

SINGLE DRIVE POSITIONING SYSTEMS AND METHODS AND MASS ANALYSIS SYSTEMS INCLUDING SAME

Related Application(s)

[001] The present application claims the benefit of and priority from U.S. Provisional Patent Application No. 63/081,976, filed September 23, 2020, the disclosure of which is incorporated herein by reference in its entirety.

Field

[002] The present technology relates to motor-driven positioning systems and, more particularly, to motor-driven multi-axis positioning systems.

Background

[003] Conventional dual axis positioning systems typically require two motors and/or other powered actuators (*e.g.*, gear changers) to drive both axes. Positioning systems are used for various purposes. For example, some inductively coupled plasma (ICP) mass spectroscopy (MS) devices use a positioning stage to align a torch to an MS interface.

Summary

[004] In one aspect, a single drive positioning system includes a drive shaft, a motor, a first worm screw, and a second worm screw. The motor has a motor output connected to the drive shaft and operable to selectively rotate the drive shaft. The first worm screw is mounted on the drive shaft for rotation therewith. The second worm screw is mounted on the drive shaft for rotation therewith.

[005] In some embodiments the single drive positioning system includes a first overrunning clutch between the first worm screw and the motor output, and a second overrunning clutch between the second worm screw and the motor output.

[006] In some embodiments, the motor is operable to rotate the drive shaft in each of a clockwise direction and a counterclockwise direction. The first overrunning clutch is configured to drive the first worm screw in the clockwise direction when the drive shaft is driven in the clockwise direction, and to permit the drive shaft to rotate independently of the first worm screw when the drive shaft is driven in the counterclockwise direction. The second overrunning clutch is configured to drive the second worm screw in the counterclockwise direction when the drive shaft is driven in the counterclockwise direction,

and to permit the drive shaft to rotate independently of the second worm screw when the drive shaft is driven in the clockwise direction.

[007] According to some embodiments, the first overrunning clutch includes a first one-way bearing coupling the first worm screw to the drive shaft, and the second overrunning clutch includes a second one-way bearing coupling the second worm screw to the drive shaft.

[008] In some embodiments, the first one-way bearing is radially interposed between the first worm screw and the drive shaft, and the second one-way bearing is radially interposed between the second worm screw and the drive shaft.

[009] According to some embodiments, the first and second one-way bearings are one-way needle bearings.

[0010] In some embodiments, the single drive positioning system includes: a first worm drive including the first worm screw and a first worm wheel intermeshed with the first worm screw; and a second worm drive including the second worm screw and a second worm wheel intermeshed with the second worm screw.

[0011] According to some embodiments, the first worm drive and the second worm drive are self-locking worm drives such that the first and second worm screws are not backwards drivable by the first and second worm wheels.

[0012] In some embodiments, the first and second worm screws are mounted on the drive shaft at axially fixed locations along the drive shaft.

[0013] According to some embodiments, the single drive positioning system includes: a first rotary-to-linear motion mechanism configured to be driven by rotation of the first worm wheel; and a second rotary-to-linear motion mechanism configured to be driven by rotation of the second worm wheel.

[0014] In some embodiments, at least one of the first and second rotary-to-linear motion mechanisms includes a slider-crank mechanism including a crank and a reciprocating connecting member.

[0015] In some embodiments, at least one of the first and second rotary-to-linear motion mechanisms includes a cam mechanism including a cam and a cam follower.

[0016] According to some embodiments, the single drive positioning system includes a slide bearing system including: a frame; a first guide member slidably mounted on the frame for movement along a first displacement axis; and a second guide member slidably mounted on the frame for movement along a second displacement axis extending transverse to the first displacement axis. The first rotary-to-linear motion mechanism is configured to displace the first guide member along the first displacement axis when the first worm screw

is driven in the clockwise direction. The second rotary-to-linear motion mechanism is configured to displace the second guide member along the second displacement axis when the second worm screw is driven in the counterclockwise direction.

[0017] In some embodiments, the single drive positioning system includes a flexure bearing system including: a frame; a carrier; and at least one bendable flexure member connecting the carrier to the frame such that the carrier is movable along each of a first displacement axis and a second displacement axis extending transverse to the first displacement axis. The first rotary-to-linear motion mechanism is configured to displace the carrier along the first displacement axis when the first worm screw is driven in the clockwise direction. The second rotary-to-linear motion mechanism is configured to displace the carrier along the second displacement axis when the second worm screw is driven in the counterclockwise direction.

[0018] According to some embodiments, the single drive positioning system is configured for use with an object, and is configured to: displace the object along or about a first displacement axis when the first worm screw is driven in the clockwise direction; and displace the object along or about a second displacement axis when the second worm screw is driven in the counterclockwise direction.

[0019] In some embodiments, the first displacement axis is a linear axis, and the second displacement axis is a linear axis extending transverse to the first displacement axis.

[0020] According to some embodiments, the motor is operable to rotate the drive shaft about a drive shaft axis, and the drive shaft axis extends at an oblique angle to the first displacement axis and at an oblique angle to the second displacement axis.

[0021] In a second aspect, a method for positioning an object includes providing a single drive positioning system including: a drive shaft; a motor having a motor output connected to the drive shaft and operable to selectively rotate the drive shaft; a first worm screw mounted on the drive shaft for rotation therewith; and a second worm screw mounted on the drive shaft for rotation therewith. The method further includes operating the motor to rotate the drive shaft.

[0022] In a third aspect, a single drive positioning system includes a drive shaft, a motor, a first worm drive, second worm drive, a first overrunning clutch, and a second overrunning clutch. The motor has a motor output connected to the drive shaft and operable to selectively rotate the drive shaft in each of a clockwise direction and a counterclockwise direction. The first worm drive includes: a first worm screw mounted on the drive shaft for rotation therewith; and a first worm wheel intermeshed with the first worm screw. The

second worm drive includes: a second worm screw mounted on the drive shaft for rotation therewith; and a second worm wheel intermeshed with the second worm screw. The first overrunning clutch is located between the drive shaft and the first worm screw. The first overrunning clutch is configured to drive the first worm screw in the clockwise direction when the drive shaft is driven in the clockwise direction, and to permit the drive shaft to rotate independently of the first worm screw when the drive shaft is driven in the counterclockwise direction. The second overrunning clutch is located between the drive shaft and the first worm screw. The second overrunning clutch is configured to drive the second worm screw in the counterclockwise direction when the drive shaft is driven in the counterclockwise direction, and to permit the drive shaft to rotate independently of the second worm screw when the drive shaft is driven in the clockwise direction.

[0023] In a fourth aspect, a mass analysis system includes an ICP torch, a sample introduction element including an inlet, and a single drive positioning system. The single drive positioning system is operable to selectively align the ICP torch with the inlet. The single drive positioning system includes: a drive shaft; a motor having a motor output connected to the drive shaft and operable to selectively rotate the drive shaft; a first worm screw mounted on the drive shaft for rotation therewith; and a second worm screw mounted on the drive shaft for rotation therewith.

