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HOARAU et al.

(54) **OPTICAL HYDROLOGY ARRAYS AND SYSTEM AND METHOD FOR MONITORING WATER DISPLACEMENT DURING TREATMENT OF PATIENT TISSUE**

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

(72) Inventors: **Carine HOARAU**, Lafayette, CA (US); **Ronald J. PODHAJSKY**, Boulder, CO (US)

(73) Assignee: **COVIDIEN LP**, Mansfield, MA (US)

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Publication Classification

(51) **Int. Cl.**

A61B 5/00	(2006.01)
A61B 18/12	(2006.01)

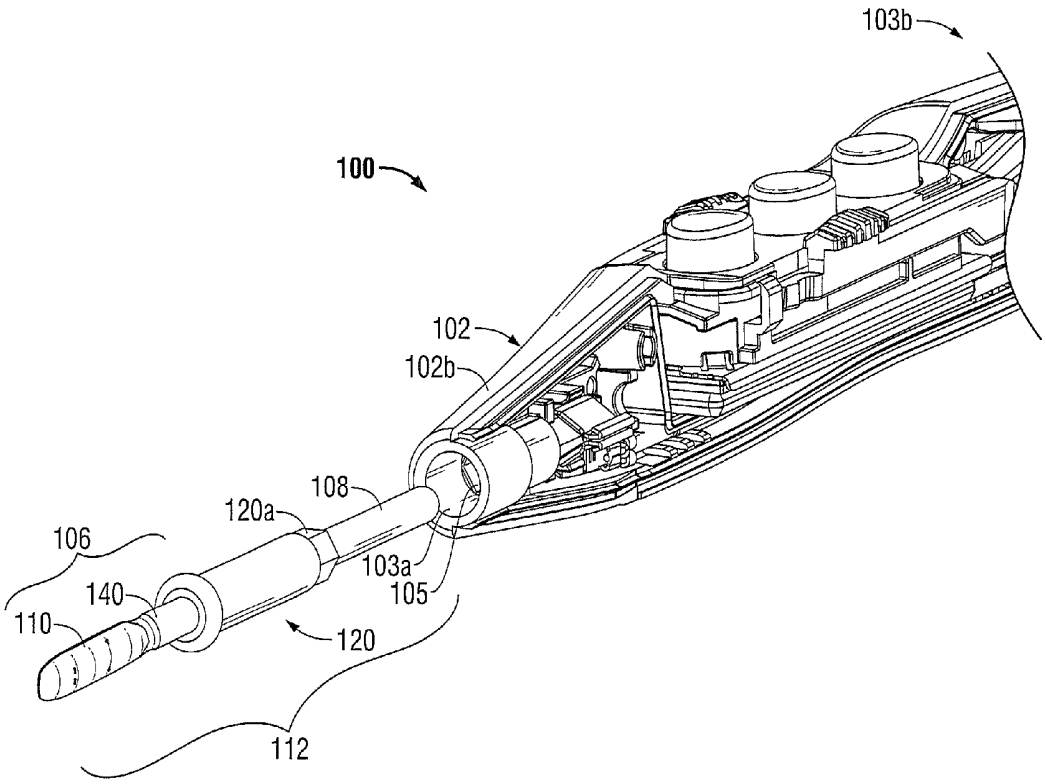
(52) **U.S. Cl.**

CPC ***A61B 5/4875*** (2013.01); ***A61B 18/12*** (2013.01); ***A61B 5/0084*** (2013.01); ***A61B 5/0075*** (2013.01)

USPC **600/342**; 606/41; 600/310

(57) **ABSTRACT**

A system that monitors water displacement in tissue during patient therapy includes a generator supplying electrosurgical energy to tissue, a spectrometer operably coupled to the generator, and a processor communicating with the generator and with the spectrometer having a light source for exposing tissue to light and a light sensor. The light sensor is configured to sense changes in light through tissue in response to tissue treatment and communicate the changes to the processor to determine tissue hydration levels and motility. A plurality of optical fibers may be configured in an array to communicate light between the generator and tissue. An optical temperature monitor may communicate with the processor and be coupled to an optical fiber. The optical fibers may have an optic fiber distance between adjacent optical fibers. The system may be incorporated within an electrosurgical pencil or a forceps. A corresponding method of detecting hydration is also disclosed.



