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(54) **SMART SURGICAL LASER TISSUE SEALING AND CUTTING APPARATUS WITH OPTICAL FIBER GUIDED SENSORS**

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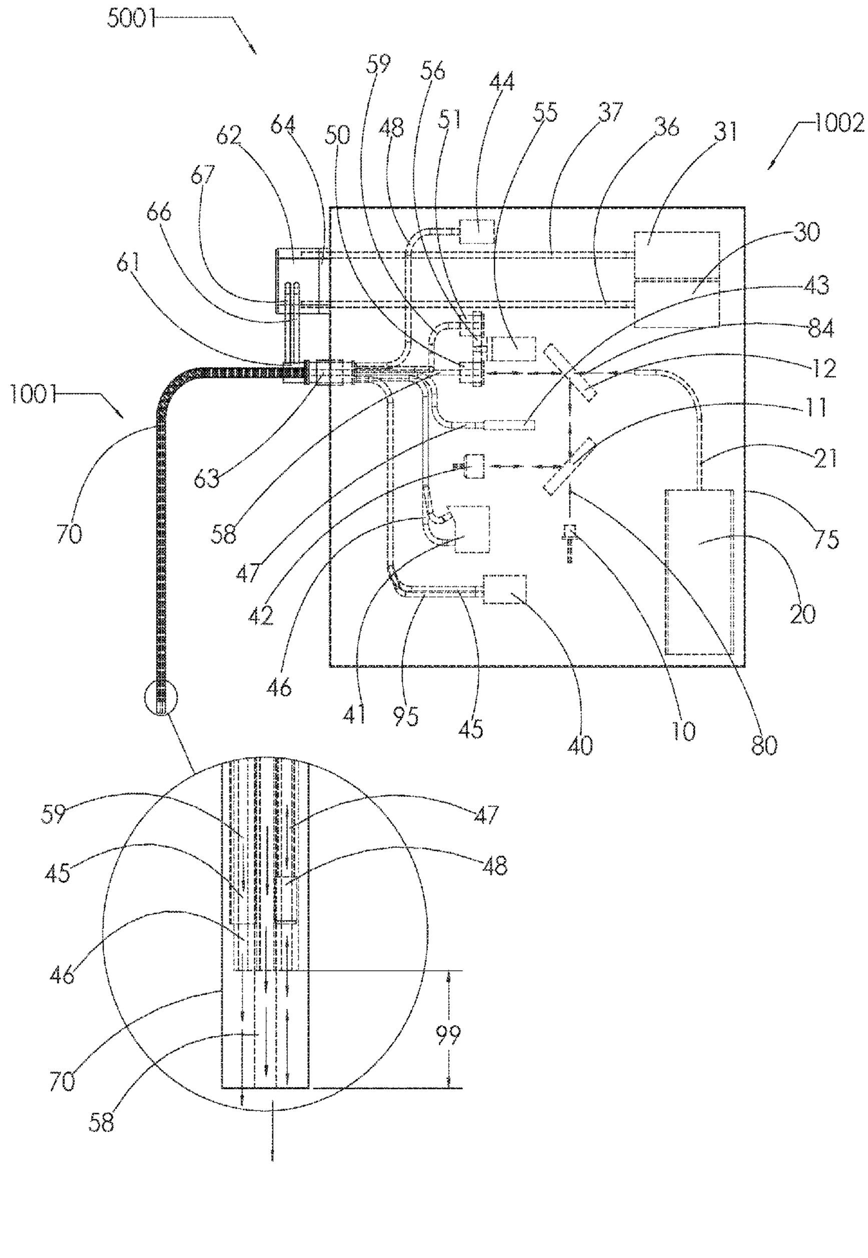
(57) **ABSTRACT**

Embodiments of an apparatus and method for sealing and cutting of tissue during surgeries, especially in general, endoscopic, laparoscopic and robotic, are described. In one aspect, an apparatus comprises a laser system and a laser beam delivery unit. The laser unit is configured to emit a laser beam suitable for tissue sealing and cutting. The laser beam delivery unit is detachably coupled to the laser unit, and is configured to guide and direct the laser beam to seal and cut tissue. Use of optical fiber guided sensors described herein further enhances the safety and efficacy of the apparatus.



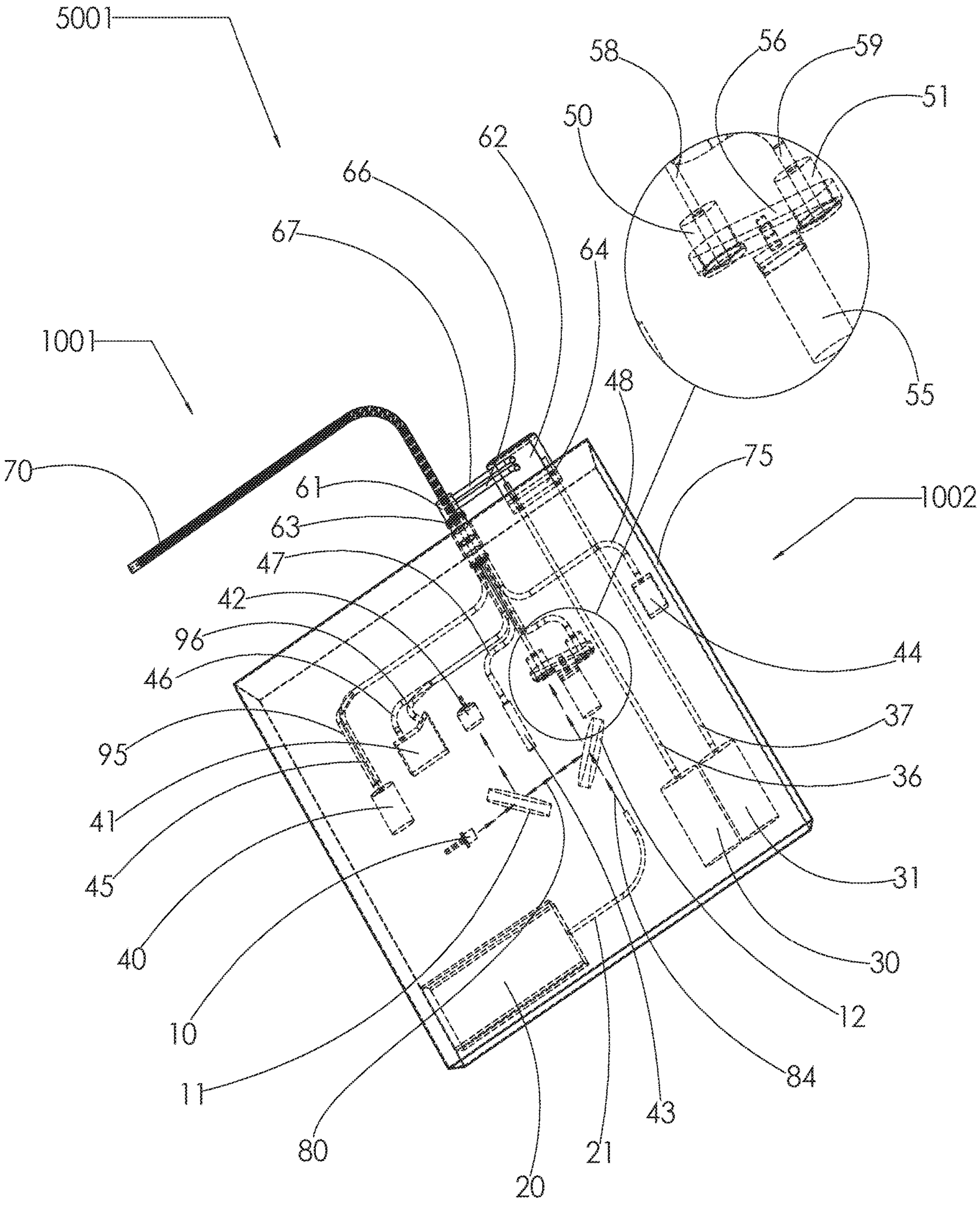

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FIG. 1

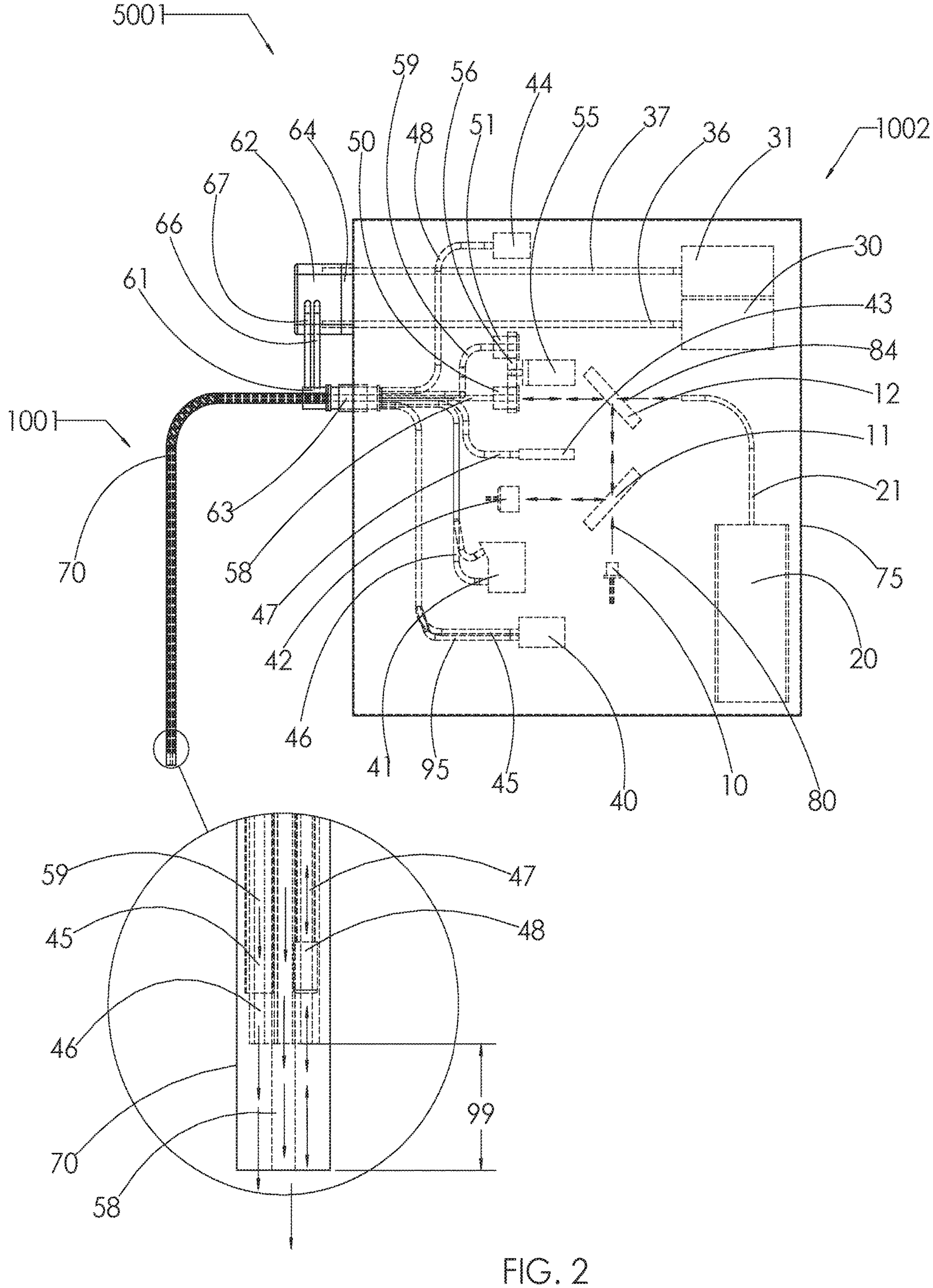
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FIG. 2

