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Kharin

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(54) **ULTRASOUND DEVICE FOR PRECISE TISSUE SEALING AND BLADE-LESS CUTTING**

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(58) **Field of Classification Search**

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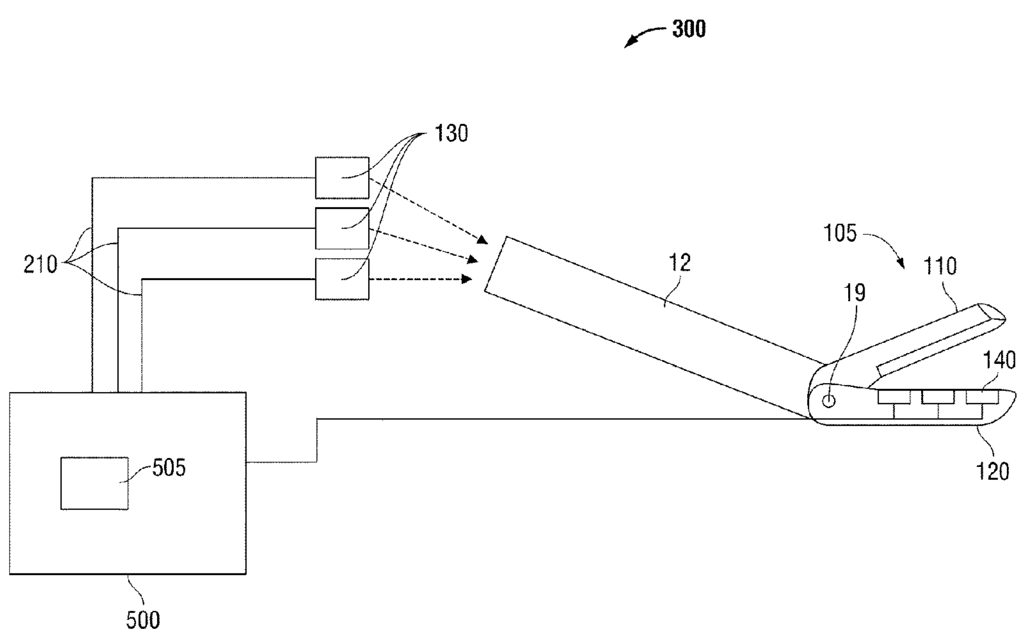
(57) **ABSTRACT**

An electrosurgical instrument for sealing and cutting tissue is provided. The instrument includes a housing having a plurality of transducers included therein and a waveguide coupled to and extending from the housing. An end effector assembly disposed at a distal end of the waveguide includes a pair of opposing jaw members, where at least one of the jaw members includes a transducer. The transducer is configured to receive an acoustic signal from the plurality of transducers in the housing.

13 Claims, 6 Drawing Sheets



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continuation of application No. 14/604,283, filed on Jan. 23, 2015, now Pat. No. 9,814,910, which is a continuation of application No. 13/111,678, filed on May 19, 2011, now Pat. No. 8,968,283.

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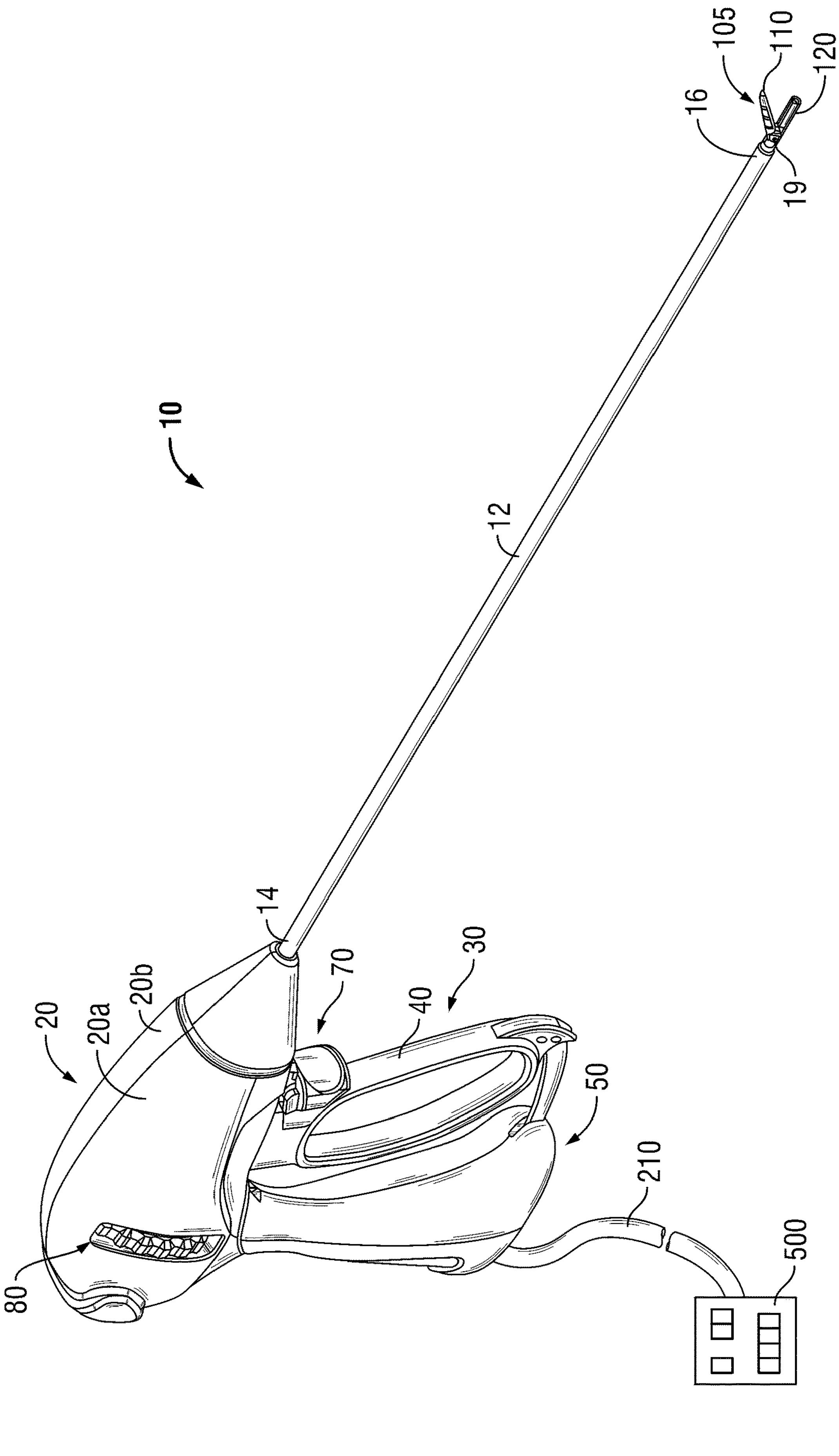

