, Melbourne, FL (US); **Catheryn D. Logan**, Melbourne, FL (US); **CHRISTOPHER A. COREY**, PALM BAY, FL (US)

(21) Appl. No.: **15/900,936**

(22) Filed: **Feb. 21, 2018**

Related U.S. Application Data

(63) Continuation-in-part of application No. 15/342,372, filed on Nov. 3, 2016, now Pat. No. 9,958,711.

Publication Classification

(51) **Int. Cl.**

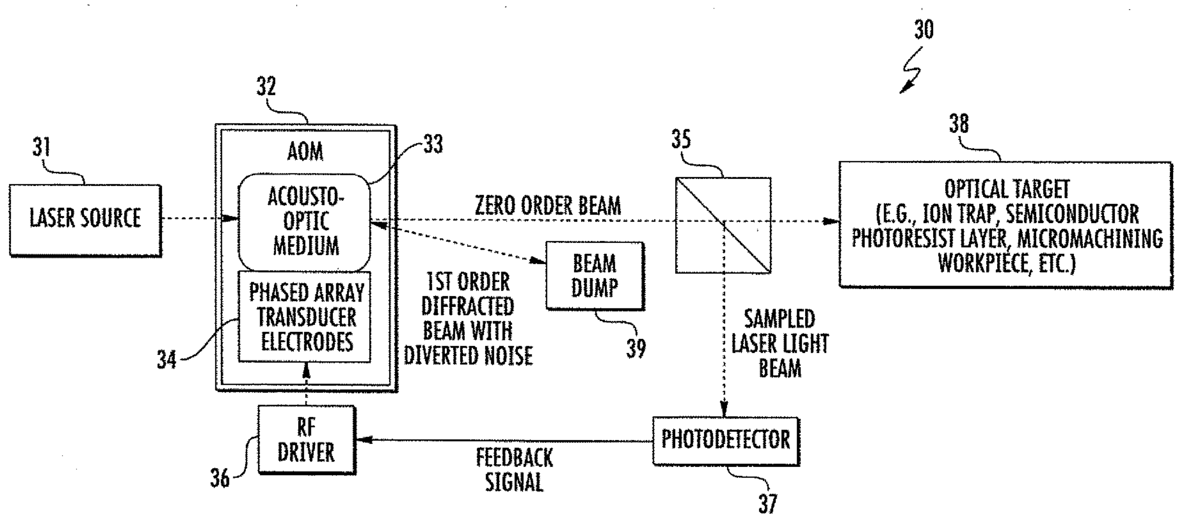
G02F 1/11	(2006.01)
G02F 1/29	(2006.01)
G02F 1/33	(2006.01)
H01S 3/00	(2006.01)

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

CPC ***G02F 1/113*** (2013.01); ***H01S 3/0085*** (2013.01); ***G02F 1/33*** (2013.01); ***G02F 1/292*** (2013.01)

(57) **ABSTRACT**

A laser system may include a laser source configured to generate a laser light beam, a beam stabilizer downstream from the laser light source, and an acousto-optic modulator (AOM). The AOM may include an acousto-optic medium configured to receive the laser light beam, and a phased array transducer including a plurality of electrodes coupled to the acousto-optic medium and configured to cause the acousto-optic medium to output a zero order laser light beam and a first order diffracted laser light beam. The system may further include a photodetector configured to receive a sampled laser light beam split from the zero order beam and generate a feedback signal associated therewith, and an RF driver configured to generate an RF drive signal to the phased array transducer electrodes so that noise is diverted to the first order diffracted laser light beam based upon the feedback signal.



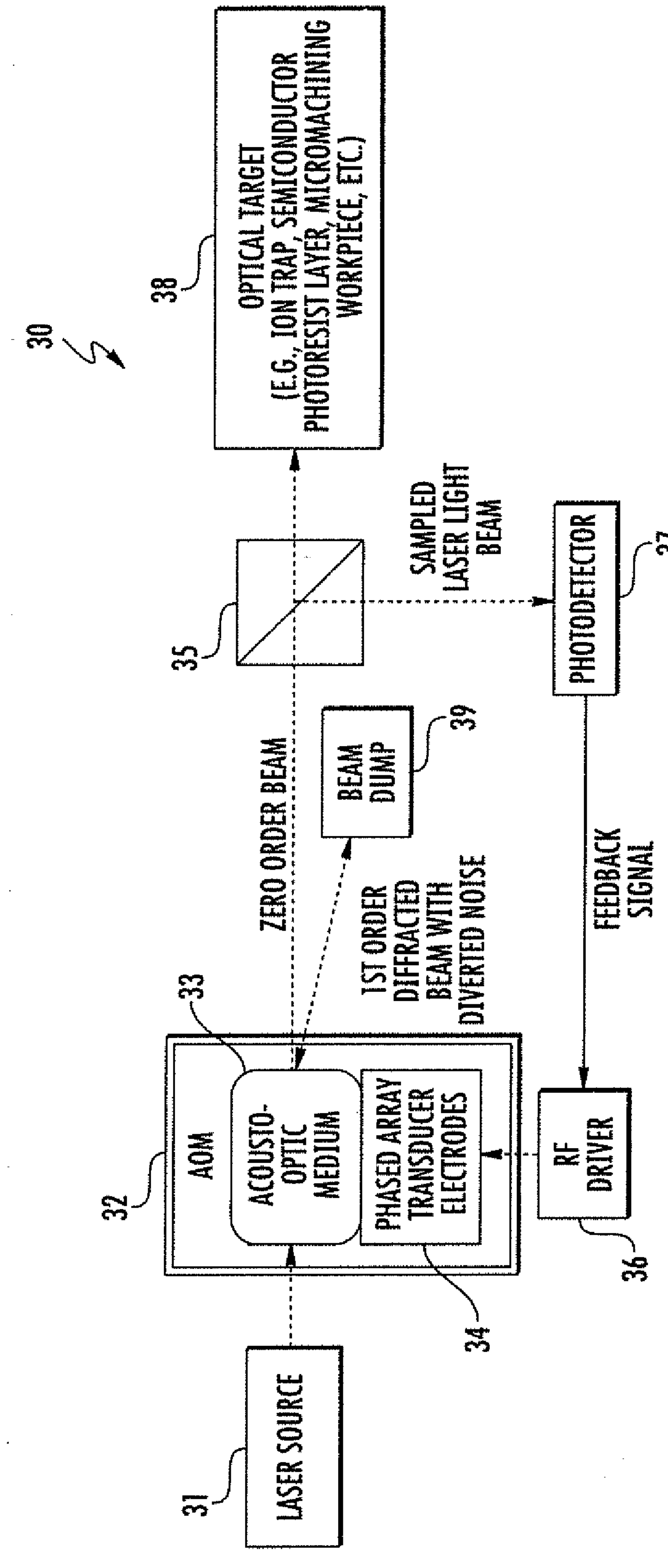

30
38
OPTICAL TARGET
(E.G., ION TRAP, SEMICONDUCTOR
PHOTORESIST LAYER, MICROMACHINING
WORKPIECE, ETC.)
SAMPLED
LASER LIGHT
BEAM
35
37
PHOTODETECTOR
ZERO ORDER BEAM
BEAM
DUMP
39
1ST ORDER
DIFFRACTED
BEAM WITH
DIVERTED NOISE
FEEDBACK
SIGNAL
33
32
AOM
ACOUSTO-
OPTIC
MEDIUM
PHASED ARRAY
TRANSDUCER
ELECTRODES
RF
DRIVER
36
34
31
LASER SOURCE