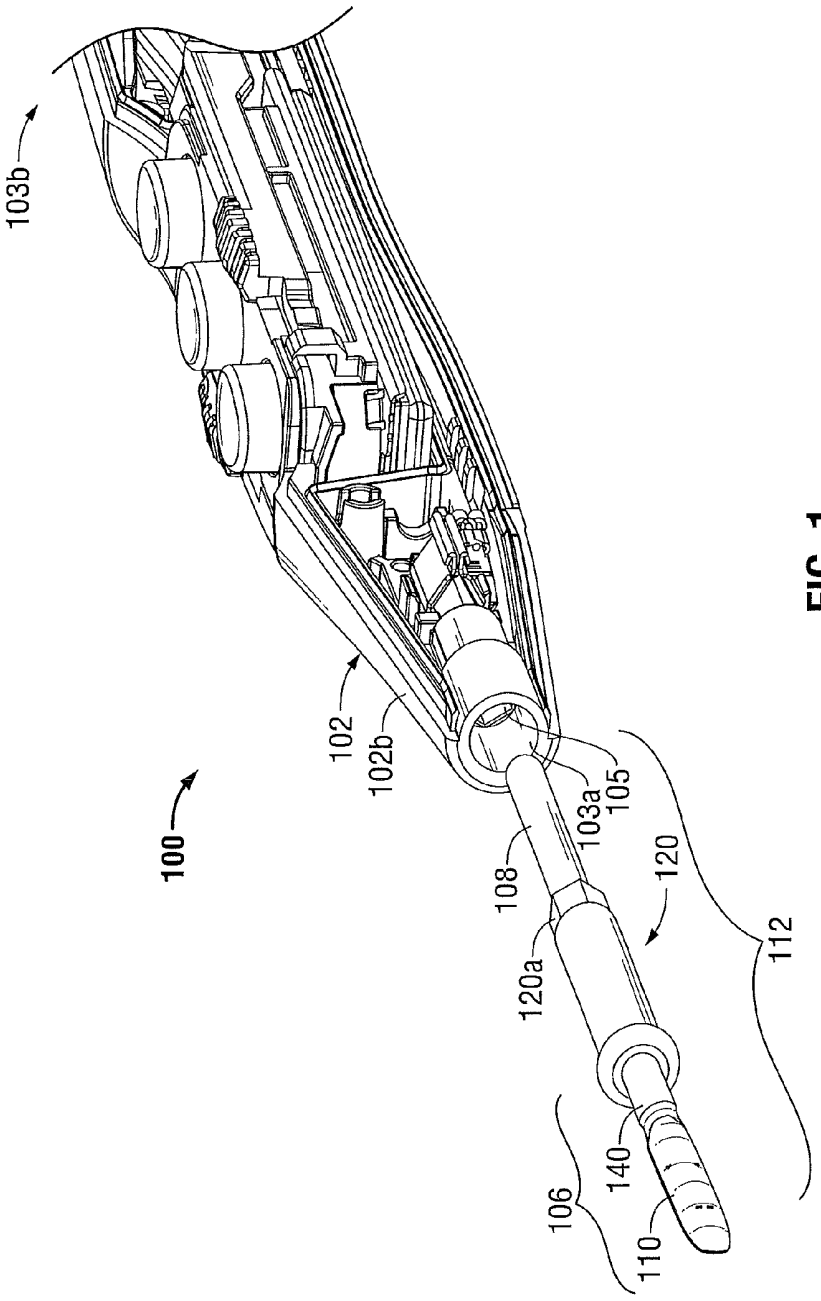


FIG. 1

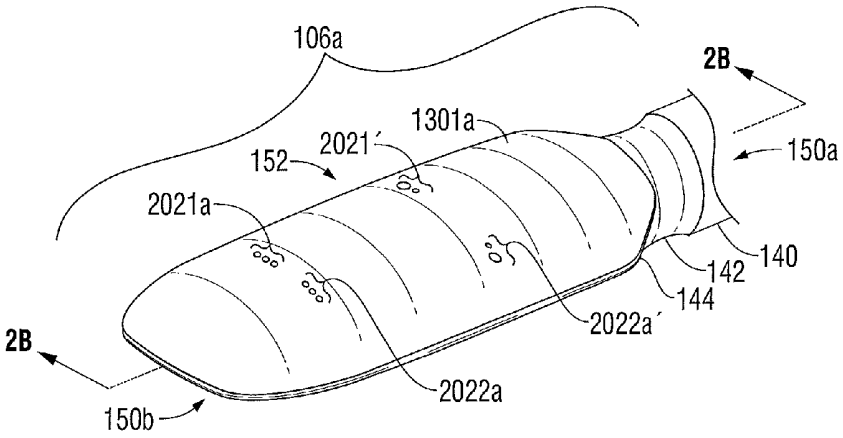
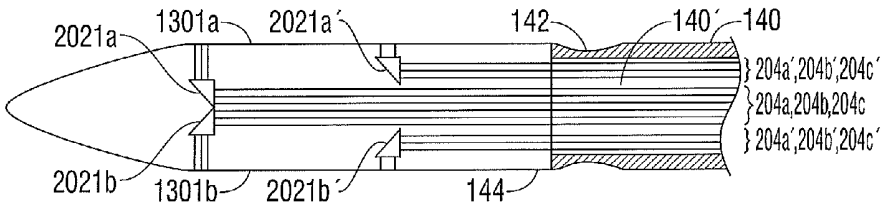

