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(54) **ARTICULATING ULTRASONIC SURGICAL INSTRUMENTS AND SYSTEMS**

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(71) Applicant: **Covidien LP**, Mansfield, MA (US)

(72) Inventors: **James R. Fagan**, Erie, CO (US);
Thomas E. Drochner, Longmont, CO (US); **Michael B. Lyons**, Boulder, CO (US); **David J. Van Tol**, Boulder, CO (US); **Matthew S. Cowley**, Frederick, CO (US)

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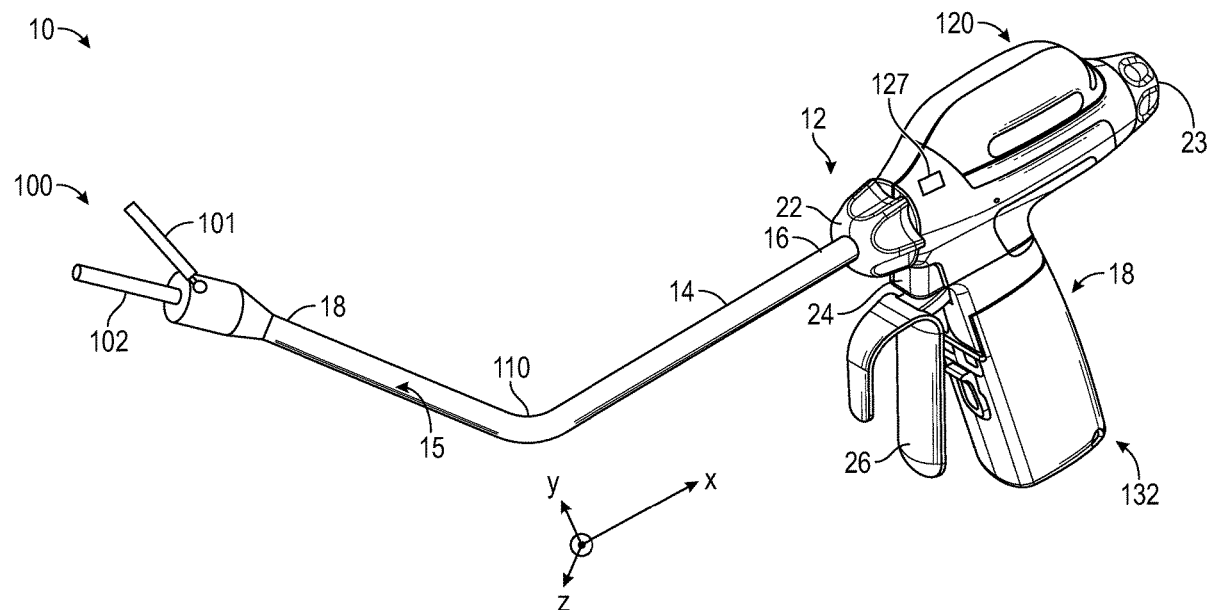
(63) Continuation of application No. 17/320,321, filed on May 14, 2021, now Pat. No. 11,766,275.

(60) Provisional application No. 63/026,323, filed on May 18, 2020, provisional application No. 63/026,377, filed on May 18, 2020.

ABSTRACT

(57)

A surgical instrument includes a housing having an elongated body extending distally therefrom. The elongated body defines a first articulating portion and a second articulating portion. The elongated body defines a lumen therein. An end effector is supported at a distal end portion of the elongated body. A flexible waveguide extends through the lumen of the elongated body. A proximal end portion of the flexible waveguide connects to an ultrasonic transducer. A distal end portion of the flexible waveguide is connected with the end effector. the flexible waveguide defines a first articulating portion having a narrower thickness than a thickness of other portions of the flexible waveguide and a second articulating portion having a narrower thickness than a thickness of other portions of the flexible waveguide.