FIG. 1

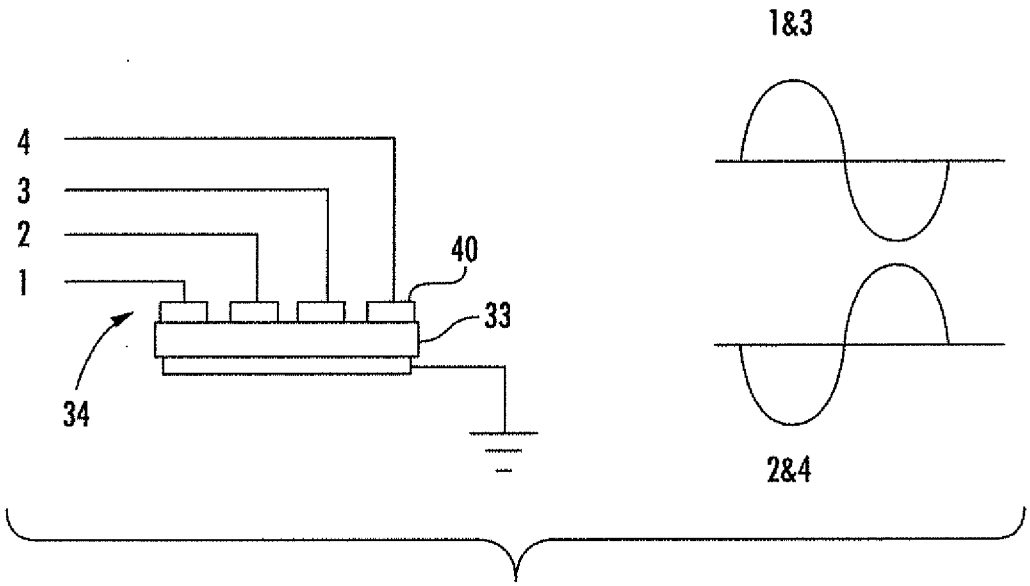


FIG. 2

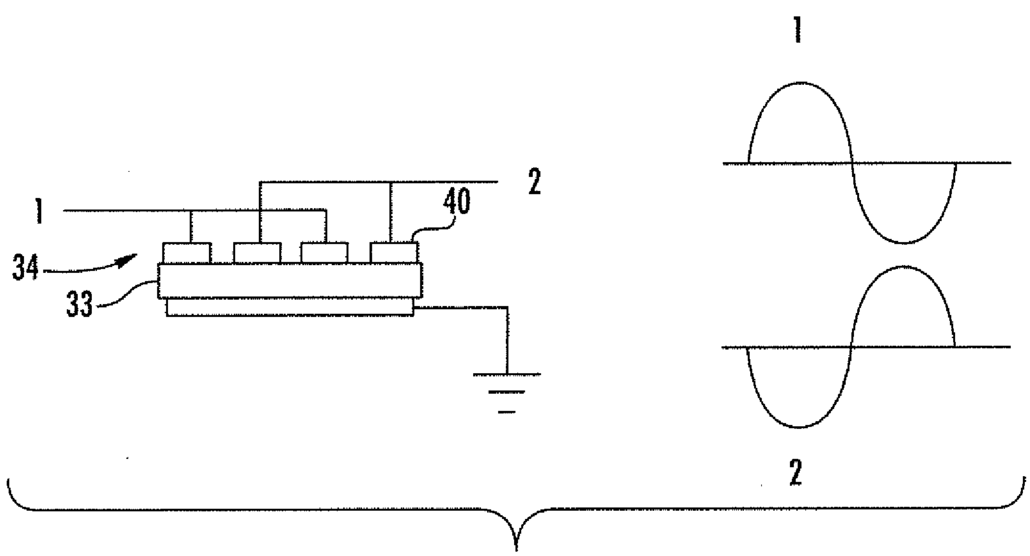


FIG. 3

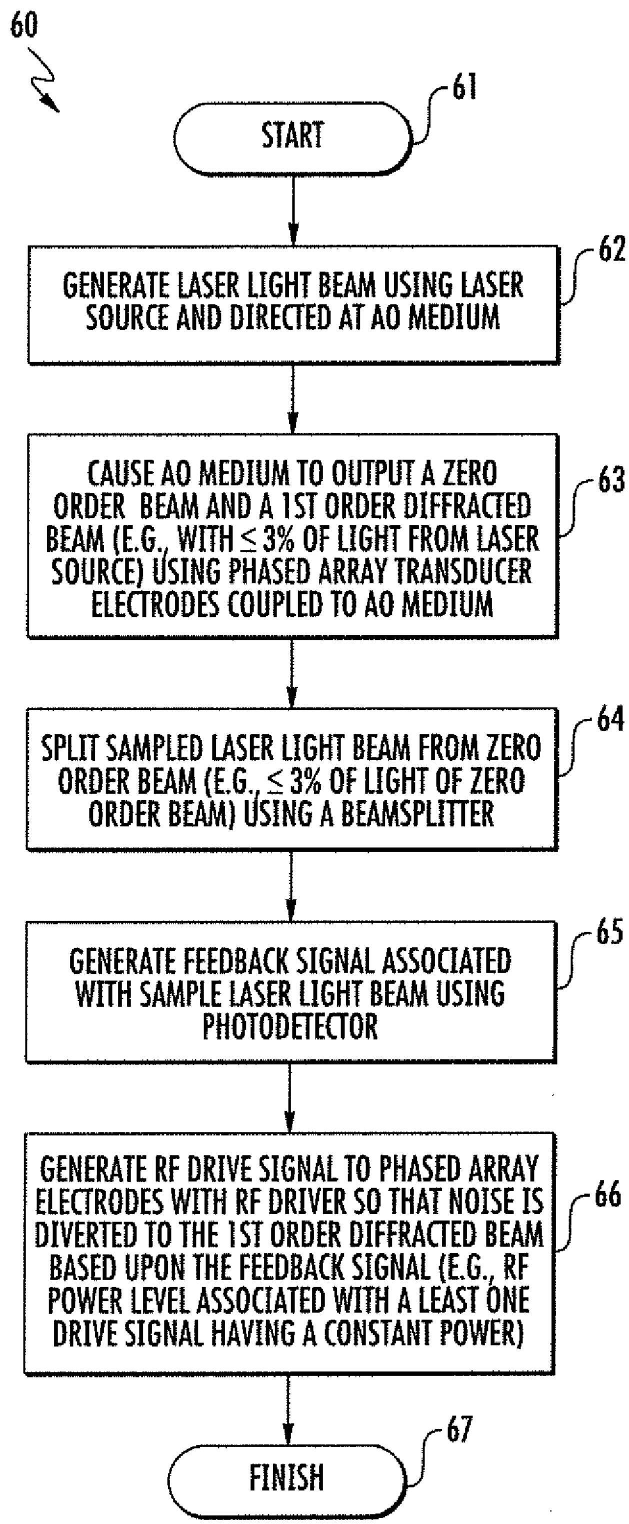

60
START
61
GENERATE LASER LIGHT BEAM USING LASER SOURCE AND DIRECTED AT AO MEDIUM
62
CAUSE AO MEDIUM TO OUTPUT A ZERO ORDER BEAM AND A 1ST ORDER DIFFRACTED BEAM (E.G., WITH ≤ 3% OF LIGHT FROM LASER SOURCE) USING PHASED ARRAY TRANSDUCER ELECTRODES COUPLED TO AO MEDIUM
63
SPLIT SAMPLED LASER LIGHT BEAM FROM ZERO ORDER BEAM (E.G., ≤ 3% OF LIGHT OF ZERO ORDER BEAM) USING A BEAMSPLITTER
64
GENERATE FEEDBACK SIGNAL ASSOCIATED WITH SAMPLE LASER LIGHT BEAM USING PHOTODETECTOR
65
GENERATE RF DRIVE SIGNAL TO PHASED ARRAY ELECTRODES WITH RF DRIVER SO THAT NOISE IS DIVERTED TO THE 1ST ORDER DIFFRACTED BEAM BASED UPON THE FEEDBACK SIGNAL (E.G., RF POWER LEVEL ASSOCIATED WITH A LEAST ONE DRIVE SIGNAL HAVING A CONSTANT POWER)
66
FINISH
67