[0024] In some embodiments, the motor is operable to rotate the drive shaft in each of a clockwise direction and a counterclockwise direction, and the single drive positioning system is configured to: adjust a position of the ICP torch along or about a first displacement axis by rotating the drive shaft in the clockwise direction; and adjust a position of the ICP torch along or about a second displacement axis by rotating the drive shaft in the counterclockwise direction.

[0025] According to some embodiments, the mass analysis system includes a mass analyzer located downstream of the inlet from the ICP torch.

[0026] In a fifth aspect, a method for conducting a mass analysis of a sample includes providing a mass analysis system including: an ICP torch; a sample introduction element including an inlet; and a single drive positioning system. The single drive positioning system is operable to selectively align the ICP torch with the inlet. The single drive positioning system includes: a drive shaft; a motor having a motor output connected to the drive shaft and operable to selectively rotate the drive shaft; a first worm screw mounted on the drive shaft for rotation therewith; and a second worm screw mounted on the drive shaft for rotation therewith. The method further includes operating the motor to rotate the drive shaft.

Brief Description of the Drawings

[0027] The accompanying drawings, which form a part of the specification, illustrate embodiments of the technology.

[0028] **FIG. 1** is a top perspective view of a single drive positioning system according to some embodiments.

[0029] **FIG. 2** is a bottom perspective view of the single drive positioning system of **FIG. 1**.

[0030] **FIG. 3** is an exploded, top view of the single drive positioning system of **FIG. 1**.

[0031] **FIG. 4** is top view of the single drive positioning system of **FIG. 1**.

[0032] **FIG. 5** is bottom view of the single drive positioning system of **FIG. 1**.

[0033] **FIG. 6** is an end view of the single drive positioning system of **FIG. 1**.

[0034] **FIG. 7** is a side view of the single drive positioning system of **FIG. 1**.

[0035] **FIG. 8** is an exploded, fragmentary view of the single drive positioning system of **FIG. 1**.

[0036] **FIG. 9** is a fragmentary, cross-sectional view of the single drive positioning system of **FIG. 1**.

[0037] **FIG. 10** is a perspective view of a one-way bearing forming a part of the single drive positioning system of **FIG. 1**.

[0038] **FIG. 11** is a schematic, side view of a mass analysis system according to some embodiments.

[0039] **FIG. 12** is a front perspective view of a single drive positioning system according to further embodiments.

[0040] **FIG. 13** is a rear perspective view of the single drive positioning system of **FIG. 12**.

[0041] **FIG. 14** is a front view of the single drive positioning system of **FIG. 12**.

[0042] **FIG. 15** is a front view of a single drive positioning system according to further embodiments.

[0043] **FIG. 16** is a rear view of the single drive positioning system of **FIG. 15**.

Detailed Description

[0044] Conventional dual axis positioning systems (*e.g.*, X-Y stages) typically require two or more motors or other powered actuators (*e.g.*, gear changers). However, these motors

and actuators may add undesirable cost, size and/or weight to the dual axis positioning system.

[0045] Single drive positioning systems according to embodiments of the present technology address one or more of these problems by eliminating the need for multiple motors and/or other powered actuators while providing effective multi-axis positioning functionality. A single drive positioning system according to the technology may include a single motor that selectively rotates a drive shaft in each of a first direction and an opposing second direction (*e.g.*, clockwise and counterclockwise). A first worm screw and a second worm screw are mounted on the drive shaft. The first worm screw is meshed with a first worm wheel to form a first worm drive. The second worm screw is meshed with a second worm wheel to form a second worm drive. The first worm drive is configured to adjust a position of an object (*e.g.*, a support platform and/or a component such as an ICP torch) along or about a first displacement axis. The second worm drive is configured to adjust a position of the object along or about a second displacement axis. Linkages may be provided between the first and second worm drives and the object.

[0046] A first overrunning clutch (*e.g.*, a one-way bearing) is provided between the drive shaft and the first worm screw. A second overrunning clutch (*e.g.*, a one-way bearing) is provided between the drive shaft and the second worm screw. The first and second overrunning clutches are mounted in opposing orientations such that: a) when the drive shaft is driven in the first direction, the first overrunning clutch transfers torque from the drive shaft to the first worm screw to rotate the first worm screw, and the second overrunning clutch permits the drive shaft to rotate freely within the second worm screw; and b) when the drive shaft is driven in the second direction, the second overrunning clutch transfers torque from the drive shaft to the second worm screw to rotate the second worm screw, and the first overrunning clutch permits the drive shaft to rotate freely within the first worm screw. As a result, the first worm drive is driven by the motor when the drive shaft is driven in the first direction, but not when the drive shaft is driven in the second direction. Similarly, the second worm drive is driven by the motor when the drive shaft is driven in the second direction, but not when the drive shaft is driven in the first direction. Accordingly, the object is repositioned along or about the first displacement axis by driving the drive shaft in the first direction using the motor, and is repositioned along or about the second displacement axis by driving the drive shaft in the second direction using the same motor, and no additional actuators (*e.g.*, a gear changer) are required.

[0047] A single drive positioning system according to embodiments of the present technology may be incorporated into a mass analysis system to selectively position an ICP torch relative to an inlet of a sample introduction element. In other embodiments, a positioning system may be used to selectively position an ICP torch in an optical emission spectroscopy (OES) system. However, embodiments are not limited to use with ICP torches. Embodiments of the positioning system described herein may be included as a component of any system or apparatus.

[0048] With reference to **FIGS. 1-10**, a single drive positioning stage or system **100** according to some embodiments is shown therein. The single drive positioning stage or system **100** includes a drive system **104** and a bearing system **110**. The drive system **104** includes a motor **108**, a transmission system **130**, and a controller **22**.

[0049] The single drive positioning system **100** is configured and operable to adjust (*i.e.*, move, displace, or reposition) the spatial position of an object **62** linearly along a first displacement axis **X-X** and to adjust the spatial position of the object **62** linearly along a second displacement axis **Y-Y**. The axes **X-X** and **Y-Y** extend transverse to one another. In the example embodiment, the axes **X-X** and **Y-Y** are perpendicular, but other configurations may be provided. The illustrated object **62** is an ICP torch; however, it will be appreciated that the single drive positioning system **100** can be used with alternative objects. Additionally, in some embodiments, the object **62** may be a device, such as a torch box, that includes the ICP torch and other components such that the single drive positioning system **100** moves the entire device, including the ICP torch.

[0050] The bearing system **110** (**FIGS. 1-3**) is a dual axis linear slide bearing system. The bearing system **110** includes a bearing frame **112**, a first guide member, yoke or shuttle **114**, a second guide member, yoke or shuttle **116**, and a platform, holder, support or carrier **118**. In some embodiments, the components **112**, **114**, **116**, **118** are each substantially rigid and may be formed of any suitable materials (*e.g.*, metal and/or polymeric).

