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(12) **United States Patent**
Truckai

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(54) **LAPAROSCOPIC DEVICE**

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A61B 17/32 (2006.01)

(Continued)

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

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(58) **Field of Classification Search**

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See application file for complete search history.

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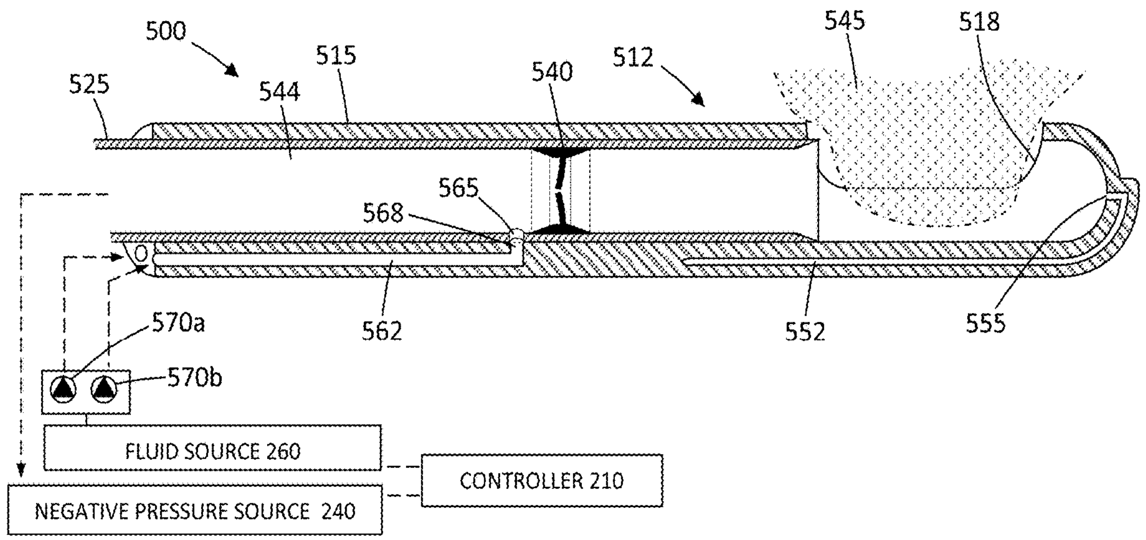
(57) **ABSTRACT**

A medical instrument includes a tubular cutter extending along an axis and having a windowed outer sleeve and a moveable inner cutting sleeve. An ultrasound transducer is operatively coupled to the inner cutting sleeve in order to induce motion in the inner cutting sleeve to enhance cutting or resection of tissue by the inner cutting sleeve as it is reciprocated or otherwise moved past the cutting window. The instrument typically will include a motor drive configured to reciprocate and/or rotate the inner cutting sleeve relative to the windowed outer sleeve, usually at a reciprocation rate between 1 and 10 Hz.

28 Claims, 11 Drawing Sheets



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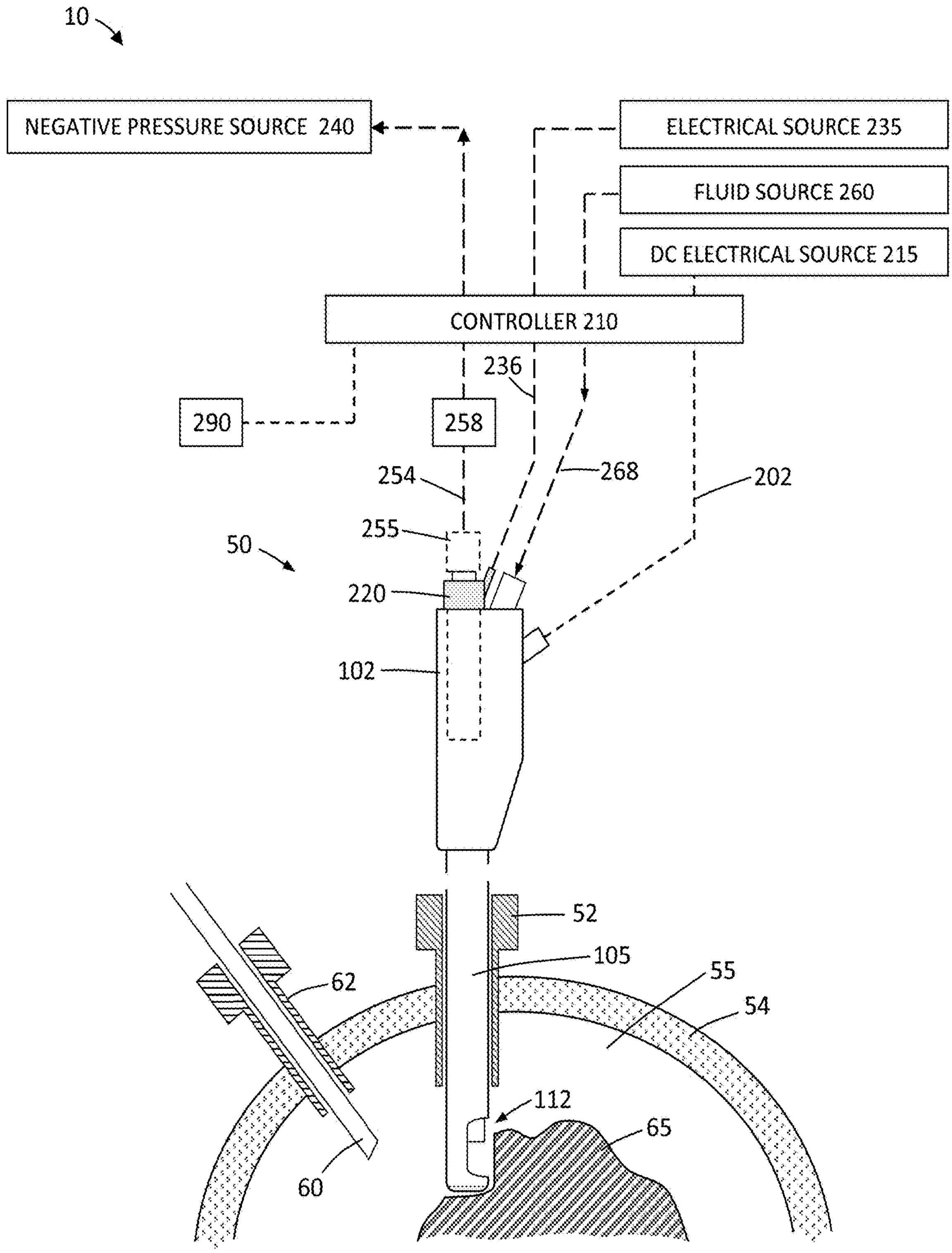
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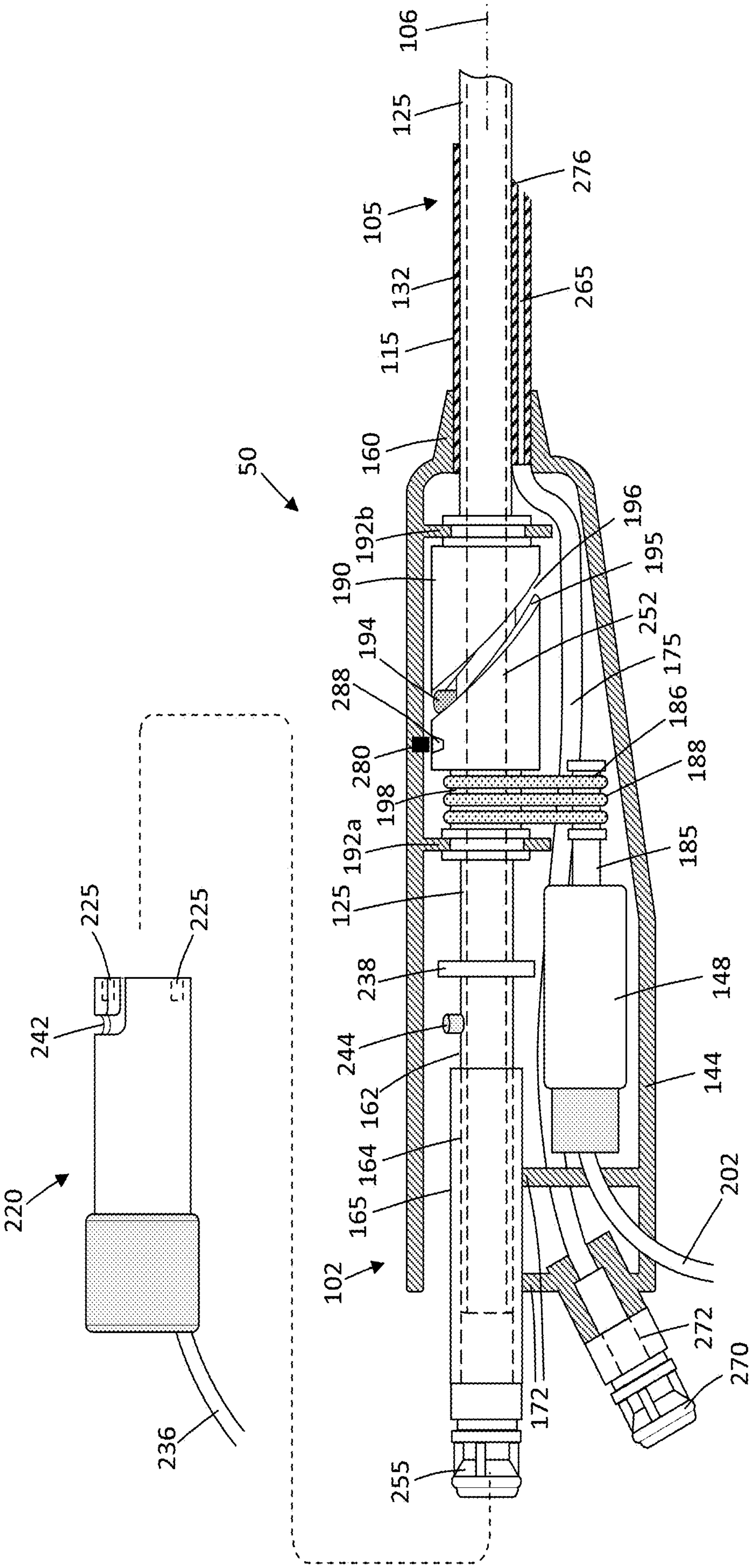
FIG. 1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255