FIG. 4

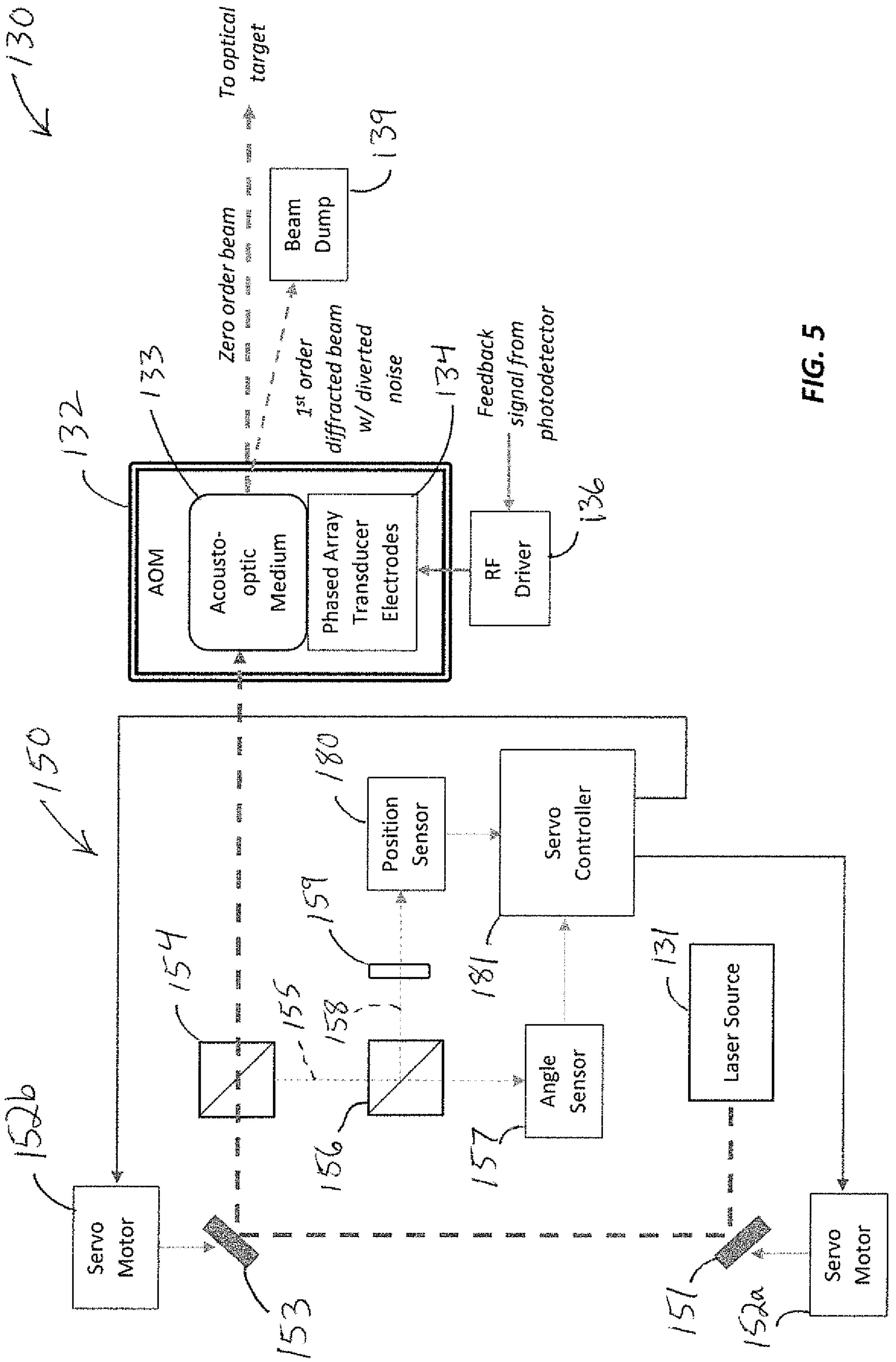

130
To optical target
139
Beam Dump
Zero order beam
1st order diffracted beam w/ diverted noise
132
133
134
Feedback signal from photodetector
AOM
Acousto-optic Medium
Phased Array Transducer Electrodes
RF Driver
136
150
180
Position Sensor
Servo Controller
181
159
154
155
158
Angle Sensor
156
157
131
Laser Source
152b
Servo Motor
153
151
152a
Servo Motor

FIG. 5

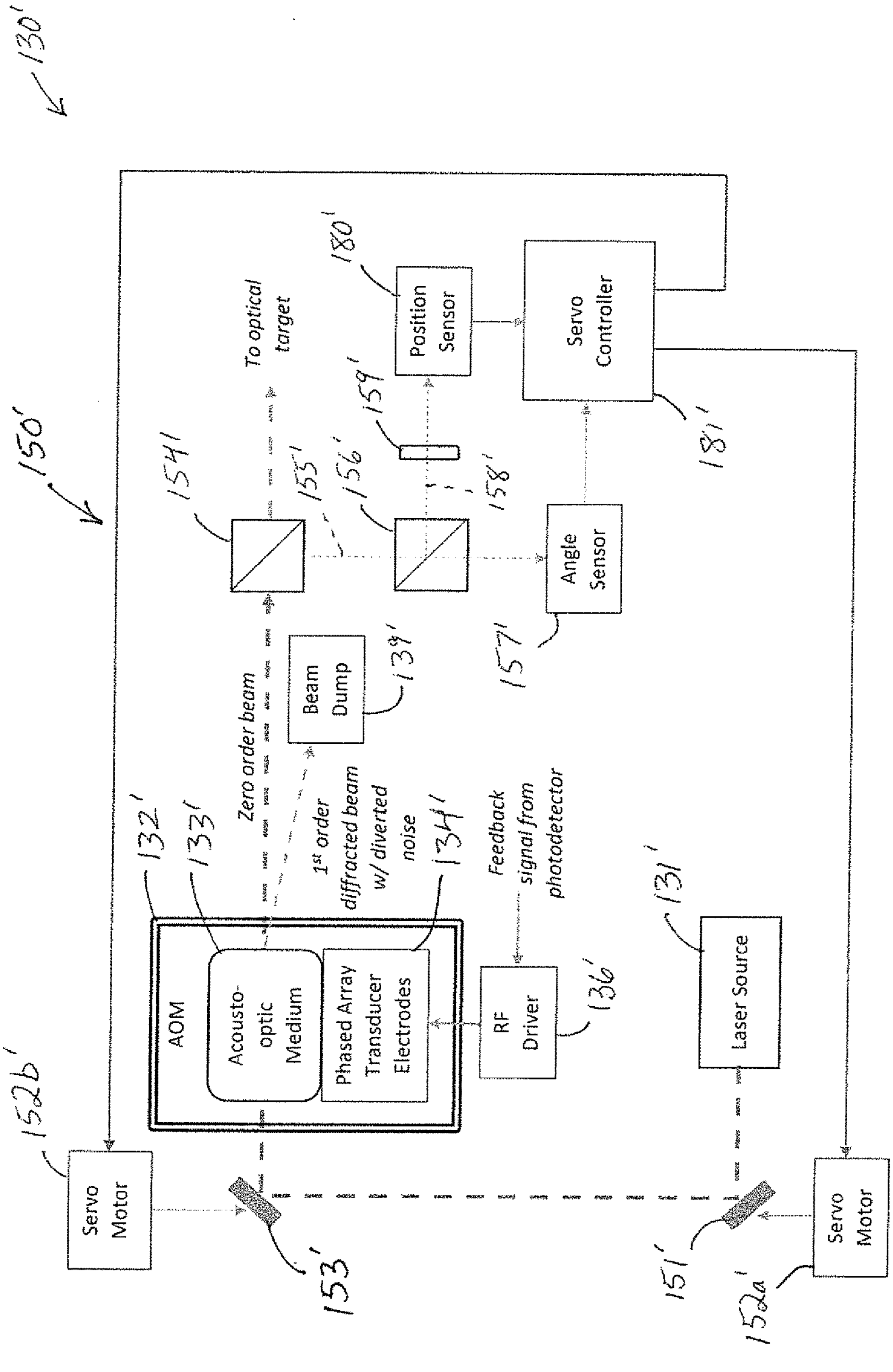

130'
150'
To optical target
180'
Position Sensor
Servo Controller
159'
154'
155'
156'
158'
181'
Angle Sensor
157'
Beam Dump
139'
Zero order beam
132'
133'
1st order diffracted beam w/ diverted noise
134'
Feedback signal from photodetector
131'
AOM
Acousto-optic Medium
Phased Array Transducer Electrodes
RF Driver
136'
Laser Source
152b'
Servo Motor
153'
151'
152a'
Servo Motor