FIG. 1A

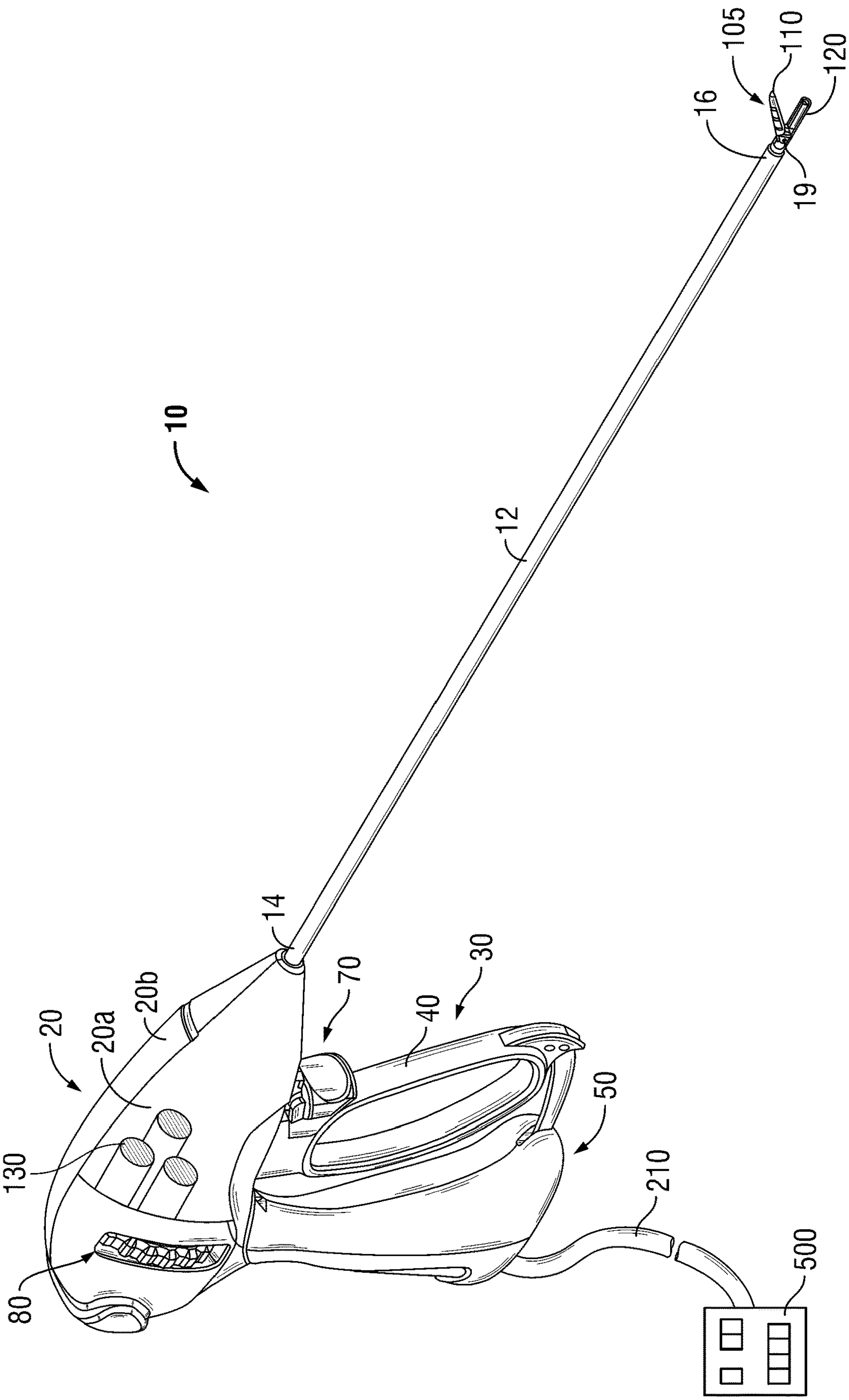

FIG. 1B

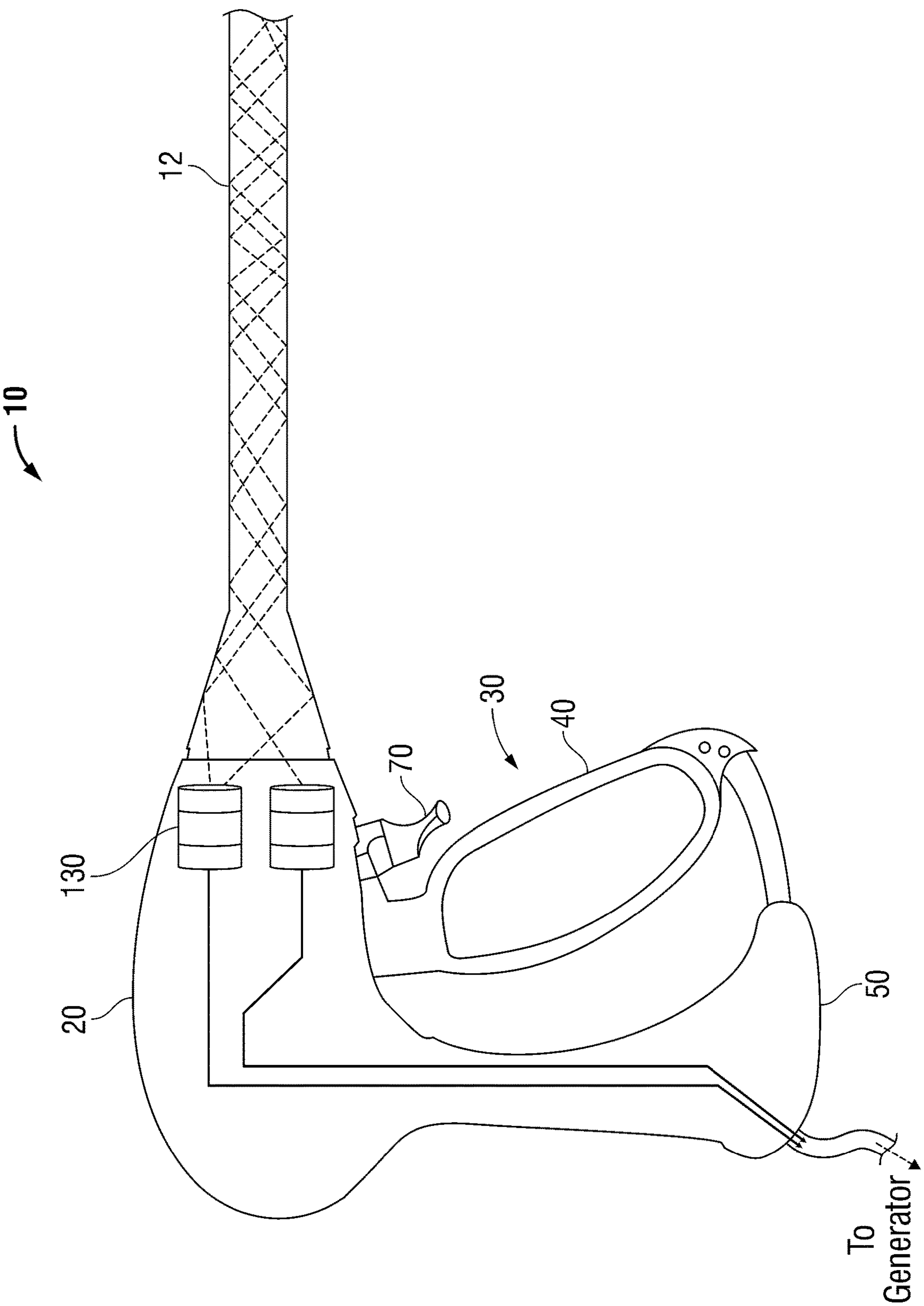

FIG. 2

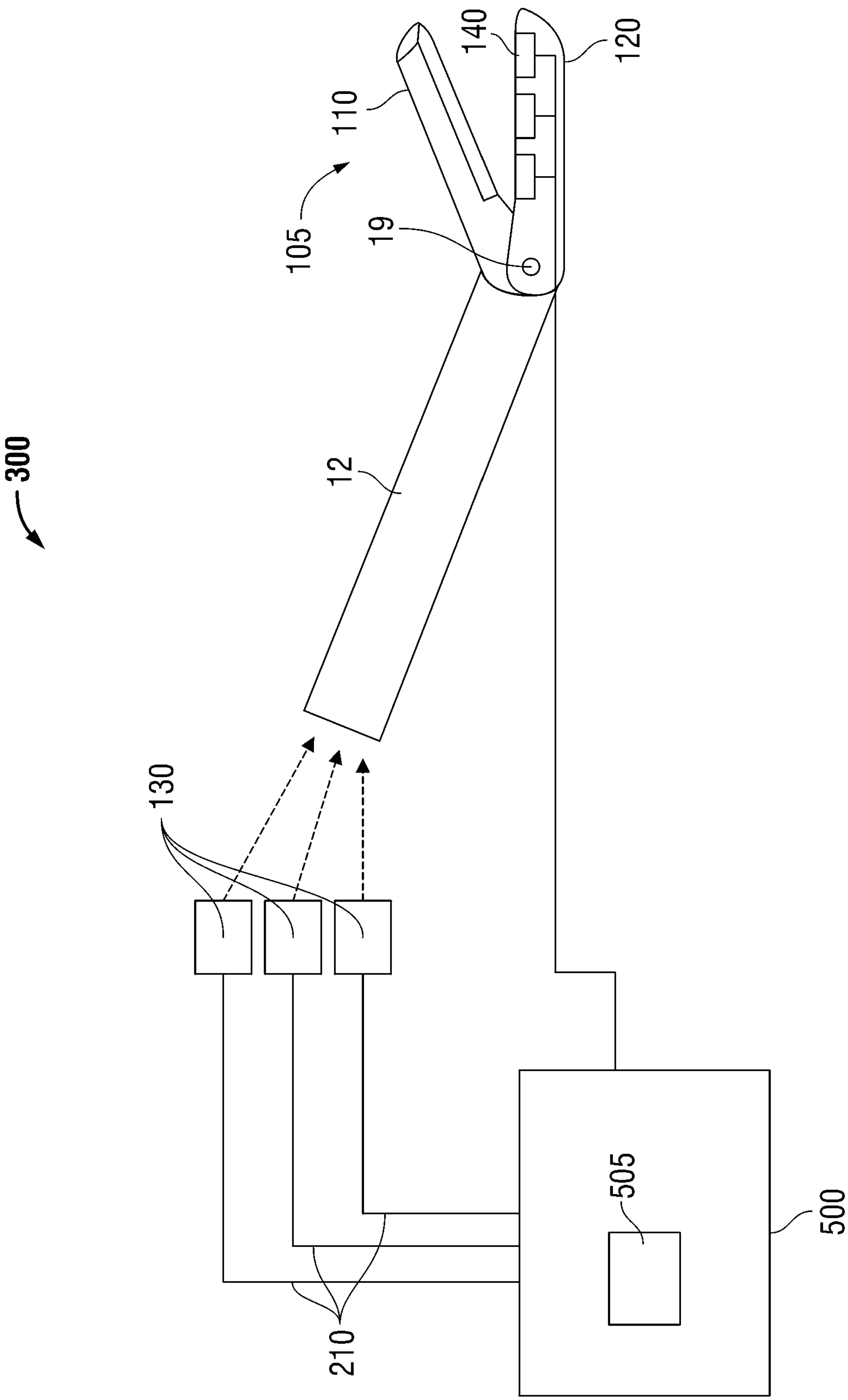

FIG. 3

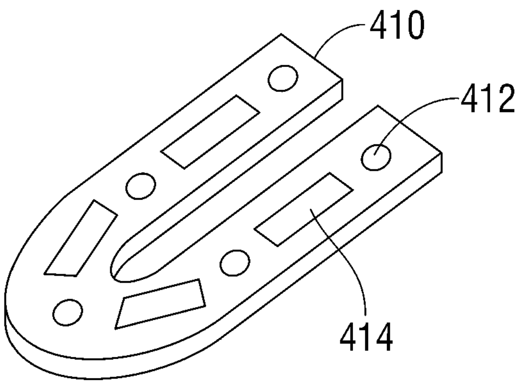

FIG. 4A

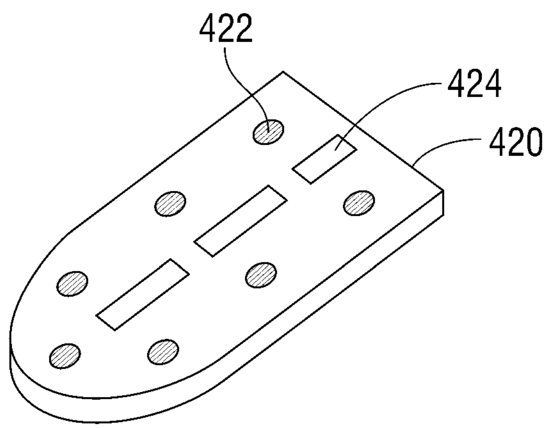

FIG. 4B

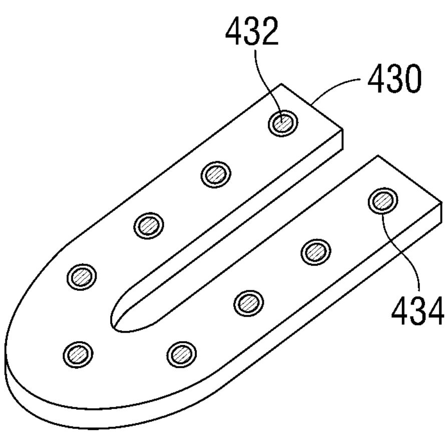

FIG. 4C

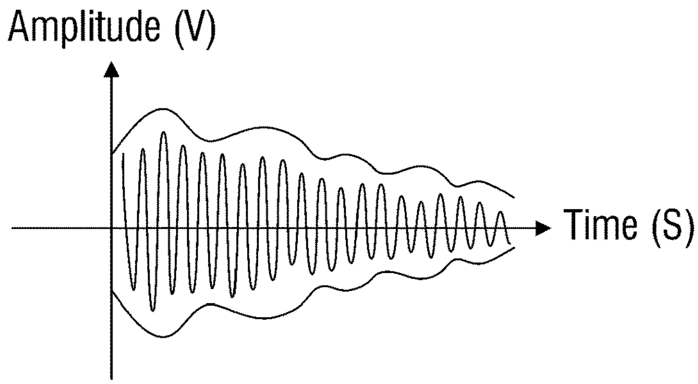

FIG. 5

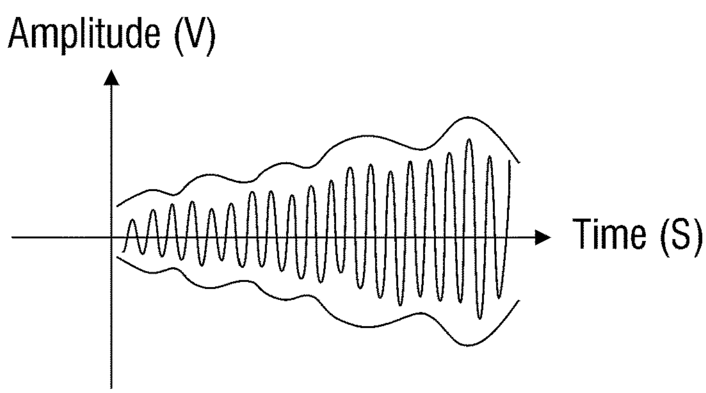

FIG. 6

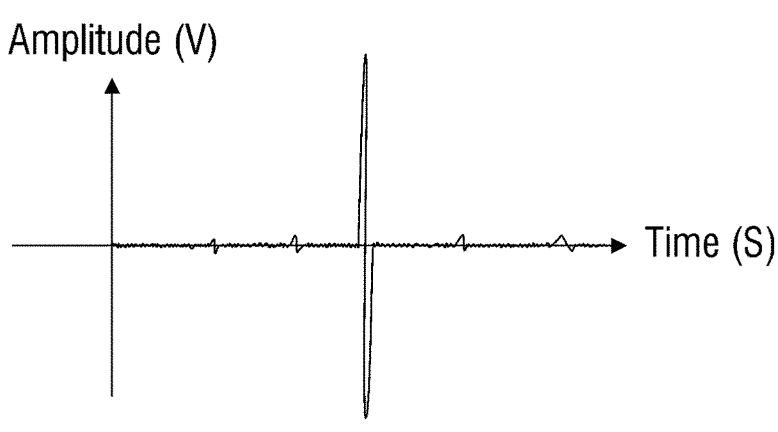

FIG. 7

ULTRASOUND DEVICE FOR PRECISE TISSUE SEALING AND BLADE-LESS CUTTING

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 15/809,304, filed Nov. 10, 2017, now U.S. Pat. No. 10,905,901, which is a continuation of U.S. patent application Ser. No. 14/604,283, filed Jan. 23, 2015, now U.S. Pat. No. 9,814,910, which is a continuation of U.S. patent application Ser. No. 