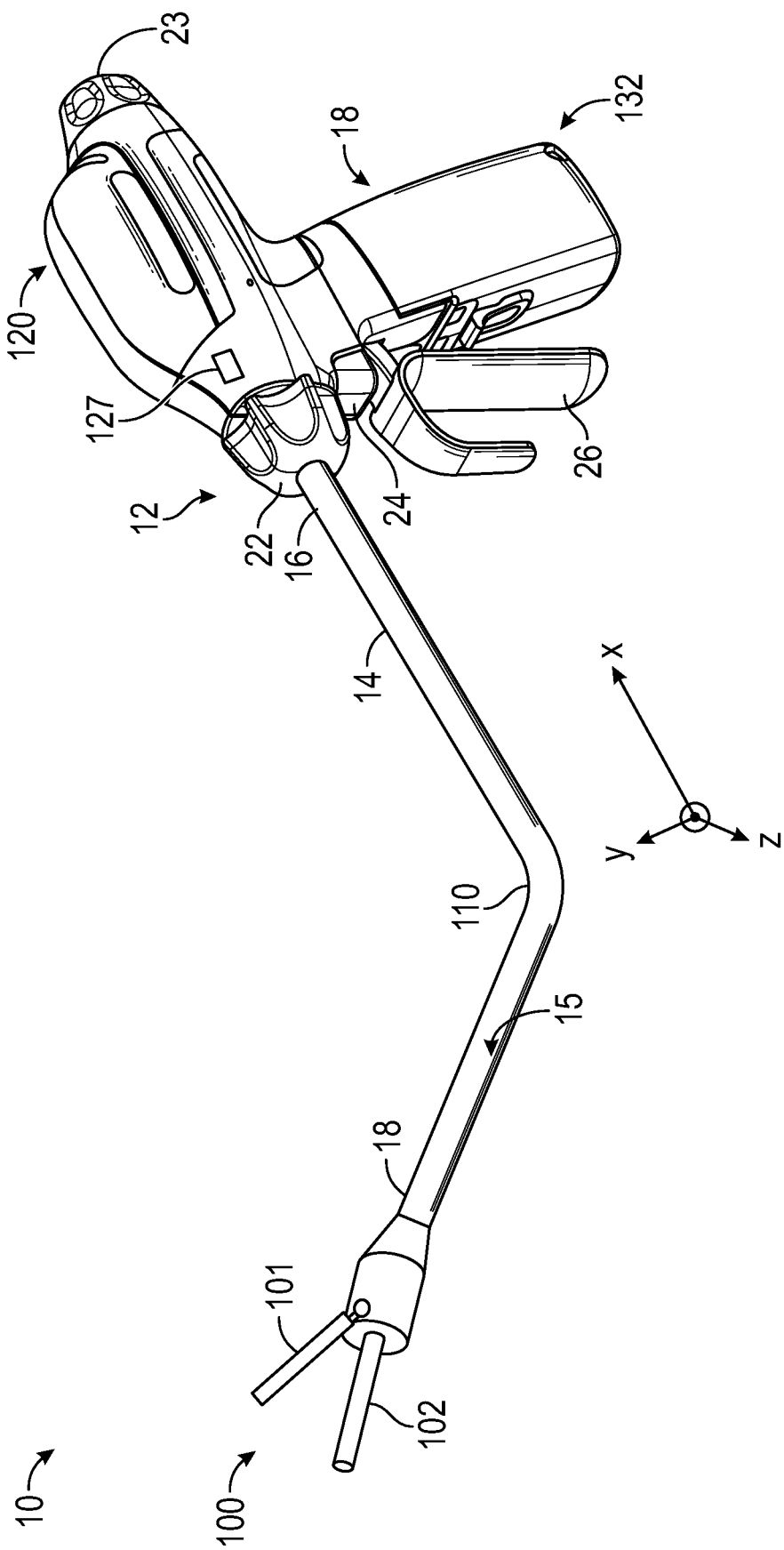


FIG. 1

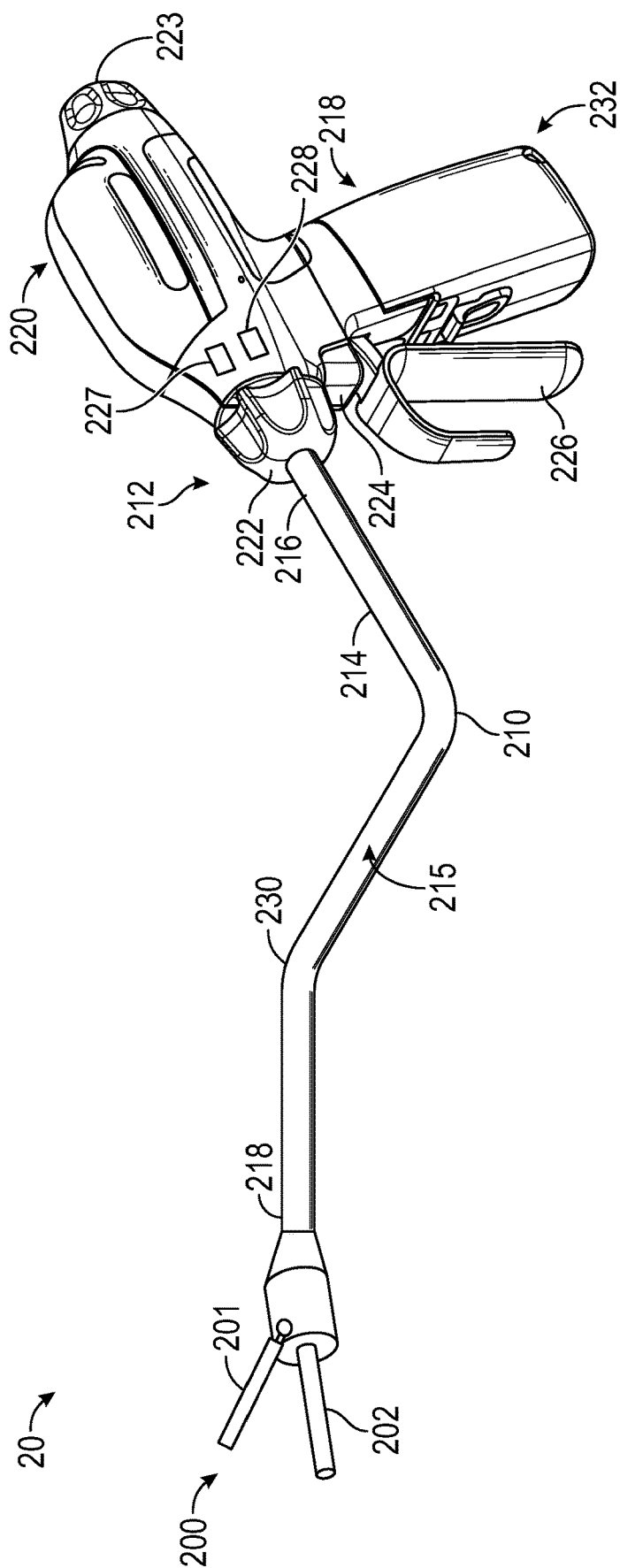


FIG. 2

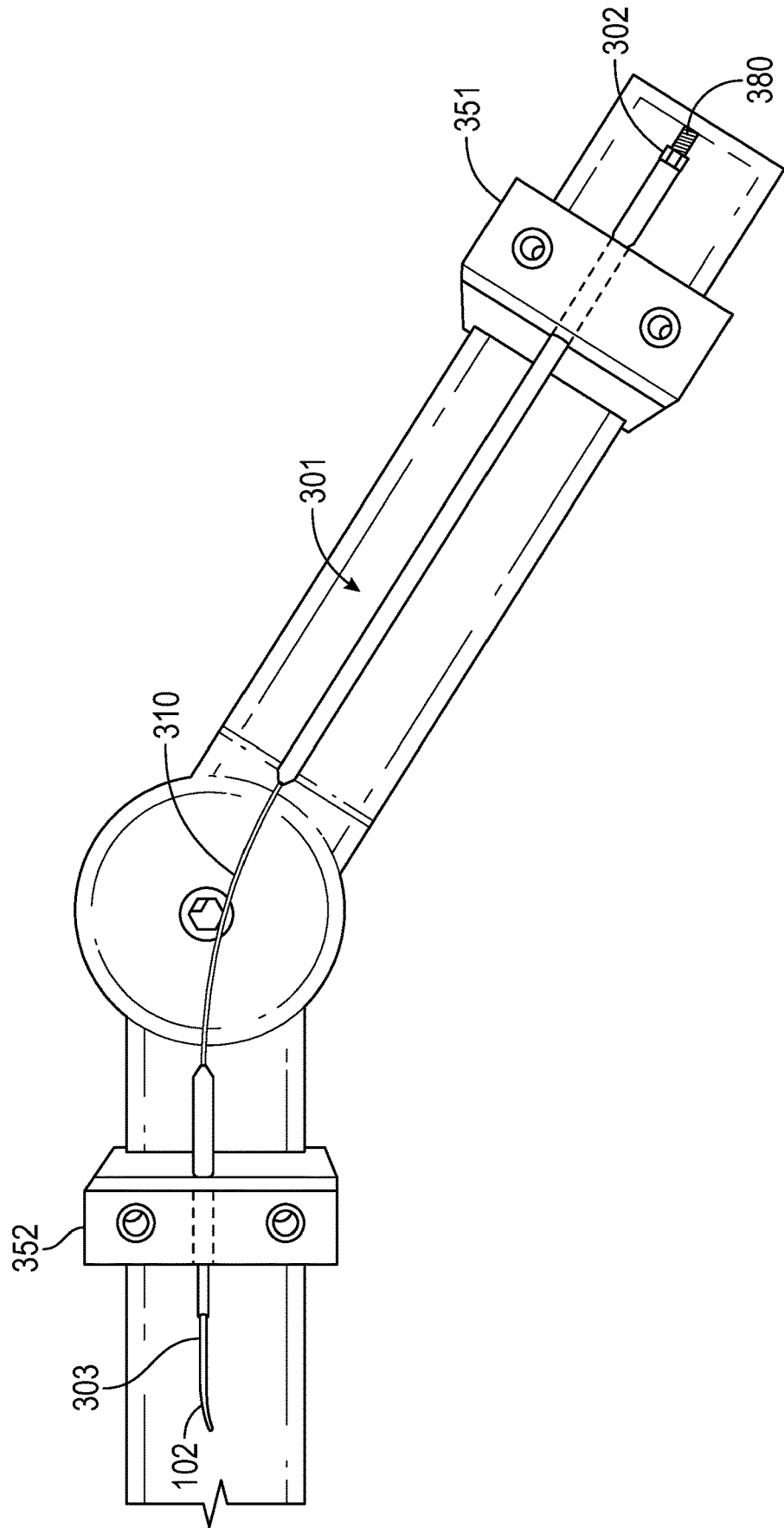


FIG. 3

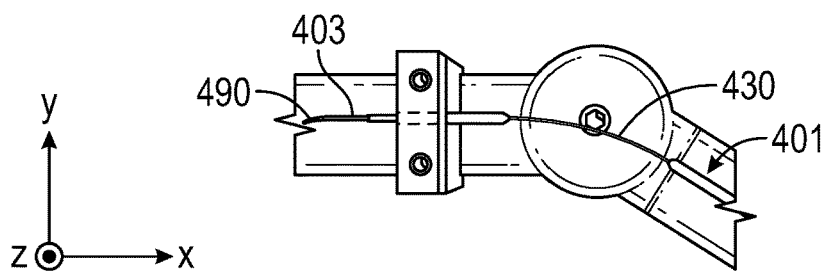


FIG. 4A

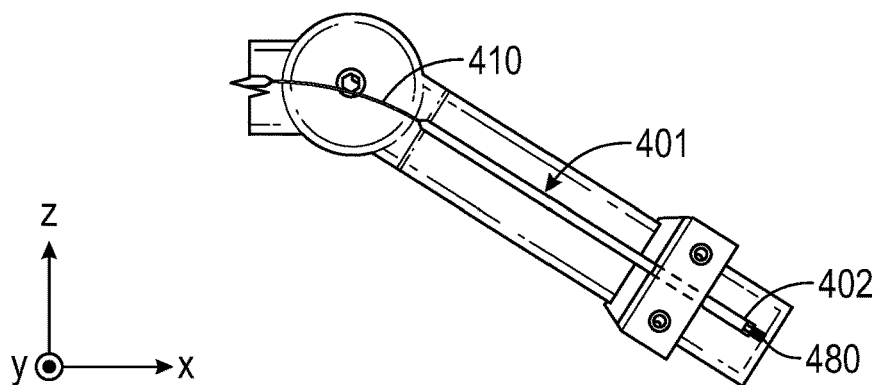


FIG. 4B

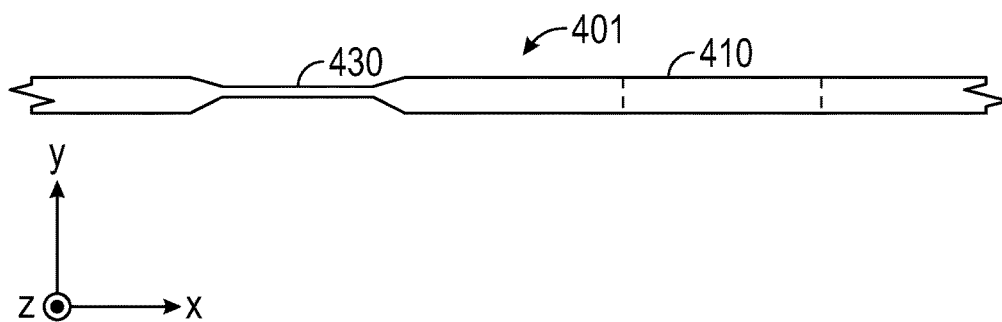


FIG. 5A

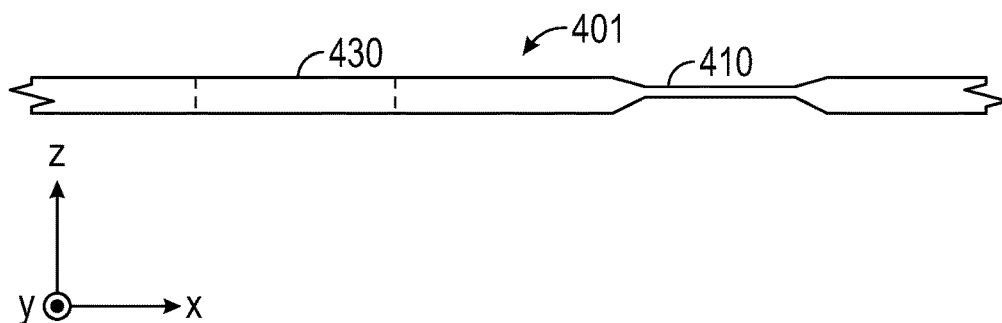


FIG. 5B

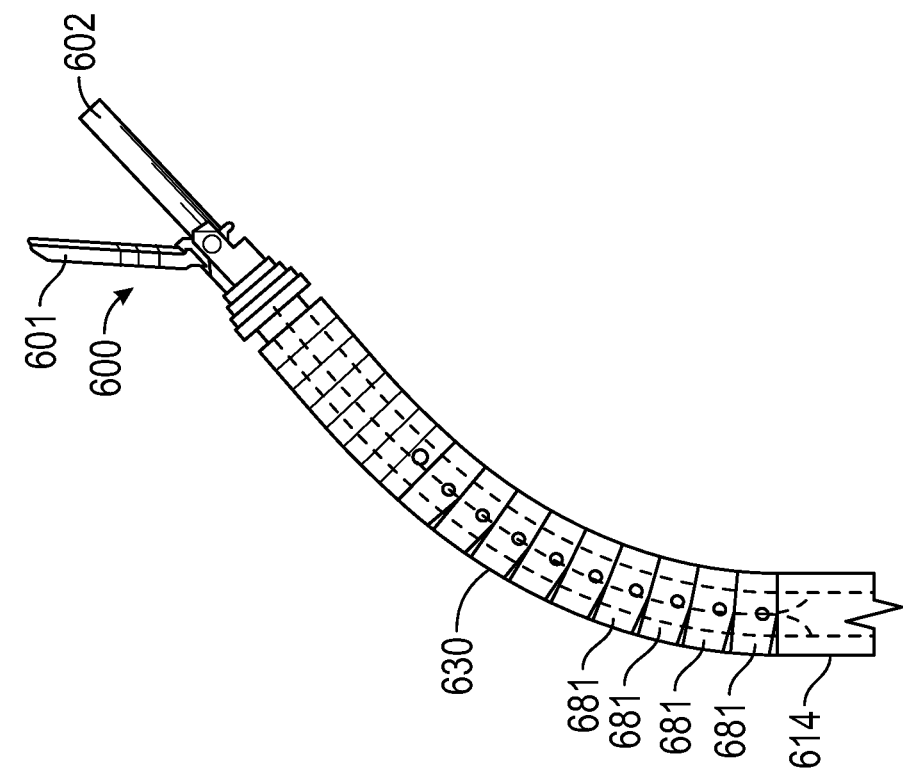


FIG. 6B

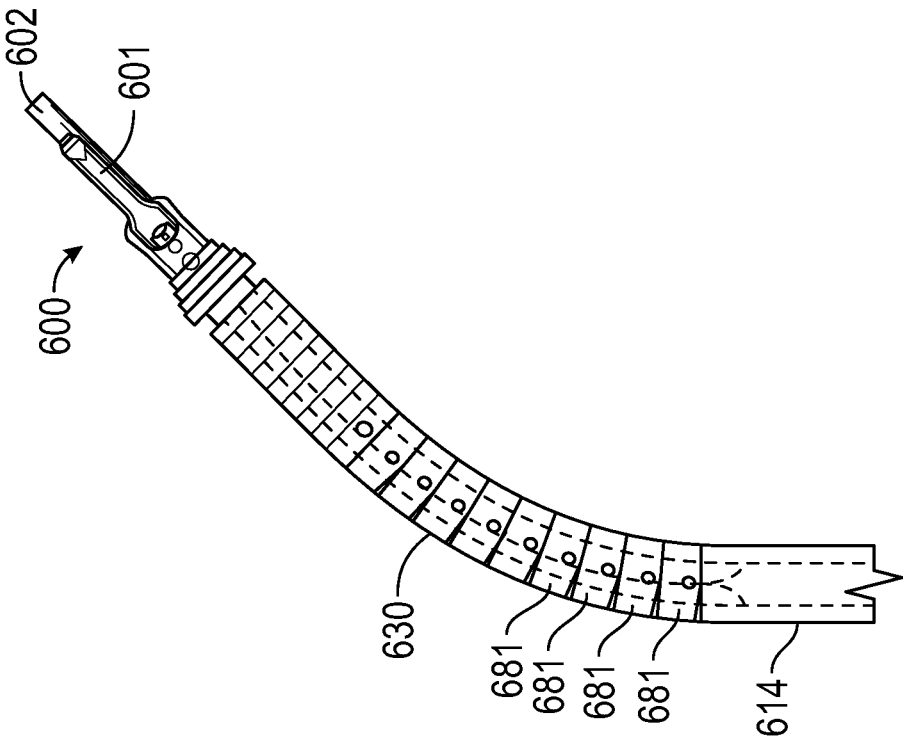


FIG. 6A

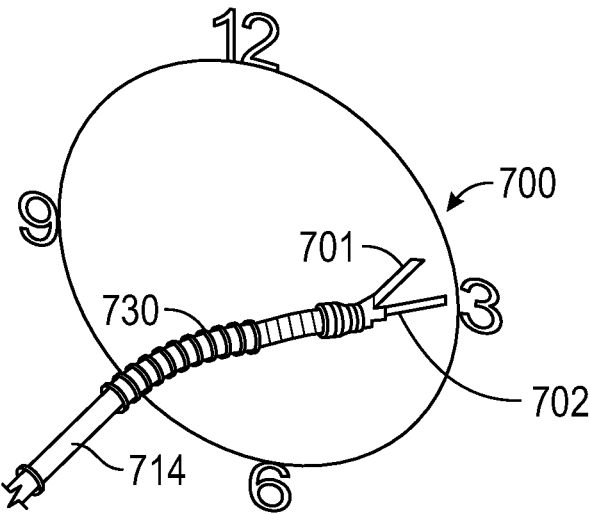


FIG. 7A

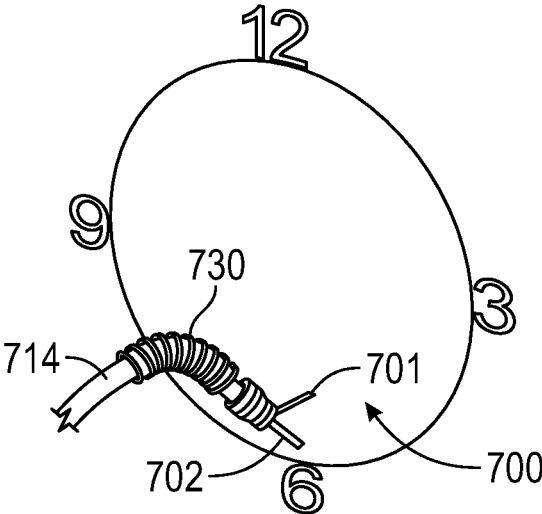


FIG. 7B

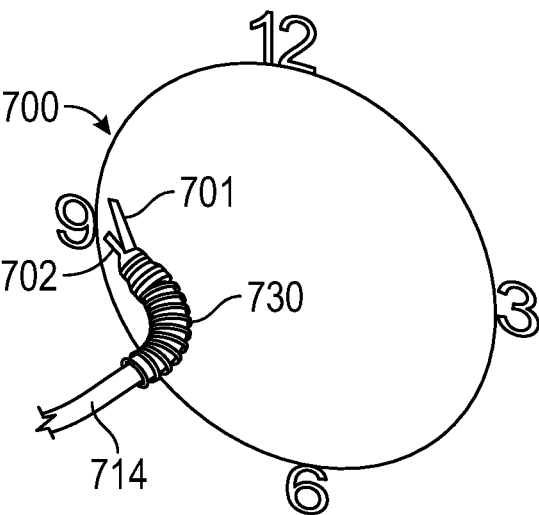


FIG. 7C

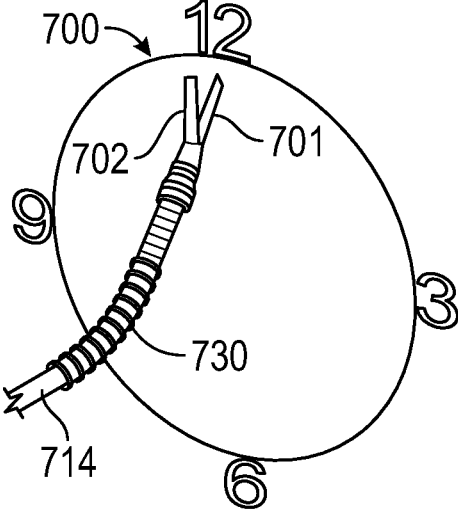


FIG. 7D

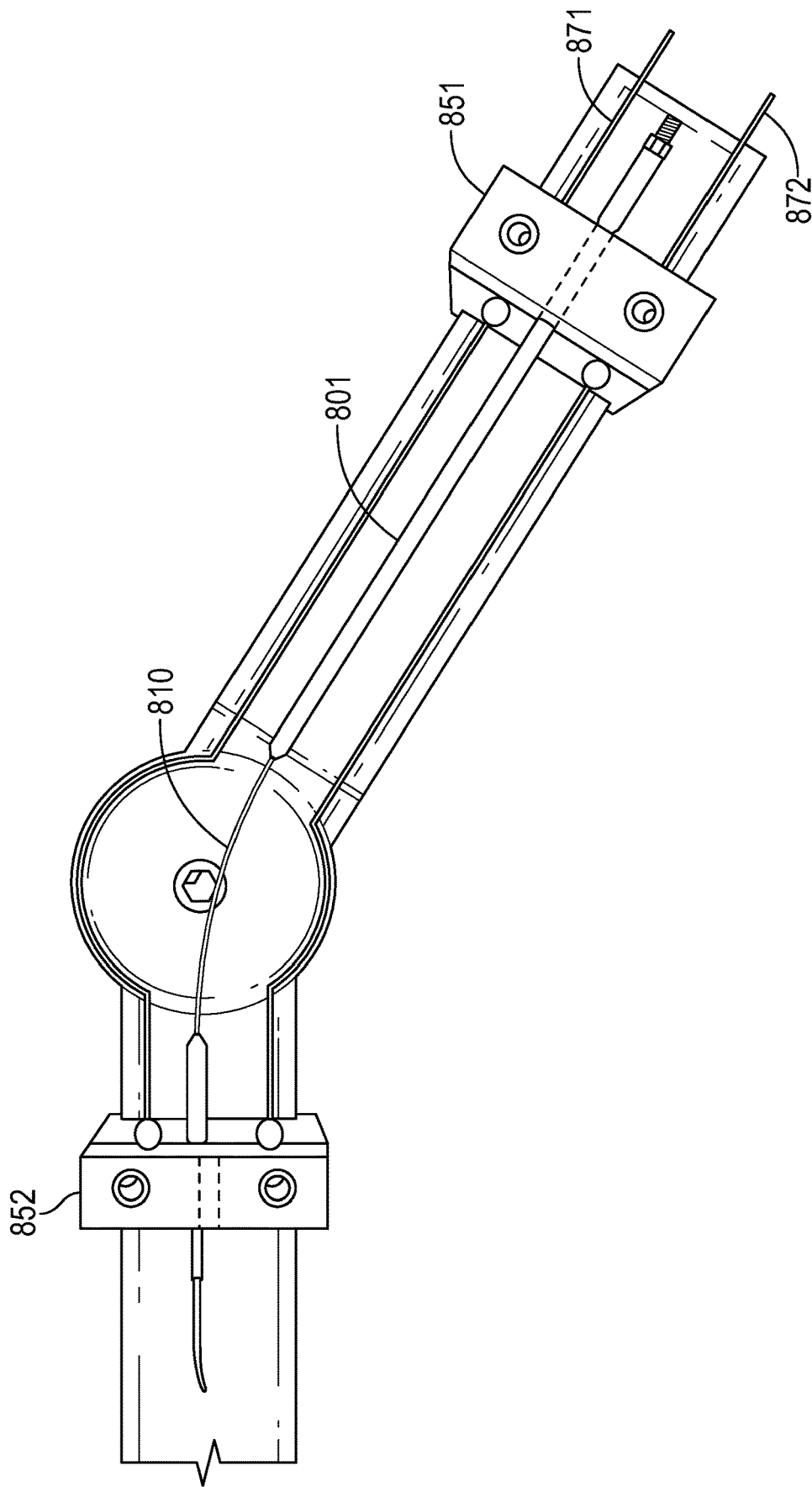


FIG. 8

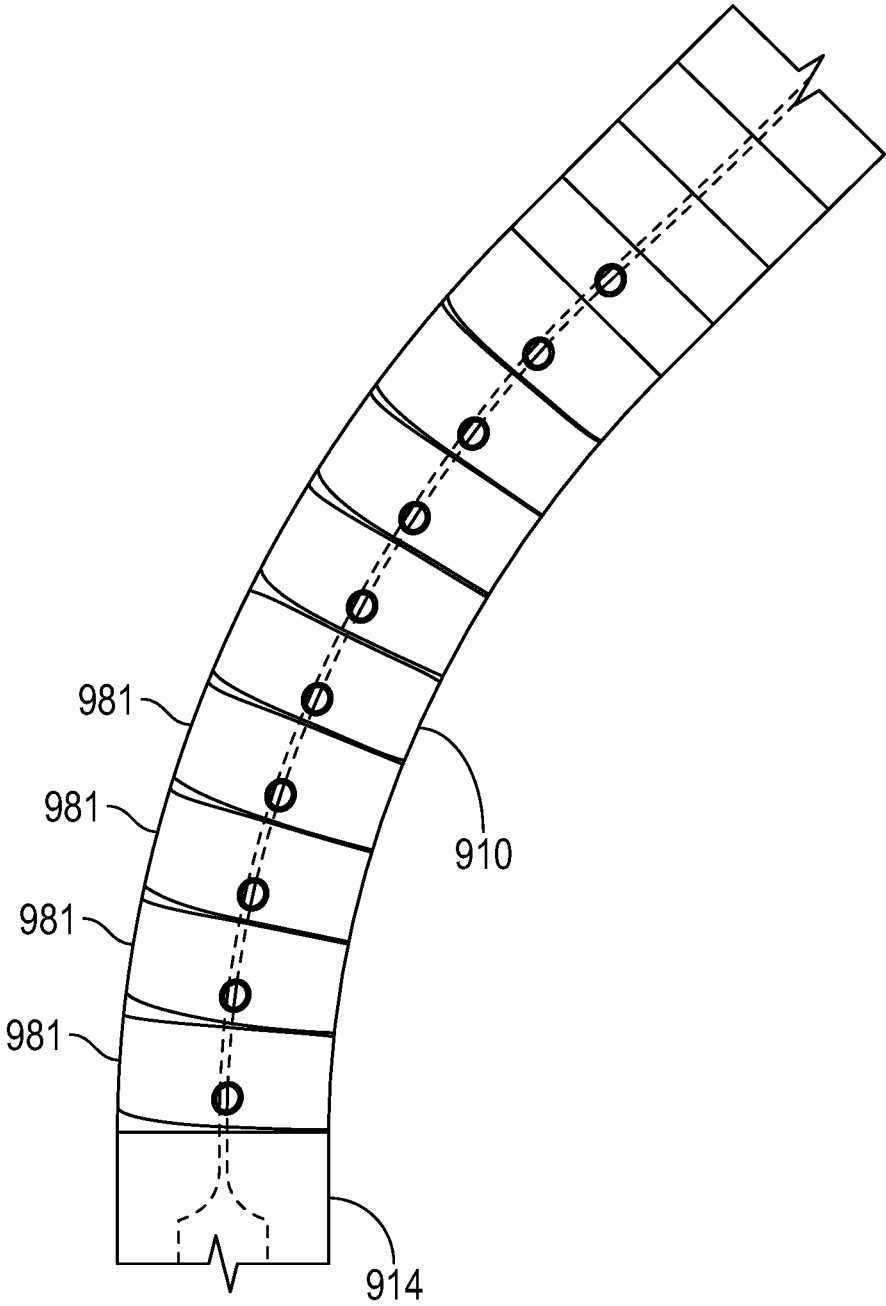


FIG. 9

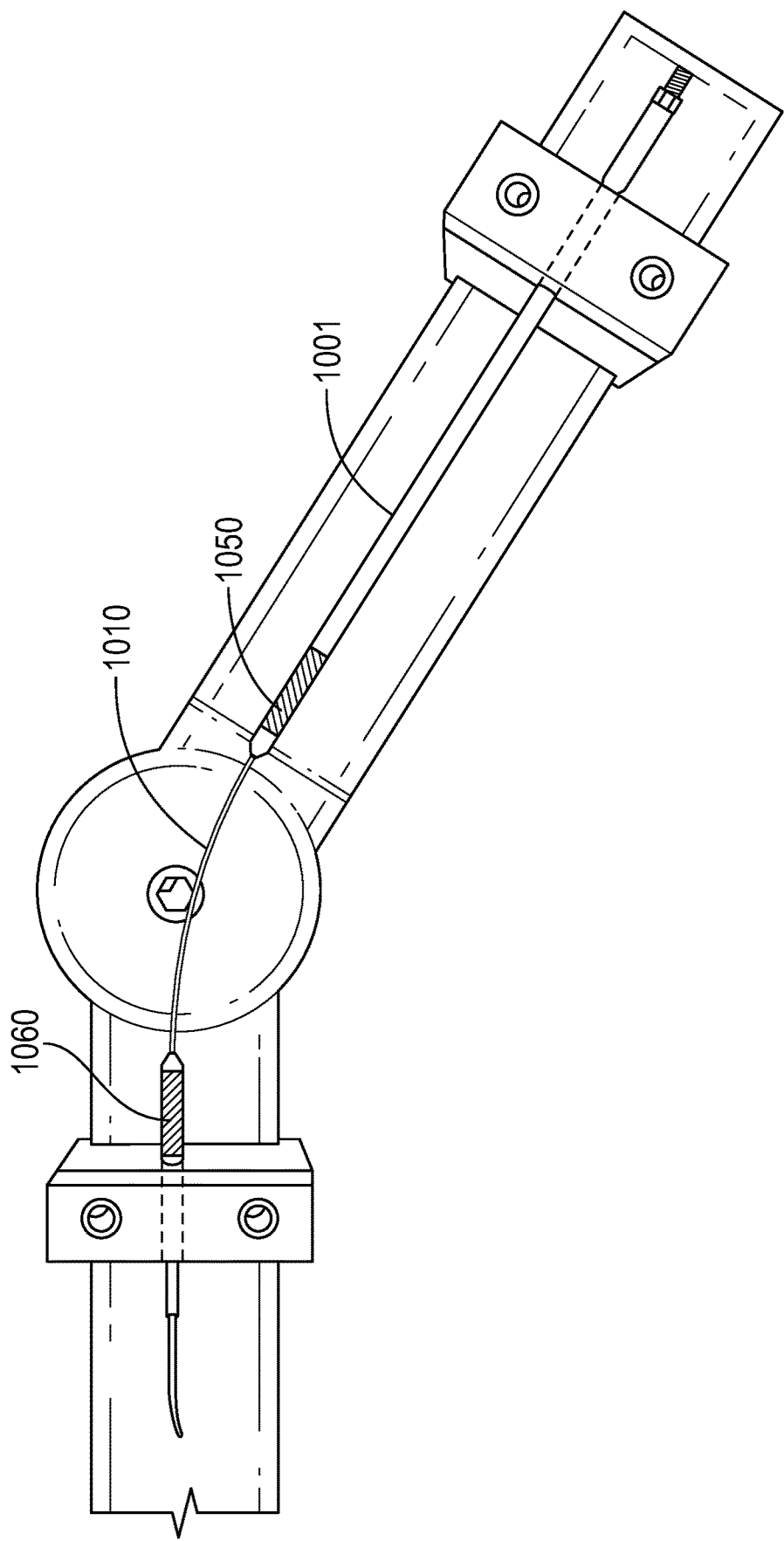


FIG. 10

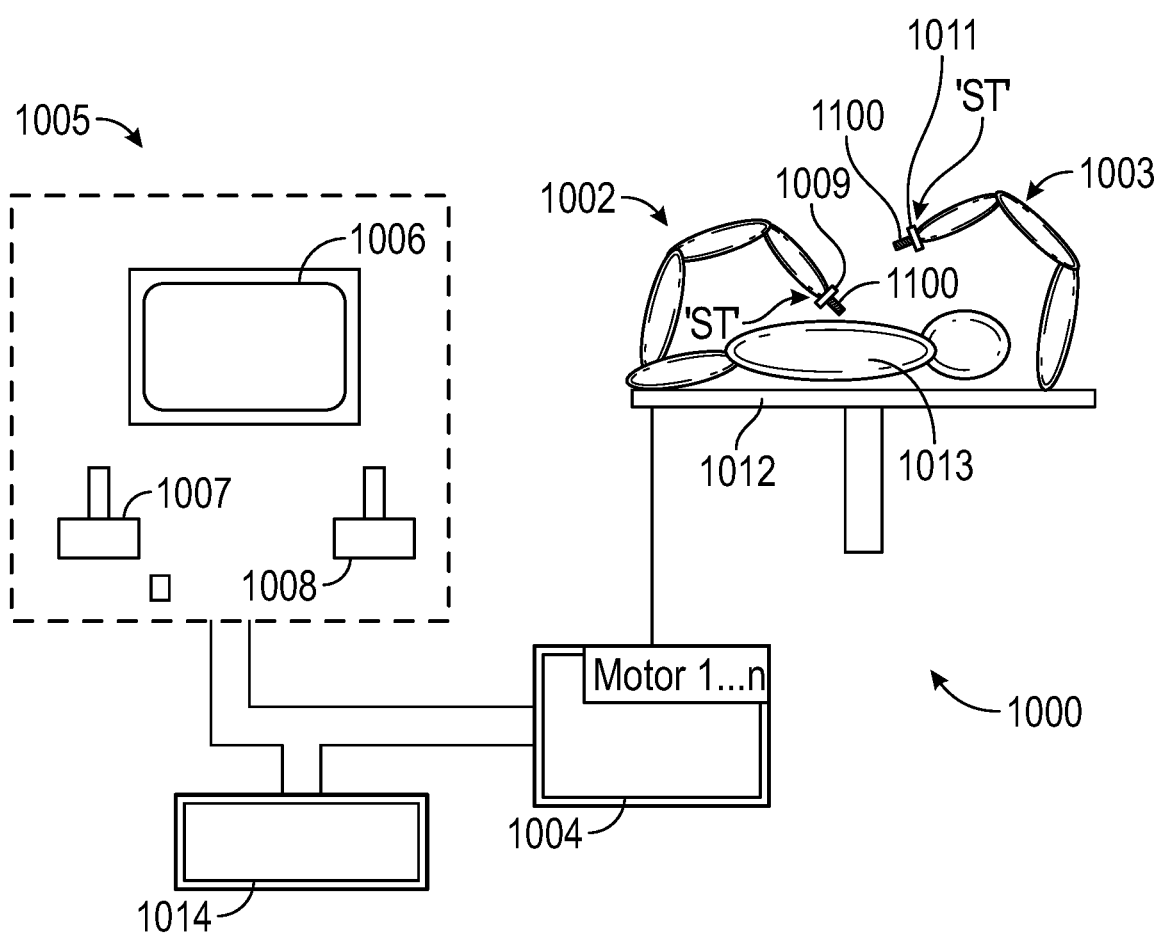


FIG. 11

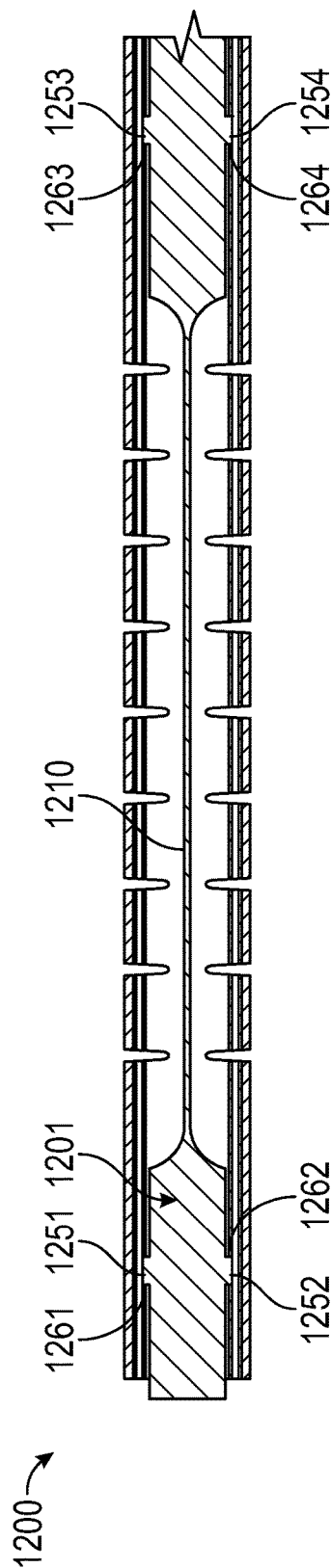


FIG. 12A

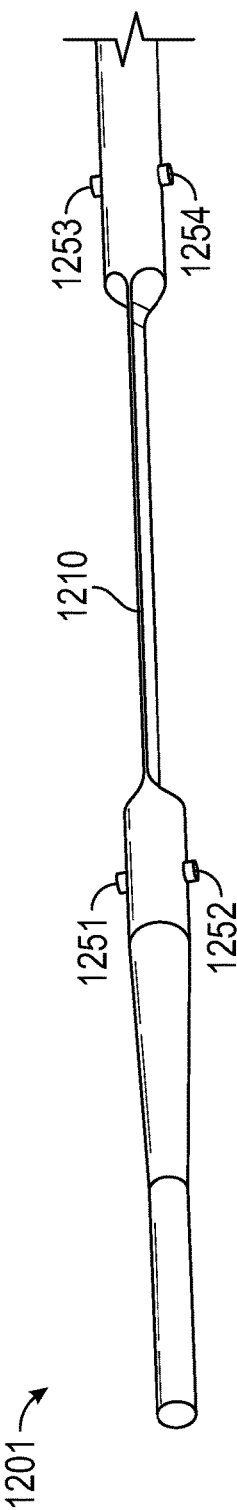


FIG. 12B

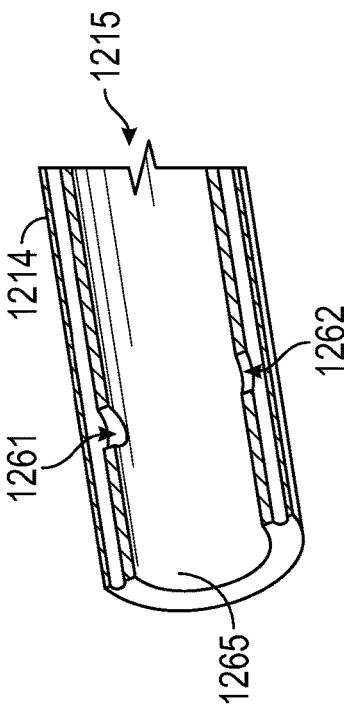


FIG. 12C

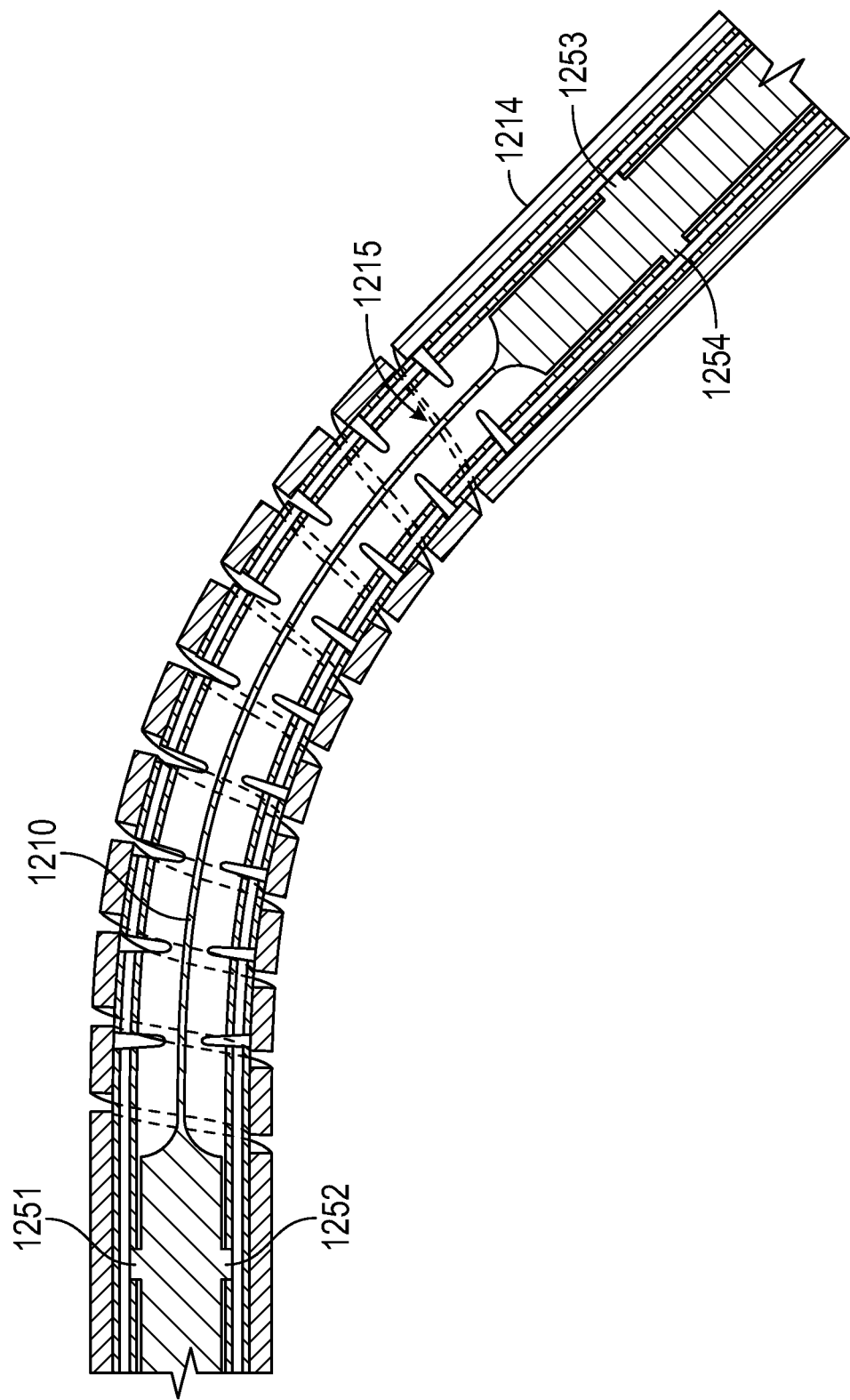


FIG. 12D

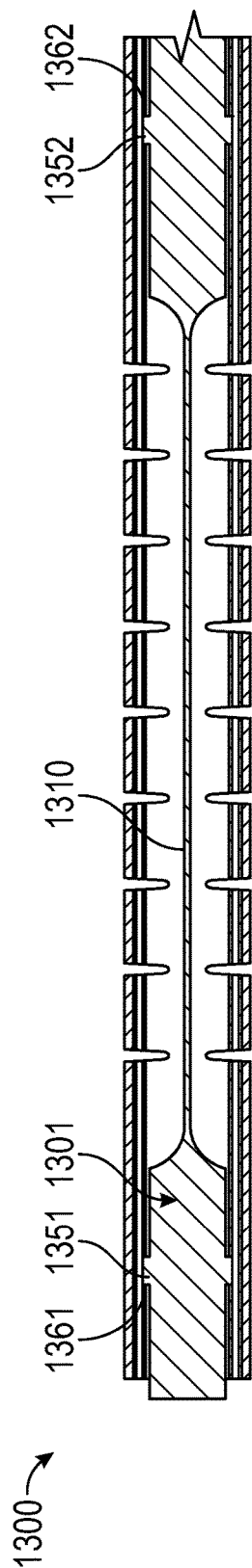


FIG. 13A

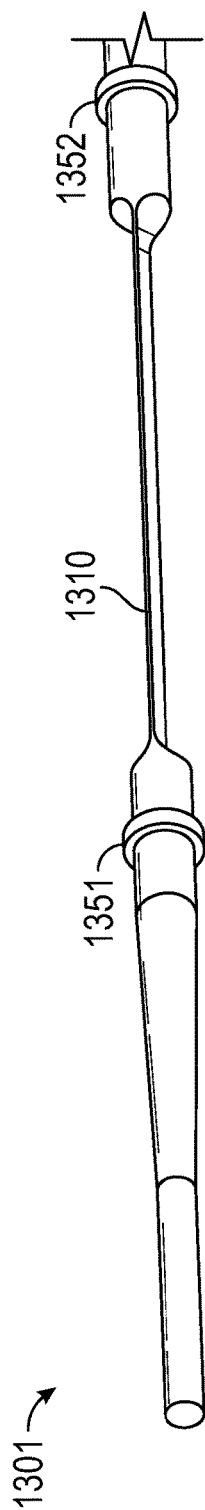


FIG. 13B

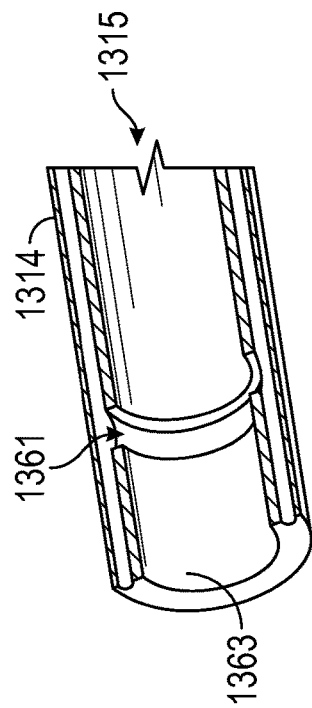


FIG. 13C