FIG. 6

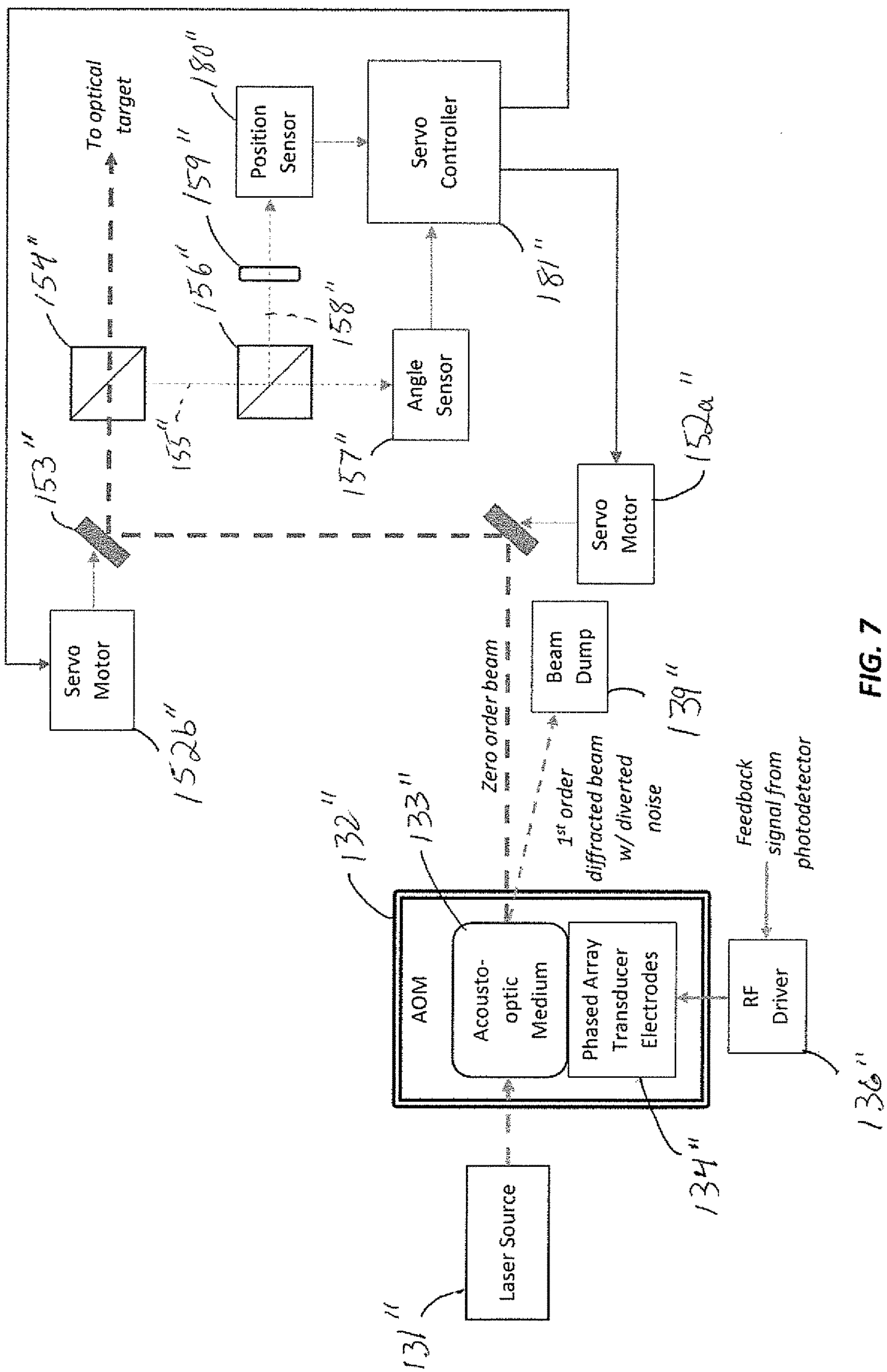

To optical target
Position Sensor
Servo Controller
Angle Sensor
Servo Motor
Servo Motor
Beam Dump
Zero order beam
1st order diffracted beam w/ diverted noise
Feedback signal from photodetector
AOM
Acousto-optic Medium
Phased Array Transducer Electrodes
RF Driver
Laser Source
131"
132"
133"
134"
136"
139"
152a"
152b"
153"
154"
155"
156"
157"
158"
159"
180"
181"