FIG. 2A

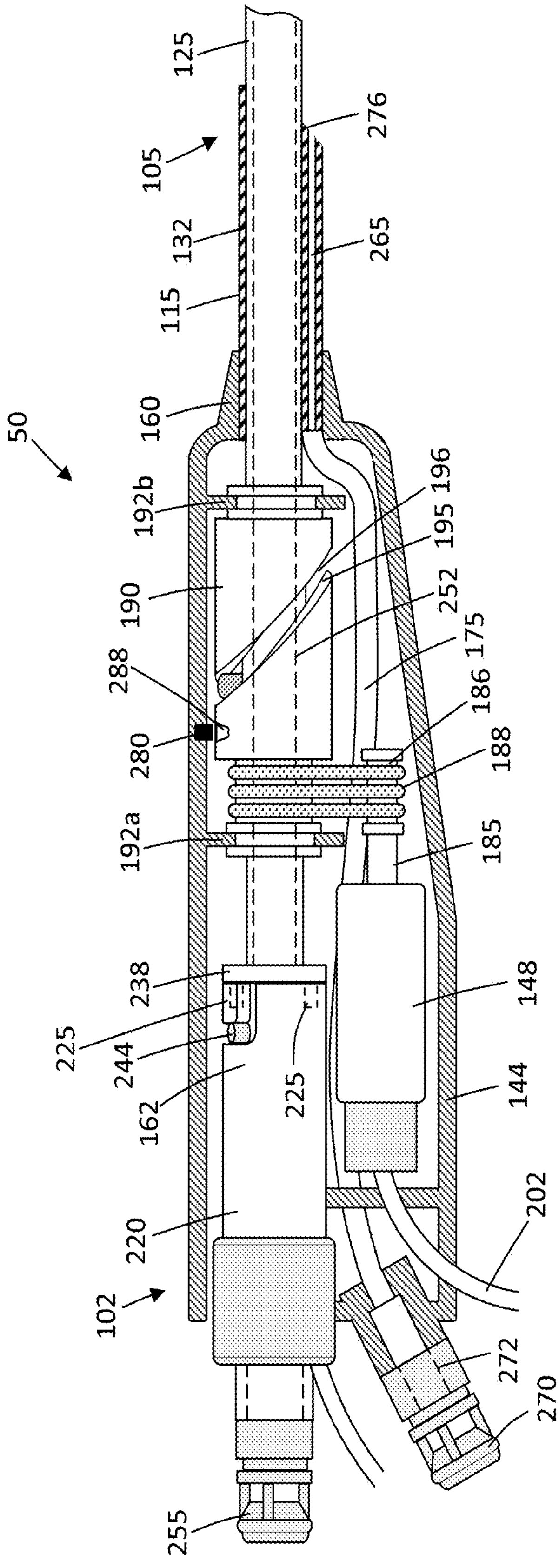
125
276
105
132
265
115
160
50
196
192b
195
190
252
175
288
186
280
188
192a
185
238
148
225
244
225
144
162
202
220
102
272
270
255