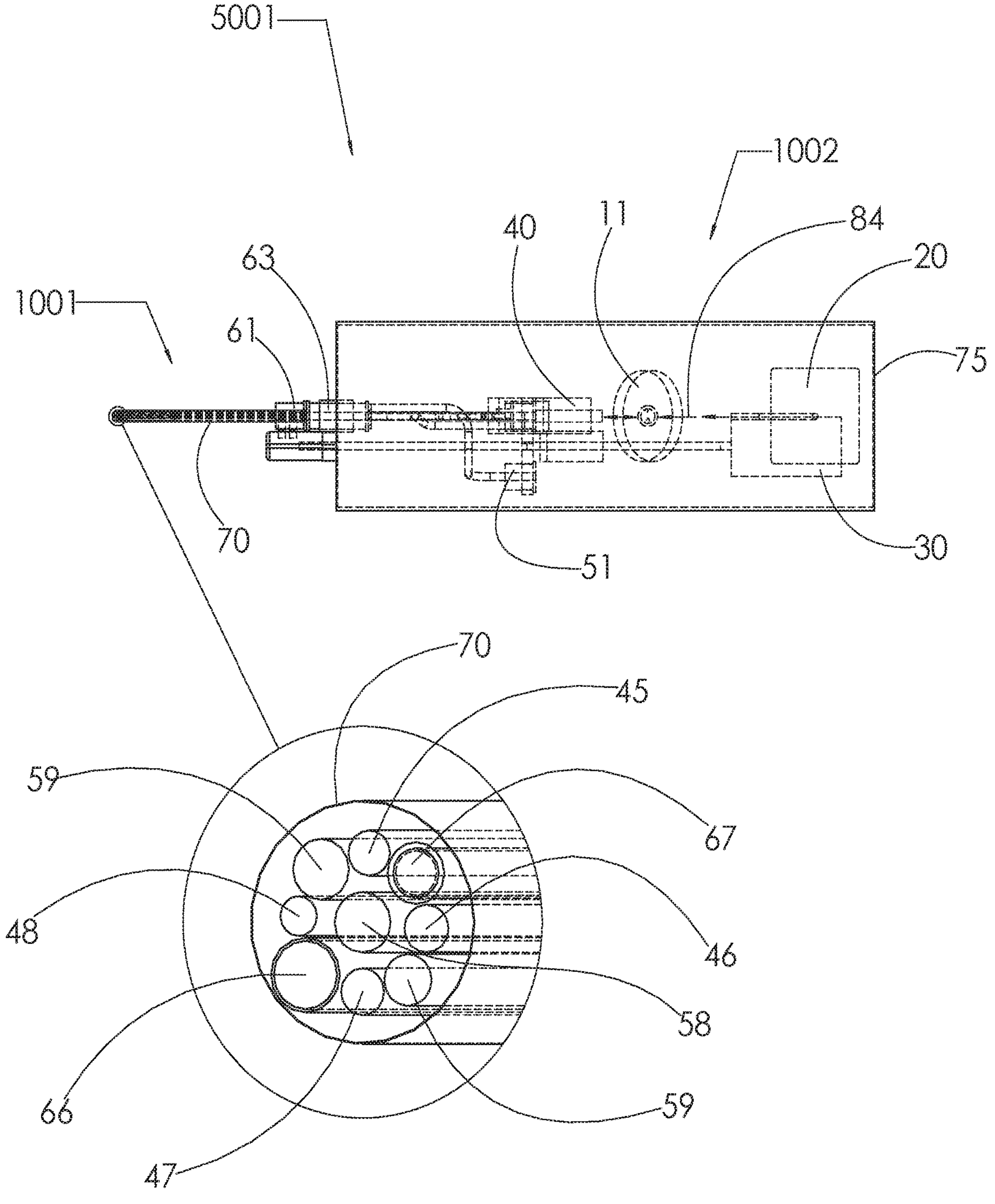
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FIG. 3