[0051] The bearing frame **112** (**FIG. 3**) includes opposed X-axis rails **114A** and opposed Y-axis rails **116A**. The guide member **114** is slidably mounted on the rails **114A** to enable the guide member **114** to translate along the axis **X-X** in each of a forward direction **X1** and an opposing rearward direction **X2** (**FIG. 4**). In some embodiments, the guide member **114** is constrained to linear movement relative to the frame **112** along the axis **X-X**. Similarly, the guide member **116** is slidably mounted on the rails **116A** to enable the guide member **116** to translate along the axis **Y-Y** in each of a forward direction **Y1** and an opposing rearward direction **Y2**. In some embodiments, the guide member **116** is

constrained to linear movement relative to the frame **112** along the axis **Y-Y**. In some embodiments, the guide members **114**, **116** and the carrier **118** are constrained from moving along the Z-axis **Z-Z** (*i.e.*, perpendicular to each of the axis **X-X** and the axis **Y-Y**) relative to the bearing frame **112**. In the example shown, the X-axis rails **114A** and the Y-axis rails **116A** are integral parts of the bearing frame **112**. However, embodiments are not limited to an integral arrangement. For example, the rails **114A**, **116A** may be independently supported.

[0052] The bearing frame **112** also includes a drive shaft mount **120** (including a drive shaft bore **120A**; **FIG. 3**), a first worm wheel mount **123**, and a second worm wheel mount **125**. The mounts **120**, **123**, **125** are each fixed in position relative to the bearing frame **112**. In some embodiments and as illustrated, the mounts **120**, **123**, **125** are each integral features formed on the bearing frame **112** or affixed (directly or indirectly) to the bearing frame **112**.

[0053] The motor **108** has an output **108A**. The motor **108** may be any suitable type of motor. In some embodiments, the motor is an electric motor. In some embodiments, the motor is a rotary motor (*e.g.*, a rotary electric motor) that generates a torque at or via the output **108A**. In some embodiments, the motor is an electric servo motor. In some embodiments, the motor is an electric stepper motor.

[0054] The transmission system **130** includes a drive shaft **132**, a first worm drive **141**, a second worm drive **151**, a first linkage **161**, and a second linkage **171**. In some embodiments and as illustrated, the first and second linkages **161**, **171** are each rotary-to-linear motion mechanisms.

[0055] The drive shaft **132** (**FIGS. 4 and 8**) extends from a proximal end **132A** to a distal end **132B** and has a longitudinal drive shaft axis **D-D**. In some embodiments, the drive shaft **132** is unitary, and in some embodiments, the drive shaft **132** is monolithic. In some embodiments, the drive shaft **132** is substantially rigid. The drive shaft **132** may be formed of any suitable material (*e.g.*, metal or polymeric material).

[0056] The proximal end **132A** is connected to (*e.g.*, affixed to or integral with) the motor output **108A** such that the motor output **108A** can selectively forcibly drive the drive shaft **132** about the drive shaft axis **D-D** in each of a clockwise rotational direction **CW** and an opposing counterclockwise rotational direction **CCW** (**FIG. 1**).

[0057] In some embodiments, the motor output **108A** is configured and operated to directly impart these rotational drives (*e.g.*, the motor output **108A** is a rotary torque output). However, in other embodiments, an intermediate transmission mechanism may be provided

between the motor output **108A** and the drive shaft **132**. For example, a gear reduction may be provided between the motor output **108A** and the drive shaft **132**. By way of further example, the motor output **108A** may be a non-rotary output (*e.g.*, a linear drive output) and a conversion mechanism (*e.g.*, a linear-to-rotary mechanism) may be provided between the motor output **108A** and the drive shaft **132** to convert the linear motor output to rotational drive on the drive shaft **132**. In some embodiments, a belt drive, bevel gears, or another transmission device may be provided between the motor output and the drive shaft **132** to enable a different position and/or orientation of the motor **108** relative to the drive shaft **132**.

[0058] The first worm drive **141** (**FIG. 1**) includes a first worm screw **140**, a first worm wheel **142**, and a first overrunning clutch **144**. In some embodiments and as illustrated, the first overrunning clutch **144** is a one-way bearing **144**.

[0059] The first worm screw **140** has a worm screw axis **E1-E1** (**FIG. 8**). The worm screw **140** has a helical outer thread **140A** that winds substantially coaxially about the axis **E1-E1**. The worm screw **140** also has an internal passage or bore **140B** that extends substantially coaxially about the axis **E1-E1**.

[0060] The first bearing **144** (**FIGS. 8-10**) is radially interposed between the drive shaft **132** and the first worm screw **140**. The first bearing **144** has a bearing axis **B1-B1** and includes an inner race **144A** and an outer race **144B**. The inner race **144A** is mounted on, coupled to or affixed to the drive shaft **132** to rotate therewith. For example, the inner race **144A** may be secured to the drive shaft **132** by an interference fit, fastener, interlock, and/or adhesive. The outer race **144B** is mounted on, coupled or affixed to the worm screw **140** in the bore **140B** such that the worm screw **140** rotates with the outer race **144B**. For example, the outer race **144B** may be secured to the worm screw **140** by an interference fit, fastener, interlock, and/or adhesive.

[0061] The first bearing **144** is a one-way bearing that allows the inner race **144A** to spin substantially freely relative to the outer race **144B** about the axis **B1-B1** in a first direction **RB2**, and couples or locks the inner race **144A** to the outer race **144B** when the inner race **144A** is rotated about the axis **B1-B1** in the opposite direction **RB1**. That is, the torque is transferred between the races **144A**, **144B** when the race **144A** is rotated in one prescribed direction, and torque is not transferred between the races **144A**, **144B** when the race **144A** is rotated in the opposite direction. One-way bearings of this type may be referred to as a unidirectional bearing, unidirectional clutch, one-way bearing, or one-way clutch. In some embodiments, the first bearing **144** is a one-way needle bearing.

[0062] The mounting arrangement between the first bearing **144** and the drive shaft **132** is also constructed such that the axial position of the worm screw **140** along the length of the drive shaft **132** is fixed.

[0063] The first worm wheel **142** has a worm wheel axis **F1-F1** (**FIG. 7**). The worm wheel **142** has teeth **142A** distributed circumferentially about and coaxial with the axis **F1-F1** (e.g., like a spur gear). The worm wheel **142** is mounted on the worm wheel mount **123** by an axle or pin **122** for rotation about the worm axis **F1-F1**.

[0064] The teeth **142A** are meshed with the worm screw thread **140A** to enable rotation of the worm screw **140** in the direction **RE1** (**FIG. 4**) to drive rotation of the worm wheel **142** in a corresponding direction **RF1** (**FIG. 4**). The worm screw axis of rotation **E1-E1** is substantially perpendicular to the worm wheel axis of rotation **F1-F1**.