FIG. 2B

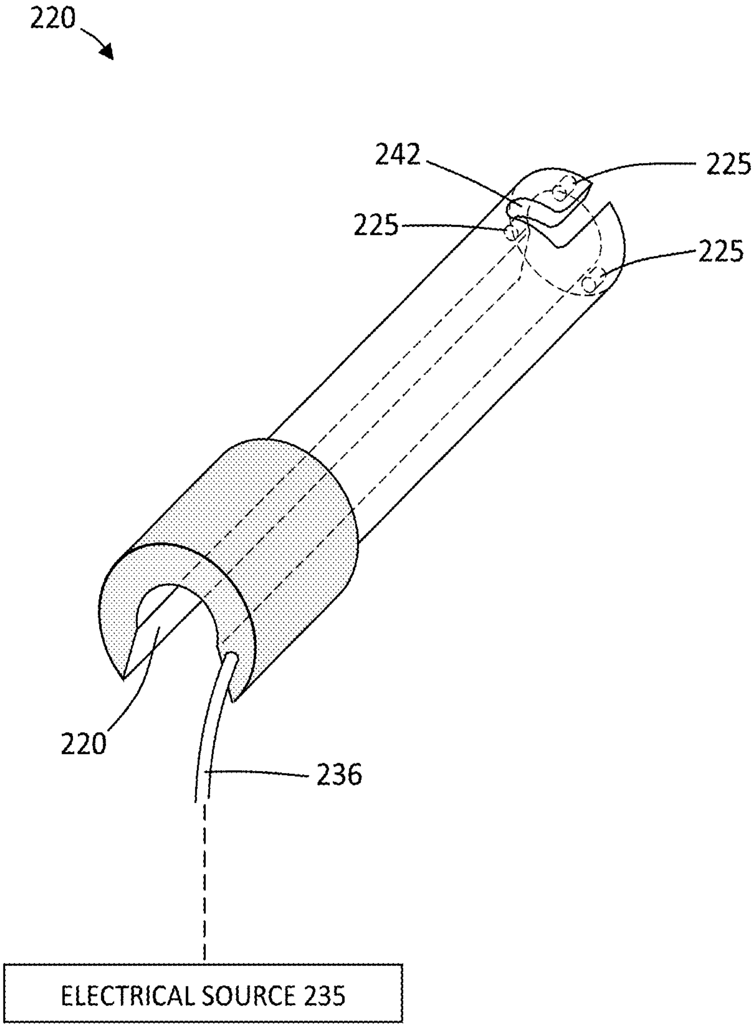

FIG. 3

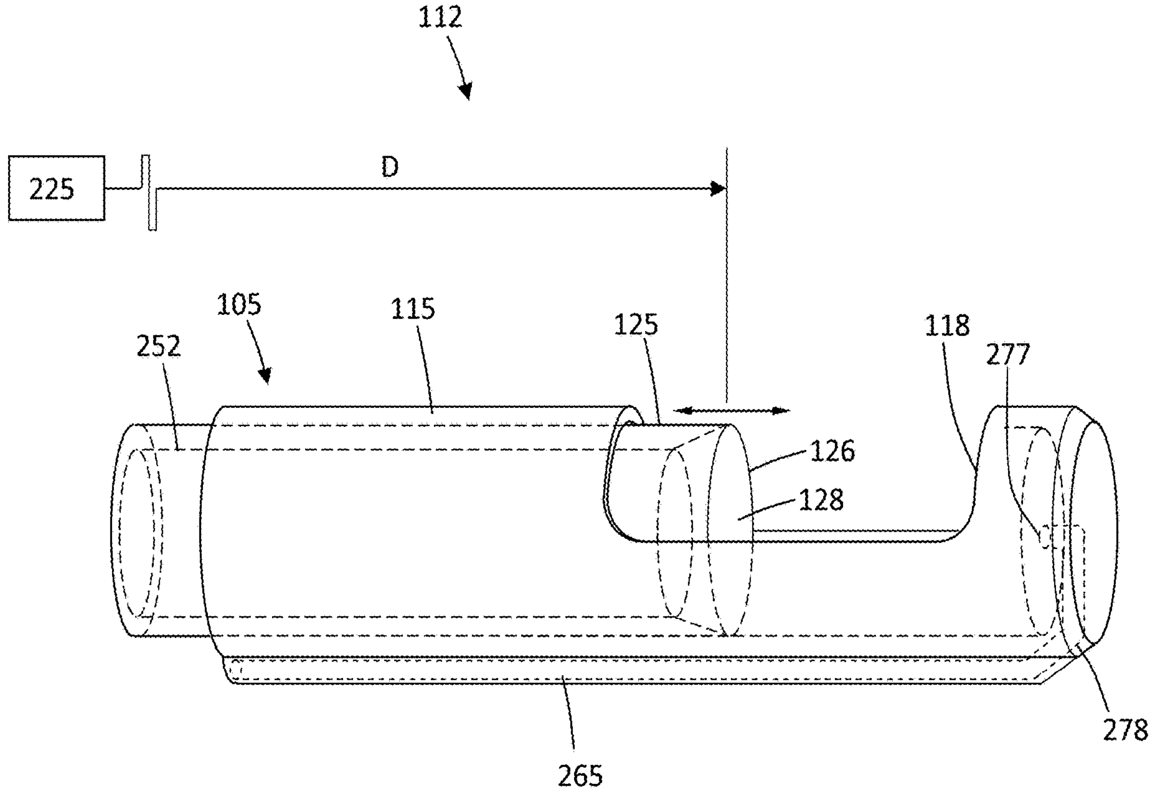

FIG. 4

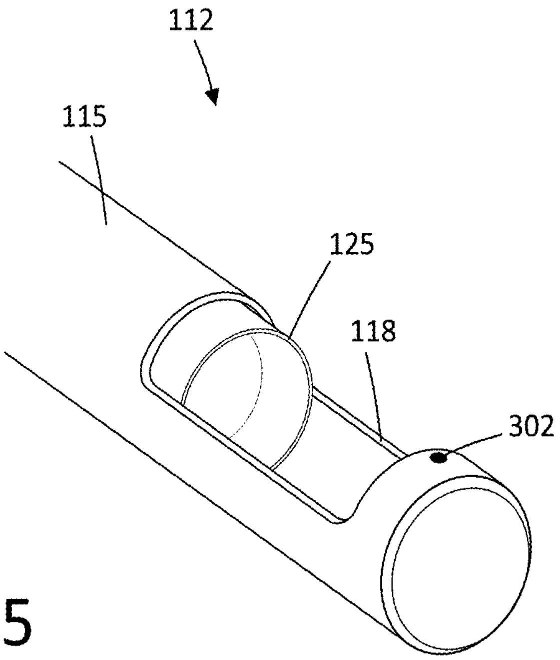

FIG. 5

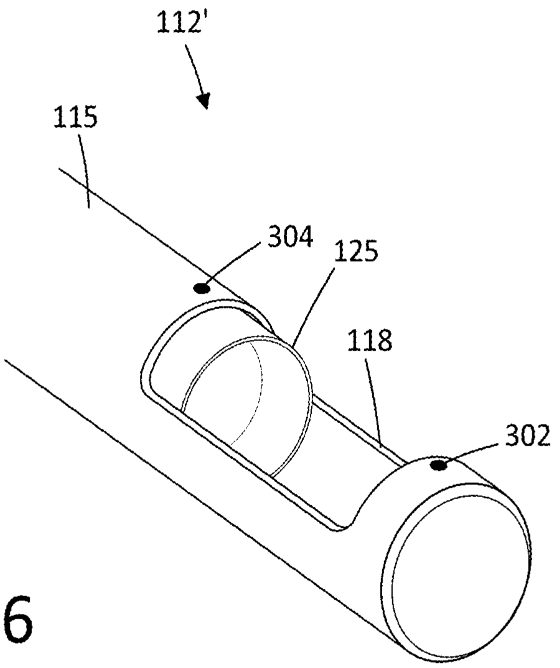

FIG. 6

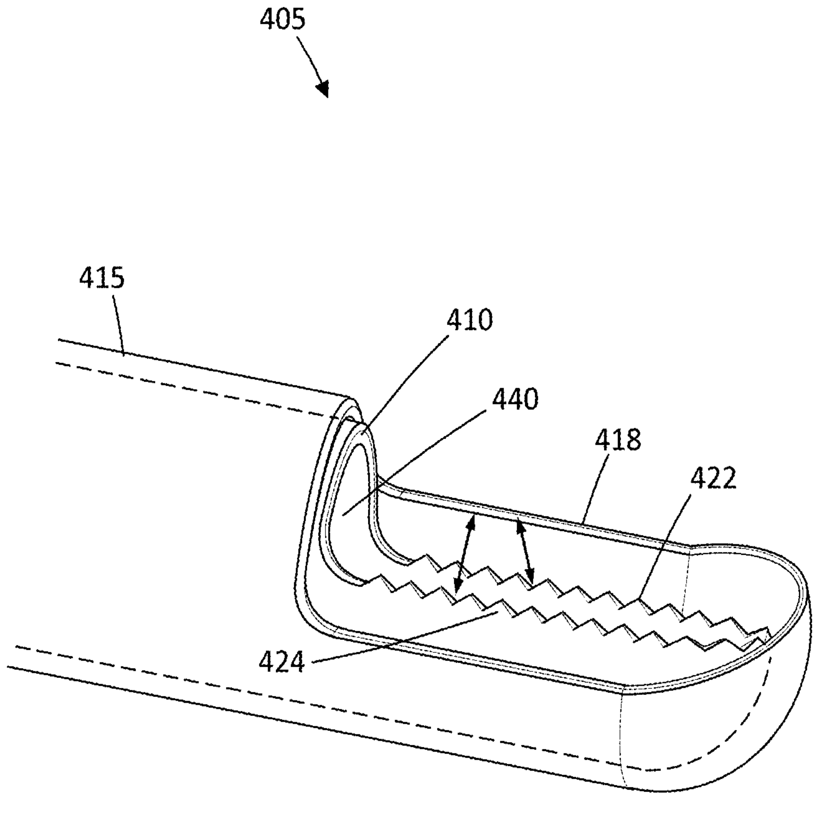

FIG. 7

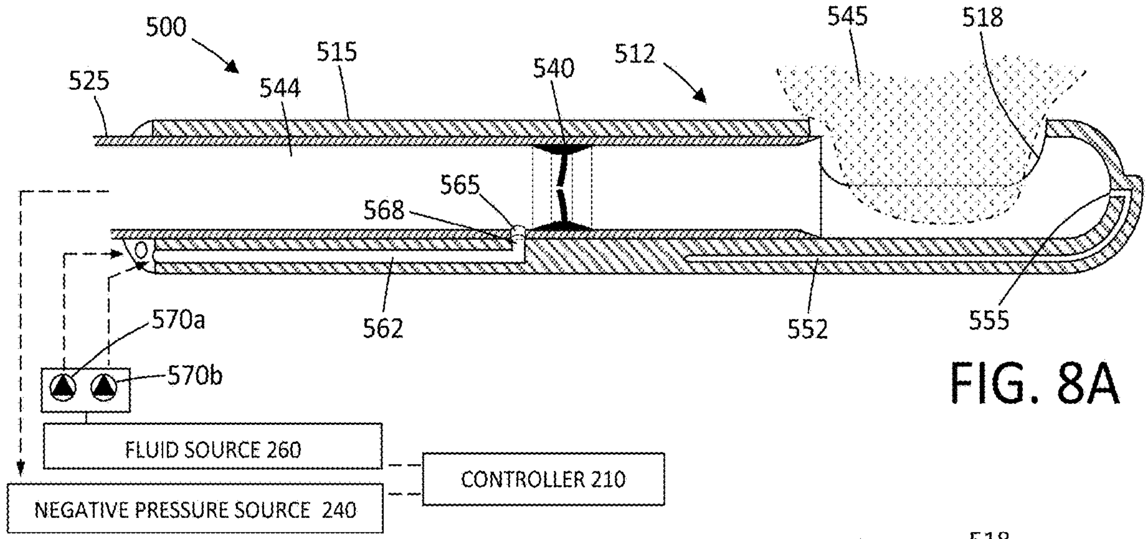

FIG. 8A

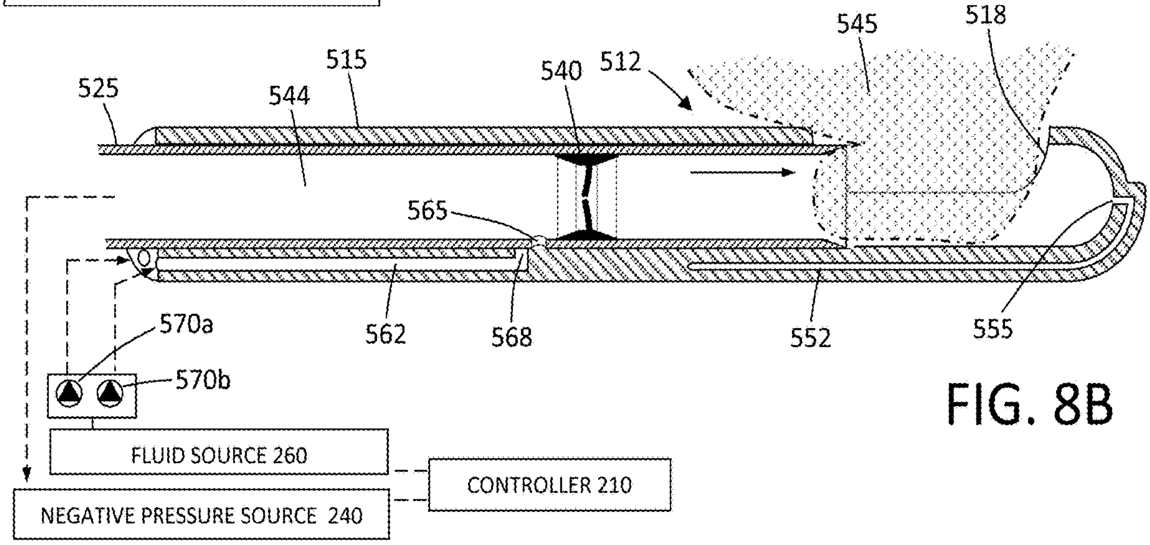

FIG. 8B