13/111,678, filed May 19, 2011, now U.S. Pat. No. 8,968,283. The entire contents of each of the above applications are hereby incorporated by reference.

BACKGROUND

1. Technical Field

The present disclosure is directed to an electrosurgical apparatus. More specifically, the present disclosure is directed to an electrosurgical apparatus that employs ultrasound for precise tissue sealing and blade-less cutting.

2. Background of the Related Art

Open or endoscopic electrosurgical forceps utilize both mechanical clamping action and electrical energy to effect hemostasis. The electrode of each opposing jaw member is charged to a different electric potential such that when the jaw members grasp tissue, electrical energy can be selectively transferred through the tissue. A surgeon can cauterize, coagulate/desiccate and/or simply reduce or slow bleeding, by controlling the intensity, frequency and duration of the electrosurgical energy applied between the electrodes and through the tissue.

Certain surgical procedures require more than simply cauterizing tissue and rely on the combination of clamping pressure, electrosurgical energy and gap distance to "seal" tissue, vessels and certain vascular bundles. More particularly, vessel sealing or tissue sealing utilizes a unique combination of radiofrequency (RF) energy, clamping pressure and precise control of gap distance (i.e., distance between opposing jaw members when closed about tissue) to effectively seal or fuse tissue between two opposing jaw members or sealing plates. Vessel or tissue sealing is more than "cauterization", which involves the use of heat to destroy tissue (also called "diathermy" or "electrodiathermy"). Vessel sealing is also more than "coagulation", which is the process of desiccating tissue wherein the tissue cells are ruptured and dried. "Vessel sealing" is defined as the process of liquefying the collagen, elastin and ground substances in the tissue so that the tissue reforms into a fused mass with significantly-reduced demarcation between the opposing tissue structures.

Many electrosurgical instruments include a cutting member for cutting sealed tissue. Existing methods involve the use mechanical or electrical cutting actions. For example, a knife may be included in an electrosurgical instrument. Alternatively, an electrode may be used to apply electrical energy in the region. The use of a knife or electrode may be disadvantageous because it may lead to uncontrollable wide thermal spread.