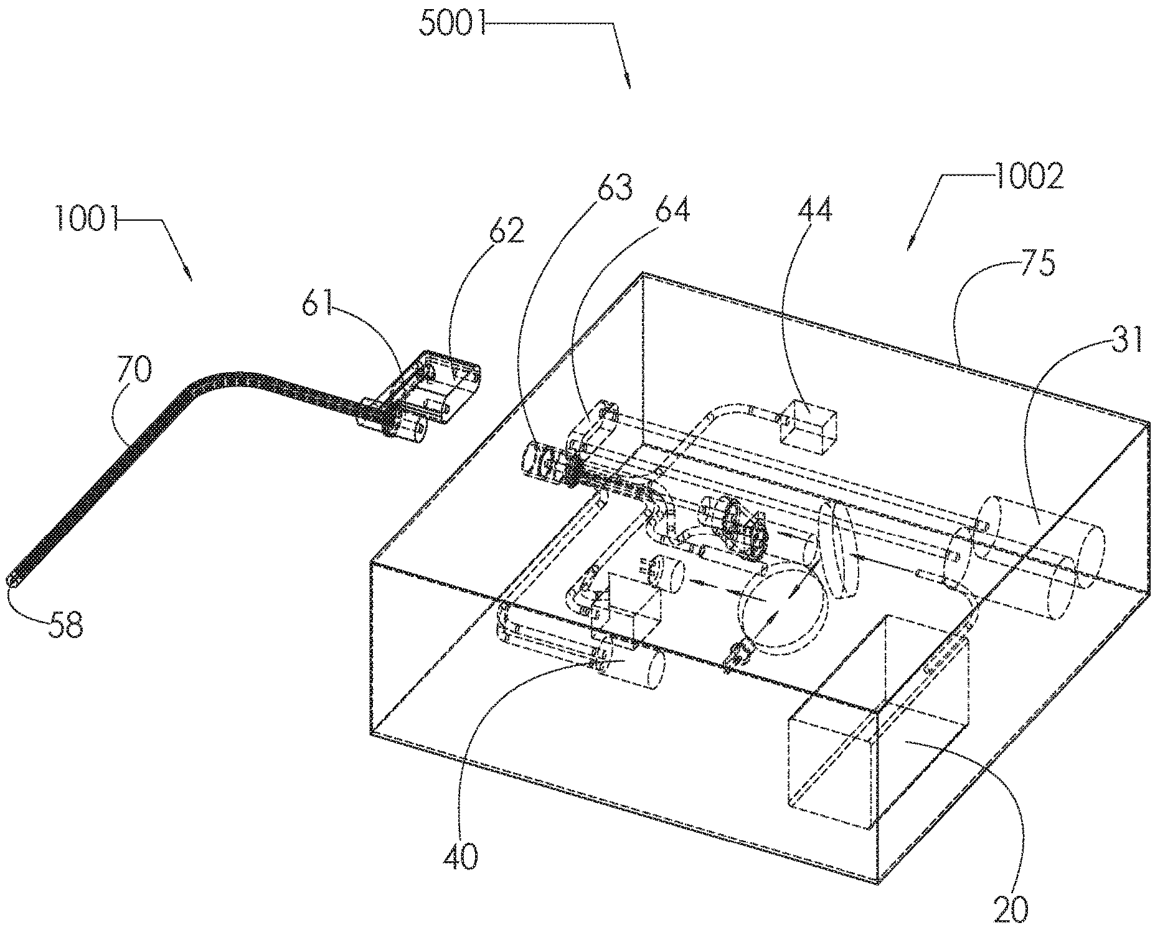

FIG. 4

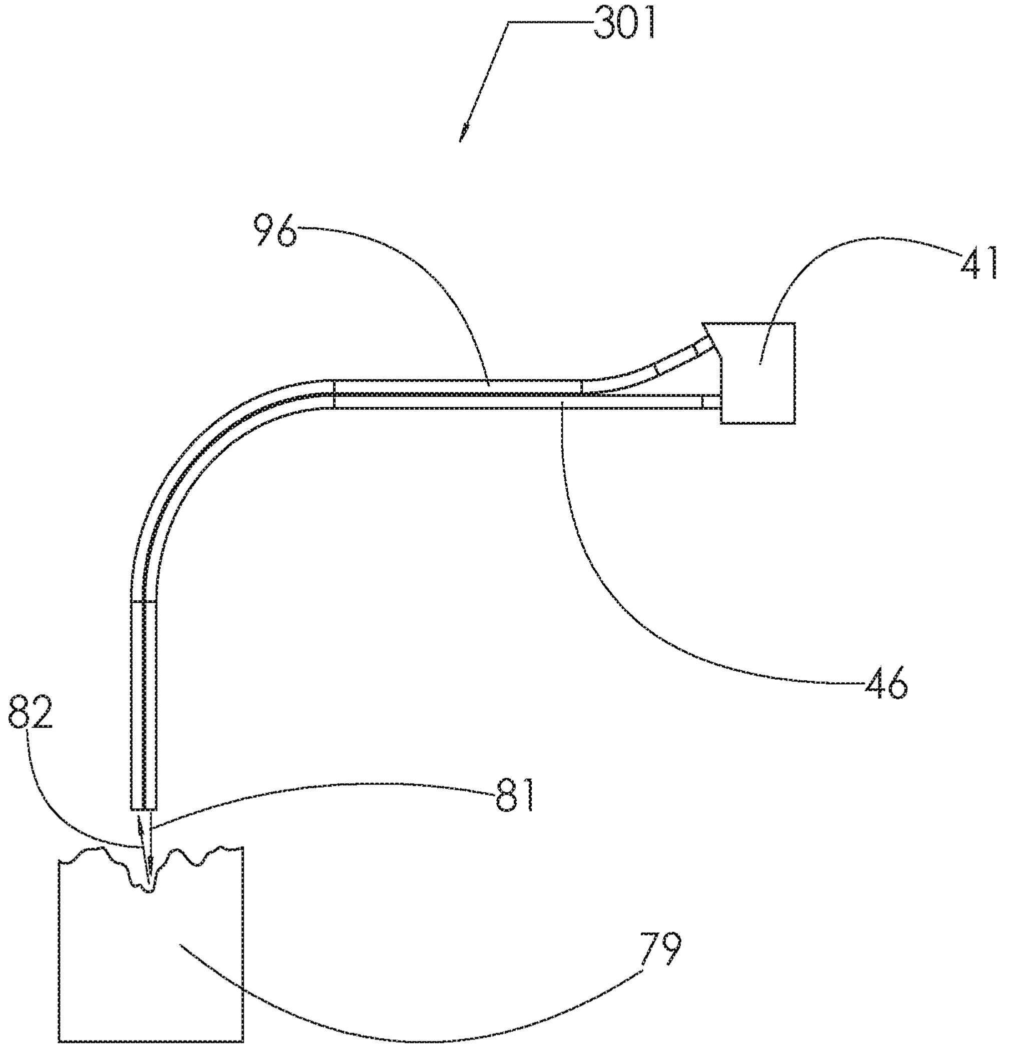

FIG. 5

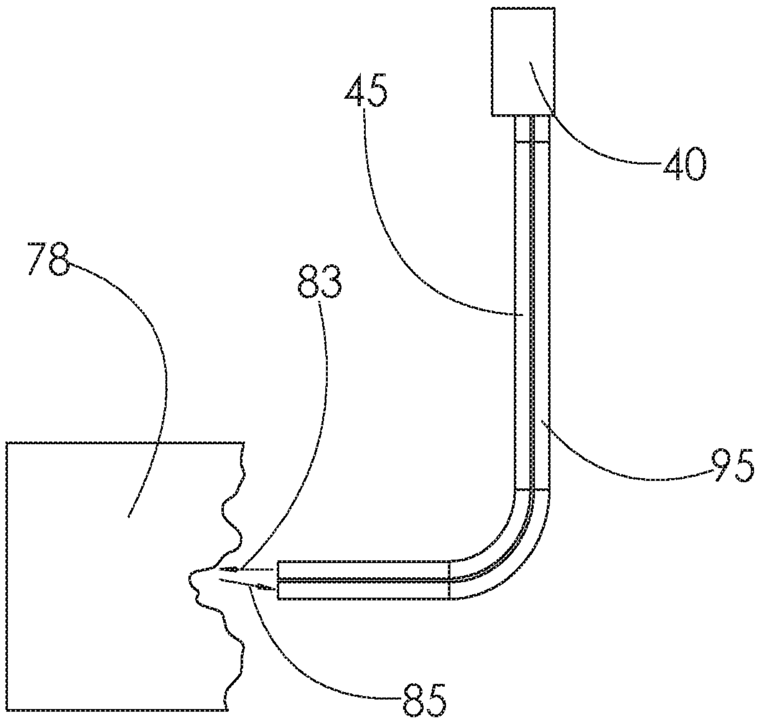

FIG. 6

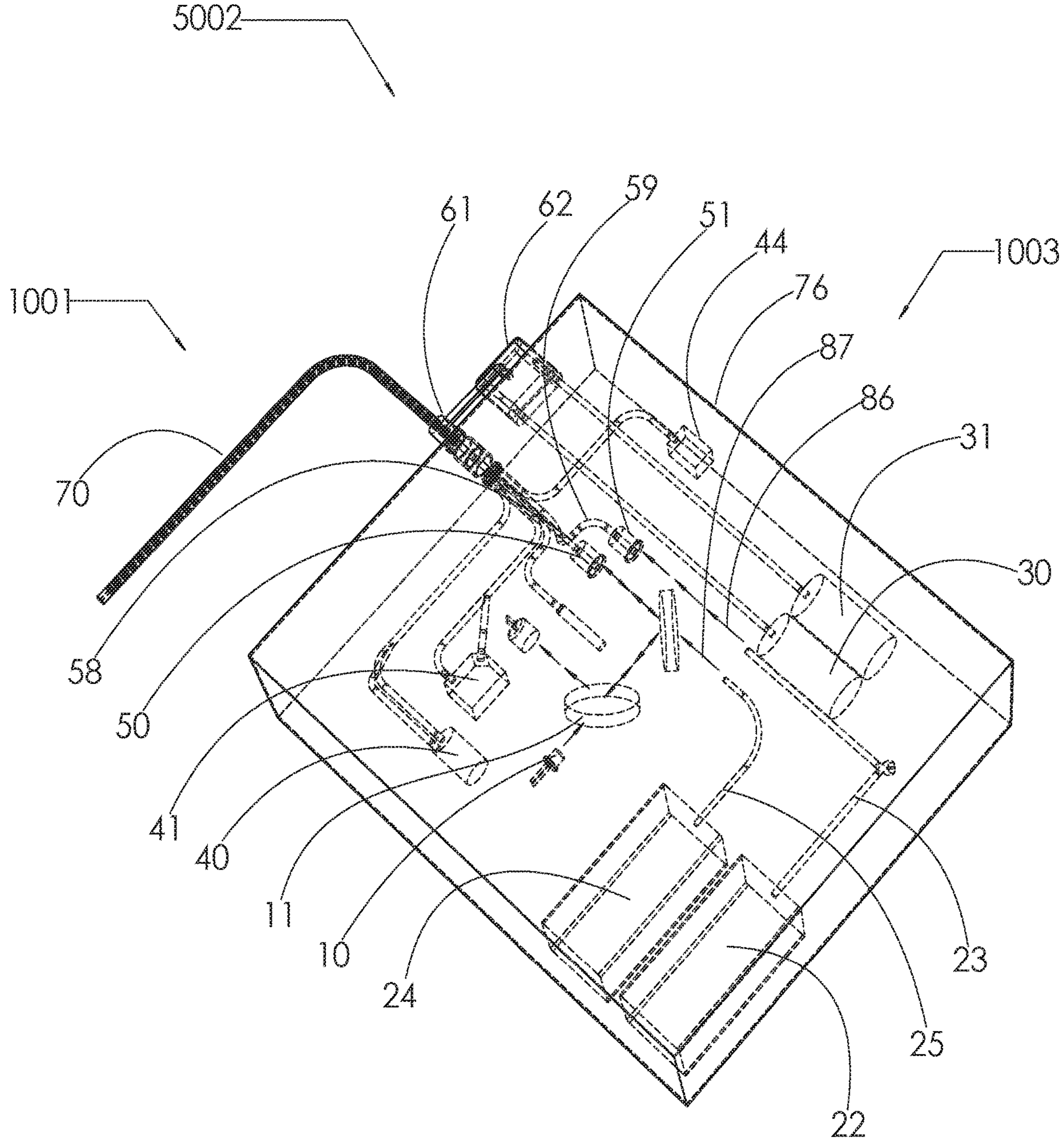
5002
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FIG. 7

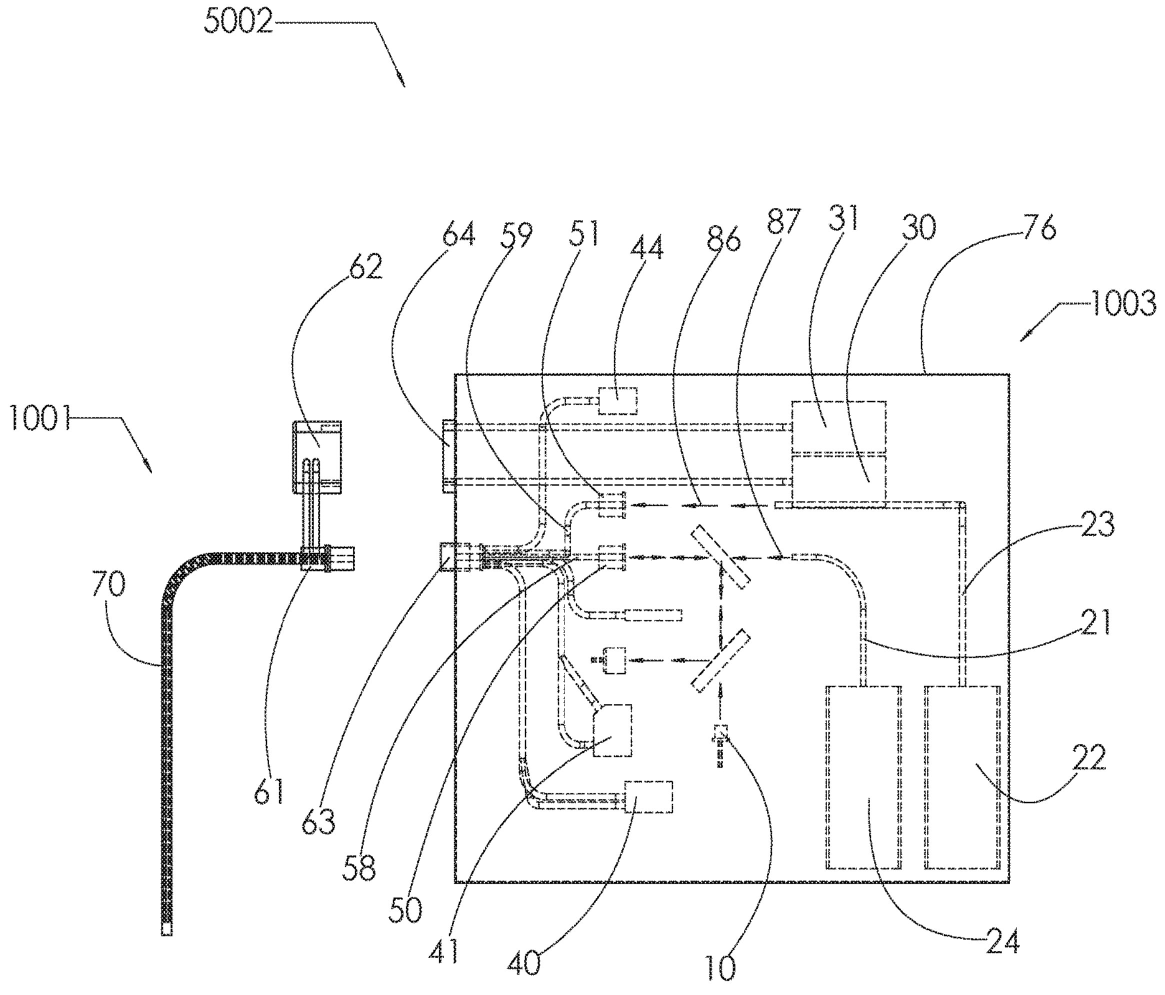
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FIG. 8