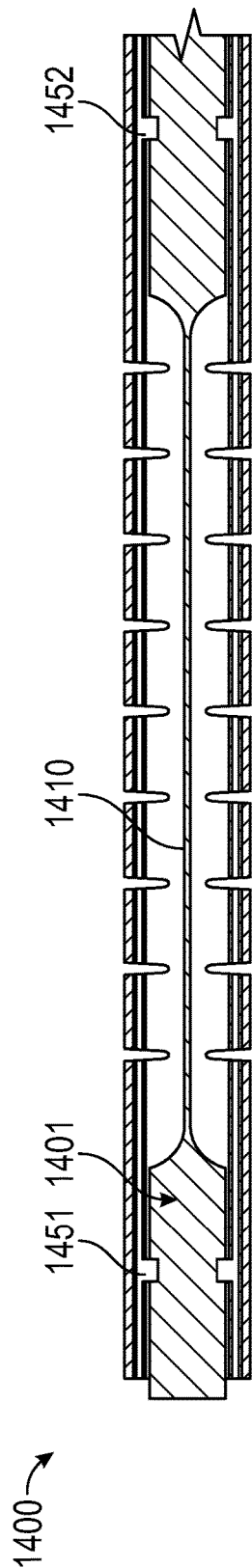


FIG. 14A

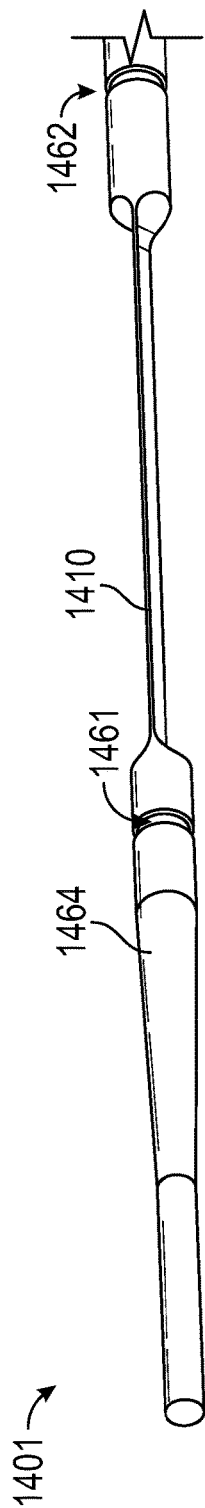


FIG. 14B

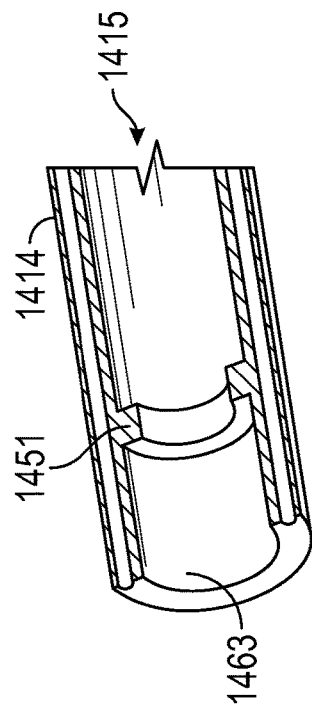
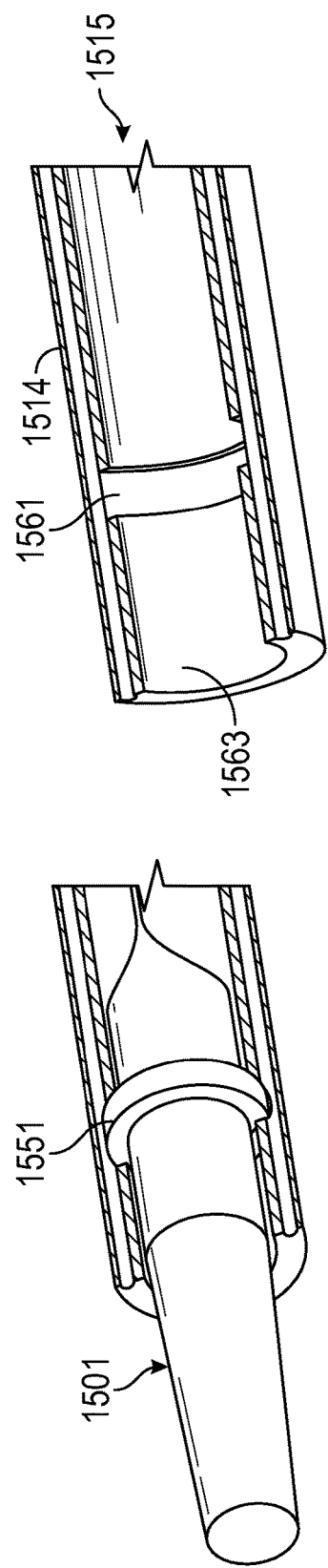
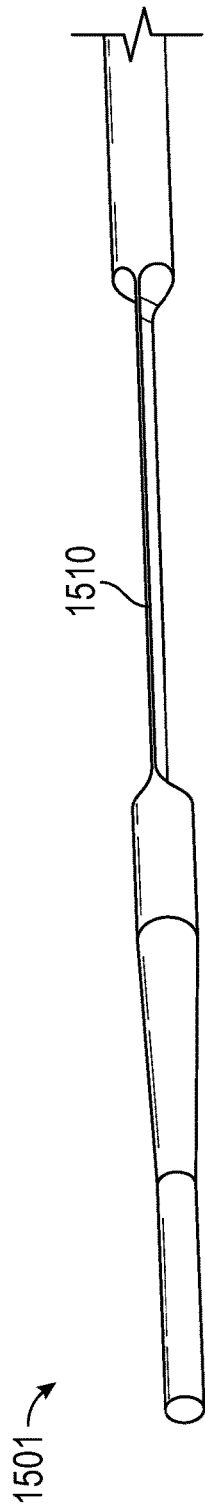
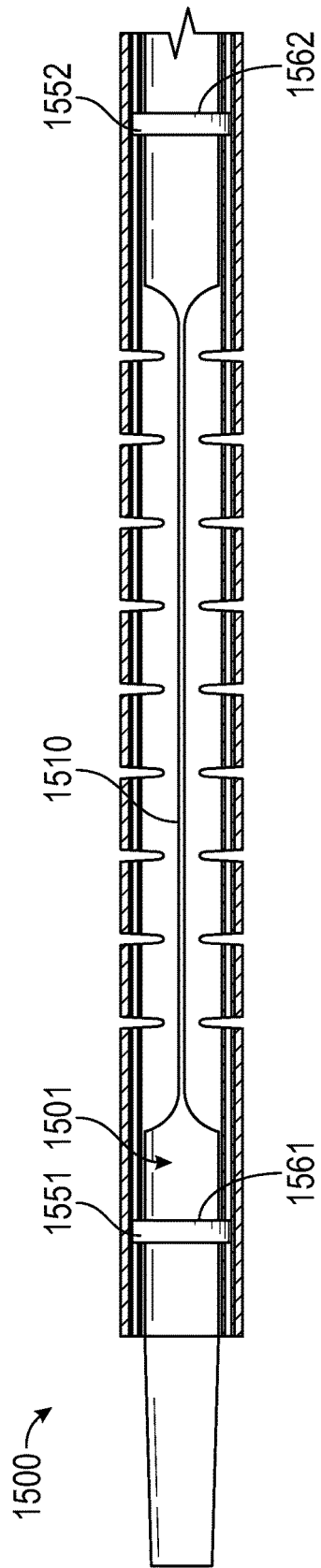


FIG. 14C



ARTICULATING ULTRASONIC SURGICAL INSTRUMENTS AND SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 17/320,321, filed on May 14, 2021, which claims the benefit of and priority to U.S. Provisional Patent Application Nos. 63/026,323 and 63/026,377, each of which was filed on May 18, 2020. The entire contents of each of the foregoing applications are incorporated by reference herein.

FIELD

[0002] The present disclosure relates to surgical instruments and systems and, more particularly, to articulating ultrasonic surgical instruments and systems.

BACKGROUND

[0003] Ultrasonic surgical instruments and systems utilize ultrasonic energy, i.e., ultrasonic vibrations, to treat tissue. More specifically, a typical ultrasonic surgical instrument or system includes a transducer configured to produce and transmit mechanical vibration energy at ultrasonic frequencies along a waveguide to an ultrasonic end effector configured to treat