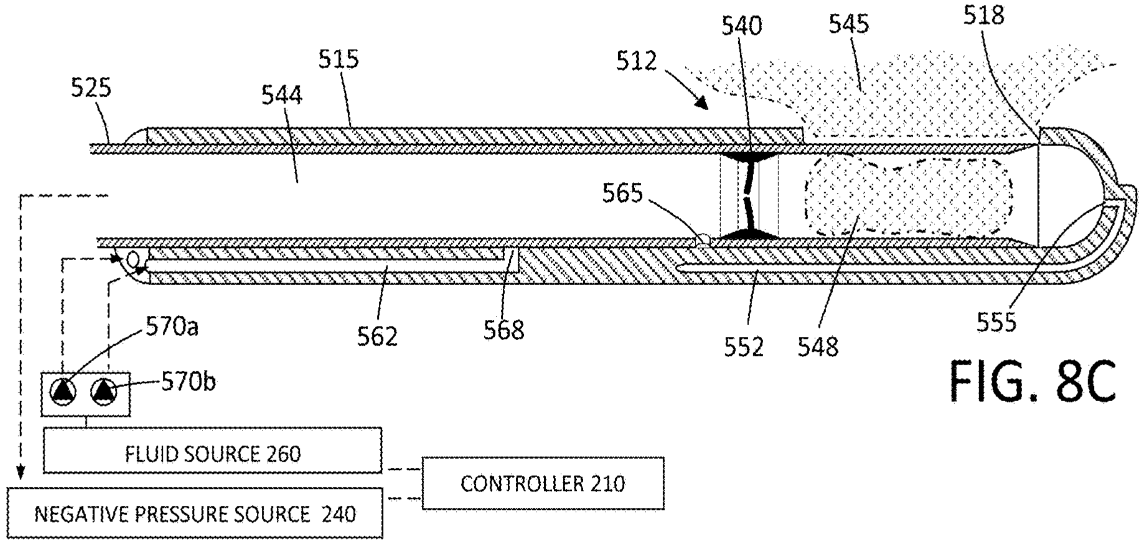

FIG. 8C

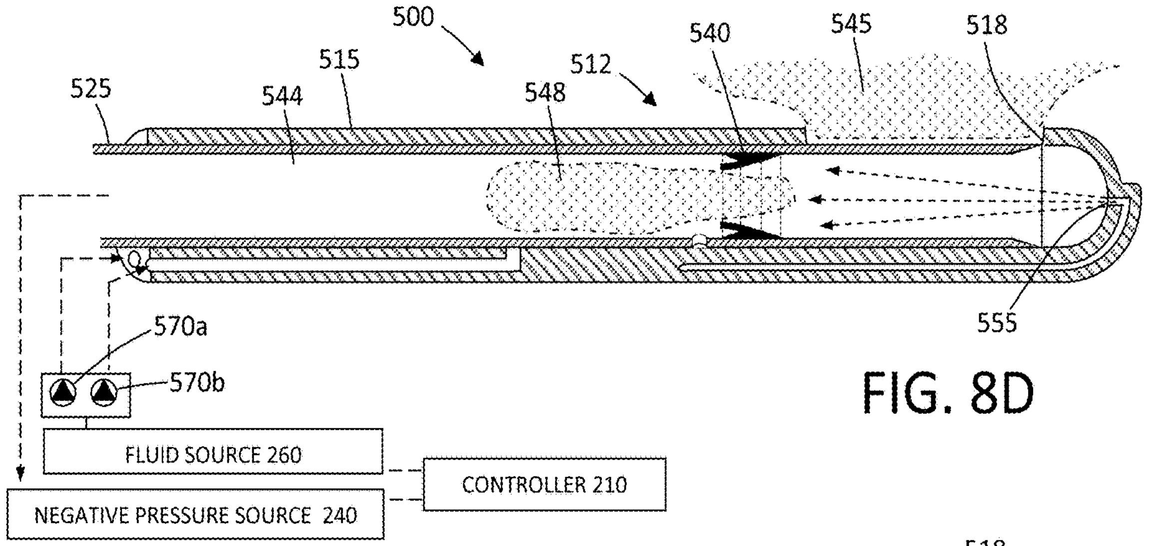

FIG. 8D

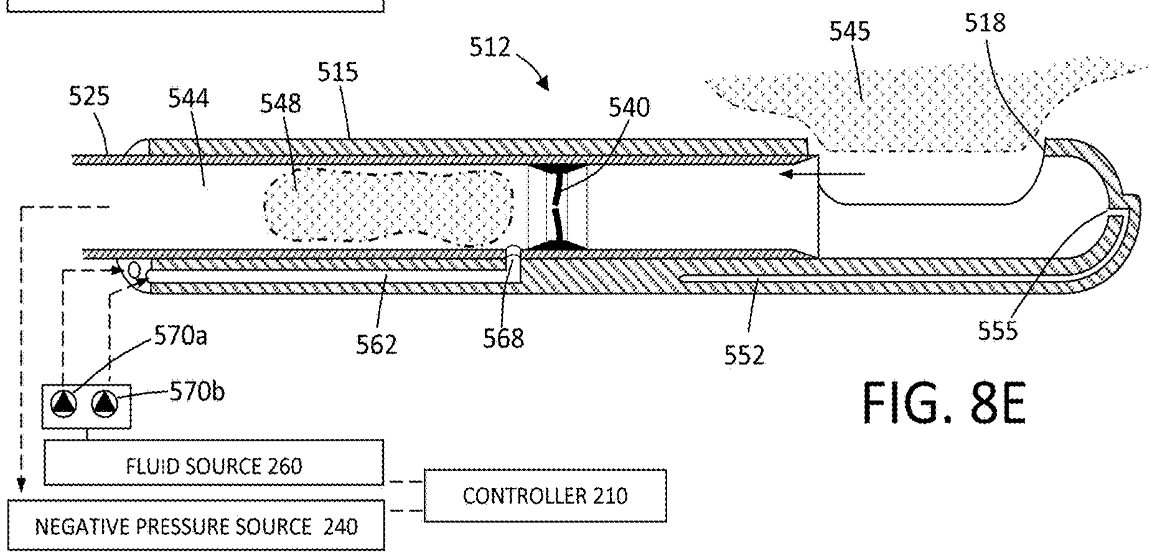

FIG. 8E

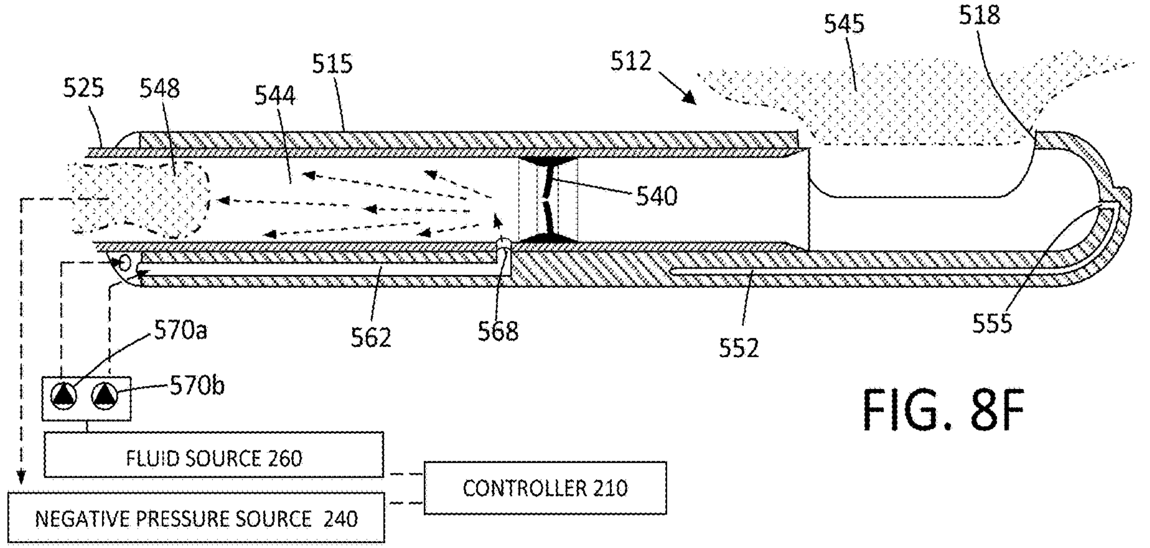

FIG. 8F

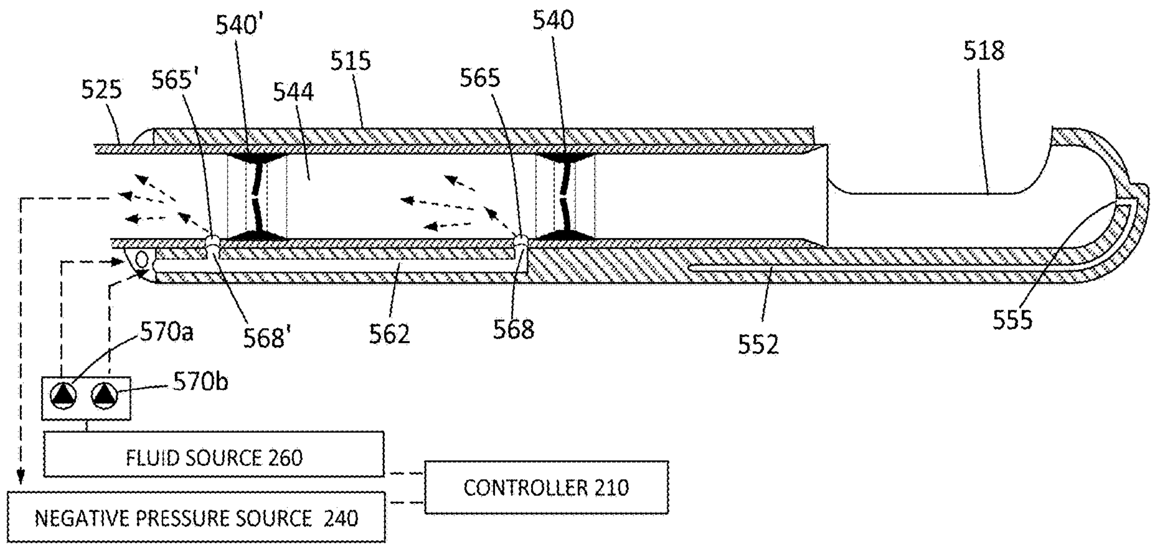
540'
540
515
518
525
565'
544
565
570a
568'
562
568
552
555
570b
FLUID SOURCE 260
CONTROLLER 210
NEGATIVE PRESSURE SOURCE 240