FIG. 7

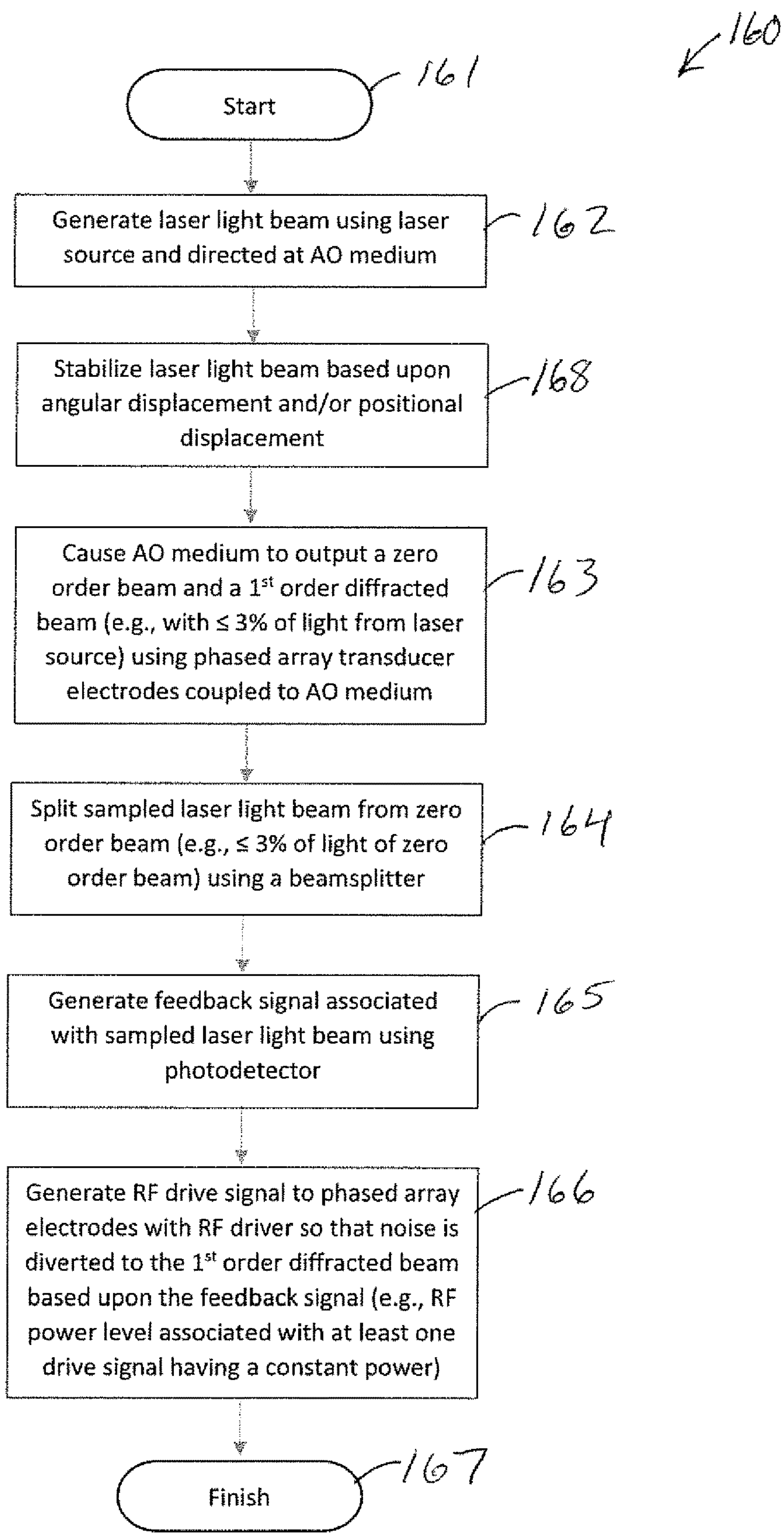

160
Start
161
Generate laser light beam using laser source and directed at AO medium
162
Stabilize laser light beam based upon angular displacement and/or positional displacement
168
Cause AO medium to output a zero order beam and a 1st order diffracted beam (e.g., with ≤ 3% of light from laser source) using phased array transducer electrodes coupled to AO medium
163
Split sampled laser light beam from zero order beam (e.g., ≤ 3% of light of zero order beam) using a beamsplitter
164
Generate feedback signal associated with sampled laser light beam using photodetector
165
Generate RF drive signal to phased array electrodes with RF driver so that noise is diverted to the 1st order diffracted beam based upon the feedback signal (e.g., RF power level associated with at least one drive signal having a constant power)
166
Finish
167

FIG. 8

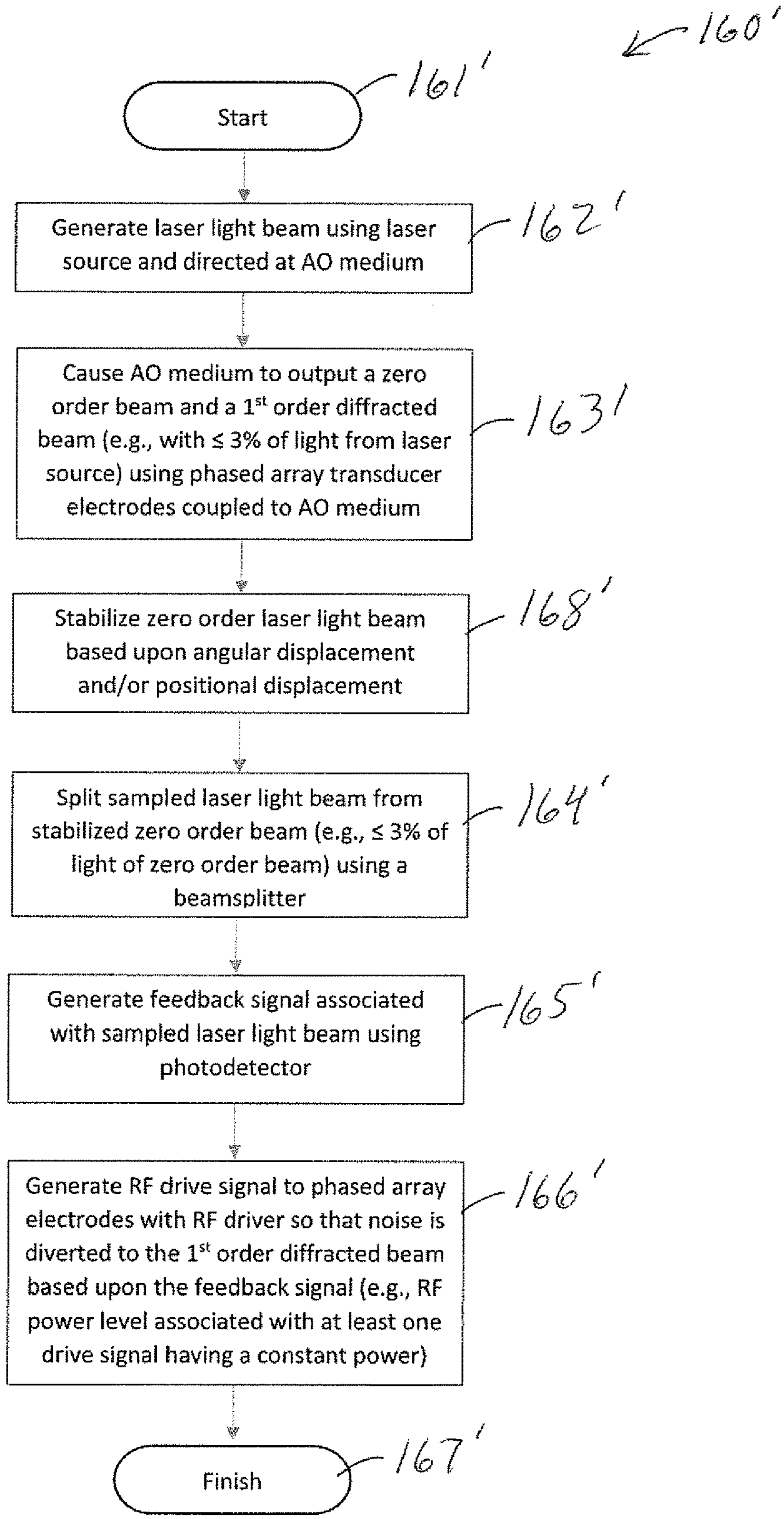

160'
161'
Start
Generate laser light beam using laser source and directed at AO medium
162'
Cause AO medium to output a zero order beam and a 1st order diffracted beam (e.g., with ≤ 3% of light from laser source) using phased array transducer electrodes coupled to AO medium
163'
Stabilize zero order laser light beam based upon angular displacement and/or positional displacement
168'
Split sampled laser light beam from stabilized zero order beam (e.g., ≤ 3% of light of zero order beam) using a beamsplitter
164'
Generate feedback signal associated with sampled laser light beam using photodetector
165'
Generate RF drive signal to phased array electrodes with RF driver so that noise is diverted to the 1st order diffracted beam based upon the feedback signal (e.g., RF power level associated with at least one drive signal having a constant power)
166'
Finish
167'

FIG. 9

CONTROL SYSTEM INCLUDING A BEAM STABILIZER AND A PHASE MODULATION CAPABLE ACOUSTO-OPTIC MODULATOR FOR DIVERTING LASER OUTPUT INTENSITY NOISE TO A FIRST ORDER LASER LIGHT BEAM AND RELATED METHODS

RELATED APPLICATIONS

[0001] This application is a continuation in part of application Ser. No. 15/342,372 filed Nov. 3, 2016, which is hereby incorporated herein in its entirety by reference.

TECHNICAL FIELD

[0002] The present invention relates to the field of optical devices, and, more particularly, to acousto-optic modulators for lasers and related methods.

BACKGROUND

[0003] Acousto-optic modulators, sometimes referred to as Bragg cells, diffract and shift light using sound waves at radio frequency. These devices are often used for Q-switching, signal modulation in telecommunications systems, laser scanning and beam intensity control, frequency shifting, and wavelength filtering in spectroscopy systems. Many other applications lend themselves to using acousto-optic devices.

[0004] In such acousto-optic devices, a piezoelectric transducer, sometimes also referred to as an RF transducer, is secured to an acousto-optic bulk medium as a transparent optical material, for example, fused silica, quartz or similar glass material. An electric RF signal oscillates and drives the transducer to vibrate and create sound waves within the transparent medium which affect the properties of an optical field in the medium via the photo elastic effect, in which a modulating strain field of an ultrasonic wave is coupled to an index of refraction for the acousto-optic bulk medium. As a result, the refractive index change in amplitude is proportional to that of sound.

[0005] The index of refraction is changed by moving periodic planes of expansion and compression in the acousto-optic bulk material. Incoming light scatters because of the resulting periodic index modulation and interference, similar to Bragg diffraction.

[0006] Acousto-optic modulators are preferred in many applications because they are faster than tiltable mirrors and other mechanical devices. The time it takes for the acousto-optic modulator to shift an exiting optical beam is limited to the transit time of the sound wave. The acousto-optic modulators are often used in Q-switches where a laser produces a pulsed output beam at high peak power, typically in the Kilowatt range. This output could be higher than lasers operating a continuous wave (CW) or constant output mode.