Ultrasound may also be used for sealing and cutting tissue. One such example is an ultrasonic scalpel that uses an acoustic transducer operating in a longitudinal mode at 55 KHz located remotely from tissue. Energy is amplified and transmitted to the blade system by an acoustic mount coupled to the housing of a hand piece. Mechanical energy propagates in a metallic rod of the blade system having jaw members at a distal end thereof. However, such a device can not concentrate ultrasound waves in a precise spot and, as a result, may have an even larger thermal spread then many radio frequency electrosurgical devices.

SUMMARY

In an embodiment of the present disclosure, an electrosurgical instrument for sealing and cutting tissue is provided. The instrument includes a housing having a plurality of transducers included therein and a waveguide coupled to and extending from the housing. An end effector assembly disposed at a distal end of the waveguide includes a pair of opposing jaw members, where at least one of the jaw members includes a transducer. The transducer is configured to receive an acoustic signal from the plurality of transducers in the housing.

The transducer in the end effector assembly is coupled to a generator and the transducer converts the received acoustic signal into an electrical signal that is transmitted to the generator. The generator receives the electrical signal and outputs a time-reversed signal to the plurality of transducers in the housing. The plurality of transducers in the housing transmits the time-reversed signal to the transducer in the end effector assembly through the waveguide.

The transducer in the end effector assembly may be a piezoceramic transducer that is formed beneath a sealing surface of the at least one jaw member, as an integral part of a sealing surface of the at least one jaw member or formed as a stop member on top of a sealing surface of the at least one jaw member.

In another embodiment of the present disclosure, an electrosurgical system is provided. The system includes an electrosurgical instrument having a housing with a plurality of transducers included therein and a waveguide coupled to and extending from the housing. An end effector assembly disposed at a distal end of the waveguide includes a pair of opposing jaw members, where at least one of the jaw members includes a transducer. The transducer is configured to receive an acoustic signal from the plurality of transducers in the housing. The system also includes a generator coupled to the plurality of transducers in the housing and the transducer in the end effector assembly.

The transducer in the end effector assembly converts the received acoustic signal from the plurality of transducers in the housing into an electrical signal that is transmitted to the generator. The generator includes a phase/time reversal unit configured to receive the electrical signal from the transducer in the end effector assembly and output a reversed electrical signal to the plurality of transducers in the housing.

The transducer in the end effector assembly may be a piezoceramic transducer that is formed beneath a sealing surface of the at least one jaw member, as an integral part of a sealing surface of the at least one jaw member or formed as a stop member on top of a sealing surface of the at least one jaw member.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects, features, and advantages of the present disclosure will become more apparent in light of the following detailed description when taken in conjunction with the accompanying drawings in which:

FIG. **1**A is a right, perspective view of an electrosurgical instrument according to an embodiment of the present disclosure;

FIG. **1**B is an internal view of the electrosurgical instrument of FIG. **1**A;

FIG. **2** is a schematic diagram of the electrosurgical instrument of FIG. **1**A;

FIG. **3** is a schematic diagram of the electrosurgical instrument of FIG. **1**A;

FIG. **4**A-**4**C are perspective views of the end effector assemblies according to embodiments of the present disclosure;

FIG. **5** is a graph depicting an electrical signal at the end effector assembly according to an embodiment of the present disclosure;

FIG. **6** is a graph depicting the electrical signal of FIG. **5** after processing by the phase/time reversal block according to an embodiment of the present disclosure; and

FIG. **7** is a graph depicting the resulting signal at a spot according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

Particular embodiments of the present disclosure are described hereinbelow with reference to the accompanying drawings; however, the disclosed embodiments are merely examples of the disclosure and may be embodied in various forms. Well-known functions or constructions are not described in detail to avoid obscuring the present disclosure in unnecessary detail. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present disclosure in virtually any appropriately detailed structure.

Like reference numerals may refer to similar or identical elements throughout the description of the figures. As shown in the drawings and described throughout the following description, as is traditional when referring to relative positioning on a surgical instrument, the term "proximal" refers to the end of the apparatus that is closer to the user and the term "distal" refers to the end of the apparatus that is farther away from the user. The term "clinician" refers to any medical professional (e.g., doctor, surgeon, nurse, or the like) performing a medical procedure involving the use of embodiments described herein.

Electromagnetic energy is generally classified by increasing energy or decreasing wavelength into radio waves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma-rays. As used herein, the term "microwave" generally refers to electromagnetic waves in the frequency range of 300 megahertz (MHz) (3×10^8 cycles/second) to 300 gigahertz (GHz) (3×10^{11} cycles/second). As used herein, the term "RF" generally refers to electromagnetic waves having a lower frequency than microwaves. As used herein, the term "ultrasound" generally refers to cyclic sound pressure with a frequency greater than the upper limit of human hearing. The terms "tissue" and "vessel" may be used interchangeably since it is believed that the present disclosure may be employed to seal and cut tissue or seal and cut vessels utilizing the same principles described herein.

FIG. **1** depicts a bipolar forceps **10** for use with various endoscopic surgical procedures and generally includes a housing **20**, a handle assembly **30**, a rotating assembly **80**, a switch assembly **70** and an end effector assembly **105** having opposing jaw members **110** and **120** that mutually cooperate to grasp, seal and/or divide tubular vessels and vascular tissue. The jaw members **110** and **120** are connected about pivot pin **19**, which allows the jaw members **110** and **120** to pivot relative to one another from the first to second positions for treating tissue.