106a
2B
1301a
2021´
152
150a
2021a
140
142
144
2022a´
2B
2022a
150b

FIG. 2A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1301a
2021a´
142
140´
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204a´,204b´,204c´
204a,204b,204c
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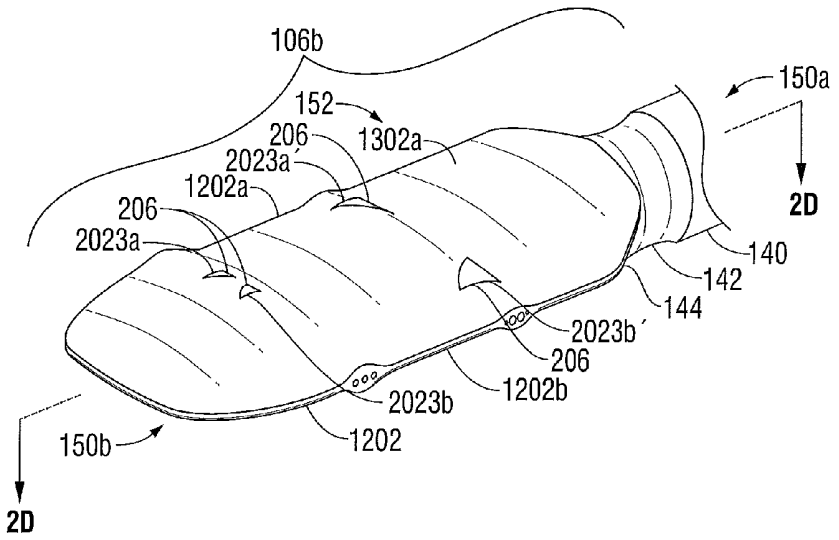
2021b
1301b
2021b´
144

FIG. 2B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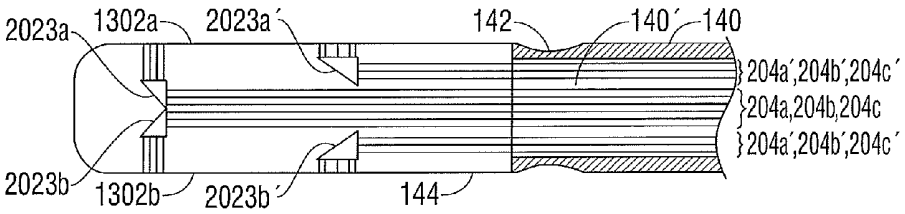
152
206
1302a
2023a
1202a
206
2023a
150a
2D
140
142
144
2023b´
206
1202b
2023b
1202
150b
2D

FIG. 2C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1302a
2023a´
142
140´
140
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204a,204b,204c
204a´,204b´,204c´
2023b
1302b
2023b´
144

FIG. 2D

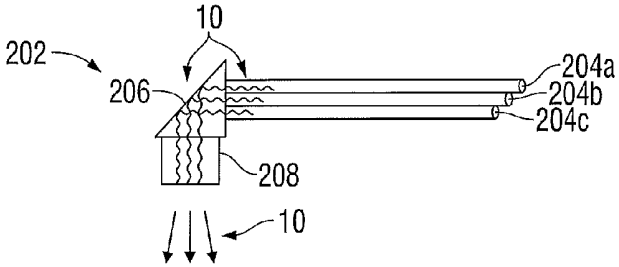


FIG. 3A

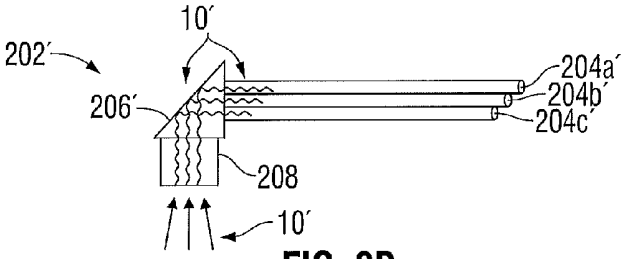


FIG. 3B

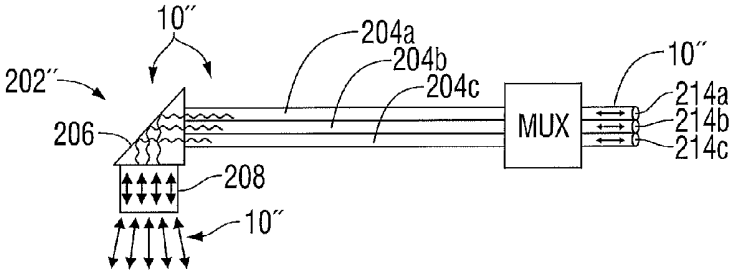


FIG. 3C

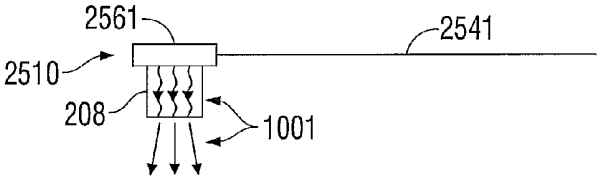


FIG. 4A

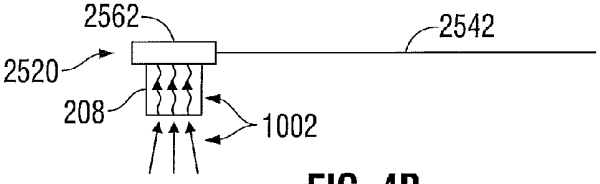
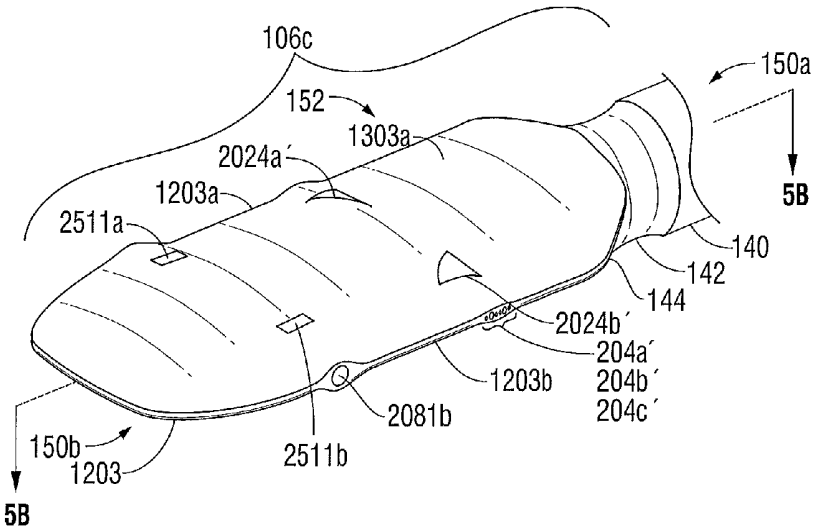