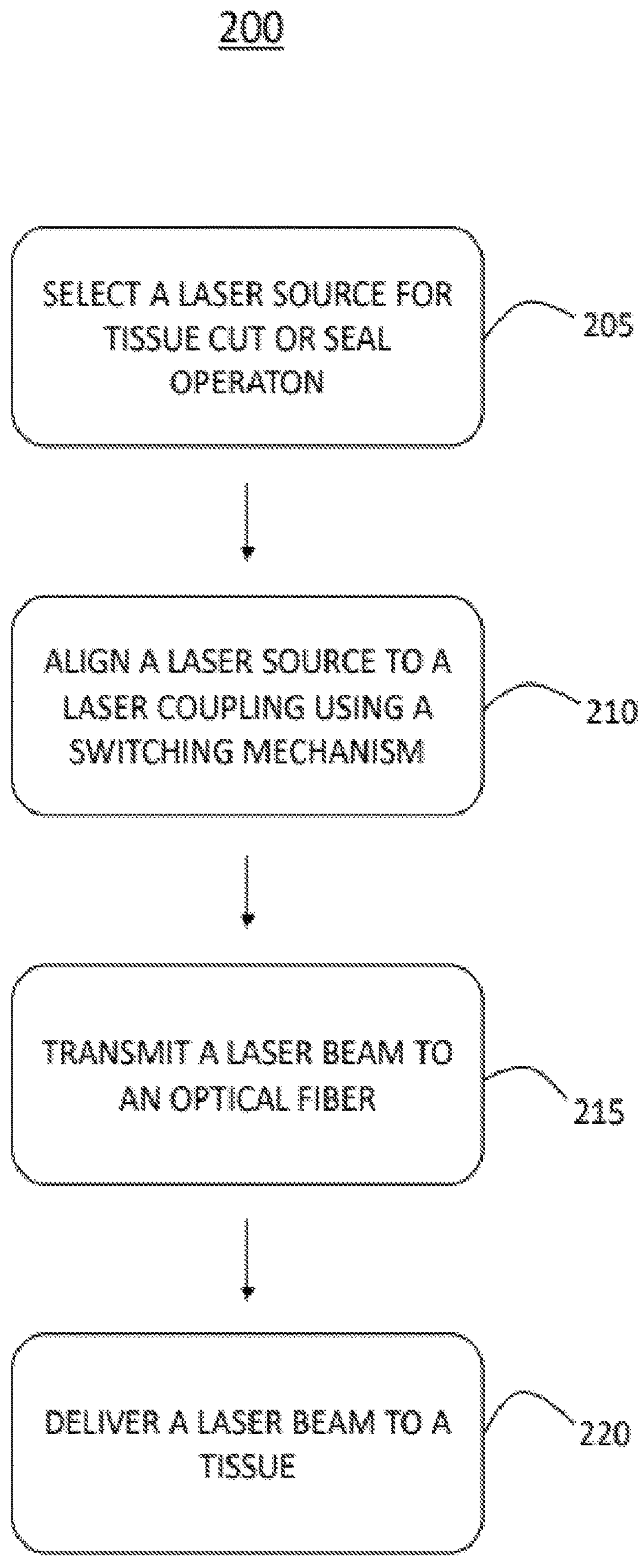
200
SELECT A LASER SOURCE FOR TISSUE CUT OR SEAL OPERATON
205
ALIGN A LASER SOURCE TO A LASER COUPLING USING A SWITCHING MECHANISM
210
TRANSMIT A LASER BEAM TO AN OPTICAL FIBER
215
DELIVER A LASER BEAM TO A TISSUE
220

FIG. 9

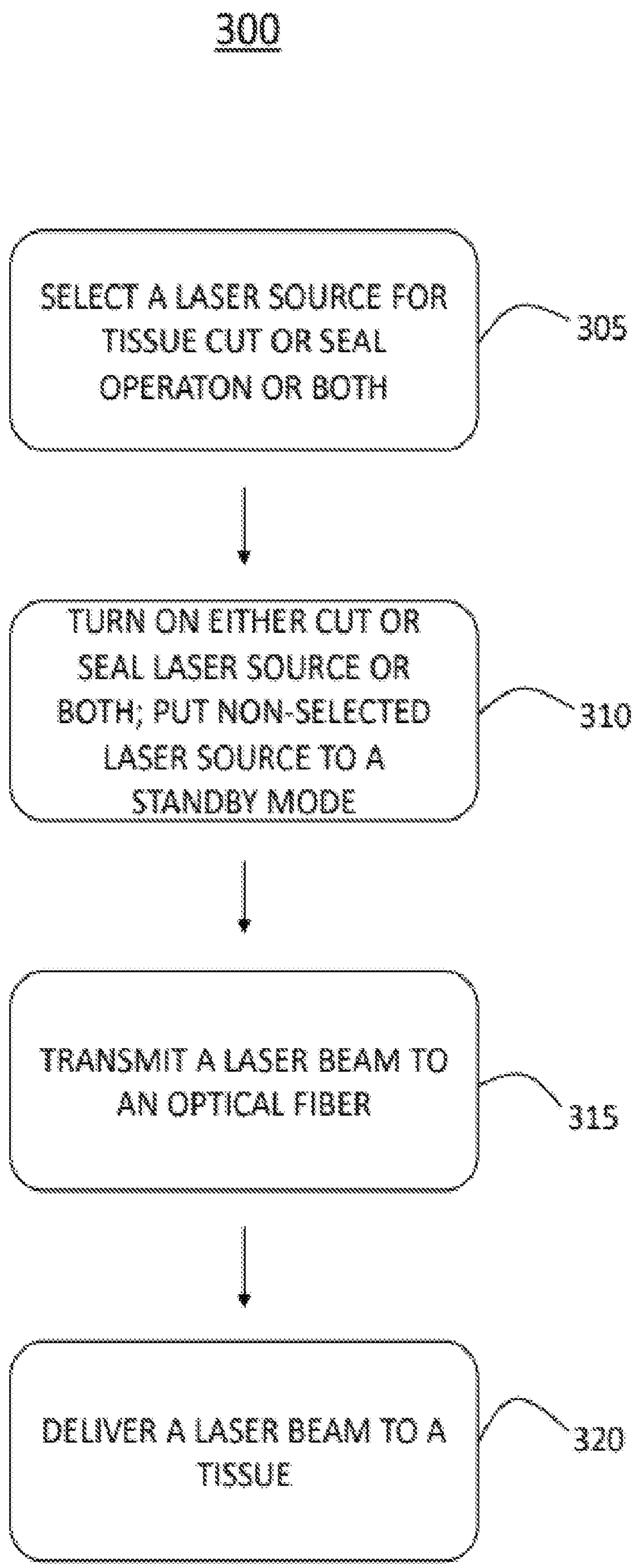
300
SELECT A LASER SOURCE FOR TISSUE CUT OR SEAL OPERATON OR BOTH
305
TURN ON EITHER CUT OR SEAL LASER SOURCE OR BOTH; PUT NON-SELECTED LASER SOURCE TO A STANDBY MODE
310
TRANSMIT A LASER BEAM TO AN OPTICAL FIBER
315
DELIVER A LASER BEAM TO A TISSUE
320

FIG. 10

SMART SURGICAL LASER TISSUE SEALING AND CUTTING APPARATUS WITH OPTICAL FIBER GUIDED SENSORS

CROSS REFERENCE TO RELATED PATENT APPLICATION(S)

[0001] The present disclosure is part of a non-provisional patent application claiming priority benefit of U.S. Provisional Patent Application No. 62/696,857 filed on 12 Jul. 2018, the content of which herein being incorporated by reference in its entirety.

BACKGROUND

Technical Field

[0002] The present disclosure generally relates to the field of medical device and, more particularly, to a tissue sealing and cutting device using laser to perform sealing and cutting of tissues, especially, in general, endoscopic, laparoscopic and robotic surgeries.

Description of the Related Art

[0003] Presently, uncontrollable bleeding during surgery is addressed with electrocauterization devices such as monopolar and bipolar systems based on high electric currents. However, there is an intrinsic risk in the use of electrocauterization devices in an operating room due to exposure of high electric currents to patients and medical staff. As an electric current traverses through the body of a patient when an electrocauterization system is used, whether monopolar or bipolar, electric shock marks or burn marks on the patient (e.g., on the ear) tend to result. For example, monopolar systems can cause thermal injury to surrounding tissues and accidental burns if used incorrectly. One main issue with monopolar devices is the interference with automatic implantable cardioverter defibrillator (AICD) as the monopolar device may trigger accidental shock to the patient. To avoid accidental triggering, the AICD may need to be turned off prior to the use of a monopolar device on the patient. Additionally, the AICD may need to be re-programmed afterwards.

[0004] Moreover, the use of saline solution during surgery tends to be limited when a high electric current system is in use. Further, the use of electrocauterization systems may not be suitable for patients with metal implants.