FIG. 9

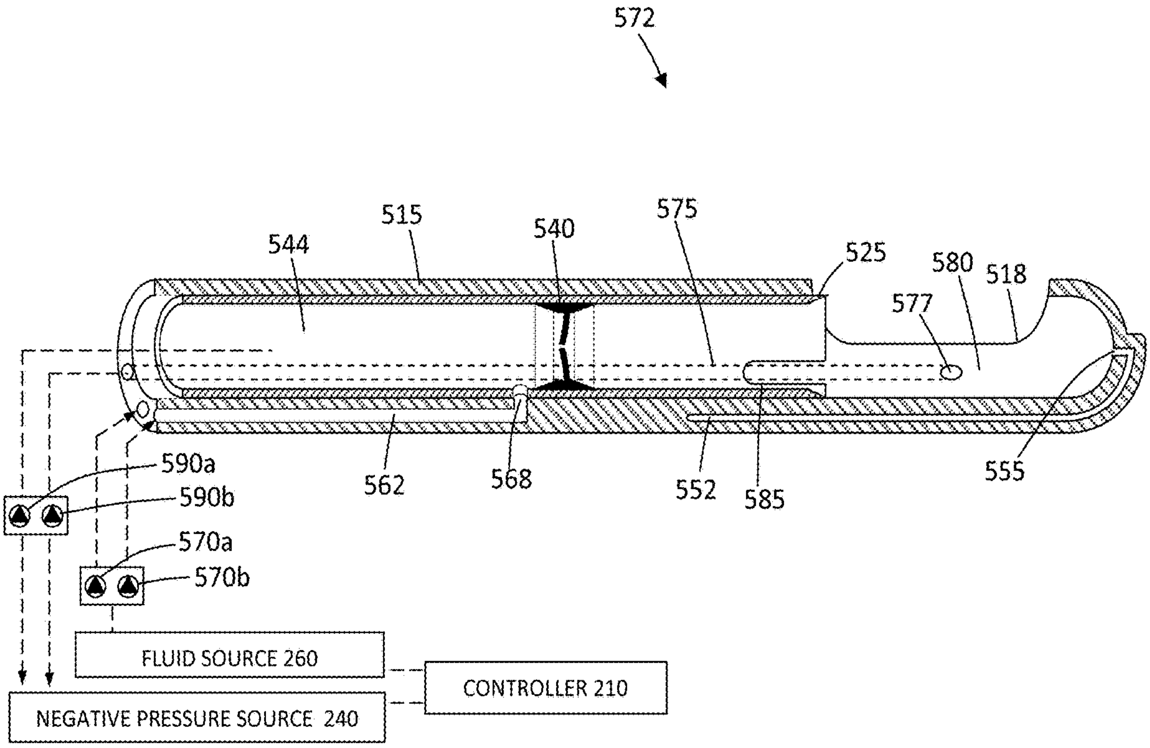
572
515
544
540
575
525
580
518
577
590a
590b
562
568
552
585
555
570a
570b
FLUID SOURCE 260
CONTROLLER 210
NEGATIVE PRESSURE SOURCE 240

FIG. 10

LAPAROSCOPIC DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 14/508,856, filed Oct. 7, 2014, now U.S. Pat. No. 9,649,125, which claims the benefit of U.S. Provisional Application No. 61/891,288, filed Oct. 15, 2013, the entire content of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates devices and methods for cutting and removal of tissue from the interior of a patient's body, typically in a laparosopic procedure.

Laparoscopic and other minimally invasive tissue cutters are known, some of which operate by advancing a tubular blade past an open window in an outer housing to resect or sever intruding tissue. Optionally the cutter may be rotated as it is axially advanced past the window to enhance cutting. Although quite effective, such cutters cannot always adequately cut difficult tissue structure, and it would therefore be advantageous to provide improved devices and methods for laparoscopic and other minimally invasive tissue resection,

2. Description of the Background Art

Reciprocating and rotational tissue cutters are described in U.S. Published Patent Applications 20130267937; 20130172870; and 20120330292. Atherectomy catheters having ultrasound imaging transducers on the cutting blades are described in U.S. Pat. No. 5,429,136.

SUMMARY OF THE INVENTION

In a first aspect, the present invention provides a medical instrument comprising a tubular cutter extending along an axis and having a windowed outer sleeve and a moveable inner cutting sleeve. An ultrasound transducer is operatively coupled to the inner cutting sleeve in order to induce motion in the inner cutting sleeve to enhance cutting or resection of tissue by the inner cutting sleeve as it is reciprocated or otherwise moved past the cutting window. The instrument typically will include a motor drive configured to reciprocate and/or rotate the inner cutting sleeve relative to the windowed outer sleeve, usually at a reciprocation rate between 1 and 10 Hz.

The ultrasound transducer is typically configured to cause at least one of axial motion and rotational motion in the distal end of the inner cutting sleeve. Usually, the inner cutting sleeve will have a cutting edge at is distal end so that the tissue may be effected by axially advancing the blade in a distal direction. Rotational and/or oscillatory motion may be superimposed on the axial reciprocation to enhance cutting with the ultrasonic motion being further superimposed to further enhance cutting. In other embodiments, the inner cutting sleeve may have an axially oriented cutting edge so that cutting is provided primarily by rotation of the sleeve about the axis. In that case, axial oscillation may be superimposed to enhance cutting together with the ultrasonic motion. In all cases, a dimension between the ultrasound transducer and the distal end of the inner sleeve may be selected to optimize at least one of axial motion and rotational motion in the distal end of the inner cutting sleeve.

In some embodiments, the instrument may further comprise at least a second ultrasound transducer, wherein first

and second ultrasound transducers are configured to cause axial and rotational motion in the distal end of the inner sleeve. The ultrasound transducer may be removably secured to a handle portion of the tubular cutter.

The instruments of the present invention may further comprise a negative pressure source coupled to a tissue extraction lumen in the tubular cutter. The instrument of the present invention may still further comprise a pressurized fluid source, either liquid, gas, or a mixed fluid, coupled to an inflow lumen in the cutter, and the inflow lumen may extend to an outlet in a distal portion of the cutter.

The instruments of the present invention may further comprise a controller coupled to the tubular cutter for controlling operating parameters of the ultrasound transducer, the motor drive, the negative pressure source, and/or the pressurized fluid source. In such cases, the instruments may still further comprise a sensor configured to send signals to the controller indicating the position of the inner sleeve relative to the window in the outer sleeve, and the controller may be adapted or configured to modulate activation of the ultrasound transducer in response to the sensor signals that indicate the position of the inner sleeve. The controller may activate the ultrasound transducer when the inner sleeve moves toward a window-closed position to cut tissue and de-activates the ultrasound transducer when the inner sleeve moves toward a window-open position. In particular, the controller may activate the pressurized fluid source when the inner sleeve is in a window-closed position and/or may de-activate the pressurized fluid source when the inner sleeve is in a window-open position.

In a second aspect, the present invention provides a medical instrument comprising a tubular assembly extending along an axis with a windowed outer sleeve and a moveable inner cutting sleeve. The inner cutting sleeve has a tissue-extraction passageway. A seal in the tissue-extraction passageway in the inner cutting sleeve has a first condition that closes the passageway and second condition that permits a tissue chip to pass through the seal. The tubular assembly typically has a flow channel terminating in a distal outlet in a region of the assembly that is distal to the seal, where the flow channel is in communication with a fluid source or a negative pressure source.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a schematic view of a tissue resecting device and block diagram of operating components corresponding to the invention in a laparoscopic resection procedure.

FIG. **2**A is a cut-away view of a handle portion of a resecting device of the invention with a detachable ultrasound component de-coupled from the device.

FIG. **2**B is a cut-away view of the resecting device handle as in FIG. **2**A with the ultrasound component coupled to the resecting device to provide vibratory motion to the inner sleeve.

FIG. **3** is a perspective view of the ultrasound component de-coupled from the resecting device illustrating a plurality of piezoelectric elements carried therein.

FIG. **4** is a perspective view of the working end of a shaft portion of the resecting device showing the assembly of the outer and inner sleeves.

FIG. **5** is a perspective view of the working end of a resecting device showing a sensor for sensing tissue contact.

FIG. **6** is a perspective view of another working end of a resecting device showing a plurality of sensors for sensing tissue contact.

FIG. **7** is a perspective view of another working end of a resecting device showing a rotating inner sleeve that can be coupled to an ultrasound source.

FIG. **8**A is a step of a method of cutting and extracting a tissue chip in a laparoscopic resection procedure using a tubular cutter as shown in FIGS. **1-4**, with FIG. **8**A being a sectional view of a resecting device working end illustrating the activation of a negative pressure source to suction tissue into a window of the cutter.

FIG. **8**B is another step of the method following the step of FIG. **8**A illustrating the activation of motor drive to reciprocate the inner cutting sleeve and actuating an ultrasound component to provide vibratory motion at the inner sleeve edge to resect tissue drawn into the window of the cutter.

FIG. **8**C is another step following the step of FIG. **8**B illustrating a resected tissue chip captured in an interior passageway of the cutting sleeve.

FIG. **8**D is another step depicting actuation of a pressurized fluid flow through an inflow channel and outward from a flow outlet distal to an interior seal to eject the tissue chip through the seal in a proximal direction in the interior passageway of the inner sleeve.

FIG. **8**E is a further step after the pressurized fluid flow of FIG. **8**D pushes the tissue chip through the seal in the interior passageway.

FIG. **8**F depicts a further step of the invention wherein another pressurized fluid flow outward from an outlet proximal of the seal to pushes the tissue chip further in the proximal direction in the interior passageway.

FIG. **9** is a perspective view of another working end of a resecting device showing a plurality of seals in the tissue extraction lumen and flow outlets for providing independent fluid flows distal of each seal to assist in expelling tissue through each seal.