FIG. 4B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152
1303a
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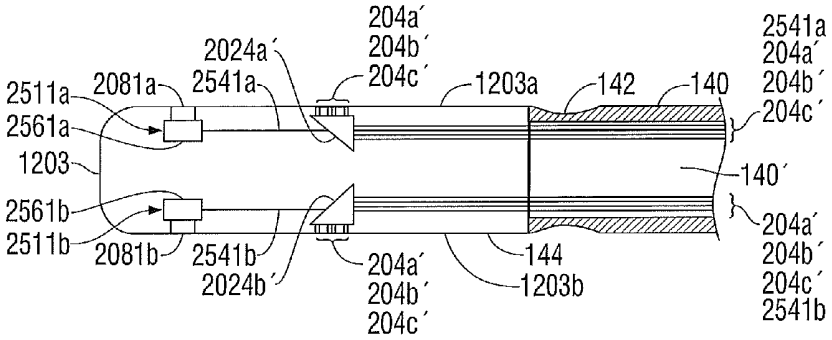
1203a
2511a
150a
5B
140
142
144
2024b´
204a´
204b´
204c´
1203b
2081b
2511b
150b
1203
5B

FIG. 5A


204a´
204b´
204c´
2024a´
2511a
2081a
2541a
1203a
142
140
2541a
204a´
204b´
204c´
2561a
1203
140´
2561b
2511b
2081b
2541b
2024b´
204a´
204b´
204c´
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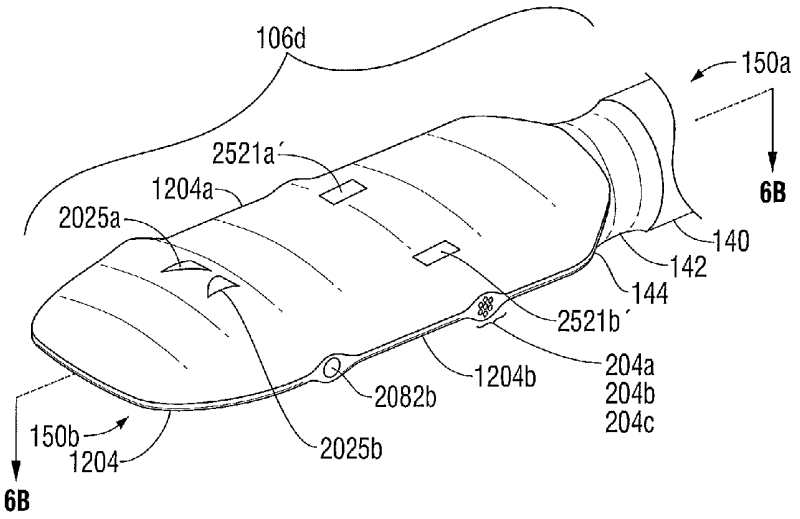
1203b
204a´
204b´
204c´
2541b

FIG. 5B


106d
150a
2521a´
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2025a
6B
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142
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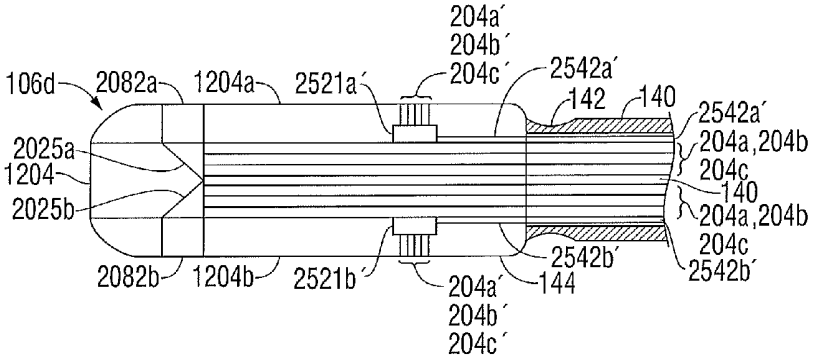
204a
204b
204c
1204b
2082b
150b
1204
2025b
6B

FIG. 6A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204b´
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106d
2082a
1204a
2521a´
142
140
2542a´
2025a
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204c
140
2025b
204a,204b
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204b´
204c´