tissue, e.g., coagulate, cauterize, fuse, seal, cut, desiccate, fulgurate, or otherwise treat tissue. Traditionally, the transducer remains external of the surgical site, while the waveguide extends from the transducer into the surgical site to provide the ultrasonic energy to the ultrasonic end effector. The ultrasonic end effector is manipulated into position to treat a desired tissue or tissues.

[0004] Some ultrasonic surgical instruments and systems incorporate rotation features, thus enabling rotation of the ultrasonic end effector to a desired orientation within the surgical site. However, even in such instruments and systems, the ability to navigate within the surgical site via rotation and manipulation alone is limited.

SUMMARY

[0005] In one aspect of the disclosure, a surgical instrument includes a housing having an elongated body extending distally therefrom. The elongated body defines a first articulating portion and a second articulating portion. The elongated body defines a lumen therein. An end effector is supported at a distal end portion of the elongated body. A flexible waveguide extends through the lumen of the elongated body. A proximal end portion of the flexible waveguide connects to an ultrasonic transducer. A distal end portion of the flexible waveguide is connected with the end effector. The flexible waveguide defines a first articulating portion having a narrower thickness than a thickness of other portions of the flexible waveguide and a second articulating portion having a narrower thickness than a thickness of other portions of the flexible waveguide.

[0006] In some aspects of the disclosure, the first articulating portion of the flexible waveguide is configured to articulate in a first orientation, and the second articulating portion of the flexible waveguide is configured to articulate in a second orientation. The first articulating portion of the flexible waveguide and the second articulating portion of the flexible waveguide may each articulate in a same orientation as each other, or different orientations from each other. The

first or second articulating portions of the flexible waveguide is configured to articulate from about 1 degree to about 45 degrees.

[0007] In some aspects of the disclosure, the end effector includes an ultrasonic blade and a jaw configured to rotate about the ultrasonic blade. The ultrasonic blade and the jaw are configured to capture and treat tissue therebetween in plural rotational orientations of the jaw relative to the ultrasonic blade.