Forceps **10** may be a unilateral or bilateral forceps that includes a waveguide **12** that has a distal end **16** configured to mechanically engage the end effector assembly **105** and a proximal end **14** that mechanically engages the housing **20**. The waveguide **12** may include one or more known mechanically-engaging components that are designed to securely receive and engage the end effector assembly **105** such that the jaw members **110** and **120** are pivotable relative to one another to engage and grasp tissue therebetween. The proximal end **14** of waveguide **12** mechanically engages the rotating assembly **80** to facilitate rotation of the end effector assembly **105**.

Handle assembly **30** includes a fixed handle **50** and a movable handle **40**. Fixed handle **50** is integrally associated with housing **20** and handle **40** is movable relative to fixed handle **50** to actuate the opposing jaw members **110** and **120** of the end effector assembly **105**. Movable handle **40** and switch assembly **70** are of unitary construction and are operatively connected to the housing **20** and the fixed handle **50** during the assembly process. Housing **20** is constructed from two component halves **20***a* and **20***b* that are assembled about the proximal end of waveguide **12** during assembly. Switch assembly **70** is configured to selectively provide ultrasound to the end effector assembly **105** via waveguide **12** as will be described in more detail below.

As mentioned above, end effector assembly **105** is attached to the distal end **16** of waveguide **12** and includes the opposing jaw members **110** and **120**. Movable handle **40** of handle assembly **30** imparts movement of the jaw members **110** and **120** from an open position wherein the jaw members **110** and **120** are disposed in spaced relation relative to one another, to a clamping or closed position wherein the jaw members **110** and **120** cooperate to grasp tissue therebetween.

FIG. **1**B depicts an internal view of housing **20** according to an embodiment of the present disclosure. As shown in FIG. **1**B, housing **20** includes a number of transducers **130** that are electrically coupled to generator **500** via conduit **210**. Alternatively, generator **500** may be incorporated into housing **20**. A battery pack (not shown) may also be included in housing **20** to supply energy to a generator disposed in housing **20**. Although only three (3) transducers are depicted, any number of transducers may be used with out departing from the scope of the present disclosure. Transducers **130** are acoustical transducers that convert electrical energy into acoustic waves. Transducer **130** may be a piezoelectric transducer that includes a piezoelectric ceramic element that creates and distributes ultrasonic sound waves. When a voltage is applied from generator **500** to transducer **130**, piezoelectric material within transducer **130** will bend, stretch, or otherwise deform. This deformation is usually very slight and proportional to the voltage applied, and, as such, offers a method of precision movement on the micro scale. The voltage generated by a piezoelectric transducer can be quite high, often in the thousands of volts, but is brief, occurring only when the material is initially deformed. The piezoelectric material may include crystals (e.g., quartz or topaz) or polymers or ceramics that show piezoelectric properties.

As shown in FIG. **2**, transducers **130** generate acoustic waves, which propagate through the waveguide **12** to miniature piezoceramic probes **140** in end effector assembly **105** as shown in FIG. **3**. Waveguide **12** is a solid metallic piece, e.g., aluminum, that transmits acoustic waves therethrough. The waveguide **12** does not vibrate. The acoustic waves undergo multiple reflections resulting in an electrical signal registered at the output of probe **140** as shown in FIG. **5**.

FIG. **3** depicts a schematic diagram of the electrosurgical system according to an embodiment of the present disclosure. As shown in FIG. **3**, the system **300** includes a generator **500**. Generator **500** can perform ultrasonic electrosurgical procedures and may include a plurality of outputs for interfacing with various electrosurgical instruments (e.g., a monopolar active electrode, return electrode, bipolar jaw members, footswitch, ultrasonic horn, etc.). Further, generator **500** includes electronic circuitry configured for generating power specifically suited for various electrosurgical modes (e.g., cutting, blending, division, fragmenting, coagulating etc.) and procedures. Generator **500** includes suitable input controls (e.g., buttons, activators, switches, touch screen, etc.) for controlling the generator **500**. In addition, the generator **500** may include one or more display screens for providing the user with variety of output information (e.g., intensity settings, treatment complete indicators, etc.). The controls allow the user to adjust power of the energy, waveform, as well as the level of maximum arc energy allowed that varies depending on desired tissue effects and other parameters to achieve the desired waveform suitable for a particular task (e.g., coagulating, tissue sealing, intensity setting, etc.). In another embodiment, generator **500** may be included in fixed handle **50** of handle assembly **30**.

Generator **500** provides an electrical signal to transducers **130**, which, in turn, generate acoustic waves or signals that are propagated through waveguide **12** to probes **140** in end effector assembly **105**. Probes **140** are piezoceramic transducers that receive acoustic waves from transducers **130** and output the acoustic waves to tissue grasped between jaw members **110** and **120**. Although FIG. **3** depicts probes **140** in lower jaw member **120**, the probes **140** may be disposed in upper jaw member **110** and/or lower jaw member **120**. Probes **140** are electrically coupled to generator **500** and transmit the electrical signal (FIG. **5**) thereto.

Generator **500** includes a phase/time reversal unit (PRU) **505**. PRU **505** performs time reversal signal processing that is a technique for focusing waves. Time reversal signal processing is based upon a feature of wave equations known as reciprocity. Reciprocity says that if one has a solution to the wave equation, then the time reversal (using a negative time) of that solution is also a solution of the wave equation. This occurs because the standard wave equation only contains even order derivatives. Time reversal techniques can be modeled as a matched filter that is included in the PRU **505**.