[0065] The second worm drive **151** (**FIG. 1**) includes a second worm screw **150**, a second worm wheel **152**, and a second overrunning clutch **154**. The second worm drive **151**, the second worm screw **150**, the second worm wheel **152**, and the second overrunning clutch **154** are constructed and operate in the same manner as the worm drive **141**, the worm screw **140**, the worm wheel **142**, and the overrunning clutch **144**, except as follows.

[0066] The second worm screw **150** has a worm screw axis **E2-E2** (**FIG. 8**). The worm screw **150** has a helical outer thread **150A** that winds substantially coaxially about the axis **E2-E2**. The worm screw **150** also has an internal passage or bore **150B** that extends substantially coaxially about the axis **E2-E2**.

[0067] The second bearing **154** (**FIGS. 8 and 9**) is radially interposed between the drive shaft **132** and the second worm screw **150**. The second bearing **154** has a bearing axis **B2-B2** and includes an inner race **154A** and an outer race **154B**. The inner race **154A** is mounted on, coupled to or affixed to the drive shaft **132** to rotate therewith. For example, the inner race **154A** may be secured to the drive shaft **132** by an interference fit, fastener, interlock, and/or adhesive. The outer race **154B** is mounted on, coupled to or affixed to the worm screw **150** in the bore **150B** such that the worm screw **150** rotates with the outer race **154B**. For example, the outer race **154B** may be secured to the worm screw **150** by an interference fit, fastener, interlock, and/or adhesive.

[0068] The second bearing **154** is a one-way bearing as described above for the first bearing **144**. The second bearing **154** allows the inner race **154A** to spin substantially freely relative to the outer race **154B** about the axis **B2-B2** in a first direction **RB1**, and couples or locks the inner race **154A** to the outer race **154B** when the inner race **154A** is rotated about the axis **B2-B2** in the opposite direction **RB2**. The second bearing **154** is constructed and

operates in the same manner as the first bearing **144**, except that the locked rotation direction **RB2** is opposite the locked rotation direction **RB1** of the first bearing **144**. That is, the first bearing **144** and the second bearing **154** are mounted on the drive shaft **132** with opposite orientations.

[0069] The mounting arrangement between the second bearing **154** and the drive shaft **132** is also constructed such that the axial position of the worm screw **150** along the length of the drive shaft **132** is fixed.

[0070] The second worm wheel **152** has a worm wheel axis **F2-F2** (FIG. 6). The worm wheel **152** has teeth **152A** distributed circumferentially about and coaxial with the axis **F2-F2** (e.g., like a spur gear). The worm wheel **152** is mounted on the worm wheel mount **125** by an axle or pin **124** for rotation about the worm axis **F2-F2**.

[0071] The teeth **152A** are meshed with the worm screw thread **150A** to enable rotation of the worm screw **150** in the direction **RE2** (FIG. 4) to drive rotation of the worm wheel **152** in a corresponding direction **RF2** (FIG. 4). The worm screw axis of rotation **E2-E2** is substantially perpendicular to the worm wheel axis of rotation **F2-F2**.

[0072] The first linkage **161** (FIGS. 1 and 4) is a slider-crank mechanism including a crank **162** and a connecting member or rod **164**. The crank **162** is secured (e.g., affixed or integral with) the first worm wheel **142** for rotation therewith about the worm wheel axis **F1-F1**. A proximal end of the connecting rod **164** is pivotably coupled to the crank **162** by a screw or pin **162A**. A distal end of the connecting rod **164** is pivotably coupled to the guide member mount **114** by a screw or pin **166**.

[0073] The axis of the pin **162A** is offset from (eccentric relative to) the worm wheel axis **F1-F1**. This causes the connecting rod **164** to translate (in some cases, reciprocate) in the directions **X1** and **X2**. The crank **162** pushes the guide member **114** in the direction **X1** or pulls the guide member **114** in the direction **X2**, depending on the angular orientation position of the crank **162**. As a result, the distance between the axis **F1-F1** and the guide member **114** varies as the crank **162** is rotated. Because the position of the worm wheel **142** relative to the frame **112** is fixed, this causes the guide member **114** to correspondingly translate relative to the frame **112** in the directions **X1** and **X2** along the axis **X-X**.

[0074] The second linkage **171** (FIGS. 1 and 5) is also a slider-crank mechanism that is constructed and operable in the same manner as described above for the first linkage **161**. The second linkage **171** includes a crank **172** and a connecting member or rod **174**. The crank **172** is secured (e.g., affixed or integral with) the second worm wheel **152** for rotation therewith about the worm wheel axis **F2-F2**. A proximal end of the connecting rod **174** is

pivotably coupled to the crank **172** by a screw or pin **172A**. A distal end of the connecting rod **174** is pivotably coupled to the guide member **116** by a screw or pin **176**.

[0075] The axis of the pin **172A** is offset from (eccentric relative to) the worm wheel axis **F2-F2**. This causes the connecting rod **174** to translate (in some cases, reciprocate) in the directions **Y1** and **Y2**. The crank **172** pushes the guide member **116** in the direction **Y1** or pulls the guide member **116** in the direction **Y2**, depending on the position of angular orientation of the crank **172**. As a result, the distance between the axis **F2-F2** and the guide member **116** varies as the crank **172** is rotated. Because the position of the worm wheel **152** relative to the frame **112** is fixed, this causes the guide member **116** to correspondingly translate relative to the frame **112** in the directions **Y1** and **Y2** along the axis **Y-Y**.

[0076] With reference to **FIG. 4**, the single drive positioning system **100** may be used as follows. In general, and as described in more detail below, the single drive positioning system **100** is operable to adjust the X-axis and Y-axis positions of the carrier **118** by operating only the single motor **108**, without the need for additional actuators, e.g., gear changers. More particularly, the position of the carrier **118** along the X-axis is adjusted by rotating the drive shaft **132** in the clockwise direction **CW**, and the position of the carrier **118** along the Y-axis is adjusted by rotating the drive shaft **132** in the counterclockwise direction **CCW**. In the description below, the controller **22** is used to control operation of the motor **108**. However, in other embodiments, the motor **108** may be controlled manually, for example.

[0077] In order to adjust the X-axis position of the carrier **118**, the controller **22** operates the motor **108** to drive the drive shaft **132** in the clockwise direction **CW**. The inner race **144A** of the first one-way bearing **144** and the inner race **154A** of the second one-way bearing **154** are thereby driven to rotate in the clockwise direction **CW**.

[0078] Because the second bearing **154** is free-spinning in the clockwise direction **CW** (*i.e.*, the direction **RB1**) and rotation of the second worm screw **150** is resisted by the second worm wheel **152**, the drive shaft **132** spins independently of the second worm screw **150** and does not drive the second worm drive **151**. The Y-axis position of the carrier **118** therefore remains unchanged.