SUMMARY

[0005] Various embodiments disclosed herein pertain to an apparatus and method for sealing and cutting of tissues during surgeries, especially general, endoscopic, laparoscopic and robotic surgeries. The apparatus comprises a laser system and a laser beam delivery unit. The laser system emits tunable laser beam with a wavelength suitable for sealing and cutting of a soft tissue. The laser beam delivery unit is disposable and is used to guide the laser beam to where tissue sealing and cutting is needed. Areas surrounding the tissue where tissue sealing and cutting occur are cooled by a liquid dispensed from a probe of the laser beam delivery unit. Fiber guided sensors of optical feedback from a photodiode and a pyrometer (or non-contact temperature sensor) detect reflected energy and temperature of a tissue, respectively. Other fiber guided sensors provide a distance measurement and a target probing on a tissue. All these optical fiber and non-optical sensors provide the smart laser system to run at safer and optimum conditions for tissue sealing and cutting operations during surgeries.

[0006] The proposed techniques are further described below in the detailed description. This summary is not intended to identify essential features of the claimed subject matter, nor is it intended for use in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The accompanying drawings are included to provide a further understanding of the disclosure and are incorporated in and constitute a part of the present disclosure. The drawings illustrate embodiments of the disclosure and, together with the description, serve to explain the principles of the disclosure. It is appreciable that the drawings are not necessarily in scale as some components may be shown to be out of proportion than the size in actual implementation in order to clearly illustrate the concept of the present disclosure.

[0008] FIG. **1** is a laser tissue sealing and cutting apparatus in accordance with an embodiment of the present disclosure.

[0009] FIG. **2** is a plan view of the laser tissue sealing and cutting apparatus of FIG. **1** with a detail view of emitting laser beams at the probe end of a laser beam delivery unit.

[0010] FIG. **3** is an enlarged view of the probe end of a laser beam delivery unit of the laser tissue sealing and cutting apparatus of FIG. **1**.

[0011] FIG. **4** shows detachment of a laser beam delivery unit from a laser system of the laser tissue sealing and cutting apparatus of FIG. **1**.

[0012] FIG. **5** shows a laser depth measurement device, which, sensing via optical fibers, is a sensor component of the laser tissue sealing and cutting apparatus of FIG. **1**.

[0013] FIG. **6** shows non-contact temperature sensor such a pyrometer, which, sensing via optical fibers, is a sensor component of the laser tissue sealing and cutting apparatus of FIG. **1**.

[0014] FIG. **7** is a laser tissue sealing and cutting apparatus with two laser sources in accordance with an embodiment of the present disclosure.

[0015] FIG. **8** shows detachment of a laser beam delivery unit from a laser system of the laser tissue sealing and cutting apparatus of FIG. **7**.

[0016] FIG. **9** is a flowchart of a process of tissue sealing and cutting from a single laser source apparatus in accordance with the present disclosure.

[0017] FIG. **10** is a flowchart of a process of tissue sealing and cutting from a dual laser source apparatus in accordance with the present disclosure.

[0018] The following is a listing of numerated components in all figures:

- **[0019]** **10** probe laser
- **[0020]** **11** beam splitter
- **[0021]** **12** beam splitter
- **[0022]** **20** tissue sealing and cutting laser
- **[0023]** **21** optical fiber
- **[0024]** **22** tissue sealing laser
- **[0025]** **23** optical fiber
- **[0026]** **24** tissue cutting laser
- **[0027]** **25** optical fiber
- **[0028]** **30** air tank
- **[0029]** **31** water tank
- **[0030]** **36** tubing for air

[0031] **37** tubing for water

[0032] **40** pyrometer (example of non-contact temperature sensors)

[0033] **41** depth sensor

[0034] **42** photodiode

[0035] **43** guide laser

[0036] **44** temperature sensor

[0037] **45** optical fiber of pyrometer

[0038] **46** optical fiber of depth sensor

[0039] **47** optical fiber of guide laser

[0040] **48** wire of temperature sensor

[0041] **50** laser coupling of tissue cutting beam

[0042] **51** laser coupling of tissue sealing beam

[0043] **55** motor

[0044] **56** switching plate

[0045] **58** optical fiber of laser cutting beam

[0046] **59** optical fiber of laser sealing beam

[0047] **61** fiber coupling of male

[0048] **62** coupling block of male of air and water

[0049] **63** fiber coupling of female

[0050] **64** coupling block of female of air and water

[0051] **66** air tube

[0052] **67** water tube

[0053] **70** fiber optic sheathing

[0054] **75** enclosure

[0055] **76** enclosure

[0056] **78** tissue sample

[0057] **79** tissue sample

[0058] **80** laser beam

[0059] **81** laser beam

[0060] **82** reflected laser beam

[0061] **83** laser beam

[0062] **84** laser beam

[0063] **85** reflected laser beam

[0064] **86** laser beam of sealing

[0065] **87** laser beam of cutting

[0066] **95** optical fiber

[0067] **96** optical fiber

[0068] **99** distance between the distal ends of sealing and cutting optical fibers

[0069] **301** depth sensor via guided optical fibers

[0070] **302** pyrometer via guided optical fibers

[0071] **1001** laser beam delivery unit

[0072] **1002** laser system

[0073] **1003** laser system of two laser sources

[0074] **5001** smart laser tissue sealing and cutting apparatus

[0075] **5002** smart laser tissue sealing and cutting apparatus with two laser sources

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Overview

[0076] During surgeries on a human patient or an animal patient, tissue sealing and cutting is intergraded part of surgical operations that a surgical tool such as electrosurgical units are used to perform tissue sealing and cutting functions. With intrinsic of hazard the electrical current based tissue sealing and cutting of electrosurgical units, the smart laser system replaces for tissue sealing and cutting operations. Its use is more prevalent in laparoscopic and robotic surgeries where grounding is difficult to achieve for electrosurgical units. Metal surgical and probe tools of the laparoscopic and robotic surgery exacerbate the risk factor.

[0077] During a laparoscopic and robotic surgical operation, one of instrument arms may be fitted with a monopolar instrument of the electrosurgical unit. The functions of monopolar instrument are to seal and cut a tissue of the patient. Another electrosurgical unit called bipolar is commonly used to seal a large vessel.

[0078] One way to eliminate the risk from the electrosurgical units is to use non-electrical current based system such as a laser tissue sealing and cutting apparatus described herein. Another non-electrical system commercially available is an ultrasonic based instrument, which is mostly used as a vessel sealer in function similar to the bipolar instrument. During a surgery, the monopolar instrument is a choice of surgical instrument to seal and cut a tissue because electrical grounding is through tissue of an intended area of seal and cut. There are many laser systems being used in the medical field; however, none of them is suitable for use in a laparoscopic and robotic surgery environment to replace the monopolar instrument. Most laser systems do not have a dual function of sealing and cutting. They also do not have a smart sensing system to monitor tissue conditions and prevent thermal damages during tissue seal and cut operations.

[0079] A laser system to replace the monopolar instrument in laparoscopic and robotic surgeries requires a dual function of tissue seal and cut. When the tissue is being sealed or cut, the laser system described herein switches to a tissue seal or cut function, respectively. Switching to a seal or cut state is executed mechanically by a motor and a switching plate in the laser system. Another way that it can be done is optically with a motor and a mirror. Another laser system described herein is two laser sources without a switching mechanism. One laser source provides sealing power, and the other provides cutting power. When the tissue is being sealed or cut, one laser source turns on, and the other goes to a standby mode. For a single laser source with a switching mechanism, the laser source consists of diode pumped or Nd:YAG laser. For a dual laser source, diode pumped or Nd:YAG laser is used for sealing, and Nd:YAG, Ho:YAG or Er:YAG laser is used for cutting. All laser sources are in a power range of 20 to 120 watt.

[0080] When laser light interacts with human tissue, there may be many issues related to burning of the tissue, and it is difficult to detect by untrained medical doctor or hospital staff. One way to reduce the risk of unwanted tissue burning using any laser interacting with human tissue is to develop a laser sensing system that will self-control the laser interaction process to prevent tissue burning. In order to achieve the self-controlled laser interaction with human tissue, a novel laser sensing system is provided herein.

[0081] The combination of the laser pulse modulation of the tissue sealing laser source **20** and photodiode **42** provides a closed-loop feedback system to prevent the emission of any excess laser energy to prevent burning of the tissue. The closed-loop feedback system also prevents under delivery of the laser energy to result in premature termination of tissue sealing or tissue cutting procedure.

[0082] Referring FIG. **1**, the laser beam delivery unit **1001** is a single use and disposable. Its purpose is to deliver laser beams to a tissue and send reflected laser beams back to sensor receivers in the laser system. The outer sheath of the laser beam delivery unit holds all fiber optic assemblies together in bundle. The laser beam delivery unit contains at least two optical fibers, one for laser sealing and the other for laser cutting. Optical fiber guided sensors presented herein are a pyrometer (or non-contact temperature sensor), depth sensor, spectral sensor and guide laser. A non-contact temperature sensor such as pyrometer detects tissue temperature via an optical fiber. A depth sensor measures a distance between the probing end of an optical fiber and a tissue. The distance measurement is performed technologies based on the time of flight or triangulation via an optical fiber. A spectral sensor is used to perform multi spectrum analysis to detect and determine tissue and cell types via an optical fiber. A guide laser is used as a laser pointer to where a tissue is targeted for sealing and cutting. It may be also used as a probing laser for the optical feedback sensing technology. In addition, water and air tanks are installed for irrigation. If air and water line infrastructure are available, they will be directed hook up to the infrastructure. A temperature sensor of thermocouple or resistance temperature detector is installed in the laser system.

[0083] FIG. **1** illustrates a smart laser tissue sealing and cutting apparatus **5001** in accordance with an embodiment of the present disclosure. In the laser tissue sealing and cutting apparatus **5001**, the laser source **20**, Nd:YAG or diode pumped laser, is used for operations of sealing and cutting of a tissue. Switching to a seal or cut state is executed mechanically by the motor **55** and the switching plate **56** in the laser system **1002**. When the tissue is being cut, the motor **55** rotates and aligns the laser coupling **50** to the laser output fiber **21**. The laser beam **84** is delivered to the laser coupling **50** and transmitted via the optical fiber **58** to the distal end for tissue cutting operation. When the tissue is being sealed, the motor **55** rotates and aligns the laser coupling **51** to the laser output fiber **21**. The laser beam **84** is delivered to the laser coupling **51** and transmitted via the optical fiber **59** to the distal end for tissue sealing operation. A switching operation shown here is an example of a mechanical switching. The switching can be done optically as well with a motor and a mirror.