FIG. 6B

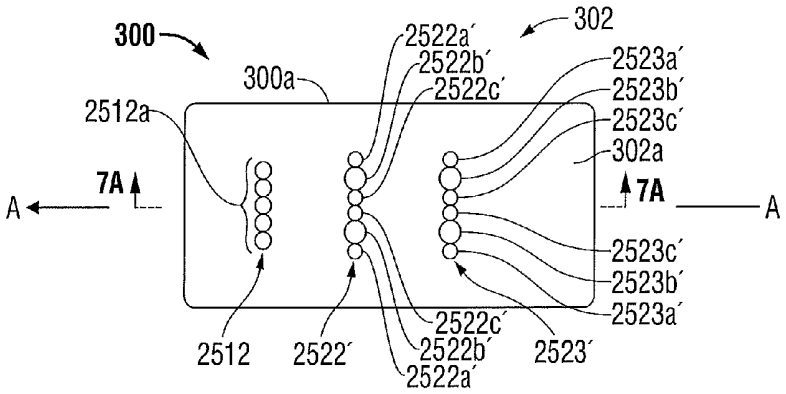


FIG. 7

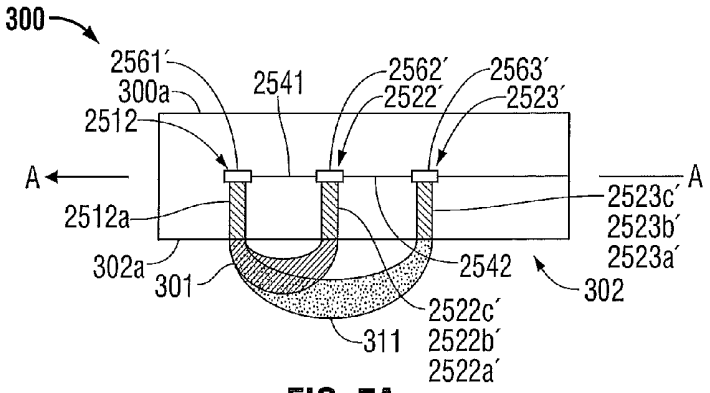


FIG. 7A

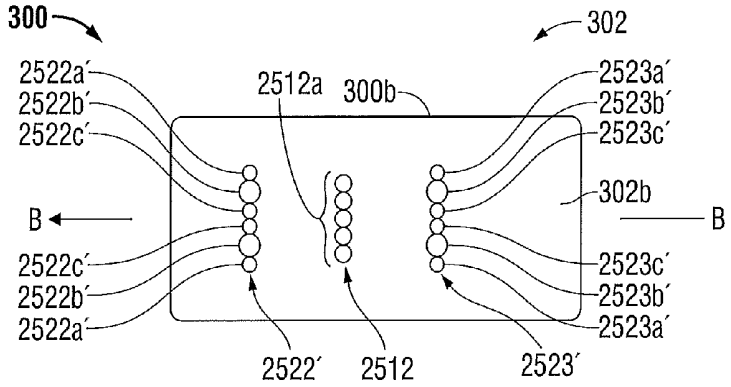


FIG. 8

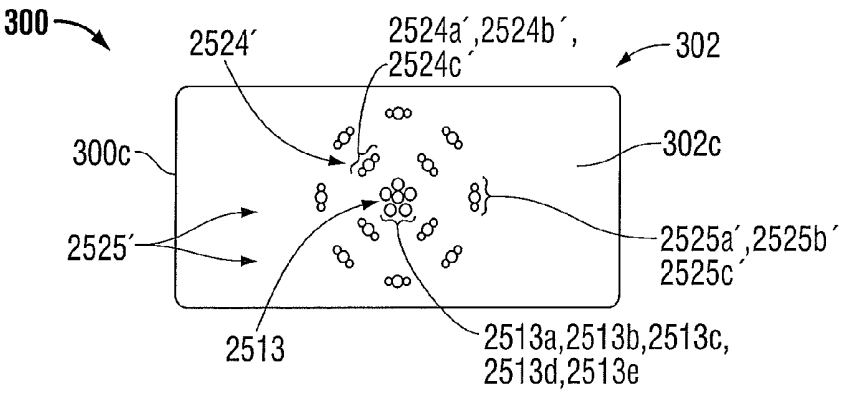


FIG. 9

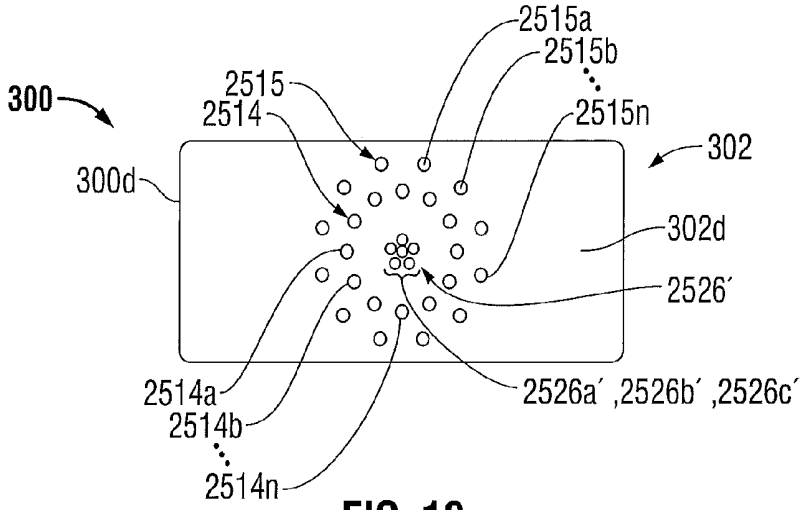


FIG. 10

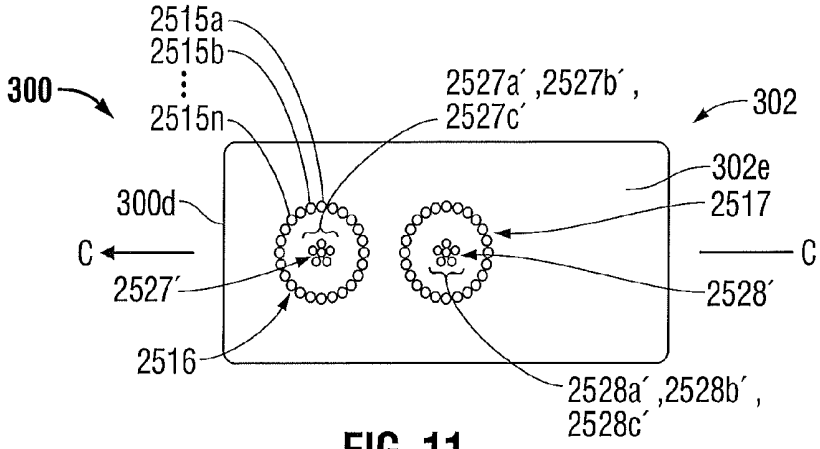


FIG. 11

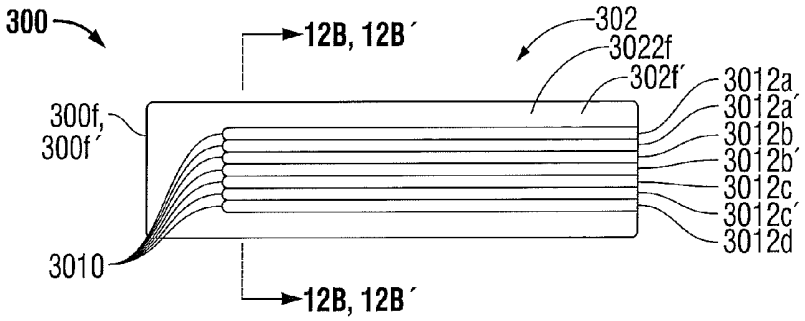


FIG. 12A

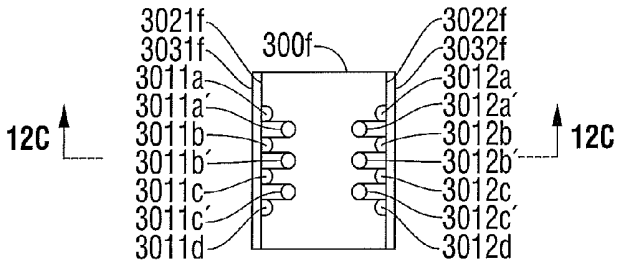