[0007] Examples of acousto-optic modulator devices and similar acousto-optic systems are disclosed in commonly assigned U.S. Pat. Nos. 4,256,362; 5,923,460; 6,320,989; 6,487,324; 6,538,690; 6,765,709; and 6,870,658, the disclosures of which are hereby incorporated by reference in their entireties.

[0008] Some applications using acousto-optic devices modulate the intensity of an optical beam. This modulation may create small deviations in the output angle of the diffracted beam because of the local thermal transients introduced when the RF modulation waveform to the device is turned ON and OFF. These thermal transients may negatively impact the resolution and location of the focused spot, which may be produced. One advantageous approach which may be used to help enhance the resolution of acousto-optic devices is set forth in U.S. Pat. No. 7,538,929 to Wasilousky, which is assigned to the present Applicant and is hereby incorporated herein in its entirety by reference. Wasilousky discloses an acousto-optic modulator which includes an acousto-optic bulk medium and transducer attached to the acousto-optic bulk medium and formed as a linear array of electrodes. A transducer driver is connected to each electrode and is coherently phase driven to alter the angular momentum distribution of an acoustic field and alternately allow and inhibit phase matching between the optical and acoustic field and produce a desired intensity modulation of an optical wavefront.

[0009] Despite the existence of such configurations, further advancements in laser systems using acousto-optic modulators may be desirable in certain applications.

SUMMARY

[0010] A laser system may include a laser source configured to generate a laser light beam, a beam stabilizer downstream from the laser light source, and an acousto-optic modulator (AOM). The AOM may include an acousto-optic medium configured to receive the laser light beam, and a phased array transducer comprising a plurality of electrodes coupled to the acousto-optic medium and configured to cause the acousto-optic medium to output a zero order laser light beam and a first order diffracted laser light beam. The system may further include a beamsplitter downstream from the AOM and configured to split a sampled laser light beam from the zero order laser light beam, a photodetector configured to receive the sampled laser light beam and generate a feedback signal associated therewith, and a radio frequency (RF) driver configured to generate an RF drive signal to the phased array transducer electrodes so that noise is diverted to the first order diffracted laser light beam based upon the feedback signal.

[0011] By way of example, the beam stabilizer may be configured to correct an angular displacement and/or a positional displacement of the laser light beam into the AOM. More particularly, the beam stabilizer may include a position mirror optically aligned with the laser light beam from the laser source, a servo motor configured to move the position mirror, a position sensor configured to measure a positional displacement of the laser light beam, and a servo controller coupled to the servo motor and configured to actuate the servo motor to stabilize the laser light beam based upon the position sensor. Similarly, the beam stabilizer may also include an angle mirror optically aligned with the laser light beam from the laser source, a servo motor configured to move the angle mirror, an angle sensor configured to measure an angular displacement of the laser light beam, and a servo controller coupled to the servo motor and configured to actuate the servo motor to stabilize the laser light beam based upon the angle sensor.

[0012] In accordance with another example, the beam stabilizer may include a position mirror optically aligned with the zero order laser light beam from the acousto-optic medium, a servo motor configured to move the position mirror, a position sensor configured to measure a positional displacement of the zero order laser light beam, and a servo controller coupled to the servo motor and configured to actuate the servo motor to stabilize the zero order laser light beam based upon the position sensor. Similarly, beam stabilizer may also include an angle mirror optically aligned with the zero order laser light beam from the acousto-optic medium, a servo motor configured to move the angle mirror, an angle sensor configured to measure an angular displacement of the zero order laser light beam, and a servo controller coupled to the servo motor and configured to actuate the servo motor to stabilize the zero order laser light beam based upon the angle sensor.

[0013] Furthermore, the RF driver may be configured to drive alternating electrodes of the phased array transducer electrodes with different phases. Moreover, an RF power level associated with the RF drive signal may have a constant power. In addition, the laser system may also include an ion trap, and the beamsplitter may be configured to direct the zero order laser light beam from the AOM to the ion trap.

[0014] A related method may include generating a laser light beam using a laser source, stabilizing the laser light beam using a beam stabilizer downstream from the laser light source, and causing an acousto-optic medium to output a zero order laser light beam from the stabilized laser light beam using a phased array transducer comprising a plurality of electrodes coupled to the acousto-optic medium. The method may further include splitting a sampled laser light beam from the zero order laser light beam using a beamsplitter downstream from the acousto-optic medium, generating a feedback signal associated with the sampled laser light beam using a photodetector, and generating a radio frequency (RF) drive signal for the phased array transducer electrodes with an RF driver so that noise is diverted to the first order diffracted laser light beam based upon the feedback signal.

[0015] Another related method may include generating a laser light beam using a laser source, causing an acousto-optic medium to output a zero order laser light beam from the laser light beam using a phased array transducer comprising a plurality of electrodes coupled to the acousto-optic medium, and stabilizing the zero order laser light beam using a beam stabilizer downstream from the acousto-optic medium. The method may further include splitting a sampled laser light beam from the stabilized zero order laser light beam using a beamsplitter downstream from the acousto-optic medium, generating a feedback signal associated with the sampled laser light beam using a photodetector, and generating a radio frequency (RF) drive signal for the phased array transducer electrodes with an RF driver so that noise is diverted to the first order diffracted laser light beam based upon the feedback signal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** is a schematic block diagram of a laser system including a phase-capable acousto-optic modulator (AOM) in accordance with an example embodiment.

[0017] FIGS. **2** and **3** are schematic circuit diagrams illustrating different electrode connection configurations and associated driving signals therefor which may be used with the systems of FIGS. **1-3**.

[0018] FIG. **4** is a flow diagram illustrating method aspects associated with the system of FIG. **1**.

[0019] FIGS. **5-7** are schematic block diagrams of different example implementations of the laser system of FIG. **1** further including respective laser light beam stabilizer configurations.

[0020] FIG. **8** is a flow diagram illustrating method aspects associated with the systems of FIGS. **5-6**.

[0021] FIG. **9** is a flow diagram illustrating method aspects associated with the system of FIG. **7**.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0022] The present description is made with reference to the accompanying drawings, in which exemplary embodiments are shown. However, many different embodiments may be used, and thus the description should not be construed as limited to the particular embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete. Like numbers refer to like elements throughout, and prime and multiple prime notation are used to indicate similar elements or steps in different embodiments.

[0023] By way of background, excessive noise levels from laser sources in optical illumination systems generate instabilities and errors. In particular, systems that manipulate the quantum states of particles, atoms and electrons, typically require extreme stability. Beam pointing errors correlate to noise in quantum state manipulation systems. Moreover, beam pointing stability due to thermal transients in the bulk material of active acousto-optic devices in an optical illumination system affect many applications, but especially those designed for quantum state illumination.

[0024] Referring initially to FIGS. **1** and **4**, a laser system **30** and associated method aspects which may provide enhanced stability and noise reduction are first described. Beginning at Block **61** of the flow diagram **60**, the laser system **30** illustratively includes a laser source **31** configured to generate a laser light beam, at Block **62**. In accordance with one example embodiment, a Paladin Advanced 355 nm mode locked UV laser source from Coherent, Inc. of Santa Clara, Calif. may be used, although other suitable laser sources may also be used in different embodiments. The system **30** further illustratively includes an acousto-optic modulator (AOM) **32**. The AOM illustratively includes an acousto-optic medium **33** configured to receive the laser light beam from the laser source **31**, and a phased array of electrodes **34** coupled to the acousto-optic medium. The acousto-optic medium **33** may include a piezoelectric transducer and bulk acousto-optic medium (e.g., silica, quartz, glass, etc.), as discussed above. The phased array of electrodes **34** are configured to cause the acousto-optic medium **33** to output a zero order laser light beam to an optical target **38**, and a first order diffracted laser light beam, at Block **63**, as will be discussed further below.