[0084] FIG. **7** illustrates another tissue sealing and cutting apparatus **5002** with two laser sources **22** and **24** in accordance with an embodiment of the present disclosure. The laser system **5002** contains two laser sources **22** and **24** and no switching mechanism. One laser source **22** provides sealing power, and the other **24** provides cutting power. When the tissue is being sealed, the laser source **22** turns on and the other **24** goes to a standby mode. Then, the laser beam **86** is delivered to the laser coupling **51** and transmitted via the optical fiber **59** to the distal end for tissue sealing operation. When the tissue is being cut, the laser source **24** turns on and the laser source **22** goes to a standby mode. Then, the laser beam **87** is delivered to the laser coupling **50** and transmitted via the optical fiber **58** to the distal end for tissue cutting operation. The seal and cut operations can be performed simultaneously, turning on both the laser source **22** and **24** at the same time. The laser source **20** uses diode pumped or Nd:YAG laser for tissue sealing and cutting. The laser source **22**, which is used for sealing, uses diode pumped or Nd:YAG laser. For the laser source **24**, it uses Nd:YAG, Ho:YAG or Er:YAG laser. All laser sources are configured to deliver a high-power laser beam in CW or pulse-mode to deliver 20 to 120 watts of laser power into a given tissue volume.

[0085] At the distal end of fiber, the distance **99** defines a height difference between tissue sealing and cutting operations away from a tissue. The tissue cutting is operated at a distance between the tissue level and 100 mm away from the tissue. The tissue sealing is operated at a distance between 5 mm and 200 mm away from a tissue. Laser power and/or laser frequency modulation (CW or pulsed) is provided different for laser tissue cutting and sealing operations. The distal end of the cutting optical fiber **58** is coated with an optical coating such as antireflective, high-reflector, dielectric and/or Teflon to supplant precarbonization of the cutting fiber tip prior to cutting operation.

[0086] The photodiode **42** and probe laser **10** may be used for the optical feedback technology for sensing tissue conditions and preventing tissue damages. Optical fiber guided sensors, pyrometer **40**, depth sensor **41**, spectral sensor and guide laser **43**, are presented herein. Fiber optics are used to transmit light energy over long distances. Optical fibers are made of optical quality glass or plastic that are in a diametric range of between 0.1 and 2 mm. In photoelectric sensing, these fibers are used to transmit and/or receive light from an emitter such as a LED or laser diode of a sensor. The pyrometer **40** sends the laser beam **83** from an emitter to a tissue via the optical fiber **45**. The reflected beam **85** off from the tissue **78** is transmitted back to a receiver in the pyrometer **40** through the optical fiber **95**. A returned signal provides temperature information of tissue. The depth sensor **41** sends the laser beam **81** from an emitter to a tissue via the optical fiber **46**. The reflected beam **82** off from the tissue **79** is transmitted back to a receiver in the depth sensor **41** through the optical fiber **96**. A returned signal provides distance information of the optical fiber **81** away from the tissue **79**. A depth distance off from the tissue **79** is measured by means of a triangulation or time of flight method. The guide laser **43** sends a laser beam from an emitter to a tissue via the optical fiber **47**. The guide laser beam is used as a laser pointer to illuminate an area where tissue sealing, cutting and sensing are performed. Its reflected laser beam from the tissue may be used as an optical feedback signal of the photodiode **42**. The wavelength of the guide laser **43** is in a visible range of light with a color of green, red or blue. A spectral sensor for multi spectrum analysis works like the pyrometer **40** and depth sensor **41**.

[0087] Two non-optical fiber probes are presented herein. The temperature sensor **44** measures temperatures of the tissue by thermocouple **48** or resistance temperature detection. The air tank **30** and water tank **31** provide air and water via tubing **36** and **37**, respectively. The air tank **30** and water tank **31** may not need if water and air lines are provided from a building infrastructure.

[0088] Referring to FIG. **1**, the smart tissue sealing and cutting apparatus **5001** utilizes temperatures and data from optical fiber probe sensors and calculates an optimum tissue cutting and sealing time and power level using a CPU in the system. In addition, feedback control data from the photodiode **42** provide energy level information. The smart laser sensing method and laser modulation techniques provide the laser system to achieve safer and effective tissue sealing and cutting for any type of medical procedure.

[0089] The use of the smart laser sensing system, e.g., the tissue sealing and cutting apparatus **5001**, is to minimize any uncertainty of medical procedure, by using a closed loop feedback system. Many medical devices failed on over-delivery of too much energy by means of RF power, electrical power or ultrasonic energy. In contrast, the tissue sealing and cutting apparatus **5001** is designed with a precision control of delivered laser energy by pulse modulation and smart sensing techniques to overcome most issues encountered by conventional devices and approaches.

[0090] The laser tissue sealing and cutting apparatus **5001** includes at least three unique inventive concepts. Firstly, the tissue sealing and cutting apparatus **5001** and **5002** performs both tissue sealing and cutting operations. The single laser source unit **5001** modulates tissue sealing and cutting by the laser source **20** and switch plate **56**. The dual laser source unit **5002** operates tissue sealing and cutting from two laser sources **22** and **24**, respectively. Both laser sources **22** and **24** can be operated simultaneously.

[0091] Secondly, the laser beam delivery unit **1001** is a single use and disposable, which is a requirement of most surgical devices. Referring to FIGS. **4** and **8**, the laser beam delivery unit **1001** is detached from the laser system **1002** and **1003**. The fiber optic coupling is made from the male coupler **61** and the female coupler **63**.

[0092] Thirdly, the tissue sealing and cutting apparatus **5001** includes optical fiber guided sensors, pyrometer **40**, depth sensor **41**, spectral sensor and guide laser **43**. These sensors are operated normally without use of optical fibers. The use of optical fibers allows sensing to be performed in an inaccessible area. Measurements from all these optical sensors are critical to an overall energy distribution calculation for algorithm development and tissue/cell type detections.

[0093] Fourthly, the distal end of the laser cutting optical fiber **58** is coated with an optical coating such as antireflective, high-reflector, dielectric and Teflon. The purpose of the optical coating is to supplant precarbonization of the cutting tip prior to laser cutting operation. Normally, precarbonization of the cutting tip is performed on a sterile cork or wooden spatula prior to cutting operation. The laser beam delivery unit **1001** may be supplied with the standard precarbonization of the sterile cork already performed. The precarbonization only applies to diode pumped and Nd:YAG laser in a laser cutting operation.

[0094] Various embodiments disclosed herein pertain to an apparatus and method for sealing and cutting of tissue during general, endoscopic, laparoscopic and robotic surgeries. The apparatus comprises a laser system and a laser beam delivery unit. The laser system emits tunable laser beam with a wavelength suitable for sealing and cutting of a soft tissue. The laser beam delivery unit is disposable and is used to guide the laser beam to where tissue sealing and cutting is needed. The optical feedback and sensing technologies provide a safe and effective energy delivery method to perform tissue sealing and cutting. The smart laser tissue sealing and cutting apparatus **5001** and **5002** could supplant the current monopolar electrosurgical device, which possesses an electric shock hazard.

[0095] Therefore, an apparatus in accordance with the present disclosure provides a number of advantages over electrosurgical devices and other existing approaches. The advantageous include, but are not limited to, the following:

[0096] (1) a laser system with tissue sealing and cutting capabilities;

[0097] (2) a single use and disposable laser beam delivery unit;

[0098] (3) an optical feedback sensing technology using a photodiode sensor via an optical fiber;

[0099] (4) tissue temperature data acquisition with non-contact temperature sensor such a pyrometer via optical fibers;

[0100] (5) depth distance data acquisition with a depth sensor via optical fibers;

[0101] (6) multi spectrum analysis using a spectral sensor via optical fibers;

[0102] (7) a guide laser functioned as a laser pointer and target illumination via an optical fiber;

[0103] (8) the cutting tip precarbonization prior to laser cut operation in a single laser system.

[0104] (9) a smart laser system utilizing above sensor data for algorithm development and tissue/cell type detection.

Illustrative Implementations

[0105] FIG. **1** illustrates a tissue sealing and cutting apparatus **5001** in accordance with an embodiment of the present disclosure. FIG. **2** is a plan view of the tissue sealing and cutting apparatus **5001**. FIG. **3** is an enlarged view of a probe tip of the tissue sealing and cutting apparatus **5001**. FIG. **4** is a detachment of the laser beam delivery unit from the laser system. The following description refers to FIGS. **1-4**.

[0106] As shown in FIG. **1**, apparatus **5001** may comprise a laser system **1002** and a laser beam delivery unit **1001**. The laser system **1002** may comprise the laser source **20** that is configured to emit a laser beam suitable for cutting to the laser coupling **50**, which transmits the beam through the optical fiber **58**. When tissue is being sealed, the motor **55** rotates the switchable plate **56** to align the laser coupling **51** to the laser output fiber **21** for tissue sealing operation. The laser beam **84** tuned for sealing power and frequency is delivered to the laser coupling **51** and transmitted via the optical fiber **59** to a tissue for sealing operation. When tissue is being cut, the motor **55** rotates the switchable plate **56** to align the laser coupling **50** to the laser output fiber **21** for tissue cut operation. The laser beam **84** tuned for cutting power and frequency is delivered to the laser coupling **50** and transmitted via the optical fiber **58** to a tissue for cutting operation. A switching operation shown here is an example of a mechanical switching. The switching can be done optically as well with a motor and a mirror. Detachment of the laser beam delivery unit **1001** from the laser system **1002** occurs at the mechanical coupling port **61** and **63** for optical fibers and the mechanical coupling block **62** and **64** for water and air lines. The laser beam delivery unit **1001** is a single use such that after each use it may be disposed of while the laser system **1002** is made to be re-used and serviceable.

[0107] FIG. **7** illustrates another tissue sealing and cutting apparatus **5002** with two laser sources **22** and **24** in accordance with an embodiment of the present disclosure. FIG. **8** is a plan view of the tissue sealing and cutting apparatus **5002** with the laser beam delivery **1001** detached. The following description refers to FIGS. **7** and **8**.