[0079] Because the first bearing **144** is locking in the clockwise direction **CW** (*i.e.*, in the direction **RB1**), the first bearing **144** imparts the torque from the drive shaft **132** to the first worm screw **140**, thereby rotating the worm screw **140** in the direction **RE1**. The rotation of the worm screw **140** in turn drives the first worm wheel **142** to rotate about the axis **F1-F1** in the direction **RF1**. The crank **162** rotates with the worm wheel **142**, causing

the connecting rod **164** to translate along the axis **X-X**. The bearing system **110** isolates the movement of the distal end of the connecting rod **164** to the axis **X-X**. The translation of the connecting rod **164** pushes or pulls the guide member **114** with respect to the bearing frame **112**, thereby adjusting the X-axis position of the carrier **118**. The X-axis position of the carrier **118** can be set as desired in this manner.

[0080] In order to adjust the Y-axis position of the carrier **118**, the controller **22** operates the motor **108** to drive the drive shaft **132** in the counterclockwise direction **CCW**. The inner race **144A** of the first one-way bearing **144** and the inner race **154A** of the second one-way bearing **154** are thereby driven to rotate in the counterclockwise direction **CCW**.

[0081] Because the first bearing **144** is free-spinning in the counterclockwise direction **CCW** (*i.e.*, in the direction **RB2**) and rotation of the first worm screw **140** is resisted by the first worm wheel **142**, the drive shaft **132** spins independently of the first worm screw **140** and does not drive the first worm drive **141**. The X-axis position of the carrier **118** therefore remains unchanged.

[0082] Because the second bearing **154** is locking in the counterclockwise direction **CCW** (*i.e.*, in the direction **RB2**), the second bearing **154** imparts the torque from the drive shaft **132** to the second worm screw **150**, thereby rotating the second worm screw **150** in the direction **RE2**. The rotation of the second worm screw **150** in turn drives the second worm wheel **152** to rotate about the axis **F2-F2** in the direction **RF2**. The crank **172** rotates with the second worm wheel **152**, causing the connecting rod **174** to translate along the axis **Y-Y**. The bearing system **110** isolates the movement of the distal end of the connecting rod **174** to the axis **Y-Y**. The translation of the connecting rod **174** pushes or pulls the guide member **114** with respect to the bearing frame **112**, thereby adjusting the Y-axis position of the carrier **118**. The Y-axis position of the carrier **118** can be set as desired in this manner.

[0083] As the first crank **162** is rotated a full revolution (*i.e.*, **360** degrees) about the axis, the connecting rod **164** will travel in the direction **X1**, then travel back in the direction **X2**, and will repeat this sequence for each subsequent revolution. Accordingly, the rotation of the crank **162** causes the connecting rod **164** to reciprocate. The slider-crank mechanism **161** provides a range of adjustment **DX** (**FIG. 4**) of the carrier **118** along the axis **X-X** corresponding to the full excursion distance from the fully extended position of the connecting rod **164** to the fully retracted position of the connecting rod **164**. The second slider-crank mechanism **171** operates in the same manner to provide a range of adjustment **DY** (**FIG. 4**) of the carrier **118** along the axis **Y-Y** corresponding to the full excursion distance from the fully extended position of the connecting rod **174** to the fully retracted

position of the connecting rod **174**. The amount or range of motion or travel of the carrier **118** along each axis **X-X**, **Y-Y** can be set by selecting a corresponding eccentricity for the crank **162**, **172**. In some embodiments, each range of adjustment **DX**, **DY** is in the range of from about 8 mm to 12 mm (*e.g.*, +/- 4 mm to +/- 6 mm). The ranges of adjustment **DX**, **DY** may be the same or different from one another. In some embodiments, each range of adjustment may be set by selecting a crank **162**, **172** having a corresponding eccentricity from its rotation axis **F1-F1**, **F2-F2**.

[0084] In some embodiments, the controller **22** programmatically and automatically controls the motor **108** to adjust and set each of the X-axis and Y-axis positions of the carrier **118**.

[0085] Thus, the single drive positioning system **100** enables an operator to independently move the carrier **118** (or other object) along two different axes with a single drive motor **108**, and without any additional actuator(s) (*e.g.*, a gear changer) by switching the direction the drive shaft **132** is driven (*i.e.*, the direction in which torque from the motor output **108A** is applied). When the drive shaft **132** is driven in the clockwise direction **CW**, the first worm wheel **142** is thereby driven and the rotational motion of the first worm wheel **142** is converted to linear motion by the slider-crank mechanism **161**. When the drive shaft **132** is driven in the counterclockwise direction **CCW**, the second worm wheel **152** is thereby driven and the rotational motion of the second worm wheel **152** is converted to linear motion by the slider-crank mechanism **171**.

[0086] As discussed above, in some embodiments, the axial positions of the worm screws **140**, **150** along the length of the drive shaft **132** are rigidly fixed. Additionally, in some embodiments, the axial position of the drive shaft **132** relative to the worm wheels **142**, **152** is fixed. The first worm drive **141** and the second worm drive **151** each form self-locking worm gear sets. As a result, the worm drives **141**, **151** are not back drivable. That is, the worm screw **140** cannot be driven to rotate about the drive shaft axis **D-D** by torque from the worm wheel **142**, and the worm screw **150** cannot be driven to rotate about the drive shaft axis **D-D** by torque from the worm wheel **152**. This aspect prevents the adjustment along one axis (*i.e.*, the X-axis or the Y-axis) from being changed when the drive shaft **132** is being driven to execute an adjustment along the other axis. This aspect may be important to prevent unintended movement of the carrier **118** when external forces (*e.g.*, gravity or a spring force) act on the carrier **118**. By nature, a one-way bearing cannot restrict inertial motion (the output moving ahead of the input) in the one-way bearing's free-spin direction. Also, although a one-way bearing does not allow back driving in its direction of lock when

static, when the drive shaft **132** is driven in the opposing direction the “locked” position of the one-way bearing is essentially rotating with the drive shaft **132**. These problems are addressed by the self-locking of the worm drives **141**, **151**.

[0087] The worm drives **141**, **151** may also be configured to provide gear reduction from the motor output **108A** to the slider cranks **161**, **171**.

[0088] In some embodiments and as shown, the drive shaft axis **D-D** forms an oblique angle **A1** (**FIG. 4**) with the first displacement axis **X-X** and an oblique angle **A2** (**FIG. 4**) with the second displacement axis **Y-Y**. In some embodiments, the angles **A1**, **A2** are each 45 degrees. However, in other embodiments the oblique angles **A1**, **A2** may be more or less than 45 degrees and, in some embodiments, may be different from one another.

[0089] In some embodiments and as shown, the drive shaft axis **D-D** is perpendicular to each of the worm wheel axes **F1-F1**, **F2-F2**.

[0090] With reference to **FIG. 11**, a single drive positioning system **100** as discussed above may be incorporated into a mass analyzer system **20**. The illustrated mass analyzer system **20** is an inductively coupled plasma mass spectroscopy (ICP-MS) analyzer. The ICP-MS analyzer system **20** may be constructed and operated as disclosed in U.S. Patent No. 9,105,457 to Badiei et al., for example, the disclosure of which is incorporated herein by reference.