FIG. **10** is a perspective view of another resecting device working end showing an independent fluid channel with a port proximate the window in the outer sleeve for suctioning tissue into the window.

DETAILED DESCRIPTION OF THE INVENTION

FIGS. **1**, and **2**A-**2**B illustrate a tissue resecting system **10** that includes a hand-held single-use tissue resection device **50**. The device **50** has a handle portion **102** that is coupled to a shaft portion **105** having an outer diameter ranging from about 3 mm to 20 mm. The shaft portion **105** extends along axis **106** and can have a length suitable for introducing directly into a body space, for introducing though a trocar in a laparoscopic procedure or for introducing through a working channel of an endoscope. A hand-held device corresponding to the invention as depicted in FIGS. **1** and **2**A-**2**B is adapted for laparoscopic resection procedures such as in a hysterectomy. FIG. **1** schematically illustrates the tissue resecting device **50** introduced through a trocar sleeve or port **52** in a body wall **54** to an insufflated working space **55**, which, for example, can be an abdominal cavity. An endoscope **60** is introduced through a second port **62** to allow viewing of the tissue volume **65** targeted for resection and extraction. An additional port can be provided for a tissue grasping instrument (not shown) that may be used in the resection procedure. In another embodiment, a similar elongate resecting device can be configured for resecting tissue in other body tracts and spaces utilizing any type of endoscope to allow endoscopic viewing of the working space.

Referring to FIGS. **1**, **2**A-**2**B and **3**, the resecting device **50** has a shaft portion **105** and working end **112** that comprises an assembly of a first or outer sleeve **115** extending along axis **106** to a distal end **116** having a window **118** therein for receiving tissue. A second or inner sleeve **125** with a distal blade edge **126** and distal opening **128** is dimensioned to reciprocate in bore **132** of outer sleeve **115**. The outer and inner sleeves, **115** and **125**, are typically fabricated of thin-wall stainless steel but any other suitable materials can be used. As can be understood from FIG. **4**, reciprocation of the inner sleeve **125** will cut tissue captured in the window **118** of the outer sleeve. FIG. **4** shows the working end **112** or the assembly of outer sleeve **115** and inner sleeve **125** with the inner sleeve in a partially window-open position.

The resecting device **50** of FIGS. **1-2**B includes subsystems operatively coupled to handle **102** and inner sleeve **125** to enhance the cutting and removal of tissue from a working space in the interior of a patient's body. FIG. **2**A is a cut-away view of handle **102** of the resecting device showing outer sleeve **115** fixed to collar portion **160** of the handle. The handle **102** typically consists of a molded plastic two-part handle shell with a hollow interior. In one variation shown in FIGS. **1** and **2**A, the reciprocatable inner sleeve **125** extends partly through the interior of handle **102** and has a proximal sleeve end **162** that is received in bore **164** of cylindrical fixed member **165** that is fixed to support brackets **172** in shell **144** of handle **102**. As will be described below, the inner sleeve **125** is reciprocated by DC electrical motor **148** in handle portion **102** (see FIGS. **2**A-**2**B).

In one embodiment, the DC motor **148** is housed within the handle with motor shaft **185** having a pulley **186** that carries one or more flexible belts **188**. The belts **188** can be fabricated of rubber, Viton® or a similar material and are adapted to rotate the cylindrical drive member **190** which in turn converts rotational motion to axial motion to thereby reciprocate the inner sleeve **125**. A gear system instead of belts **188** also can be used to rotate the drive member **190**. The drive member **190** is rotatable and secured in the handle **102** at rotation-permitting collars **192***a* and **192***b* at ends of the drive member. The inner sleeve **125** extends through the drive member **190** and has a projecting first pin **194** that engages the inner surfaces **195** of arcuate slot **196** in drive member **190**. The DC motor is geared (together with pulleys **186** and **198**) to rotate the drive member **190** at suitable speed to reciprocate the inner sleeve **125** within a range of 1 Hz to 10 Hz. The DC motor **148** has an electrical cable **202** extending to the controller **210** and a DC electrical source **215**.

Referring to FIGS. **2**A, **2**B and **3**, the resecting device **10** may be part of a system that includes a vibratory or ultrasound component **220** that is re-useable and removable from the resecting device **50**. As can be seen in FIG. **3**, the ultrasound component **220** has an elongate slot **222** therein that is configured to allow the component to slide axially over cylindrical fixed member **165** and the inner sleeve **125**. Component **220** carries a vibrating mechanism such as at least one piezoelectric element **225** for applying vibratory motion to the inner sleeve **125** and more particularly to the distal blade edge **126** of the inner sleeve **125**. In one variation shown in FIGS. **2**A-**3**, three piezoelectric elements **225** are shown. An electrical source **235** is coupled to the piezoelectric elements **225** (see FIGS. **1** and **3**) through electrical cable **236** and electrical leads (not shown) in the ultrasound component **220** to drive the piezoelectric elements. As can be seen in FIGS. **2**A-**3**, the ultrasound component **220** has a J-lock **242** that engages second pin **244** of the inner sleeve **125** for securely locking the component **220** to the inner sleeve. The piezoelectric elements **225** are locked to inner sleeve **125** and are adapted to transmit energy to flange **238** of inner sleeve **125** and to its distal blade edge **126** (see FIGS. **2**A-**2**B and **4**). In one variation, the dimension between the piezoelectric element **225** and the distal blade edge **126** (see FIG. **4**) of inner sleeve **125** is selected to optimize motion in the blade edge. The dimension D relates to the length of a standing wave caused by the piezoelectric element in the material of sleeve **125** as is known in that art of utilizing ultrasound to activate the working end of medical instruments. It should be appreciated that any suitable locking feature can be used to detachably couple the ultrasound component **220** to the inner sleeve **125** such as a threaded connector, a clamp, catches, magnets or the like. It should further be appreciated that independent electrical cable **236** that is directly coupled to the ultrasound component **220** can be eliminated. Instead, the electrical power for the ultrasound component **220** can be provided with electrical cable **202** and a slidable electrical contact (not shown) between handle **102** and the ultrasound component **220** can deliver current to the piezoelectric elements **225**.

As can be seen in FIGS. **1**, **2**A-**2**B, and **4**, the resecting device **10** may be part of a system that includes a negative pressure source **240** operatively coupled to a tissue extraction channel **252** in the device which is in part the passageway in the inner sleeve **125**. As can be understood from FIGS. **1** and **2**A, a flexible outflow tube **254** can extend from the negative pressure source **240** to a quick-connect fitting **255** at the end of the fixed member **165**. The tissue extraction channel **252** extends through inner sleeve **125** and handle **102** to the cylindrical fixed member **165** (FIG. **2**A). In one variation, the negative pressure source **240** is a peristaltic pump but any other source such as hospital wall suction may be used. In another variation, the extraction channel **252** in the combination of inner sleeve **125** and fixed member **165** can transition from a smaller cross-section to a larger cross-section to facilitate the extraction of cut tissue chips. The controller **210** is adapted to control the negative pressure source **240** as indicated in FIG. **1**. A tissue catch structure **258** is provided in outflow tube **254** to collect tissue chips.

In FIGS. **1**, **2**A-**2**B, and **4**, it can be seen that the resecting device **10** may be part of a system that includes a fluid source **260** that includes positive pressure mechanism for providing a pressurized fluid flow through an inflow lumen **265** in the resecting device shaft **105** which is used to assist in applying pressure to expel captured tissue chips from the instrument's working end **112**. In one variation, the fluid source **260** can comprise a reservoir containing saline solution and the pressurization mechanism can be a peristaltic pump. In another variation, the fluid source can be a hospital source of an insufflation gas such as CO_2. The fluid is delivered by tubing **268** to the quick-connect fitting **270** in handle **102**. The flow pathway **272** in the quick-connect **270** extends through tubing **275** in the handle **102** to inflow lumen **265** in the shaft portion of the resecting device **50**. As can be seen in FIG. **4**, the inflow lumen **265** has a small cross section, e.g., a diameter from 0.05" to 0.25", and can be formed in the wall **276** of outer sleeve **115** or can be provided in a hypotube affixed to the outer sleeve **115**. In one aspect of the invention, the inflow lumen **265** extends to an outlet **277** that is proximate to or distal to the window **118** to allow a fluid flow from the outlet in the window-closed position to apply proximally-directed fluid pressure on a tissue chip (not shown) captured in the extraction channel **252**. In one variation shown in FIG. **4**, the inflow lumen **275** has a distal region **278** that includes a 180° turn to provide a flow from outlet **277** that is aligned with the axis **106** of the shaft **105**.

Referring to FIGS. **2**A-**2**B, the system further includes a sensor **285** in the handle that is adapted to determine the rotational position of drive member **190** and to send a signal to the controller **200** that indicates the drive member position. As can be easily understood from FIGS. **2**A-**2**B and **4**, the rotational position of drive member **190** determines the axial position of the inner sleeve and thus can indicate a fully window-open position, a window-closed position or any intermediate window-open position. In one embodiment, the sensor **285** is a Hall effect sensor that is actuated when a magnet **288** in the drive member **190** passes the sensor. In another variation, the sensor can be a mechanically-actuated switch that is actuated by an indent or projection carried by the drive member **190**. In other embodiments, any sensor known it the art can be used and the sensor can be activated by either rotation of the drive member **190** or axial movement of the inner sleeve **125** in the handle **102**.