[0025] The system further illustratively includes a beamsplitter **35** downstream from the AOM **32** which is configured to split a sampled laser light beam from the zero order laser light beam, at Block **64**. The beamsplitter **35** need only divert a small portion of light from the zero order laser light beam into the sampled laser light beam (e.g., 3%) to provide adequate feedback to a radio frequency (RF) driver **36** for driving the phase array of electrodes **34**. More particularly, a photodetector **37** is configured to receive the sampled laser light beam and generate an electrical feedback signal for the RF driver **36** based upon the sampled laser light beam. As such, the RF driver **36** is able to generate one or more RF drive signals to the phased array of electrodes **34** to generate the zero order beam and the first order diffracted beam accordingly, which illustratively concludes the method of FIG. **4** (Block **67**).

[0026] In particular, the RF driver **36** drives the phased array of electrodes **34** such that noise measured from the feedback signal is diverted to the first order diffracted laser light beam, which may be directed to a beam dump **39** (or simply away from the optical target **38**). This advantageously provides noise cancellation by diffracting a relatively small amount of light from the zero order beam (e.g., <3%) into the first order diffracted beam by changing the phase of the RF drive signal to alternating electrode elements of the phased array of electrodes **34**. In particular, the feedback signal is inverted and sent to the phase modulation capable AOM **32** to subtract and correct for the inherent noise in the laser.

[0027] This may be done while the RF power applied to the acousto-optic medium **33** remains essentially constant which helps to eliminate beam pointing errors which may otherwise be associated with varying thermal transients due to changing RF power levels, as may be experienced with typical amplitude modulation AOMs, for example. Stated alternatively, by only effecting the phase of the RF drive signal to the N element phased array electrode pattern on the AOM and leaving the RF power level essentially constant, this advantageously reduces the laser intensity noise appearing on the zero order beam while still retaining a positionally stable beam.

[0028] More particularly, referring additionally to FIGS. **2** and **3**, two example configurations for driving alternating electrodes **40** of the phased array of electrodes **34** with different phases to provide the zero and first order beam configuration described above are now described. In the first configuration (FIG. **2**), the first and third driving signals (shown on the right hand side of FIG. **2**) provided to corresponding odd numbered electrodes are 180° out of phase with the second and fourth driving signals provided to corresponding even numbered electrodes. In the second configuration (FIG. **3**), first and second drive signals are respectively connected to odd and even electrodes in an interdigitated fashion as shown, and as before these drive signals are 180° out of phase to one another. In this way, directly adjacent electrodes are driven at opposite phases to one another. However, it should be noted that the RF drive signals need not always be 180° out of phase, i.e., they may be somewhere between 0° and 180° to vary the level of phase matching occurring in the AO diffraction process, thereby selectively altering the amount of light directed from the zero order beam into the first order beam.

[0029] The system **30** accordingly combines intensity modulation via RF-phase variation on a phased array transducer with active optical feedback to accomplish noise cancellation in an optical illumination system. Moreover, performing phase modulation by flipping the phase of alternating elements of a multi-element phased array has inherently better pointing stability because the RF power applied to the device remains essentially constant, as noted above. Further, applying this to the zero order beam allows the RF power to remain low, reducing the potential of thermal gradients and thermal transients.

[0030] The system **30** may accordingly provide advantages with respect to numerous different types of optical targets. By way of example, in one configuration the optical target **38** may be an ion trap, such as in a quantum computing device. In accordance with another example, the optical target **38** may be a semiconductor workpiece to perform photolithographic patterning of a photoresist layer, for example. In still another example, the optical target **38** may be a micromachining workpiece. It should be noted that the laser system **30** may be used with other optical targets in different embodiments as well.

[0031] Other example systems in which the above-described stability and noise reduction techniques may be used are set forth in the following co-pending applications: attorney docket no. GCSD-2899 (62084) U.S. patent application Ser. No. 15/342,357 filed Nov. 3, 2016, entitled MULTI-CHANNEL LASER SYSTEM INCLUDING AN ACOUSTO-OPTIC MODULATOR (AOM) AND RELATED METHODS; and attorney docket no. GCSD-2900 (62087) U.S. patent application Ser. No. 15/342,350 filed Nov. 3, 2016, entitled MULTI-CHANNEL ACOUSTO-OPTIC MODULATOR (AOM) AND RELATED METHODS. Both of these applications are assigned to the present Applicant Harris Corporation and are hereby incorporated herein in their entireties by reference.

[0032] Turning now to FIGS. **5-6** and **8**, another example implementation of a laser system **130** illustratively includes a beam stabilizer **150** to help address "wandering" of the laser light beam from the laser source **131** which tends to occur over time. In the illustrated example, the laser source **131**, AOM **132**, acousto-optic medium **133**, phased array transducer electrodes **134**, RF driver **136**, and beam dump **139** are similar to the elements **31**, **32**, **33**, **34**, **36**, and **39** described above, respectively. Furthermore, it should be noted that counterparts of the beamsplitter **35**, photodetector **37**, and optical targets would also be present in the system **130** as described above and shown in FIG. **1**, but they are omitted from FIGS. **5-7** for clarity of illustration of the beam stabilizer components.

[0033] In the present example, the beam stabilizer **150** is configured to correct an angular displacement and a positional displacement of the laser light beam from the laser source **131** (although both positional and angular displacement need not be corrected in all embodiments). More particularly, the beam stabilizer **150** illustratively includes a position mirror **151** optically aligned with the laser light beam from the laser source **131**, a servo motor **152*a*** configured to move the position mirror, an angle mirror **153** optically aligned with the position mirror to redirect the laser light beam therefrom to the acousto-optic medium **133**, and a servo motor **152*b*** configured to move the angle mirror.

[0034] Furthermore, a beamsplitter **154** is positioned in the optical path between the angle mirror **153** and the acousto-optic medium **133** downstream from the angle mirror and configured to split a sampled laser light beam **155** from the original laser light beam from the laser source **131**, and direct this sampled laser light beam to an angle sensor **157**. Furthermore, in the illustrated example another beamsplitter **156** is positioned in the optical path of the sampled laser light beam **155** between the beamsplitter **154** and the angle sensor **157** to split off another sampled laser light beam **158** which is directed through a lens **159** to image the angle mirror to a position sensor **180**. The angle sensor **157** is configured to measure an angular displacement of the laser light beam from the laser source, and the position sensor **180** is configured to measure a positional displacement of the laser light beam from the laser source **131**. These measurements are provided to a servo controller **181**, which in turn controls or actuates the servo motors **152***a*, **152***b* to correct the positional and angular displacements caused by drift or wandering of the laser light beam at the laser source **131**.

[0035] In accordance with another example of the system **130'** now described with reference to FIG. **6**, portions of the beam stabilizer **150'** are positioned both upstream and downstream from the AOM **132'**, rather than all upstream as in the system **130**. In this example, the position mirror **151'** and **153'** remain upstream from the AOM **132'**, but the beamsplitters **154'**, **155'**, angle sensor **157'**, and position sensor **180'**, are downstream of the AOM, meaning they are splitting/measuring the zero order beam exiting the acousto-optic medium **133'**, as opposed to the laser light beam from the laser source **131'** as in the system **130**. Nevertheless, the servo controller **181'** still causes the servo motors **152***a*', **152***b*' to adjust the position mirror **151'** and angle mirror **153'** to perform beam correction to the laser light beam exiting the laser source **131'** as noted above.

[0036] Still another example implementation is now described with reference to FIG. **7**. In this embodiment, the beam stabilizer **150"** is downstream from the AOM **132"**, including the position mirror **151"** and the angle mirror **153"**. As such, the mirrors **151"**, **153"** are directing, and the beamsplitters **154'**, **155'**, angle sensor **157'**, and position sensor **180'**, are splitting/measuring, the zero order beam exiting the acousto-optic medium **133'**. Moreover, the corrections performed by the servo motor(s) **152"** and portion mirror **151"** are to the zero order beam, not the laser light beam from the laser source **131"** as in the preceding two embodiments. All of the systems **130**, **130'**, **130"** may advantageously be used to correct positional and/or angular displacement, and the choice of which one to implement may depend on the particular application, space constraints, and other considerations that will be appreciated by those skilled in the art.