After probes **140** receive the acoustic signal from transducers **130**, probes **140** transmit an electrical signal generated from the acoustic signal to the PRU **505**. PRU **505** sends the reversed version (see FIG. **6**) of the electrical signal of FIG. **5** to transducers **130** that transmit an acoustic signal back to probes **140** thereby, effectively autocorrelating the signal. Due to the principle of acoustical reciprocity, the reversed signal will be focused precisely in the same spot where it came from, i.e., probe **140**. The resulting signal is concentrated in both time and space resulting in a signal that resembles a delta function as shown in FIG. **7**. This precise focusing allows acoustic energy to be concentrated in a very small spot, thereby reducing thermal spread.

Using the inputs on generator **500**, a clinician can select between sealing tissue grasped between jaw members **110** and **120** or cutting tissue between jaw members **110** and **120**.

A lower power setting may be used for sealing tissue while a higher power setting may be used to cut tissue. Using time reversal signal processing reduces the amount of energy needed (e.g., up to 5 times less energy) and eliminates the need for an amplifier, thereby reducing the components necessary in generator **500**.

FIGS. **4**A and **4**B depicts different sealing surfaces for one of the jaw members of end effector assembly **105**. As shown in FIG. **4**A, sealing surface **410** includes a plurality of stop members **412** and piezoceramic transducers **414**. Stop members **412** may provide a gap between jaw members **110** and **120** of end effector assembly **105** to effectively seal tissue. As shown in FIG. **4**B, sealing surface **420** includes stop members **422** along the outer edges of sealing surface **420**. Piezoceramic transducers **424** are disposed along the center of sealing surface **420**. Transducers **414** and **424** may be formed beneath the sealing surfaces **410** and **420** respectively or be an integral part of sealing surface **410** and **420**.

FIG. **4**C depicts a top view of seal plate **430** according to another embodiment of the present disclosure. Seal plate **430** is made from stainless steel, and as described above, has piezoceramic transducers **432** disposed in locations **434** instead of stop members as shown in FIGS. **4**A and **4**B. Seal plate **430** may be formed by any suitable method. For instance, a layer of stainless steel may be provided and shaped to form seal plate **430**. Then, a photolithography mask is applied to seal plate **430** leaving locations **434** exposed. An etching solution is applied to seal plate **430** to etch away exposed locations **434**. Then the mask is removed leaving seal plate **430** with locations **434** etched away. When the jaw member is assembled, piezoceramic transducers **432** are placed in locations **434** of seal plate **430** and are coupled to generator **500**.

The foregoing description is only illustrative of the present disclosure. Various alternatives and modifications can be devised by those skilled in the art without departing from the disclosure. Accordingly, the present disclosure is intended to embrace all such alternatives, modifications and variances. The embodiments described with reference to the attached drawing figures are presented only to demonstrate certain examples of the disclosure. Other elements, steps, methods and techniques that are insubstantially different from those described above and/or in the appended claims are also intended to be within the scope of the disclosure.

What is claimed is:

1. A surgical system, comprising:

a surgical instrument including a housing having an end effector operably coupled thereto;

a generator adapted to couple to the surgical instrument, the generator configured to provide a first electrical signal to a transducer disposed within the housing, the transducer, in turn, generating a first acoustic wave; and

a probe configured to receive the first acoustic wave at a first location and, in response to receiving the first acoustic wave at the first location, to both: output a second electrical signal to the generator; and cause a second acoustic wave to be output to the first location to treat tissue supported by the end effector.

2. The surgical system according to claim **1**, wherein the transducer is a piezoelectric transducer including a piezoelectric ceramic element to create and distribute ultrasonic sound waves.

3. The surgical system according to claim **1**, wherein the probe is a piezoceramic transducer.

4. The surgical system according to claim **1**, wherein the end effector has a first jaw member and a second jaw member, wherein the probe is disposed along at least one of the first jaw member or the second jaw member.

5. The surgical system according to claim **4**, wherein the probe disposed on at least one of the first jaw member or the second jaw member is spaced apart by a plurality of stop members configured to provide a gap between the first jaw member and the second jaw members.

6. The surgical system according to claim **4**, wherein the probe is disposed along a center of at least one of the first jaw member or the second jaw member, and a plurality of stop members are disposed along an outer edge of the first jaw member or second jaw member.

7. The surgical system according to claim **4**, wherein the probe is disposed beneath a sealing surface of at least one of the first jaw member or the second jaw.

8. The surgical system according to claim **4**, wherein the probe is integrally formed with a sealing surface of one of the first jaw member or the second jaw member.

9. The surgical system according to claim **4**, wherein the first jaw member is disposed in opposing registration relative to the second jaw member.

10. The surgical system according to claim **9**, wherein at least one of the first jaw member or the second jaw member is moveable between a first spaced-apart position and a second approximated position relative to the other one of the first and second jaw members.

11. The surgical system according to claim **1**, wherein the probe is electrically coupled to the generator, and wherein the probe transmits the electrical signal to the generator.

12. The surgical system according to claim **1**, wherein the generator further includes a controller configured to perform time reversal signal processing to focus waves.

13. The surgical system according to claim **12**, wherein the probe transmits the electrical signal to the controller, and the controller is further configured to transmit a reversed version of the electrical signal to the transducer to autocorrelate the electrical signal.

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