FIG. 12B

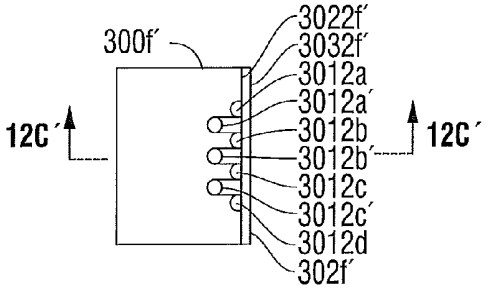


FIG. 12B´

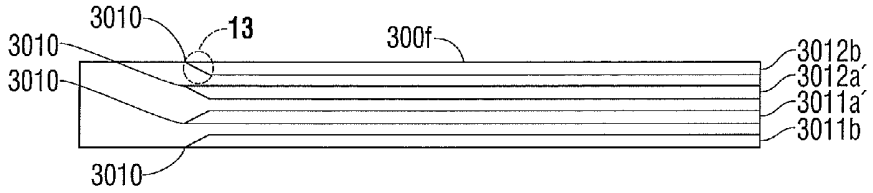


FIG. 12C

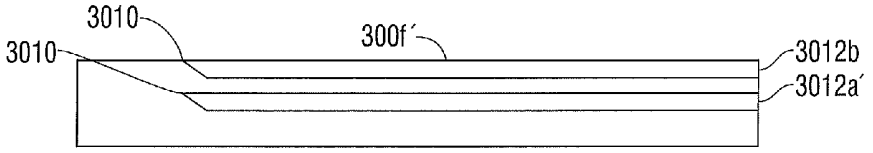


FIG. 12C´

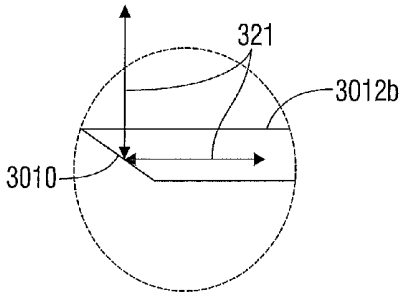
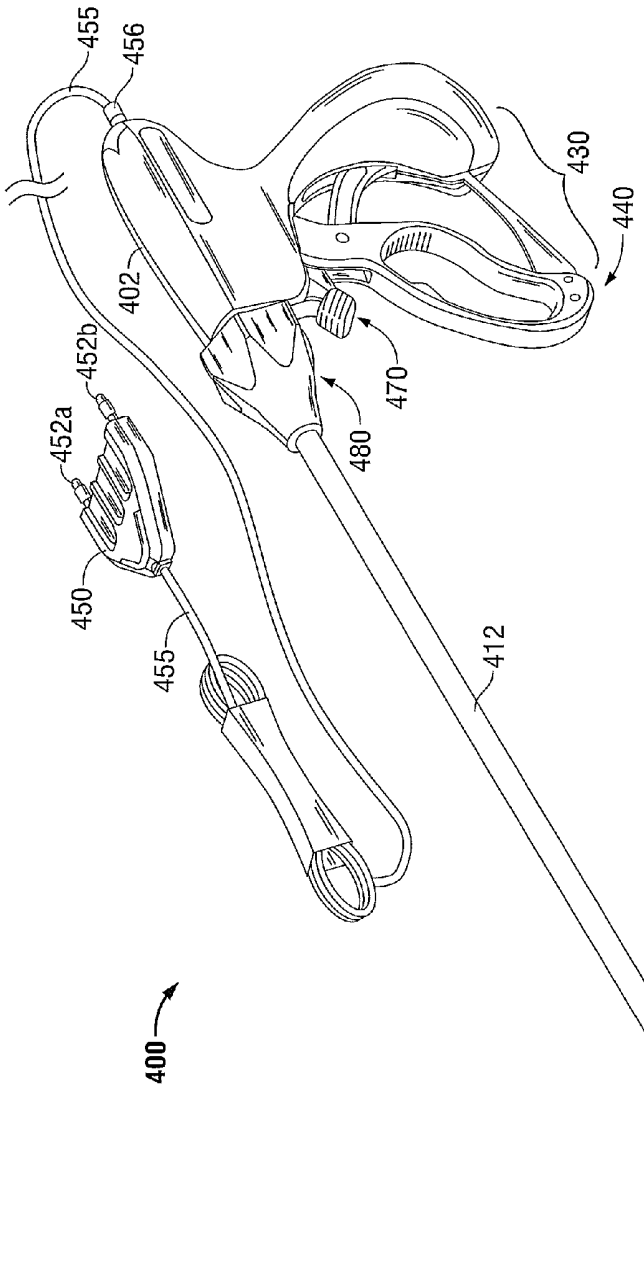


FIG. 13


455
456
430
440
402
452b
452a
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412
400
414
405
420
420
410
410