[0108] The tissue sealing and cutting apparatus **5002** contains two laser sources **22** and **24** and no switching mechanism. The laser source **22** provides sealing power, and the other laser source **24** provides cutting power. When the tissue is being sealed, the laser source **22** turns on and the other **24** goes to a standby mode. The laser beam **86** is delivered to the laser coupling **51** and transmitted via an optical fiber **59** to a tissue for sealing operation. When the tissue is being cut, the laser source **24** turns on and the laser source **22** goes to a standby mode. The laser beam **87** is delivered to the laser coupling **50** and transmitted via the optical fiber **58** to a tissue for cutting operation. Both laser source **22** and **24** can be operated simultaneously.

[0109] In one embodiment, at least one parameter of the laser beam **84** may be tunable for cutting or sealing. For example, a frequency of the laser beam **84**, a power level of the laser beam **84**, or a combination thereof, may be tunable.

[0110] In one embodiment, the laser beam **84** may be tunable to be suitable for sealing or cutting a tissue. For example, the laser unit **20** may be configured such that the laser beam **84** is tunable to a suitable wavelength and/or power level and/or pulsing frequency for the laser beam to seal or cut tissue. In other words, apparatus **5001** may be dual-functional in that it is not only configured to seal tissue but also cut tissue for surgical purposes.

[0111] In one embodiment, the laser source **20**, **22**, **24** may comprise a solid state laser, a fiber laser, or a combination thereof. In other embodiments, the laser unit **20** may comprise Nd:YAG, diode pumped laser or a combination thereof. The laser source **24** comprises Nd:YAG, diode pumped laser or a combination thereof. The laser source **22** comprises Nd:YAG, Er:YAG, Ho:YAG laser or a combination thereof.

[0112] In one embodiment, the laser source **20** may emit the laser beam **84** in a pulsed mode.

[0113] In one embodiment, the laser beam delivery unit **1001** may comprise at least one cutting **58** and one sealing **59** optical fibers. The outer sheathing **70** contains 3 to 16 optical fibers of glass and plastic.

[0114] In one embodiment, the combination of the laser pulse modulation of the photodiode **42** and probing laser **10** provides a closed-loop feedback system to prevent the emission of any excess laser energy to prevent burning of the tissue. The closed-loop feedback system also prevents under delivery of the laser energy to result in premature termination of tissue sealing or cutting procedure. The combination of laser pulse modulation and smart sensing techniques of the present disclosure provides a laser tissue sealing and cutting device, e.g., the apparatus **5001**, to minimize interference with medical doctor and staff to thereby improve laser tissue sealing and cutting technique.

[0115] In one embodiment, the laser beam delivery unit **1001** may comprise the depth sensor **41** to measure a distance between the distal end of the optical fiber **46** and the tissue **79**. According to FIG. **5**, the depth sensor **41** emits the laser beam **81** to the tissue **79** via the optical fiber **46**. The reflected laser beam **82** is transmitted through the optical fiber **96** to a receiver in the depth sensor **41**. The method of detection is based on the triangulation or time of flight technology.

[0116] In one embodiment, the laser beam delivery unit **1001** may comprise the pyrometer **40** for remote tissue temperature detection. According to FIG. **6**, the pyrometer **40** emits the laser beam **83** to the tissue **78** via the optical fiber **45**. The reflected laser beam **85** is transmitted through the optical fiber **95** to a receiver in the pyrometer **40**.

[0117] In one embodiment, the laser beam delivery unit **1001** may further comprise the guide laser **43** for a laser beam target illumination. This also could be a signal laser beam for the optical feedback technology.

[0118] In one embodiment, the laser beam delivery unit **1001** may further comprise the temperature sensor **44** to measure temperatures of the tissue via the temperature sensor wire **48**. The temperature detection is based on the thermocouple or resistance temperature detection.

[0119] In one embodiment, the laser beam delivery unit **1001** may further comprise one air and one water dispensing tube of **66** and **67**, respectively.

[0120] In one embodiment, the laser system **1002** may further comprise one air and one water tank of **30** and **31**, respectively.

Illustrative Operations

[0121] FIG. **2** shows laser beams at the probe tip of the tissue sealing and cutting apparatus **5001**. Optical fibers are used to transmit laser signal beams to tissue and reflected laser beams back to detectors in the laser system **1002**.

[0122] As shown in FIG. **5**, the laser signal beam **81** and reflected laser beam **82** of the depth sensor **41**. The reflected laser beam **82**, which is the laser signal beam **81** reflected off from the tissue **79**, returns to a receiver in the depth sensor **41** via the optical fiber **96**.

[0123] As shown in FIG. **6**, the laser signal beam **83** and reflected laser beam **84** of the pyrometer **40**. The reflected laser beam **84**, which is the laser signal beam **83** reflected off from the tissue **78**, returns to a receiver in the pyrometer **40** via the optical fiber **95**.

Illustrative Processes

[0124] FIG. **9** illustrates a process **200** of sealing and cutting a tissue with an apparatus in accordance with the present disclosure.

[0125] Example process **200** includes one or more operations, actions, or functions as illustrated by one or more of blocks **205**, **210**, **215** and **220**. Although illustrated as discrete blocks, various blocks may be divided into additional blocks, combined into fewer blocks, or eliminated, depending on the desired implementation. Further, process **200** may be implemented using apparatus **5001**. For illustrative purposes, the operations described below are performed by medical personnel using apparatus **5001**. Process **200** may begin at block **205**.

[0126] At **205**, process **200** may comprise selecting a laser source for tissue seal or cut. For example, the laser source **20** may be configured for tissue sealing or cutting.

[0127] At **210**, process **200** may comprise aligning a laser source to a laser coupling via a switchable mechanism. For example, the alignment of the fiber coupling **50** or **51** to the laser beam **84** of the laser source **20** is done by the switchable plate **56** and the motor **55**.

[0128] At **215**, process **200** may comprise delivering a laser beam to an optical fiber. For example, the laser beam **84** may be transmitted to a tissue via the optical fiber **58** or **59**.

[0129] At **220**, process **200** may comprise delivering a laser beam to a tissue for a sealing or cutting operation. For example, the laser beam **84** is delivered onto a tissue.

[0130] FIG. **10** illustrates a process **300** of sealing and cutting a tissue with an apparatus in accordance with the present disclosure.

[0131] Example process **300** includes one or more operations, actions, or functions as illustrated by one or more of blocks **305**, **310**, **315** and **320**. Although illustrated as discrete blocks, various blocks may be divided into additional blocks, combined into fewer blocks, or eliminated, depending on the desired implementation. Further, process **300** may be implemented using apparatus **5002**. For illustrative purposes, the operations described below are performed by medical personnel using apparatus **5002**. Process **300** may begin at block **305**.

[0132] At **305**, process **300** may comprise selecting a laser source for tissue sealing, cutting or both. For example, the laser source **22** or **24** may be selected for tissue sealing and cutting, respectively. Or both laser source **22** and **24** may be selected for tissue sealing and cutting operations simultaneously.

[0133] At **310**, process **300** may comprise turning on of either laser cut, seal or both sources. One that isn't selected goes to a standby mode. For example, the laser source **24** may turn on for tissue cutting and the laser source **22** goes to a standby mode. Or both laser source **22** and **24** may be selected for tissue sealing and cutting operations simultaneously, and no laser goes to a standby mode.

[0134] At **315**, process **300** may comprise delivering a laser beam to an optical fiber. For example, the laser beam **87** may be transmitted to a tissue via the optical fiber **58** for tissue cutting.

[0135] At **320**, process **300** may comprise delivering a laser beam to a tissue for sealing, cutting and both operations. For example, the laser beam **87** is delivered onto a tissue for cutting.

[0136] In one embodiment, process **300** may have both laser sources **22** and **24** turn on for tissue sealing and cutting simultaneously.

Feature Highlights

[0137] In view of the above, select features of various embodiments of the present disclosure are highlighted below.

[0138] In one aspect, an apparatus may include a laser system configured to emit one or more laser beams suitable for sealing and cutting a tissue. The apparatus may also include a laser beam delivery unit detachably coupled to the laser system, the laser beam delivery unit configured to guide and direct the one or more laser beams to seal and cut the tissue.

[0139] In some implementations, the laser beam delivery unit may be configured for single use and is disposable.

[0140] In some implementations, the laser system may include a single laser source with a mechanically or optically switchable mechanism to deliver the laser beam to different optical fibers to perform tissue cutting and sealing.

[0141] In some implementations, the laser system may include two laser sources that provide a first laser beam to a first optical fiber for sealing and a second laser beam to a second optical fiber for cutting. In some implementations, the laser sources may include a Nd:YAG or diode pumped laser to provide the first laser beam for tissue sealing. Alternatively, the laser sources may include a Nd:YAG, Er:YAG, Ho:YAG or diode pumped laser to provide the second laser beam for tissue cutting. In some implementations, the laser sources may operate in a power range between 20 watts and 120 watts.

[0142] In some implementations, the laser system may be configured to perform tissue cutting at a distance up to 100 mm away from the tissue.

[0143] In some implementations, a distal end of a tissue cutting optical fiber of the laser beam delivery unit may be coated with an optical coating comprising antireflective, high-reflector, dielectric, Teflon, or a combination thereof.

[0144] In some implementations, the laser system may be configured to perform tissue sealing at a distance between 5 mm and 200 mm away from the tissue.

[0145] In some implementations, the laser system may be configured to automatically switch between a tissue sealing function from a tissue cutting function.

[0146] In some implementations, the laser system may be configured to perform a tissue sealing function and a tissue cutting function simultaneously.

[0147] In some implementations, the laser system may further include a sensor. In such cases, the laser beam delivery unit may include a fiber optic bundle coupled to the laser system, the fiber optic bundle comprising a plurality of optical fibers configured to function as a delivery guide for the one or more laser beams for the sealing and cutting of the tissue and to transmit one or more sensor signals such that at least one reflected laser beam from the tissue is provided as an optical feedback to the sensor of the laser system via the fiber optic bundle.

[0148] In some implementations, the sensor may include a photodiode sensor configured to detect an energy level of the at least one reflected laser beam.