[0091] The mass analyzer system **20** includes the single drive positioning system **100**, a torch assembly **60**, a sample source **40**, a sampler **50**, a skimmer **54**, ion optics **42**, a mass analyzer **44**, a detector **46**, an interface vacuum chamber **32**, an ion optics vacuum chamber **34**, a mass analyzer vacuum chamber **36**, and the controller **22**.

[0092] The torch assembly **60** includes an ICP torch **62** and a substrate, subframe, or housing **70** supporting the torch **62**. The torch **62** includes an injector **62A**, an intermediate or auxiliary tube **62B** formed of quartz, for example), an outer or plasma tube **62C**, and an induction coil **64** (*e.g.*, an RF energy coil). The torch assembly **60** may further include electrical connections for the induction coil **64**, a clamp or mount for securing the torch **62** to the housing **70**, connections for introducing the sample and gas streams discussed below to the torch **62**, and/or other components.

[0093] The sample source **40** (*e.g.*, a nebulizer) supplies a sample stream **75** including a sample contained in a carrier gas (*e.g.*, argon) through the injector **62A** into the auxiliary tube **62B**. An auxiliary gas flow **76** (*e.g.*, argon) is also introduced into the auxiliary tube **62B**. A plasma gas flow **77** (*e.g.*, argon; typically having a higher flow rate auxiliary gas flow **76**) is provided in the plasma tube **62C**.

[0094] In use, a plasma **80** is generated by the induction coil **64** from the auxiliary gas flow **76**. The plasma **80** is generated close to atmospheric pressure by the induction coil **64** encircling the plasma tube **62C**. Plasma **80** can also be generated in any other suitable fashion known in the art. The plasma **80** atomizes the sample stream **75** and ionizes the atoms, creating a mixture of ions and free electrons. A portion of the plasma **80** is sampled through (*i.e.*, travels or flows through) an orifice or inlet **52** in the sampler **50**. The sampler **50** and the skimmer **54** may form opposing walls of the interface vacuum chamber **32**. The interface vacuum chamber **32** may be evacuated to a moderately low pressure (*e.g.* 1-5 Torr) by a vacuum pump (not shown). The skimmer **54** has an orifice **54A** which leads to the ion optics vacuum chamber **34**. The ion optics vacuum chamber **34** is evacuated to a lower pressure (*e.g.*, 10^{-3} Torr or less) than that of the interface vacuum chamber **32**. The ion optics vacuum chamber **34** includes the ion optics **42** for focusing the ion beam.

[0095] The ions emerging from the ion optics **42** travel through an orifice **34A** in a wall and into the mass analyzer vacuum chamber **36**. In certain embodiments, the mass analyzer vacuum chamber **36** may be part of the ion optics vacuum chamber **34**. The mass analyzer **44** is disposed in the mass analyzer vacuum chamber **36** downstream of the inlet **52**. The mass analyzer **44** may be a quadrupole mass spectrometer, an ion trap, a magnetic sector analyzer, a time of flight analyzer, an ion mobility analyzer, or any other suitable mass analyzer known to those of skill in the art.

[0096] In use, ions from the plasma **80** travel with the plasma gas through the sampler orifice **52**. Ions then pass through the skimmer aperture **54A**, carried by the bulk gas flow. The ions are then charge separated, partly because of the diffusion of high mobility electrons and partly because of the ion optics **42** and the bias potentials thereon. The ions are focused by the ion optics **42** through orifice **34A** and into the mass analyzer **44**. The mass analyzer **44** is controlled to produce a mass spectrum for the sample being analyzed.

[0097] In other embodiments, the mass analyzer system **20** may include a second skimmer, *e.g.*, as disclosed in U.S. Patent No. 9,105,457 to Badiei et al., the disclosure of which is incorporated herein by reference in its entirety.

[0098] The torch assembly **60** is mounted on the carrier **118** of the single drive positioning system **100**. The torch tip **62D** of the torch **62** is positioned such that the plasma **80** is directed or aimed at the inlet **52** along a Z-axis. In order to increase the performance and detection precision of the mass analyzer system **20**, the plasma **80** should be properly aligned with the inlet **52**, which in some cases means centering the plasma **80** with the inlet **52**, but in other cases may mean running the ICP-MS analyzer while altering the position of

the plasma **80** with the positioning system **100** until the detection rate of the ICP-MS analyzer is above a desired threshold. The single drive positioning system **100** is operable to center or align the torch assembly, and thereby the torch **62** and the plasma **80** generated thereby, relative to the inlet **52**. More particularly, the single drive positioning system **100** is arranged and configured to adjust (*i.e.*, selectively reposition and set) the position of the tip **62D** of the torch **62** along each of the X-axis and the Y-axis (which extend perpendicular to one another and the Z-axis) as described above. Thus, for example, the motor output **108A** may be operated to drive the drive shaft **132** in the clockwise direction **CW** to move the torch assembly **60** along the X-axis, and the motor output **108A** may be operated to drive the drive shaft **132** in the counterclockwise direction **CCW** to move the torch assembly **60** along the Y-axis, until the torch tip **62D** is set at the desired X,Y coordinates for alignment.

[0099] In some embodiments, the controller **22** programmatically and automatically controls the motor **108** to adjust and set each of the X-axis and Y-axis positions of the torch tip **62D** relative to the inlet **52** to achieve an alignment. In some embodiments, the operator or the controller **22** executes a calibration procedure. In the calibration procedure, the mass analysis system is operated to generate a plasma via the torch **62** and analyze a sample (*e.g.*, a reference sample). The controller **22** (or operator) adjusts the X-axis and Y-axis positions of the torch assembly **60** while the sample is ionized by the torch **62** and monitors the detection signal from the detector **46**. Based on the detection efficiency (signal optimization) at different torch X,Y positions, the controller **22** (or operator) determines when an optimal or desired alignment has been achieved.

[00100] With reference to **FIGS. 12-14**, a single drive positioning system **200** according to further embodiments is shown therein. The system **200** may be constructed and operate in the same manner as the single drive positioning system **100** except as follows.

[00101] The single drive positioning system **200** includes a flexure bearing system **210** (**FIGS. 12 and 14**) in place of the linear bearing system **110**. The flexure bearing system **210** includes a carrier **218**, a frame **212**, a first set of flexure members **214**, and a second set of flexure members **216**. The outer ends of the flexure members **214**, **216** are each secured to the frame **212** by corresponding anchor brackets **215A-D**. The inner ends of the flexure members **214**, **216** are coupled to the carrier **218**.

[00102] The flexure members **214**, **216** are substantially rigid against deflection or bending along the Z-axis. The flexure members **214** are configured to deflect or bend resiliently along the X-axis. The flexure members **216** are configured to deflect or bend resiliently along the Y-axis. In this manner, the carrier **218** is effectively suspended or

supported by the flexure members **214**, **216** and constrained to displacement only along the X-axis and Z-axis.