FIG. 14

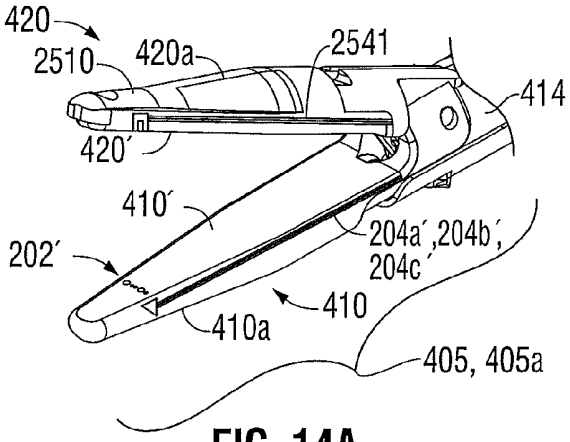

FIG. 14A

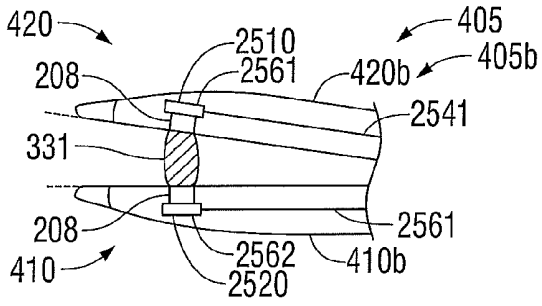

FIG. 14B

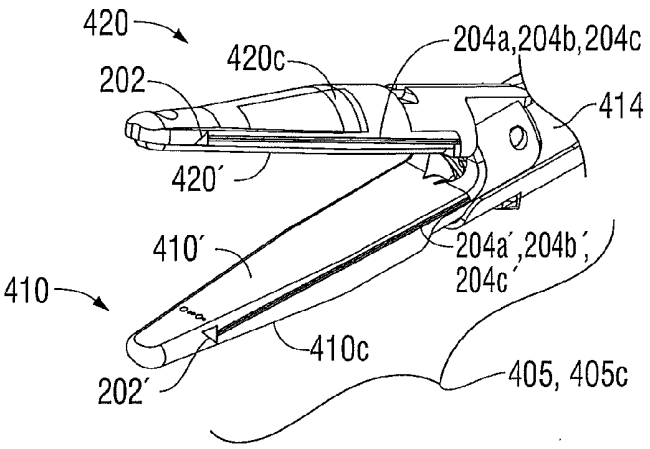

FIG. 14C

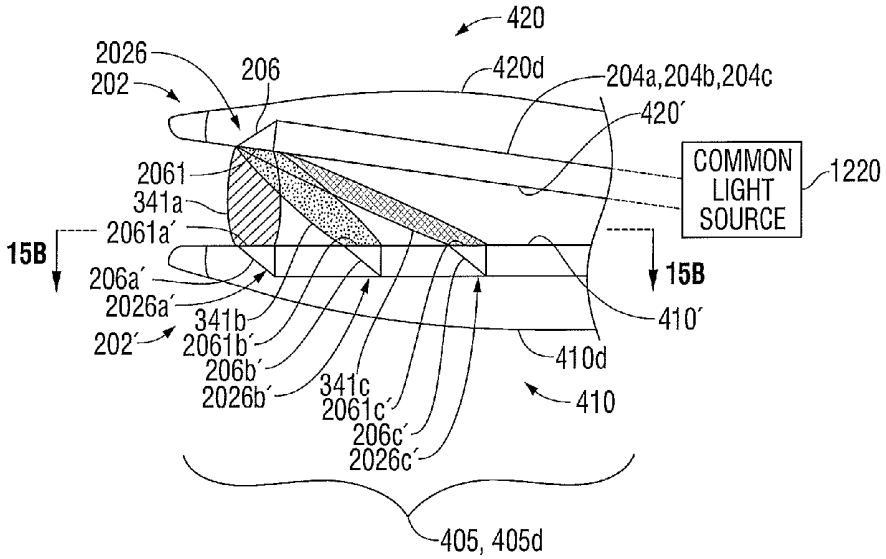