Referring back to FIG. **1**, the controller **210** of system **10** is adapted to receive signals from sensor **285** and in response can control operating parameters of the ultrasound transducer, the negative pressure source and the pressurized fluid source in relation to a window-open or window-closed position of the cutter. In one embodiment, a footswitch **290** is utilized to actuate the resecting device **50**, but a finger-operated switch in the handle **102** also may be used (not shown). In one variation, the controller includes algorithms that activate the piezoelectric element **225** only when the inner sleeve **125** is moving forward or in distal direction from the fully window-open position to the window-closed position. In this variation, the piezoelectric element **225** is de-activated on the return or proximal stroke from the window-closed position to the window-open position. Thus, the ultrasonic or vibratory effect at the blade edge **126** of the inner sleeve **125** is only activated when tissue is being cut on the forward stroke of the inner sleeve.

Still referring to FIG. **1**, the controller **210** can further control the pressurized fluid source **260** in response to signals from sensor **285** and the window-open or window-closed position of the inner sleeve **125**. In one variation, the controller **210** has an algorithm that activates the fluid source **260** for a selected time interval only when the inner cutting sleeve **125** is in a fully window-closed position. Thus, at the moment the inner cutting sleeve **125** cuts and captures a tissue chip in the extraction channel **252**, the controller **210** can provide a high pressure flow through the inflow lumen **275** and outlet **277** to push the tissue chip proximally in the extraction channel **252**. In one embodiment, the controller **200** can have an algorithm that de-activates the motor **148** to thereby stop reciprocation of inner sleeve **125** in the window-closed position for a time interval to allow a longer pressurized flow from the fluid source **260** to push a captured tissue chip through the extraction lumen **252**. For example, the inner sleeve **125** may be stopped for a time interval ranging from 0.1 second to 2 seconds.

Referring to FIG. **1**, the controller **210** can include algorithms to modulate the negative pressure source **240** in response to signals from a sensor and the corresponding window-open or window-closed condition of the resecting device. In one variation of working end **112** shown in FIG. **5**, the at least one sensor **302** is provided proximate the window **118** to sense tissue contact with the window. For example, the sensor **302** can be a capacitance sensor that is configured to send a signal to the controller when the sensor contacts tissue. It can be easily understood that the capacitance reading from the sensor **302** when in contact with tissue would differ greatly from a capacitance reading in the absence of tissue contact. Any similar type sensor **302** could be used, such as an impedance sensor, pressure sensor and the like. As can be seen in FIG. **6**, another variation of working end **212'** can have a plurality of sensors **302** and **304** and can be used to modulate the negative pressure source **240**. In one variation, the controller **210** can activate the negative pressure source **240** only when a sensor **302** and/or **304** (FIGS. **5** and **6**) is in contact with tissue which then provides suction force to suction tissue into the window **118**. At other times, for example when the physician is re-positioning the working end relative to tissue targeted for resection, the negative pressure source **240** would be de-activated to thus prevent insufflation gas from being withdrawn from the working space **55** (see FIG. **1**).

In another aspect of the invention, the controller **210** can include an algorithm adapted to move the inner cutting sleeve **125** to a predetermined position relative to the window **118** each time the physician de-activates the device. In one variation, when the physician lifts his or foot from the footswitch, or lifts finger from a trigger, a "stop-reciprocation" signal is sent to controller **210** which in turn determines the location of the inner sleeve **125** relative to the window **118** by means of a timer and the next signal (or previous signal) from the position sensor **285** that determines the rotational position of drive member **190**. The controller **210** then can calculate the time interval needed to stop the drive member **190** and sleeve **125** at a predetermined location based on a library of known time intervals following de-activation of the motor **148** to allow the inner sleeve **125** to coast (overcome momentum) to the predetermined position. In one embodiment, the predetermined position can be a fully window-open condition, which would then allow the physician to position the open window **118** against the targeted tissue to commence resection. In one variation, the edge of window **118** and the tissue-contact sensor **302** would contact tissue which then cause the controller **210** to activate the negative pressure source **240** to suction tissue into the window and also actuate reciprocation and the piezoelectric elements **225**. It should be appreciated that the controller algorithm may be programmed to activate the negative pressure source **240** and reciprocation simultaneously or the reciprocation may be actuated in a sequence, for example 0.1 seconds to 2 seconds after the negative pressure. Alternatively, the device may be provided with a two stage trigger, with a first trigger actuation movement activating the negative pressure source and an additional second trigger movement activating the reciprocation and piezoelectric element **225**.

Referring back to FIGS. **3** and **4**, it can be seen that the piezoelectric elements **225** are configured to cause axial motion in the distal end of the inner sleeve **125**. In another variation, the piezoelectric elements can be oriented to cause rotational motion in a keyed flange **138** (see FIGS. **2A-2B**) to rotationally vibrate the blade edge **126** of the inner sleeve. In another variation, a plurality of piezoelectric elements can be provided to cause both axial and rotational motion in the distal end of the inner sleeve. Such motion can be sequential or contemporaneous. The blade edge **126** can have any suitable configuration such as being smooth or having teeth, etc.

FIG. **7** illustrates another variation of a working end **405** corresponding to the invention in which an inner sleeve **410** is configured to rotate relative to outer sleeve **415** rather that reciprocating as in the embodiment of FIGS. **1-5**. It can be easily understood that a handle similar to that of FIG. **2**A can use an appropriately geared motor to rotate the inner sleeve **415** at a selected speed or rotate the sleeve **415** sequentially in clockwise and counter-clockwise directions. Contemporaneously, the at least one piezoelectric element can be used to vibrate the inner sleeve **415** in the manner described previously. As can be seen in FIG. **7**, the window **418** of inner sleeve **415** has sharp teeth **422** at its edge **424**, and the combination of rotation and ultrasonic or vibratory movement of edge **424** will assist is cutting or sawing tougher tissues. In one variation, the controller can include an algorithm that will sequentially rotate the inner sleeve from a window-open start position in clockwise direction from 5° to 30°, then back past the start position and then 5° to 30°, in a counter-clockwise direction followed by one or more increased sequential angular rotation to cut a tissue chip. After successive cutting by such sequential rotations, the inner sleeve **415** can be rotated to the fully window closed position to capture the tissue in the extraction lumen **440** of the inner sleeve. In one variation, an inflow channel **265** as shown in FIG. **4** can be provided in the device of FIG. **7** to allow proximally directed fluid flow to push the tissue chip in the proximal direction in the extraction channel.

In general, the controller **210** can control all operating parameters of the ultrasound component, the motor drive that reciprocates or rotates the inner sleeve, the negative pressure source and the pressurized fluid source, as well as responding to signals from sensors to provide sequential actuation of different component as well as to provide interlocks between various operations and functions of the resecting devices and systems of the present invention.

FIGS. **8**A-**8**F illustrate another resecting device **500** of the invention that has a working end **512** including an outer sleeve **515** with window **518** and a reciprocating, ultrasound-actuated inner cutting sleeve **525**. The resecting device **500** has at least one deformable seal **540** or valve in the tissue extraction channel **544** which allows a cut tissue chip to pass thru the seal **540**. The seal **540** is configured to close to its repose state to prevent the loss of insufflation gas after tissue passes through the seal. More in particular, FIGS. **8**A-**8**F schematically illustrate one variation of resecting device **500** and a sequence of operating the pressurized fluid source **260** and the negative pressure source **240** to assist in cutting and extraction of tissue chips in a laparoscopic procedure.

In FIG. **8**A, the working end **512** of the resecting device is positioned so that the window **518** is in contact with a targeted tissue volume **545**. As described above, the controller **210** has algorithms that stop the inner sleeve in a window-open position of FIG. **8**A. At this point in time, none of the operational mechanisms (ultrasound component, motor drive, negative pressure source and pressurized fluid source) are activated, thus no insufflation gas is lost though the device. The insufflation pressure is maintained automatically by an independent insufflator system as is known in the art. In one variation, the physician then partially actuates a trigger switch **290** (see FIG. **1**) which signals the controller **210** to activate the negative pressure source **240**. In FIG. **8**A, the negative pressure source thus suctions a portion of the targeted tissue **545** into the window **518**. In FIG. **8**B, the physician further actuates the trigger switch **290** which maintains activation of the negative pressure source **240** and activates the motor **148** (FIG. **2**B) to cause reciprocation of the inner sleeve **525** and simultaneously activates the ultrasound component. As can be seen in FIG. **8**B, the distal movement of the inner sleeve **525** begins to cut tissue. FIG. **8**C illustrates the inner sleeve **525** at the distal end of its stroke which captures a tissue chip **548** in the extraction channel **544** of the inner sleeve.

In FIG. **8**D, the position of inner sleeve **525** at the distal end of its stroke can cause a controller algorithm to optionally terminate the ultrasound component and optionally halt reciprocation for a brief interval as described above. With the inner sleeve **525** in the window closed position in FIG. **8**D, the controller **210** causes the fluid source **260** to provide a high pressure fluid flow through first inflow channel **552** and outward from outlet **555** to thus push the tissue chip **548** through the seal **540** in extraction channel **544** as depicted in FIG. **8**E. The controller **210** can control the fluid volume, pressure and duration of the flow to optimize the expulsion of the tissue chip through the seal **540**. An instant after the fluid flow has applied proximally-directed forces to the tissue chip, FIG. **8**E shows the controller has activated the motor **148** to thereby move the inner sleeve **525** to the window open position.