[0037] Related method aspects corresponding to the systems **130**, **130'** are now described with reference to the flow diagram **160** of FIG. **8**. In the illustrated example, the steps illustrated at Blocks **161-167** are similar to those discussed above with reference to Blocks **61-67** of FIG. **4** above. However, the illustrated method further includes a step of stabilizing the laser light beam from the laser light source **131**, **131'** using the beam stabilizer **150** or **150'** based upon angular displacement and/or positional displacement, at Block **168**, as discussed further above.

[0038] Still further method aspects corresponding to the system **130"** are now described with reference to the flow diagram **160'** of FIG. **9**. In the illustrated example, the steps illustrated at Blocks **161'-167'** are similar to those discussed above with reference to Blocks **61-67** of FIG. **4** above. However, the illustrated method further includes a step of stabilizing the zero order laser light beam from the acousto-optic medium **133"** using the beam stabilizer **150"** based upon angular displacement and/or positional displacement, at Block **168'**, as discussed further above.

[0039] Many modifications and other embodiments will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is understood that the disclosure is not to be limited to the specific embodiments disclosed, and that modifications and embodiments are intended to be included within the scope of the appended claims.

That which is claimed is:

1. A laser system comprising:

a laser source configured to generate a laser light beam;

a beam stabilizer downstream from the laser light source;

an acousto-optic modulator (AOM) comprising

an acousto-optic medium configured to receive the laser light beam, and

a phased array transducer comprising a plurality of electrodes coupled to the acousto-optic medium and configured to cause the acousto-optic medium to output a zero order laser light beam and a first order diffracted laser light beam;

a beamsplitter downstream from the AOM and configured to split a sampled laser light beam from the zero order laser light beam;

a photodetector configured to receive the sampled laser light beam and generate a feedback signal associated therewith; and

a radio frequency (RF) driver configured to generate an RF drive signal to the phased array transducer electrodes so that noise is diverted to the first order diffracted laser light beam based upon the feedback signal.

2. The laser system of claim **1** wherein the beam stabilizer is configured to correct a positional displacement of the laser light beam.

3. The laser system of claim **1** wherein the beam stabilizer comprises:

a position mirror optically aligned with the laser light beam from the laser source;

a servo motor configured to move the position mirror;

a position sensor configured to measure a positional displacement of the laser light beam; and

a servo controller coupled to the servo motor and configured to actuate the servo motor to stabilize the laser light beam based upon the position sensor.

4. The laser system of claim **1** wherein the beam stabilizer comprises:

a position mirror optically aligned with the zero order laser light beam from the acousto-optic medium;

a servo motor configured to move the position mirror;

a position sensor configured to measure a positional displacement of the zero order laser light beam; and

a servo controller coupled to the servo motor and configured to actuate the servo motor to stabilize the zero order laser light beam based upon the position sensor.

5. The laser system of claim **1** wherein the beam stabilizer is configured to correct an angular displacement of the laser light beam.

6. The laser system of claim **1** wherein the beam stabilizer comprises:

an angle mirror optically aligned with the laser light beam from the laser source;

a servo motor configured to move the angle mirror;

an angle sensor configured to measure an angular displacement of the laser light beam; and

a servo controller coupled to the servo motor and configured to actuate the servo motor to stabilize the laser light beam based upon the angle sensor.

7. The laser system of claim **1** wherein the beam stabilizer comprises:

an angle mirror optically aligned with the zero order laser light beam from the acousto-optic medium;
a servo motor configured to move the angle mirror;
an angle sensor configured to measure an angular displacement of the zero order laser light beam; and
a servo controller coupled to the servo motor and configured to actuate the servo motor to stabilize the zero order laser light beam based upon the angle sensor.

8. The laser system of claim **1** wherein the RF driver is configured to drive alternating electrodes of the phased array transducer electrodes with different phases.

9. The laser system of claim **1** wherein an RF power level associated with the RF drive signal has a constant power.

10. The laser system of claim **1** further comprising an ion trap, and wherein the beamsplitter is configured to direct the zero order laser light beam from the AOM to the ion trap.

11. A laser system comprising:
a laser source configured to generate a laser light beam;
a beam stabilizer downstream from the laser light source and configured to correct at least one of an angular displacement and a positional displacement of the laser light beam;
an acousto-optic modulator (AOM) comprising
an acousto-optic medium configured to receive the laser light beam from the beam stabilizer, and
a phased array transducer comprising a plurality of electrodes coupled to the acousto-optic medium and configured to cause the acousto-optic medium to output a zero order laser light beam and a first order diffracted laser light beam;
a beamsplitter downstream from the AOM and configured to split a sampled laser light beam from the zero order laser light beam;
a photodetector configured to receive the sampled laser light beam and generate a feedback signal associated therewith; and
a radio frequency (RF) driver configured to generate an RF drive signal to the phased array transducer electrodes so that noise is diverted to the first order diffracted laser light beam based upon the feedback signal.

12. The laser system of claim **11** wherein the beam stabilizer comprises:
a position mirror optically aligned with the laser light beam from the laser source;
a servo motor configured to move the position mirror;
a position sensor configured to measure a positional displacement of the laser light beam; and
a servo controller coupled to the servo motor and configured to actuate the servo motor to stabilize the laser light beam based upon the position sensor.

13. The laser system of claim **11** wherein the beam stabilizer comprises:
an angle mirror optically aligned with the laser light beam from the laser source;
a servo motor configured to move the angle mirror;
an angle sensor configured to measure an angular displacement of the laser light beam; and
a servo controller coupled to the servo motor and configured to actuate the servo motor to stabilize the laser light beam based upon the angle sensor.

14. The laser system of claim **11** wherein the RF driver is configured to drive alternating electrodes of the phased array transducer electrodes with different phases.

15. The laser system of claim **11** further comprising an ion trap, and wherein the beamsplitter is configured to direct the zero order laser light beam from the AOM to the ion trap.

16. A method comprising:
generating a laser light beam using a laser source;
stabilizing the laser light beam using a beam stabilizer downstream from the laser light source;
causing an acousto-optic medium to output a zero order laser light beam from the stabilized laser light beam using a phased array transducer comprising a plurality of electrodes coupled to the acousto-optic medium;
splitting a sampled laser light beam from the zero order laser light beam using a beamsplitter downstream from the acousto-optic medium;
generating a feedback signal associated with the sampled laser light beam using a photodetector; and
generating a radio frequency (RF) drive signal for the phased array transducer electrodes with an RF driver so that noise is diverted to the first order diffracted laser light beam based upon the feedback signal.

17. The method of claim **16** wherein stabilizing comprises stabilizing an angular displacement of the laser light beam.

18. The method of claim **16** wherein stabilizing comprises stabilizing a positional displacement of the laser light beam.

19. The method of claim **16** wherein causing comprises driving alternating electrodes of the phased array transducer electrodes with different phases.

20. A method comprising:
generating a laser light beam using a laser source;
causing an acousto-optic medium to output a zero order laser light beam from the laser light beam using a phased array transducer comprising a plurality of electrodes coupled to the acousto-optic medium;
stabilizing the zero order laser light beam using a beam stabilizer downstream from the acousto-optic medium;
splitting a sampled laser light beam from the stabilized zero order laser light beam using a beamsplitter downstream from the acousto-optic medium;
generating a feedback signal associated with the sampled laser light beam using a photodetector; and
generating a radio frequency (RF) drive signal for the phased array transducer electrodes with an RF driver so that noise is diverted to the first order diffracted laser light beam based upon the feedback signal.

21. The method of claim **20** wherein stabilizing comprises stabilizing an angular displacement of the laser light beam.

22. The method of claim **20** wherein stabilizing comprises stabilizing a positional displacement of the laser light beam.

23. The method of claim **20** wherein causing comprises driving alternating electrodes of the phased array transducer electrodes with different phases.

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