[0008] In some aspects of the disclosure, the elongated body is configured to rotate to achieve different directional orientations of the end effector. Independent controls are configured to rotate the elongated body, rotate the jaw about the ultrasonic blade, and articulate the first articulating portion and the second articulating portion of the elongated body. Thus, the first articulating portion of the flexible waveguide and the second articulating portion of the flexible waveguide are correspondingly rotated by the independent controls.

[0009] In some aspects of the disclosure, first and second transducers are at opposite sides of the first articulating portion of the flexible waveguide. At least one of the first or second transducers is configured to amplify an ultrasonic wave transmitted through the first articulating portion of the flexible waveguide.

[0010] In some aspects of the disclosure, the flexible waveguide may define a single articulating portion having a narrower width than a width of other portions of the flexible waveguide, and the elongated body may be configured to rotate to achieve different directional orientations of the end effector.

[0011] Other features of the disclosure will be appreciated from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate aspects and features of the disclosure and, together with the detailed description below, serve to further explain the disclosure, in which:

[0013] FIG. 1 is a side, perspective view of a surgical instrument having an articulating portion configured for use in accordance with the aspects and features of present disclosure;

[0014] FIG. 2 is a side, perspective view of a surgical instrument having first and second articulating portions configured for use in accordance with the aspects and features of present disclosure;

[0015] FIG. 3 is a side view of a single conceptualized articulating portion including a flexible waveguide shown restrained in a test fixture representing support, pivot, and other features, the flexible waveguide configured for use with the surgical instrument of FIG. 1;

[0016] FIG. 4A is a side view of a conceptualized first articulating portion including a first portion of a flexible waveguide shown restrained in a test fixture representing support, pivot, and other features, the flexible waveguide configured for use with the surgical instrument of FIG. 2 articulated in a first plane;

[0017] FIG. 4B is a side view of a conceptualized second articulating portion including a second portion of a flexible waveguide shown restrained in a test fixture representing

support, pivot, and other features, the flexible waveguide configured for use with the surgical instrument of FIG. 2, articulated in a second plane;

[0018] FIG. 5A is a side view of the flexible waveguide of FIG. 4A;

[0019] FIG. 5B is a top plan view of the flexible waveguide of FIG. 4A;

[0020] FIG. 6A is a side view of a distal end of an elongated body, and end effector including a rotatable jaw member, configured for use with the surgical instrument of FIG. 1 or 2 in a first rotational position;

[0021] FIG. 6B is a side view of the distal end of the elongated body, and the end effector of FIG. 6A in a second rotational position;

[0022] FIGS. 7A-7D are side, perspective views of the elongated body, and end effector including a rotatable jaw member, of FIG. 6A, in various rotational and articulated orientations;

[0023] FIG. 8 is a side view of a conceptualized articulation portion including a cable system for articulating the articulating portion and the flexible waveguide, the flexible waveguide shown restrained in a test fixture representing support, pivot, and other features and configured for use with the surgical instrument of FIG. 1 or 2;

[0024] FIG. 9 is a side view of another articulating portion configured for use with the elongated body of the surgical instrument of FIG. 1 or 2 having a plurality of flexing sections;

[0025] FIG. 10 is a side view of a conceptualized articulation portion including a flexible waveguide shown restrained in a test fixture representing support, pivot, and other features, the flexible waveguide configured for use with the surgical instrument of FIG. 1 or 2 and including transducers positioned at opposite sides of the articulating portion of the flexible waveguide;

[0026] FIG. 11 is a schematic illustration of a robotic surgical system configured for use in accordance with the present disclosure;

[0027] FIG. 12A is a longitudinal, cross-sectional view of a flexible waveguide secured within a lumen of an elongated body by a post and hole attachment structure;

[0028] FIG. 12B is a perspective view of the flexible waveguide of FIG. 12A;

[0029] FIG. 12C is a longitudinal, cross-sectional view of the holes formed in an inner surface of the elongated body of FIG. 12A;

[0030] FIG. 12D is a longitudinal, cross-sectional view of the elongated body and the flexible waveguide of FIG. 12A in an articulated configuration;

[0031] FIG. 13A is a longitudinal, cross-sectional view of a flexible waveguide secured within a lumen of an elongated body by an annular collar protruding outwardly from the flexible waveguide;

[0032] FIG. 13B is a perspective view of the flexible waveguide of FIG. 13A;

[0033] FIG. 13C is a longitudinal, cross-sectional view of a recess formed in an inner surface of the elongated body and configured to receive the annular collar of FIG. 13A;

[0034] FIG. 14A is a longitudinal, cross-sectional view of a flexible waveguide secured within a lumen of an elongated body by an annular collar protruding inwardly from an inner surface of the elongated body;

[0035] FIG. 14B is a perspective view of the flexible waveguide including a recess configured to receive the annular collar of FIG. 14A;

[0036] FIG. 14C is a longitudinal, cross-sectional view of the annular collar protruding from the inner surface of the elongated body of FIG. 14A;

[0037] FIG. 15A is a longitudinal, cross-sectional view of a flexible waveguide secured within a lumen of an elongated body by a removable annular collar;

[0038] FIG. 15B is a perspective view of the flexible waveguide of FIG. 15A with the removable annular collar omitted;

[0039] FIG. 15C is a longitudinal, cross-sectional view of the removable annular collar positioned about the flexible waveguide and secured in the lumen by a recess formed in an inner surface of the elongated body of FIG. 15A; and

[0040] FIG. 15D is a longitudinal, cross-sectional view of the recess of FIG. 15C.

DETAILED DESCRIPTION

[0041] As used herein, the term “distal” refers to the portion that is being described which is further from a user, while the term “proximal” refers to the portion that is being described which is closer to a user. Further, to the extent consistent, any of the aspects and features detailed herein may be used in conjunction with any or all of the other aspects and features detailed herein.

[0042] As used herein, the terms parallel and perpendicular are understood to include relative configurations that are substantially parallel and substantially perpendicular up to about + or -10 degrees from true parallel and true perpendicular.

[0043] Exemplary axes or directions such as an X-axis direction, a Y-axis direction and a Z-axis direction may be illustrated in the accompanying drawings and/or described herein. As an example, the X-axis direction may be perpendicular to the Y-axis direction, and the Z-axis direction may be orthogonal to the X-axis direction and the Y-axis direction.

[0044] “About” or “approximately” or “substantially” as used herein may be inclusive of the stated value and means within an acceptable range of variation for the particular value as determined by one of ordinary skill in the art, considering the measurement in question and the error associated with measurement of the particular quantity (e.g., the limitations of the measurement system). For example, “about” may mean within one or more standard variations, or within $\pm 30\%$, 20%, 10%, 5% of the stated value.

[0045] Descriptions of technical features or aspects of an exemplary embodiment of the disclosure should typically be considered as available and applicable to other similar features or aspects in another exemplary embodiment of the disclosure. Accordingly, technical features described herein according to one exemplary embodiment of the disclosure may be applicable to other exemplary embodiments of the disclosure, and thus duplicative descriptions may be omitted herein.

[0046] Exemplary embodiments of the disclosure will be described more fully below (e.g., with reference to the accompanying drawings). Like reference numerals may refer to like elements throughout the specification and drawings.

[0047] Generally, in the flexible waveguide described herein (e.g., flexible waveguides 301, 401, 801, 1001, 1201,

1301, 1401 and 1501), the ultrasonic waveguide is thinned down enough at articulating portions thereof (e.g., articulating portions **310, 410, 430, 810, 1010, 1210, 1310, 1410 and 1510**) to be elastically flexible, but still has enough material to carry the ultrasonic wave to the tip of the instrument (e.g. to end effectors **100, 200, and 600 and 700**). While the flexible waveguide has a substantially cylindrical shape, the thinned down and elastically flexible sections may be at least partially flattened to create an at least partially flattened cylindrical shape, e.g., including opposed planar surfaces. The term “flattened” relates to the end configuration and not the method of achieving the flexible section(s). The above configuration enables an articulating ultrasonic surgical instrument wherein the ultrasonic transducer would be “outside” the body and the ultrasonic wave would be carried through the flex in the waveguide to the end effector.

[0048] End effectors **100, 200, 600 and 700** described herein are substantially the same as each other unless otherwise indicated. Flexible waveguides **301, 401, 801, 1001, 1201, 1301, 1401 and 1501** described herein are substantially the same as each other, unless otherwise indicated. Articulating portions **310, 410, 430, 810, 1010, 1210, 1310, 1410 and 1510** described herein are substantially the same as each other, unless otherwise indicated. Jaw members **101, 201, 601 and 701** described herein are substantially the same as each other, unless otherwise indicated. Blade members **102, 202, 602 and 702** described herein are substantially the same as each other, unless otherwise indicated. Housings **12 and 212** as described herein are substantially the same as each other, unless otherwise indicated. Handle assemblies **132 and 232** described herein are substantially the same as each other, unless otherwise indicated. Stabilizers **351 and 851** described herein are substantially the same as each other, unless otherwise indicated. Stabilizers **352 and 852** described herein are substantially the same as each other, unless otherwise indicated.

[0049] Referring generally to FIG. 1, an embodiment of a surgical instrument (e.g., an endoscopic surgical instrument) exemplifying the aspects and features of the present disclosure is shown generally identified by reference numeral **10**. For the purposes herein, surgical instrument is generally described. Aspects and features of surgical instrument **10** not germane to the understanding of the present disclosure are omitted to avoid obscuring the aspects and features of the present disclosure in unnecessary detail.

[0050] Surgical instrument **10** generally includes a housing **12** (defining a handle assembly **132**), an elongated body **14**, and an end effector **100**. Handle assembly **132** supports a battery assembly **18** and a transducer and generator assembly (“TAG”) **120**, and includes a first rotation knob **22**, a second rotation knob **23**, an activation button **24**, and a clamp trigger **26**.

[0051] Elongated body **14** defines a proximal end portion **16** connected with the first rotation knob **22** and a distal end portion **18** supporting end effector **100**. End effector **100** includes an ultrasonic blade **102** and a pivoting jaw **101**. In embodiments, ultrasonic blade **102** is cylindrical or otherwise includes one or more radial symmetries (or is fully radially symmetric) and jaw **101** is configured to rotate about the ultrasonic blade **102** to enable clamping tissue therebetween at plural (or an infinite number of) orientations. A lumen **15** is defined within elongated body **14**.

[0052] Clamp trigger **26** of surgical instrument **10** is selectively manipulatable to actuate a motor, other powered drive mechanism, or a manual drive mechanism, e.g., gears, pulleys, tension cables, etc., to pivot jaw **101** relative to ultrasonic blade **102** to thereby transition end effector **100** between an open condition and a clamping condition.

[0053] First rotation knob **22** is selectively manipulatable to rotate elongated body **14** and, thus, end effector **100** relative to housing **12**. Second rotation knob **23** is selectively manipulatable to actuate a motor, other powered drive mechanism, or a manual drive mechanism, e.g., gears, pulleys, tension cables, etc., to rotate jaw member **101** relative to ultrasonic blade **102**. As an alternative to first and second rotation knobs **22, 23**, other suitable actuation mechanism, e.g., toggle switches, joysticks, buttons, etc., may be provided. Third rotation knob **127** is selectively manipulatable to articulate articulating portion **110**.

[0054] Battery assembly **18** and the generator of TAG **120** cooperate, upon activation of activation button **24**, to supply power to the transducer of TAG **120** to enable the generation of ultrasonic energy that is transmitted to blade **102** of end effector **100** for treating tissue therewith, e.g., to coagulate, cauterize, fuse, seal, cut, desiccate, fulgurate, or otherwise treat tissue, as detailed below. Battery assembly **18** and TAG **20** are each releasably secured to handle assembly **132**, and are removable therefrom to facilitate disposal of handle assembly **132**, with the exception of battery assembly **18** and TAG **120**. However, it is contemplated that any or all of the components of surgical instrument **10** be configured as disposable single-use components or sterilizable multi-use components, and/or that surgical instrument **10** be connectable to a remote power source or generator rather than having such components on-board.