[00103] The single drive positioning system **200** includes a motor **208**, drive shaft **232**, first worm drive **241**, second worm drive **251**, first linkage **261**, and a second linkage **271** corresponding to the motor **108**, drive shaft **132**, first worm drive **141**, second worm drive **151**, first linkage **161**, and a second linkage **171**, respectively. It will be appreciated that the single drive positioning system **200** can be operated in the same or similar manner to the single drive positioning system **100** to position the carrier **218**.

[00104] The flexure members **214**, **216** may be formed of any suitable material such as metal or polymer.

[00105] With reference to **FIGS. 15** and **16** a single drive positioning system **300** according to further embodiments is shown therein. The system **300** may be constructed and operate in the same manner as the single drive positioning system **100** except as follows.

[00106] The single drive positioning system **300** includes a first cam and follower linkage **361** and a second cam and follower linkage **371** in place of the first and second slider-crank linkages **161**, **171** to convert the rotary motion of the worm wheels **342** and **352** to translational X-axis and Y-axis movement of the carrier **318**.

[00107] The first linkage **361** includes a first cam **362** fixed to the first worm wheel **342** for rotation therewith. The outer peripheral profile of the first cam **362** is eccentric about the rotation axis **F1-F1** of the first worm wheel **342**. A first follower **364** converts the movement of the cam **362** to translational movement of the carrier **318**. The first follower **364** may be biased into engagement with the first cam **362** by the resilience of the flexure members **314** and/or a supplemental biasing mechanism (*e.g.*, spring(s)), for example.

[00108] Likewise, the second linkage **371** includes a second cam **372** fixed to the second worm wheel **352** for rotation therewith. The outer peripheral profile of the second cam **372** is eccentric about the rotation axis **F2-F2** of the second worm wheel **352**. A second follower **374** converts the movement of the cam **372** to translational movement of the carrier **318**. The second follower **374** may be biased into engagement with the second cam **372** by the resilience of the flexure members **316** and/or a supplemental biasing mechanism (*e.g.*, spring(s)), for example.

[00109] While single drive positioning systems have been shown and described herein including a carrier, stage or platform that is displaced by the linkages (*e.g.*, linkages **161**, **171**), in other embodiments an object to be positioned may be directly coupled to the guide members or linkages and the carrier, stage or platform may be omitted. In some

embodiments, the object may have integral features to constrain movement of the object to the intended axis of adjustment.

[00110] Single drive positioning systems according to some embodiments may be configured to adjust the position of an object along different axes or relative to the axes in different ways (*i.e.*, not translational adjustment along an X-axis and translational adjustment along a Y-axis). For example, the linkages between the worm wheels **142**, **152** and the object may be configured to change a rotational (angular) position or attitude of the object about a displacement axis, or to translate the object along a Z-axis.

[00111] Single drive positioning systems as disclosed herein may be incorporated into apparatus other than ICP mass analyzers, such as other types of mass analyzers, other types of devices employing an ICP torch, other types of analytical instruments, and apparatus other than analytical instruments.

[00112] Single drive positioning systems as disclosed herein may include bearing systems of different configurations than those shown herein, including bearing systems other than dual-axis linear or flexure bearing systems.

[00113] A dual-axis single drive positioning system as disclosed herein can be used in combination to an additional or supplemental positioning system including a second motor or other actuator. For example, a single drive positioning system configured to adjust the position of an object along an X-axis and a Y-axis may be paired with a second drive system that adjusts the position of the object along a Z-axis, a rotational position of the object, or an attitude of the object.

[00114] Single drive positioning systems as disclosed herein may include additional intermediate gearing or linkages between the motor output and the object to be adjusted. For example, reduction gears may be provided between the motor output and the drive shaft, and/or between the worm wheel and the crank.

[00115] Other types of linkages may be provided between the worm wheels and the final outputs (*e.g.*, the guide members **114**, **116**).

[00116] While the applicant's teachings are described in conjunction with various embodiments, it is not intended that the applicant's teachings be limited to such embodiments. On the contrary, the applicant's teachings encompass various alternatives, modifications, and equivalents, as will be appreciated by those of skill in the art. For example, the illustrated system is described with respect to an ICP-MS, however the systems and method described herein may be used in with any type of sample analysis system using any suitable type of ionizer or mass spectrometer.

[00117] Embodiments of the controller **22** logic may take the form of an entirely software embodiment or an embodiment combining software and hardware aspects, all generally referred to herein as a "circuit" or "module." In some embodiments, the circuits include both software and hardware and the software is configured to work with specific hardware with known physical attributes and/or configurations. Furthermore, controller logic may take the form of a computer program product on a computer-usable storage medium having computer-usable program code embodied in the medium. Any suitable computer readable medium may be utilized including hard disks, CD-ROMs, optical storage devices, a transmission media such as those supporting the Internet or an intranet, or other storage devices.

[00118] The present technology has been described herein with reference to the accompanying drawings, in which illustrative embodiments of the technology are shown. In the drawings, the relative sizes of regions or features may be exaggerated for clarity. This technology may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the technology to those skilled in the art.

[00119] It will be understood that, although the terms first, second, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer or section from another region, layer or section. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the present technology.

[00120] Spatially relative terms, such as "beneath", "below", "lower", "above", "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the exemplary term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90° or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[00121] As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless expressly stated otherwise. It will be further understood that the terms “includes,” “comprises,” “including” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. It will be understood that when an element is referred to as being “connected” or “coupled” to another element, it can be directly connected or coupled to the other element or intervening elements may be present. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[00122] The term "automatically" means that the operation is substantially, and may be entirely, carried out without human or manual input, and can be programmatically directed or carried out.

[00123] The term "programmatically" refers to operations directed and/or primarily carried out electronically by computer program modules, code and/or instructions.

[00124] The term "electronically" includes both wireless and wired connections between components.

[00125] Many alterations and modifications may be made by those having ordinary skill in the art, given the benefit of present disclosure, without departing from the spirit and scope of the invention. Therefore, it must be understood that the illustrated embodiments have been set forth only for the purposes of example, and that it should not be taken as limiting the invention as defined by the following claims. The following claims, therefore, are to be read to include not only the combination of elements which are literally set forth but all equivalent elements for performing substantially the same function in substantially the same way to obtain substantially the same result. The claims are thus to be understood to include what is specifically illustrated and described above, what is conceptually equivalent, and also what incorporates the essential idea of the invention.