[0149] In some implementations, the laser system may further include a non-contact temperature sensor configured to detect a temperature of the tissue using a signal transmitted by the fiber optic bundle.

[0150] In some implementations, the non-contact temperature sensor may include a pyrometer.

[0151] In some implementations, the sensor may include a depth sensor, which operates based on a time-of-flight technology, that is configured to detect a distance of a distal end of an optical fiber of the fiber optic bundle away from the tissue using a signal transmitted by the fiber optic bundle.

[0152] In some implementations, the sensor may include a spectral sensor configured to perform multi-spectrum analysis to detect and determine a tissue type and a cell type of the tissue using a signal transmitted by the fiber optic bundle.

[0153] In some implementations, the sensor may include a guide laser configured to deliver one of the one or more laser beams via an optical fiber of the fiber optic bundle to illuminate a location where sealing or cutting occurs on the tissue.

[0154] In another aspect, an apparatus may include a laser system configured to emit one or more laser beams suitable for sealing and cutting a tissue. The apparatus may also include a laser beam delivery unit detachably coupled to the laser system. The laser beam delivery unit may be configured to guide and direct the one or more laser beams to seal and cut the tissue. The laser beam delivery unit may include a fiber optic bundle coupled to the laser system. The fiber optic bundle may include a plurality of optical fibers configured to function as a delivery guide for the one or more laser beams for the sealing and cutting of the tissue and to transmit one or more sensor signals such that at least one reflected laser beam from the tissue is provided as an optical feedback to the laser system via the fiber optic bundle. In some implementations, the laser system may also include one or more of the following: (a) a sensor configured to detect an energy level of the at least one reflected laser beam; (b) a non-contact temperature sensor configured to detect a temperature of the tissue using one of the one or more sensor signals transmitted by the fiber optic bundle; (c) a depth sensor configured to detect a distance of a distal end of an optical fiber of the fiber optic bundle away from the tissue using one of the one or more sensor signals transmitted by the fiber optic bundle; (d) a spectral sensor configured to perform multi-spectrum analysis to detect and determine a tissue type and a cell type of the tissue using one of the one or more sensor signals transmitted by the fiber optic bundle; and (e) a guide laser configured to deliver one of the one or more laser beams via an optical fiber of the fiber optic bundle to illuminate a location where sealing or cutting occurs on the tissue.

Additional and Alternative Implementation Notes

[0155] The above-described embodiments and techniques pertain to an apparatus and method for sealing and cutting of tissue during surgeries, especially in laparoscopic and robotic. Although the techniques have been described in language specific to certain applications, it is to be understood that the appended claims are not necessarily limited to the specific features or applications described herein. Rather, the specific features and applications are disclosed as example forms of implementing such techniques.

[0156] In the above description of example implementations, for purposes of explanation, specific numbers, materials configurations, and other details are set forth in order to better explain the invention, as claimed. However, it will be apparent to one skilled in the art that the claimed invention may be practiced using different details than the example ones described herein. In other instances, well-known features are omitted or simplified to clarify the description of the example implementations.

[0157] The described embodiments are intended to be primarily examples. The described embodiments are not meant to limit the scope of the appended claims. Rather, the claimed invention might also be embodied and implemented in other ways, in conjunction with other present or future technologies.

[0158] Moreover, the word "example" is used herein to mean serving as an example, instance, or illustration. Any aspect or design described herein as "example" is not necessarily to be construed as preferred or advantageous over other aspects or designs. Rather, use of the word example is intended to present concepts and techniques in a concrete fashion. The term "techniques," for instance, may refer to one or more devices, apparatuses, systems, methods, articles of manufacture, and/or computer-readable instructions as indicated by the context described herein.

[0159] As used in this application, the term "or" is intended to mean an inclusive "or" rather than an exclusive "or." That is, unless specified otherwise or clear from context, "X employs A or B" is intended to mean any of the natural inclusive permutations. That is, if X employs A; X employs B; or X employs both A and B, then "X employs A or B" is satisfied under any of the foregoing instances. In addition, the articles "a" and "an" as used in this application and the appended claims should generally be construed to mean "one or more," unless specified otherwise or clear from context to be directed to a singular form.

What is claimed is:

1. An apparatus, comprising:

a laser system configured to emit one or more laser beams suitable for sealing and cutting a tissue; and

a laser beam delivery unit detachably coupled to the laser system, the laser beam delivery unit configured to guide and direct the one or more laser beams to seal and cut the tissue.

2. The apparatus of claim **1**, wherein the laser beam delivery unit is configured for single use and is disposable.

3. The apparatus of claim **1**, wherein the laser system comprises a single laser source with a mechanically or optically switchable mechanism to deliver the laser beam to different optical fibers to perform tissue cutting and sealing.

4. The apparatus of claim **1**, wherein the laser system comprises two laser sources that provide a first laser beam to a first optical fiber for sealing and a second laser beam to a second optical fiber for cutting.

5. The apparatus of claim **4**, wherein the laser sources comprise a Nd:YAG or diode pumped laser to provide the first laser beam for tissue sealing.

6. The apparatus of claim **4**, wherein the laser sources comprise a Nd:YAG, Er:YAG, Ho:YAG or diode pumped laser to provide the second laser beam for tissue cutting.

7. The apparatus of claim **4**, wherein the laser sources operate in a power range between 20 watts and 120 watts.

8. The apparatus of claim **1**, wherein the laser system is configured to perform tissue cutting at a distance up to 100 mm away from the tissue.

9. The apparatus of claim **1**, wherein a distal end of a tissue cutting optical fiber of the laser beam delivery unit is coated with an optical coating comprising antireflective, high-reflector, dielectric, Teflon, or a combination thereof.

10. The apparatus of claim **1**, wherein the laser system is configured to perform tissue sealing at a distance between 5 mm and 200 mm away from the tissue.

11. The apparatus of claim **1**, wherein the laser system is configured to automatically switch between a tissue sealing function from a tissue cutting function.

12. The apparatus of claim **1**, wherein the laser system is configured to perform a tissue sealing function and a tissue cutting function simultaneously.

13. The apparatus of claim **1**, wherein the laser system further comprises a sensor, and wherein the laser beam delivery unit comprises a fiber optic bundle coupled to the laser system, the fiber optic bundle comprising a plurality of optical fibers configured to function as a delivery guide for the one or more laser beams for the sealing and cutting of the tissue and to transmit one or more sensor signals such that at least one reflected laser beam from the tissue is provided as an optical feedback to the sensor of the laser system via the fiber optic bundle.

14. The apparatus of claim **13**, wherein the sensor comprises a photodiode sensor configured to detect an energy level of the at least one reflected laser beam.

15. The apparatus of claim **13**, wherein the laser system further comprises a non-contact temperature sensor configured to detect a temperature of the tissue using a signal transmitted by the fiber optic bundle.

16. The apparatus of claim **15**, wherein the non-contact temperature sensor comprises a pyrometer.

17. The apparatus of claim **13**, wherein the laser system further comprises a depth sensor, which operates based on a time-of-flight technology, that is configured to detect a distance of a distal end of an optical fiber of the fiber optic bundle away from the tissue using a signal transmitted by the fiber optic bundle.

18. The apparatus of claim **13**, wherein the laser system further comprises a spectral sensor configured to perform multi-spectrum analysis to detect and determine a tissue type and a cell type of the tissue using a signal transmitted by the fiber optic bundle.

19. The apparatus of claim **13**, wherein the laser system further comprises a guide laser configured to deliver one of the one or more laser beams via an optical fiber of the fiber optic bundle to illuminate a location where sealing or cutting occurs on the tissue.

20. An apparatus, comprising:

a laser system configured to emit one or more laser beams suitable for sealing and cutting a tissue; and

a laser beam delivery unit detachably coupled to the laser system, the laser beam delivery unit configured to guide and direct the one or more laser beams to seal and cut the tissue, the laser beam delivery unit comprising a fiber optic bundle coupled to the laser system, the fiber optic bundle comprising a plurality of optical fibers configured to function as a delivery guide for the one or more laser beams for the sealing and cutting of the tissue and to transmit one or more sensor signals such that at least one reflected laser beam from the tissue is provided as an optical feedback to the laser system via the fiber optic bundle,

wherein the laser system further comprises one or more of:

a sensor configured to detect an energy level of the at least one reflected laser beam;

a non-contact temperature sensor configured to detect a temperature of the tissue using one of the one or more sensor signals transmitted by the fiber optic bundle;

a depth sensor configured to detect a distance of a distal end of an optical fiber of the fiber optic bundle away from the tissue using one of the one or more sensor signals transmitted by the fiber optic bundle;

a spectral sensor configured to perform multi-spectrum analysis to detect and determine a tissue type and a cell type of the tissue using one of the one or more sensor signals transmitted by the fiber optic bundle; and

a guide laser configured to deliver one of the one or more laser beams via an optical fiber of the fiber optic bundle to illuminate a location where sealing or cutting occurs on the tissue.

* * * * *

专利名称(译)	带有光纤导引传感器的智能手术激光组织密封和切割设备
公开(公告)号	US20200015892A1	公开(公告)日	2020-01-16
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[标]申请(专利权)人(译)	KIM JAY EUNJAE
申请(专利权)人(译)	KIM，JAY EUNJAE
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CPC分类号	A61B2018/1253 A61B18/14 A61B2018/0063 A61B2017/00477 A61B2018/00601 A61B18/1206 A61B2018/2205 A61B18/22 A61B2018/126 A61B2018/00595 A61B34/30 A61B2017/00061 A61B2017/00066 A61B2017/0007 A61B2018/00642 A61B2018/00785 A61B2018/00791 A61B2018/00815 A61B2018/00821 A61B2018/2025 A61B2018/207 A61B2018/208 A61B2018/2211 A61B2018/2233 A61B2018/2244 A61B2090/061
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摘要(译)

描述了用于在手术期间特别是通常在内窥镜，腹腔镜和机器人的过程中密封和切割组织的设备和方法的实施例。 在一个方面，一种设备包括激光系统和激光束输送单元。 激光单元被配置为发射适合于组织密封和切割的激光束。 激光束传输单元可拆卸地耦合到激光单元，并且被配置为引导和引导激光束以密封和切割组织。 本文所述的光纤引导传感器的使用进一步增强了设备的安全性和有效性。