FIG. **8**F illustrates another step in the sequence of resecting tissue wherein the controller **210** causes the fluid source **260** to provide another high pressure fluid flow through a second inflow channel **562** and outward from outlet **565** to push tissue chip **548** further outward (proximally) through the extraction channel **544**. It can be seen that the inflow channel **562** is within wall of outer sleeve **515** which has an outlet **568** that is aligned with port **565** in the inner sleeve **525** to thus permit a high pressure flow to reach the extraction channel **544** in the inner sleeve. In order to provide the fluid flows sequentially through the first inflow channel **552** and then the second inflow channel **562**, the controller **210** can control solenoid valves **570***a* and **570***b* as shown schematically in FIGS. **8**A-**8**F. Following the step of using the fluid flow to expel tissue as depicted in FIG. **8**F, the sequence of steps **8**A-**8**F can automatically be repeated to rapidly resect the targeted tissue volume. It should be appreciated that the inner sleeve **525** may reciprocate at a constant rate and the controller **210** can actuate the fluid source **260** at selected intervals to provide the sequential fluid flows through the first and second inflow channels **552** and **562**. Further, the system can be configured to cause the pressurized fluid flow through the second inflow channel **562** with the inner sleeve **525** in any axial position relative to window **518**.

In another variation, referring to FIG. **9**, the inner sleeve **525** may be configured with a plurality of seals, for example seals **540** and **540'** with inflow ports **565** and **565'** (which can be elongated slots) to allow for a plurality of flow pulses in different axial locations to push and expel tissue chips through the extraction channel **544**. The flow pulses can be contemporaneous or sequential through inflow ports **565** and **565'** from a single inflow channel **562** and outlets **568** and **568'** or can be sequenced through a plurality of independent inflow channels each in communication with an inflow ports **565** and **565'**. In various embodiments, the number of seals **540** and corresponding inflow ports **565** can range from 1 to 10.

In any embodiment, the passageway seal **540** can be any type of flexible leaflet-type seal, hinged-door seal, duckbill-type seal or the like that is adapted to close the passageway in a repose condition.

FIG. **10** illustrates another resecting device **570** that is similar to that of FIGS. **8**A-**8**F except that outer sleeve **515** carries an independent passageway **575** coupled to negative pressure source **240** that is controlled independently by controller **210** to provide suction forces in the interior of window **518**. More in particular, the independent passageway **575** in outer sleeve **515** extends to a distal opening **577** in a distal region of the bore **580** of sleeve **515** proximate window **518**. Thus, the controller **210** can actuates the negative pressure source **240** to suction tissue into the window independent of suction force provided through the tissue extraction channel **544** of the inner sleeve **525**. Further, the controller **210** can use an algorithm to modulate suction pressure through passageway **575** and opening **577** during different portions of the stroke of the inner sleeve **515** to optimize suction for pulling tissue into the window and to minimize loss of insufflation gas. The controller **210** can operate solenoid valves **590***a* and **590***b* to control negative pressure in the channels **544** and **575**. In one variation, the inner sleeve **515** can have a slot or notch **585** that is axially aligned with opening **577** so that the opening is not covered by the inner sleeve **515** during a distal region of the sleeve's reciprocation. Thus, suction forces can be applied to tissue throughout reciprocation of the inner sleeve **515**.

In the various embodiments described above, the inflows from fluid source have been described as any suitable fluid or flow media. It should be appreciated the flow media can be a liquid (e.g., saline or sorbital) or a gas such as CO_2. Either a liquid or gas can be used to assist in expelling tissue, with each having its advantages. The use of a incompressible liquid could apply greater expelling forces to a captured tissue chip. The use of an insufflation gas can reduce the complexity of the system. In a variation, the system could use a gas media to expel a just-cut tissue chip from the region of the window through the seal **540** in the step shown in FIG. **8**D and then use a liquid flow in the step depicted in FIG. **8**F. In such a variation, pulse liquid flows can operate continuously or intermittently during operation of the device.

It should be appreciated that the features described in the system embodiments of FIGS. **8**A-**10** including seals **540** and independent suction passageway **570** can be provided in a "rotating" inner cutting sleeve as illustrated in FIG. **7**.

In another variation, a plurality of piezoelectric element can each be coupled to a separate elongated member or component that is a part of an assembly that comprises the reciprocating or rotating cutting sleeve. Thus each piezoelectric element can drive a member that has a selected length to cooperate with a standing wave in the material caused by the piezoelectric element to optimize the tissue effect at the distal end of the cutting sleeve. Each elongated member can have an axial or spiral configuration.

Although particular embodiments of the present invention have been described above in detail, it will be understood that this description is merely for purposes of illustration and the above description of the invention is not exhaustive. Specific features of the invention are shown in some drawings and not in others, and this is for convenience only and any feature may be combined with another in accordance with the invention. A number of variations and alternatives will be apparent to one having ordinary skills in the art. Such alternatives and variations are intended to be included within the scope of the claims. Particular features that are presented in dependent claims can be combined and fall within the scope of the invention. The invention also encompasses embodiments as if dependent claims were alternatively written in a multiple dependent claim format with reference to other independent claims.

What is claimed is:

1. A method for cutting tissue, said method comprising:
providing a cutting sleeve;
actuating a first ultrasound transducer operatively coupled to the cutting sleeve to cause at least one of axial and rotational oscillatory motion in a distal end of the cutting sleeve;
advancing the distal end of the cutting sleeve through tissue to cut said tissue; and
actuating a second ultrasound transducer operatively coupled to the cutting sleeve to cause the other of axial and rotational oscillatory motion in the distal end of the cutting sleeve.

2. The method of claim **1** wherein advancing the cutter sleeve comprises reciprocating said sleeve.

3. The method of claim **2** wherein advancing the cutter sleeve further comprises rotating the cutter sleeve.

4. The method of claim **3** wherein the cutting sleeve is reciprocated and rotated within an outer sleeve past a window in the outer sleeve, wherein the tissue to be cut has been drawn into the window by a negative pressure.

5. The method of claim **4** wherein the negative pressure extracts tissue through a lumen in the cutting sleeve.

6. The method of claim **4** wherein the cutting sleeve is reciprocated at a reciprocation rate between 1 and 10 Hz.

7. The method of claim **4** wherein reciprocating and/or rotating the cutting sleeve comprises driving the sleeve with a motor drive.

8. The method of claim **7** further comprising controlling operating parameters of the ultrasound transducer(s), the motor drive, the negative pressure source with a controller.

9. The method of claim **8** further comprising sending signals from sensors to the controller indicating a position of the cutting sleeve relative to the window in the outer sleeve.

10. The method of claim **9** wherein the controller modulates activation of the ultrasound transducer(s) in response to the sensor signals that indicate the position of the inner sleeve.

11. The method of claim **10** wherein the controller activates the ultrasound transducer when the cutting sleeve moves toward a window-closed position to cut tissue and de-activates the ultrasound transducer when the cutting sleeve moves toward a window-open position.

12. The method of claim **8** wherein the controller activates a pressurized fluid source when the inner sleeve is in a window-closed position.

13. The method of claim **12** wherein the controller de-activates the pressurized fluid source when the inner sleeve is in a window-open position.

14. The method of claim **12** wherein the pressurized fluid source comprises a liquid source.

15. The method of claim **12** wherein the pressurized fluid source comprises a gas source.

16. A method for cutting tissue, said method comprising:
providing a cutting sleeve;
actuating a first ultrasound transducer operatively coupled to the cutting sleeve to cause at least one of axial and rotational oscillatory motion in a distal end of the cutting sleeve; and
advancing the distal end of the cutting sleeve through tissue to cut said tissue;
wherein advancing the cutter sleeve comprises reciprocating and rotating said sleeve within an outer sleeve past a window in the outer sleeve, wherein the tissue to be cut has been drawn into the window by a negative pressure.

17. The method of claim **16** further comprising actuating a second ultrasound transducer operatively coupled to the cutting sleeve to cause the other of axial and rotational oscillatory motion in the distal end of the cutting sleeve.

18. The method of claim **16** wherein the negative pressure extracts tissue through a lumen in the cutting sleeve.

19. The method of claim **16** wherein the cutting sleeve is reciprocated at a reciprocation rate between 1 and 10 Hz.

20. The method of claim **16** wherein reciprocating and/or rotating the cutting sleeve comprises driving the sleeve with a motor drive.

21. The method of claim **20** further comprising controlling operating parameters of the ultrasound transducer(s), the motor drive, the negative pressure source with a controller.

22. The method of claim **21** further comprising sending signals from sensors to the controller indicating a position of the cutting sleeve relative to the window in the outer sleeve.

23. The method of claim **22** wherein the controller modulates activation of the ultrasound transducer(s) in response to the sensor signals that indicate the position of the inner sleeve.

24. The method of claim **23** wherein the controller activates the ultrasound transducer when the cutting sleeve moves toward a window-closed position to cut tissue and de-activates the ultrasound transducer when the cutting sleeve moves toward a window-open position.

25. The method of claim **21** wherein the controller activates a pressurized fluid source when the inner sleeve is in a window-closed position.

26. The method of claim **25** wherein the controller de-activates the pressurized fluid source when the inner sleeve is in a window-open position.

27. The method of claim **25** wherein the pressurized fluid source comprises a liquid source.

28. The method of claim **25** wherein the pressurized fluid source comprises a gas source.

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当前申请(专利权)人(译)	HERMES INNOVATIONS LLC		
[标]发明人	TRUCKAI CSABA		
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摘要(译)

一种医疗器械，包括沿轴线延伸的管状切割器，该管状切割器具有开窗的外套管和可移动的内切套。 超声换能器可操作地耦合到内部切割套筒，以便在内部切割套筒中引起运动，以在内部切割套筒往复运动或以其他方式移动通过切割窗口时增强内部切割套筒对组织的切割或切除。 器械通常将包括电动机驱动器，该电动机驱动器构造成通常以1Hz至10Hz之间的往复运动速率使内切割套筒相对于开窗的外部套筒往复运动和/或旋转。