[0055] Referring particularly to FIGS. 1, 3, 6A, 6B, and 7A-7D, surgical instrument **10**, as noted above, includes housing **12** and elongated body **14** extending therefrom. Elongated body **14** defines a lumen **15** therein, a proximal end portion **16** and a distal end portion **18** supporting end effector **100**. Elongated body **14** includes at least one articulating portion **110** between the proximal end portion **16** and the distal end portion **18**. A flexible waveguide (e.g. flexible waveguide **301** of FIG. 3) extends through lumen **15** and includes an articulating portion **310**. The articulating portion **110** of elongated body **14** and the articulating portion **310** of flexible waveguide are positioned in substantially a same location along the elongated body **14** such that articulating portion **110** and articulating portion **310** can articulate in a similar manner as each other. Elongated body **14** is configured to rotate in unison with flexible waveguide **310** extending through lumen **15** and jaw member **101** is configured to rotate about blade **102** (see also, e.g., jaw member **601** and blade **602** FIGS. 6A and 6B). Thus, surgical instrument **10** can achieve any desired directional orientation for end effector **100** through a combination of rotating elongated body **14**, articulation of articulating portions **110** and **310**, and rotating jaw member **101** about blade **102** (see also, e.g., elongated body **714**, articulation portion **730**, jaw member **701**, and blade **702** of FIGS. 7A to 7D). This may be achieved with a single articulating region along elongated body **14**, or with multiple articulating regions.

[0056] Referring to FIGS. 1 and 3, flexible waveguide **301** extends through the lumen **15** of the elongated body **14**. A proximal end portion **302** of the flexible waveguide **301** is connected with the ultrasonic generator **120**. A distal end

portion **303** of the flexible waveguide **301** is connected, e.g., attached, formed integrally with, etc., to the blade **102** of the end effector **100**. The flexible waveguide **301** defines the articulating portion **310** having a narrower dimension, e.g., width, than other portions of the flexible waveguide **301**. In this manner, the articulating portion **310** is flexible while the remainder of waveguide **301** is substantially inflexible (e.g., not configured to significantly flex during use). Proximal end portion **302** may define a threaded end **380** for connecting with ultrasonic generator **120** and distal end portion **303** may define blade **102**.

[0057] The articulating portion including articulation portion **110** of elongated body **14**, and articulating portion **310** of waveguide **301** may enable articulation relative to a single plane defined by the thinned portion (articulating portion **310**) of the flexible waveguide **301**. Blade **102**, as noted above, is cylindrical or otherwise defines one or more radial symmetries and rotatable jaw **101** is rotatable about blade **102**. The blade **102** may have a curved or partially curved configuration (see, e.g., FIG. 3) or a substantially straight configuration (see, e.g., FIG. 6B). By making the blade **102** cylindrical or otherwise defining one or more radial symmetries, it allows for clamping jaw **101** on the blade **102** at plural points or any point on an outer surface thereof while allowing for achievement of the same tissue effect. The flexible waveguide **301** is substantially cylindrical along a majority of the length thereof, and further includes articulating portion **310** having a flattened cylindrical shape. Because of the cylindrical waveguide, the jaw **101** can rotate around the blade **102**, while the blade **102** is stationary.

[0058] Referring to FIGS. 2, 4A, 4B, 5A, and 5B, surgical instrument **20** is substantially the same as surgical instrument **10**, except for having a first articulating portion **210** and a second articulating portion **230**. Each articulating portion **210** and **230** may achieve a somewhat gentle bend (e.g., from about 1 degree to about 45 degrees) about a single, but different plane from each other. Surgical instrument **20** generally includes a housing **212** (defining a handle assembly **232**), an elongated body **214** defining a proximal end portion **216** and a distal end portion **218** and a lumen **215** therein, and an end effector **200**. End effector **200** includes an ultrasonic blade **202** and a jaw **201** pivotable relative to ultrasonic blade **202** and that may be configured to rotate about the ultrasonic blade **202**. Handle assembly **232** supports a battery assembly **218** and a transducer and generator assembly (“TAG”) **220**, and includes a first rotation knob **222**, a second rotation knob **223**, an activation button **224**, a clamp trigger **226**, a third rotation knob **227** and a fourth rotation knob **228**.

[0059] Flexible waveguide **401** including first articulating portion **410** and second articulating portion **430** extending through lumen **215** of elongated body **214**. The first articulating portion **210** of elongated body **214** and the first articulating portion **410** of flexible waveguide **401** are positioned in substantially a same location as each other along the elongated body **214** such that first articulating portion **210** and first articulating portion **410** can articulate in a similar manner as each other. The second articulating portion **230** of elongated body **214** and the second articulating portion **430** of flexible waveguide **401** are positioned in substantially a same location as each other along the elongated body **214** such that second articulating portion **230** and second articulating portion **430** can articulate in a similar manner as each other, e.g., in a second plane different

from a plane of articulation of the first portions **210**, **410**. Alternatively, the second plane may be substantially the same as the first plane (e.g., the first and second planes may each be along the Y-Axis direction of FIGS. 4A, 4B, 5A, and 5B). For example, the first plane may be along the Y-axis direction of FIGS. 4A, 4B, 5A, and 5B and the second plane may be along the Z-axis direction of FIGS. 4A, 4B, 5A, and 5B. Thus, elongated member **214** and the flexible waveguide **401** extending therethrough may articulate about two different directions to achieve a desired directional orientation of end effector **200** and/or to achieve desired placement of various segments of elongated member **214**.

[0060] Referring particularly to FIGS. 5A and 5B, because the articulating portions **410**, **430** of flexible waveguide **401** are formed to have flattened shapes, the thinning of articulation portion **430** of flexible waveguide **401** might only be visible about a single plane (e.g., a side view as in FIG. 5A), while the thinning of articulation portion **410** of flexible waveguide **401** might only be visible about a different single plane (e.g., a plan view as in FIG. 5B).

[0061] Referring particularly to FIG. 8, a cable system including first cable **871** and second cable **872** may be employed for articulating an articulating portion **810** of a flexible waveguide **801**. While two cables may be employed, a single cable on a spool may also be employed or more than two cables may be utilized. The cables **871**, **872** may route beside the flexible waveguide **801** within a lumen (e.g., lumen **15** or **215** described herein (FIGS. 1 and 2, respectively)). By pulling on one cable **871**, **872**, and releasing slack in the other cable **871**, **872**, the articulating portion **810** is urged to articulate in the direction of the tensioned cable. Alternatively, articulating the articulating portion **810** of the flexible waveguide **801** may be achieved by use of a thin wire of nitinol or other material, to push and pull on an inner tube of the elongated portion for flexing actuation. The thin wire may be held in a sleeve or channel to allow for pushing, without buckling. The inner lumen described is employed to house the flexible waveguide **801**, while the cable systems and the like described herein employ cables or similar apparatus housed within separate lumens or channels to maintain separation from the flexible waveguide **801**.

[0062] Referring particularly to FIGS. 3 and 8, stabilizers **351**, **851** and **352**, **852** may be employed for assisting in the controlled articulation of the flexible waveguide **301**, **801**. The stabilizers **351**, **851** are secured to the flexible waveguide **301**, **801** at positions proximal and distal of the articulating portions **310**, **810** of the flexible waveguide **301**, **801**. The stabilizers **351**, **851** and **352**, **852** may be secured to an inner surface of the elongated member described herein. Thus, proximal/distal movement of the flexible waveguide **301**, **801** is inhibited. Holding/stabilizing the flexible waveguide **301**, **801** at these locations allows formation of a gradual bend of articulation, without causing a heating/friction point or causing unnecessary noise in the flexible waveguide **301**, **801**. Although FIGS. 3 and 8 conceptually illustrate elongated bodies including stabilizers **351**, **851** holding/stabilizing the flexible waveguides **301**, **801**, a person of skill in the art would readily appreciate how such stabilizers would, in practice, be incorporated into elongated body **14** (FIG. 1), for holding/stabilizing flexible waveguides **301**, **801** therein. Additional stabilizing structures for the flexible waveguide **301**, **801** are described below with reference to FIGS. 12A to Referring particularly to FIGS. 6A, 6B and 9, articulating portions **630**, **910** of

elongated bodies **614**, **914** may include a plurality of flexing sections **681**, **981** to control a degree of articulation of articulating portions **630**, **910**. The flexing sections **681**, **981** allowing a gentle bend to be achieved by only allowing a certain amount of flex per section. As an example, each flexing sections **681**, **981** may allow about 5 degrees of flex, thus using 9 flexing sections **681**, **981** allows about 45 degrees total of bend. The flexing sections **681**, **981** may only allow bend in one plane, by means of a pinned joint or hinge or partial cuts, or may be configured to bend in multiple planes.

[0063] Referring generally to FIGS. **2** and **4A**, **4B**, **5A**, and **5B** again, the surgical instrument **20** includes a housing **212** having the elongated body **214** extending distally therefrom. The elongated body **214** defines the first articulating portion **210** and the second articulating portion **230** distal of the first articulating portion **210**. The elongated body **214** defines lumen **215** therein. End effector **200** is supported at distal end portion **218** of the elongated body **214**. Ultrasonic transducer and generator assembly **220** is supported on the housing **212**. Flexible waveguide **401** extends within the lumen **215** of the elongated body **214**. Proximal end portion **480** of the flexible waveguide **401** is connected with the ultrasonic generator **220**. Distal end portion **490** of the flexible waveguide **401** is connected with (attached to, integrally formed with, etc.) the blade **202** of the end effector **200**. The flexible waveguide **401** defines first articulating portion **410** having a narrower dimension, e.g., width, than a width of other portions of the flexible waveguide **401**. The flexible waveguide **401** defines second articulating portion **430** configured to articulate in a different direction (e.g., about the Z-axis direction of FIG. **4B**) from the articulating direction of the first articulating portion **410** (e.g., about the Y-axis direction of FIG. **4A**). Second articulating portion **430** has a different narrower dimension (as compared to first articulating portion **410**), e.g., a narrowed height, than a height of other portions of the flexible waveguide **401**.

[0064] The end effector **200** includes ultrasonic blade **202**, which may be cylindrical or otherwise define one or more radial symmetries, and jaw **201**, which may be configured to rotate about the ultrasonic blade **202**. The ultrasonic blade **202** and the jaw **201** are configured to capture and treat tissue therebetween in a clamping position of jaw **201**. Alternatively or additionally, ultrasonic blade **202** may be utilized to treat unclamped tissue in close proximity therewith. The elongated body **214** is configured to rotate (see, e.g., elongated body **614** of FIGS. **6A** and **6B**) to achieve different directional orientations of end effector **200**.

[0065] The first rotation knob **222** is configured to rotate the elongated body **214** (e.g., to rotate the portion of the elongated body **214** proximal to the first articulating portion **210**). The second rotation knob **223** is configured to rotate the jaw **201** about the ultrasonic blade **202**, in embodiments where such rotation is provided. The third rotation knob **227** is configured to articulate the first articulating portion **210** of the elongated body **214** and, thus, the first articulating portion of the waveguide **410**. The fourth rotation knob **228** is configured to articulate the second articulating portion **230** of the elongated body **214** and, thus, the second articulating portion **430** of the flexible waveguide.

[0066] Referring to FIG. **10**, a first transducer **1050** and a second transducer **1060** are positioned at opposite sides, e.g., proximally and distally, of an articulating portion **1010** of a flexible waveguide **1001**. The first and second transducers

1050 and **1060** amplify an ultrasonic wave transmitted through the articulating portion **1010** of the flexible waveguide **1001**, e.g., the portion having the narrower width than the width of other portions of the flexible waveguide **1001**. For example, the second transducer **1060** distal of the articulating portion **1010** amplifies the ultrasonic energy as the wave continues down the waveguide (i.e., makes up for any loss in energy resulting from the articulating portion **1010**). In embodiments, only the transducer distal of articulation portion **1010**, e.g., second transducer **1060**, is provided. Similar transducers may be positioned at opposite sides (or only on the distal side) of each articulating portion of a flexible waveguide having multiple articulating portions along a length thereof.

[0067] The various embodiments disclosed herein may also be configured to work with robotic surgical systems and what is commonly referred to as “Telesurgery.” Such systems employ various robotic elements to assist the surgeon and allow remote operation (or partial remote operation) of surgical instrumentation. Various robotic arms, gears, cams, pulleys, electric and mechanical motors, etc. may be employed for this purpose and may be designed with a robotic surgical system to assist the surgeon during the course of an operation or treatment. Such robotic systems may include remotely steerable systems, automatically flexible surgical systems, remotely flexible surgical systems, remotely articulating surgical systems, wireless surgical systems, modular or selectively configurable remotely operated surgical systems, etc.

[0068] The robotic surgical systems may be employed with one or more consoles that are next to the operating theater or located in a remote location. In this instance, one team of surgeons or nurses may prep the patient for surgery and configure the robotic surgical system with one or more of the instruments disclosed herein while another surgeon (or group of surgeons) remotely controls the instruments via the robotic surgical system. As can be appreciated, a highly skilled surgeon may perform multiple operations in multiple locations without leaving his/her remote console which can be both economically advantageous and a benefit to the patient or a series of patients.