WHAT IS CLAIMED IS:

1. A single drive positioning system comprising:
a drive shaft;
a motor having a motor output connected to the drive shaft and operable to selectively rotate the drive shaft;
a first worm screw mounted on the drive shaft for rotation therewith; and
a second worm screw mounted on the drive shaft for rotation therewith.
2. The single drive positioning system of Claim 1 including:
a first overrunning clutch between the first worm screw and the motor output;
and
a second overrunning clutch between the second worm screw and the motor output.
3. The single drive positioning system of Claim 2 wherein:
the motor is operable to rotate the drive shaft in each of a clockwise direction and a counterclockwise direction;
the first overrunning clutch is configured to drive the first worm screw in the clockwise direction when the drive shaft is driven in the clockwise direction, and to permit the drive shaft to rotate independently of the first worm screw when the drive shaft is driven in the counterclockwise direction; and
the second overrunning clutch is configured to drive the second worm screw in the counterclockwise direction when the drive shaft is driven in the counterclockwise direction, and to permit the drive shaft to rotate independently of the second worm screw when the drive shaft is driven in the clockwise direction.
4. The single drive positioning system of Claim 3 wherein:
the first overrunning clutch includes a first one-way bearing coupling the first worm screw to the drive shaft; and
the second overrunning clutch includes a second one-way bearing coupling the second worm screw to the drive shaft.
5. The single drive positioning system of Claim 4 wherein:

the first one-way bearing is radially interposed between the first worm screw and the drive shaft; and

the second one-way bearing is radially interposed between the second worm screw and the drive shaft.

6. The single drive positioning system of Claim 5 wherein the first and second one-way bearings are one-way needle bearings.
7. The single drive positioning system of Claim 3 including:
 - a first worm drive including the first worm screw and a first worm wheel intermeshed with the first worm screw; and
 - a second worm drive including the second worm screw and a second worm wheel intermeshed with the second worm screw.
8. The single drive positioning system of Claim 7 wherein the first worm drive and the second worm drive are self-locking worm drives such that the first and second worm screws are not backwards drivable by the first and second worm wheels.
9. The single drive positioning system of Claim 8 wherein the first and second worm screws are mounted on the drive shaft at axially fixed locations along the drive shaft.
10. The single drive positioning system of Claim 7 including:
 - a first rotary-to-linear motion mechanism configured to be driven by rotation of the first worm wheel; and
 - a second rotary-to-linear motion mechanism configured to be driven by rotation of the second worm wheel.
11. The single drive positioning system of Claim 10 wherein at least one of the first and second rotary-to-linear motion mechanisms includes a slider-crank mechanism including a crank and a reciprocating connecting member.
12. The single drive positioning system of Claim 10 wherein at least one of the first and second rotary-to-linear motion mechanisms includes a cam mechanism including a cam and a cam follower.

13. The single drive positioning system of Claim 10 including a slide bearing system including:
- a frame;
 - a first guide member slidably mounted on the frame for movement along a first displacement axis; and
 - a second guide member slidably mounted on the frame for movement along a second displacement axis extending transverse to the first displacement axis;
- wherein:
- the first rotary-to-linear motion mechanism is configured to displace the first guide member along the first displacement axis when the first worm screw is driven in the clockwise direction; and
 - the second rotary-to-linear motion mechanism is configured to displace the second guide member along the second displacement axis when the second worm screw is driven in the counterclockwise direction.
14. The single drive positioning system of Claim 10 including a flexure bearing system including:
- a frame;
 - a carrier; and
 - at least one bendable flexure member connecting the carrier to the frame such that the carrier is movable along each of a first displacement axis and a second displacement axis extending transverse to the first displacement axis;
- wherein:
- the first rotary-to-linear motion mechanism is configured to displace the carrier along the first displacement axis when the first worm screw is driven in the clockwise direction; and
 - the second rotary-to-linear motion mechanism is configured to displace the carrier along the second displacement axis when the second worm screw is driven in the counterclockwise direction.
15. The single drive positioning system of Claim 3, wherein the single drive positioning system is configured for use with an object, and is configured to:

displace the object along or about a first displacement axis when the first worm screw is driven in the clockwise direction; and
displace the object along or about a second displacement axis when the second worm screw is driven in the counterclockwise direction.

16. The single drive positioning system of Claim 15 wherein:
the first displacement axis is a linear axis; and
the second displacement axis is a linear axis extending transverse to the first displacement axis.

17. The single drive positioning system of Claim 16 wherein:
the motor is operable to rotate the drive shaft about a drive shaft axis; and
the drive shaft axis extends at an oblique angle to the first displacement axis and at an oblique angle to the second displacement axis.

18. A method for positioning an object, the method comprising:
providing a single drive positioning system comprising:
a drive shaft;
a motor having a motor output connected to the drive shaft and operable to selectively rotate the drive shaft;
a first worm screw mounted on the drive shaft for rotation therewith;
and
a second worm screw mounted on the drive shaft for rotation therewith; and
operating the motor to rotate the drive shaft.

19. A single drive positioning system comprising:
a drive shaft;
a motor having a motor output connected to the drive shaft and operable to selectively rotate the drive shaft in each of a clockwise direction and a counterclockwise direction;
a first worm drive including:
a first worm screw mounted on the drive shaft for rotation therewith;
and

a first worm wheel intermeshed with the first worm screw;
a second worm drive including:
a second worm screw mounted on the drive shaft for rotation therewith; and
a second worm wheel intermeshed with the second worm screw;
a first overrunning clutch between the drive shaft and the first worm screw, wherein the first overrunning clutch is configured to drive the first worm screw in the clockwise direction when the drive shaft is driven in the clockwise direction, and to permit the drive shaft to rotate independently of the first worm screw when the drive shaft is driven in the counterclockwise direction; and
a second overrunning clutch between the drive shaft and the first worm screw, wherein the second overrunning clutch is configured to drive the second worm screw in the counterclockwise direction when the drive shaft is driven in the counterclockwise direction, and to permit the drive shaft to rotate independently of the second worm screw when the drive shaft is driven in the clockwise direction.

20. A mass analysis system comprising:
an inductively coupled plasma (ICP) torch;
a sample introduction element including an inlet; and
a single drive positioning system operable to selectively align the ICP torch with the inlet, wherein the single drive positioning system includes:
a drive shaft;
a motor having a motor output connected to the drive shaft and operable to selectively rotate the drive shaft;
a first worm screw mounted on the drive shaft for rotation therewith;
and
a second worm screw mounted on the drive shaft for rotation therewith.

21. The mass analysis system of Claim 20 wherein:
the motor is operable to rotate the drive shaft in each of a clockwise direction and a counterclockwise direction;
the single drive positioning system configured to:

adjust a position of the ICP torch along or about a first displacement axis by rotating the drive shaft in the clockwise direction; and
adjust a position of the ICP torch along or about a second displacement axis by rotating the drive shaft in the counterclockwise direction.

22. The mass analysis system of Claim 20 including a mass analyzer located downstream of the inlet from the ICP torch.
23. A method for conducting a mass analysis of a sample, the method comprising:
providing a mass analysis system comprising:
an inductively coupled plasma (ICP) torch;
a sample introduction element including an inlet; and
a single drive positioning system operable to selectively align the ICP torch with the inlet, wherein the single drive positioning system includes:
a drive shaft;
a motor having a motor output connected to the drive shaft and operable to selectively rotate the drive shaft;
a first worm screw mounted on the drive shaft for rotation therewith;
and
a second worm screw mounted on the drive shaft for rotation therewith; and
operating the motor to rotate the drive shaft.