[0069] The robotic arms of the surgical system are typically coupled to a pair of master handles by a controller. The handles can be moved by the surgeon to produce a corresponding movement of the working ends of any type of surgical instrument (e.g., end effectors, graspers, knives, scissors, etc.) which may complement the use of one or more of the embodiments described herein. The movement of the master handles may be scaled so that the working ends have a corresponding movement that is different, smaller or larger, than the movement performed by the operating hands of the surgeon. The scale factor or gearing ratio may be adjustable so that the operator can control the resolution of the working ends of the surgical instrument(s).

[0070] The master handles may include various sensors to provide feedback to the surgeon relating to various tissue parameters or conditions, e.g., tissue resistance due to manipulation, cutting or otherwise treating, pressure by the instrument onto the tissue, tissue temperature, tissue impedance, etc. As can be appreciated, such sensors provide the surgeon with enhanced tactile feedback simulating actual operating conditions. The master handles may also include a variety of different actuators for delicate tissue manipula-

tion or treatment further enhancing the surgeon's ability to mimic actual operating conditions.

[0071] FIG. 11 illustrates a medical work station shown generally as work station 1000 and generally may include a plurality of robot arms 1002, 1003; a control device 1004; and an operating console 1005 coupled with control device 1004. Operating console 1005 may include a display device 1006, which may be set up in particular to display three-dimensional images; and manual input devices 1007, 1008, by means of which a person (not shown), for example a surgeon, may be able to telemanipulate robot arms 1002, 1003 in a first operating mode.

[0072] Each of the robot arms 1002, 1003 may include a plurality of members, which are connected through joints, and an attaching device 1009, 1011, to which may be attached, for example, a surgical tool "ST" supporting an end effector 1100, in accordance with any one of several embodiments disclosed herein, as will be described in greater detail below. In embodiments, end effector 1100 may include, for example the elongated body (or portion thereof) and end effector of any of the embodiments detailed therein; thus, robot arm 1003 (together with relevant portions of control device 1004, operating console 1005, and/or manual input devices 1007, 1008) functions are the housings 12, 212 (FIGS. 1 and 2, respectively) of the ultrasonic surgical instrument.

[0073] Robot arms 1002, 1003 may be driven by electric drives (not shown) that are connected to control device 1004. Control device 1004 (e.g., a computer) may be set up to activate the drives, in particular by means of a computer program, in such a way that robot arms 1002, 1003, their attaching devices 1009, 1011 and thus the surgical tool (including end effector 1100) execute a desired movement according to a movement defined by means of manual input devices 1007, 1008. Control device 1004 may also be set up in such a way that it regulates the movement of robot arms 1002, 1003 and/or of the drives.

[0074] Medical work station 1000 may be configured for use on a patient 1013 lying on a patient table 1012 to be treated in a minimally invasive manner by means of end effector 1100. Medical work station 1000 may also include more than two robot arms 1002, 1003, the additional robot arms likewise being connected to control device 1004 and being telemanipulatable by means of operating console 1005. A medical instrument or surgical tool (including an end effector 1100) may also be attached to the additional robot arm. Medical work station 1000 may include a database 1014, in particular coupled to with control device 1004, in which are stored, for example, pre-operative data from patient/living being 1013 and/or anatomical atlases.

[0075] Referring particularly to FIGS. 12A to 12D, a support system 1200 for flexible waveguide 1201 is described. The flexible waveguide 1201 includes a plurality of protruding posts 1251, 1252, 1253, 1254 extending from the flexible waveguide 1201. The protruding posts 1251 and 1252 are shaped and dimensioned to be received in corresponding recesses 1261 and 1262, respectively. Protruding posts 1253 and 1254 are similarly received in corresponding recesses 1263 and 1264, respectively. The recesses 1261 and 1262 are formed in an inner surface 1265 of elongated member 1214 and are configured to receive the protruding posts 1253 and 1254, respectively, therein to secure the flexible waveguide 1201 within lumen 1215 of elongated member 1214. Some of the plurality of protruding posts

1251, 1252, 1253, 1254 are positioned proximally of articulating portion 1210 and others of the plurality of protruding posts 1251, 1252, 1253, 1254 are positioned distally of articulating portion 1210 to allow articulation of the articulating portion 1210 within lumen 1215 and to prevent contact between articulating portion 1210 and the inner surface 1265 of elongated member 1214 (see, e.g., FIG. 12D).

[0076] Referring particularly to FIGS. 13A to 13C, a support system 1300 for flexible waveguide 1301 is described. The flexible waveguide 1301 includes a first annular collar 1351 and a second annular collar 1352 circumferentially protruding from the flexible waveguide 1301. first and second annular collars 1351 and 1352 are shaped and dimensioned to be received in a corresponding recess 1361, 1362, respectively. The recesses 1361 and 1362 are circumferentially formed in an inner surface 1363 of elongated member 1314 and are configured to receive the annular collars 1351 and 1352, respectively, therein to secure the flexible waveguide 1301 within lumen 1315 of elongated member 1314. The annular collars 1351, 1352 and recesses 1361, 1362 are positioned proximally and distally, respectively, of articulating portion 1310 to allow articulation of the articulating portion 1310 within lumen 1315 and to prevent contact between articulating portion 1310 and the inner surface 1363 of elongated member 1314.

[0077] Referring particularly to FIGS. 14A to 14C, a support system 1400 for flexible waveguide 1401 is described. The flexible waveguide 1401 includes a first recess 1461 and a second recess 1462 circumferentially formed in an outer surface 1464 of the flexible waveguide 1401. The first and second recesses 1461 and 1462 are shaped and dimensioned to receive annular collars 1451 and 1452, respectively. The annular collars 1451 and 1452 protrude circumferentially from an inner surface 1463 of elongated member 1414 and are configured to be received in the first and second recesses 1461 and 1462, respectively, to secure the flexible waveguide 1401 within lumen 1415 of elongated member 1414. The annular collars 1451, 1452 and recesses 1461, 1462 are positioned proximally and distally, respectively, of articulating portion 1410 to allow articulation of the articulating portion 1410 within lumen 1415 and to prevent contact between articulating portion 1410 and the inner surface 1463 of elongated member 1414.

[0078] Referring particularly to FIGS. 15A to 15D, a support system 1500 for flexible waveguide 1501 is described. Removable annular collars 1551 and 1552 are positioned about flexible waveguide 1501. The removable annular collars 1551 and 1552 may each be formed of or include plastic or silicone. The removable annular collars 1551 and 1552 may allow some degree of longitudinal movement within lumen 1515 of elongated member 1514 to prevent stress to the flexible waveguide 1501. The removable annular collars 1551 and 1552 are positioned proximally and distally, respectively, of articulating portion 1510 to allow articulation of the articulating portion 1510 within lumen 1515 and to prevent contact between articulating portion 1510 and the inner surface 1563 of elongated member 1514.

[0079] The lumen 1515 may include a first recess 1561 and a second recess 1562 circumferentially formed in the inner surface 1563 of the lumen 1515. The first and second

recesses **1561** and **1562** are shaped and dimensioned to receive removable annular collars **1551** and **1552**, respectively.

[0080] From the foregoing and with reference to the various figure drawings, those skilled in the art will appreciate that certain modifications can also be made to the disclosure without departing from the scope of the same. While several embodiments of the disclosure have been shown in the drawings, it is not intended that the disclosure be limited thereto, as it is intended that the disclosure be as broad in scope as the art will allow and that the specification be read likewise. Therefore, the above description should not be construed as limiting, but merely as exemplifications of particular embodiments. Those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

1-20. (canceled)

21. An ultrasonic surgical instrument, comprising:

a housing;

an elongate body extending distally from the housing, the elongate body including an articulating portion and a lumen extending through the elongate body;

an end effector supported at a distal end portion of the elongate body; and

an ultrasonic waveguide extending through the lumen, a proximal end portion of the ultrasonic waveguide extending into the housing and a distal end portion of the ultrasonic waveguide extending to the end effector, wherein the ultrasonic waveguide is engaged with an internal wall of the elongate body within the lumen at a first location and at a second location, wherein one of the first location or the second location is proximal of the articulating portion, and wherein another of the first location or the second location is distal of the articulating portion.

22. The ultrasonic surgical instrument according to claim **21**, wherein the ultrasonic waveguide is engaged with the internal wall of the elongate body at the first location via at least one protrusion-recess engagement.

23. The ultrasonic surgical instrument according to claim **22**, wherein the at least one protrusion-recess engagement includes a pair of opposed protrusion-recess engagements.

24. The ultrasonic surgical instrument according to claim **22**, wherein the at least one protrusion-recess engagement includes a protrusion extending from the ultrasonic waveguide and a recess defined within the internal wall of the elongate body.

25. The ultrasonic surgical instrument according to claim **22**, wherein the ultrasonic waveguide is engaged with the internal wall of the elongate body at each of the first and second locations via at least one protrusion-recess engagement.

26. The ultrasonic surgical instrument according to claim **21**, wherein an annular spacing within the lumen between the ultrasonic waveguide and the internal wall of the elongate body is maintained via at least one of the engagement of the ultrasonic waveguide with the internal wall of the elongate body at the first location or the engagement of the ultrasonic waveguide with the internal wall of the elongate body at the second location.

27. The ultrasonic surgical instrument according to claim **21**, wherein the engagement of the ultrasonic waveguide with the internal wall of the elongate body at the first location fixes the ultrasonic waveguide relative to the elongate

body at the first location and wherein the engagement of the ultrasonic waveguide with the internal wall of the elongate body at the second location fixes the ultrasonic waveguide relative to the elongate body at the second location.

28. The ultrasonic surgical instrument according to claim **21**, wherein the end effector includes an ultrasonic blade connected to the distal end portion of the ultrasonic waveguide and a jaw configured to cooperate with the ultrasonic blade to capture tissue between the ultrasonic blade and the jaw.

29. The ultrasonic surgical instrument according to claim **21**, wherein the housing is adapted to connect to a robotic arm of a robotic surgical system.

30. The ultrasonic surgical instrument according to claim **21**, wherein the housing includes a handle configured to enable manual manipulation of the ultrasonic surgical instrument.

31. An ultrasonic surgical instrument, comprising:

a housing;

an ultrasonic transducer supported by the housing;

an elongate body extending distally from the housing, the elongate body including an articulating portion and a lumen extending through the elongate body;

an end effector supported at a distal end portion of the elongate body; and

an ultrasonic waveguide extending through the lumen, a proximal end portion of the ultrasonic waveguide operably connected to the ultrasonic transducer and a distal end portion of the ultrasonic waveguide operably coupled to the end effector,

wherein the ultrasonic waveguide is engaged with the elongate body at a first location and at a second location, wherein one of the first location or the second location is disposed between the housing and the articulating portion of the elongate body and wherein another of the first location or the second location is disposed between the articulating portion of the elongate body and the end effector assembly.

32. The ultrasonic surgical instrument according to claim **31**, wherein the ultrasonic waveguide is engaged to an internal wall of the elongate body at at least one of the first location or the second location.

33. The ultrasonic surgical instrument according to claim **31**, wherein the ultrasonic waveguide is engaged to the elongate body at at least one of the first location or the second location via at least one protrusion-recess engagement.

34. The ultrasonic surgical instrument according to claim **33**, wherein the at least one protrusion-recess engagement includes a protrusion extending from the ultrasonic waveguide and a recess defined within the elongate body.

35. The ultrasonic surgical instrument according to claim **31**, wherein an annular spacing within the lumen between the ultrasonic waveguide and an internal wall of the elongate body is maintained via at least one of the engagement of the ultrasonic waveguide with the elongate body at the first location or the engagement of the ultrasonic waveguide with the elongate body at the second location.

36. The ultrasonic surgical instrument according to claim **31**, wherein the engagement of the ultrasonic waveguide with the elongate body at the first location fixes the ultrasonic waveguide relative to the elongate body at the first location and wherein the engagement of the ultrasonic

waveguide with the elongate body at the second location fixes the ultrasonic waveguide relative to the elongate body at the second location.

37. The ultrasonic surgical instrument according to claim **31**, wherein the ultrasonic waveguide includes a flexible portion extending through the articulating portion of the elongate body, wherein one of the first location or the second location is proximal of the flexible portion, and wherein another of the first location or the second location is distal of the flexible portion.

38. The ultrasonic surgical instrument according to claim **31**, wherein the ultrasonic waveguide is engaged with the elongate body via first and second opposed engagements at the first location and via third and fourth opposed engagements at the second location.

39. The ultrasonic surgical instrument according to claim **31**, wherein the housing is adapted to connect to a robotic arm of a robotic surgical system.

40. The ultrasonic surgical instrument according to claim **31**, wherein the housing includes a handle configured to enable manual manipulation of the ultrasonic surgical instrument.

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