FIG. 15A

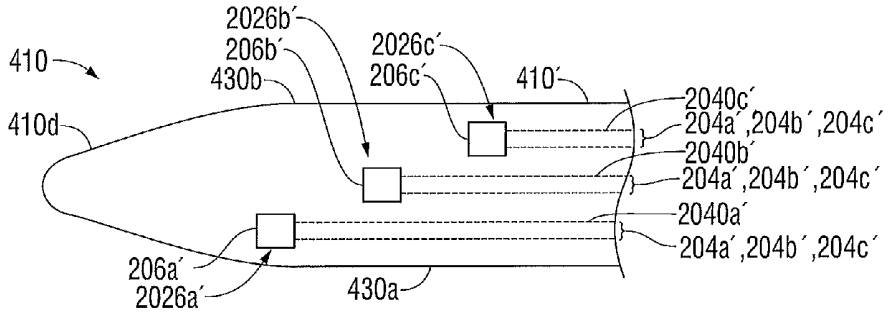

FIG. 15B

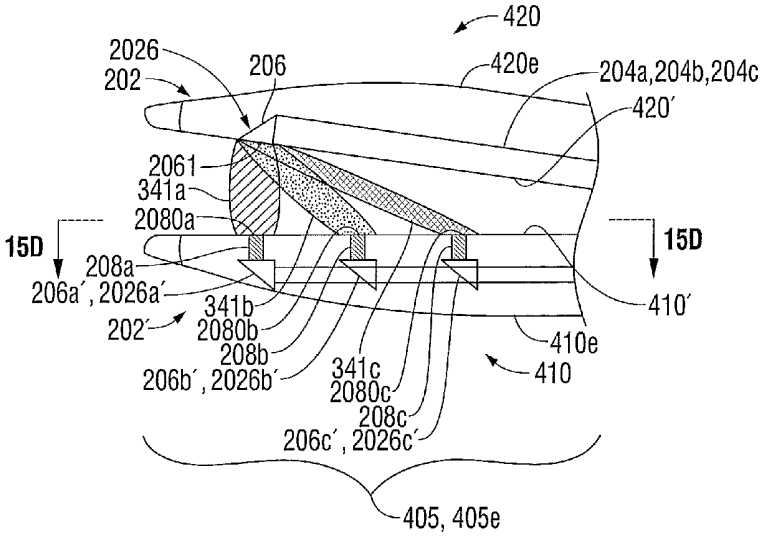

FIG. 15C

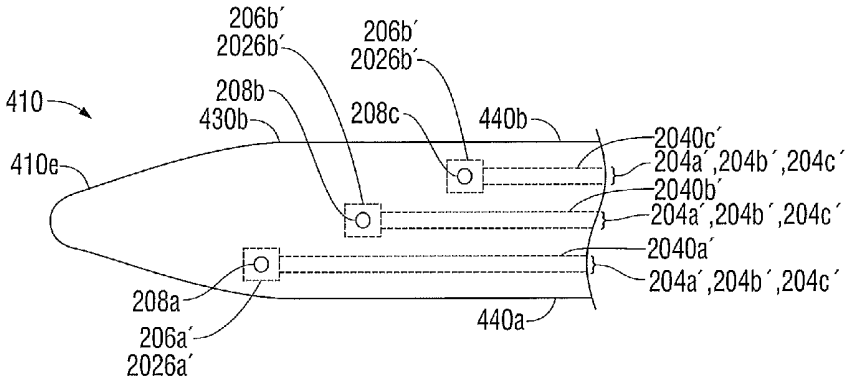

FIG. 15D

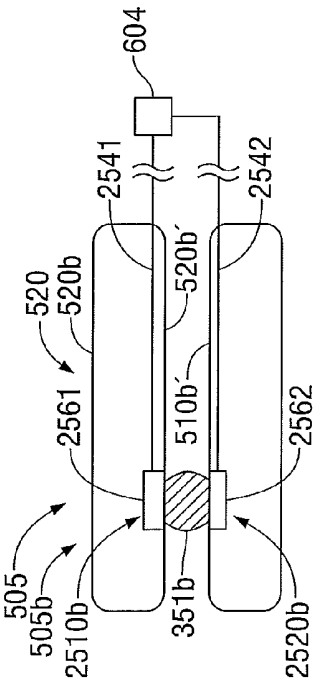

FIG. 17

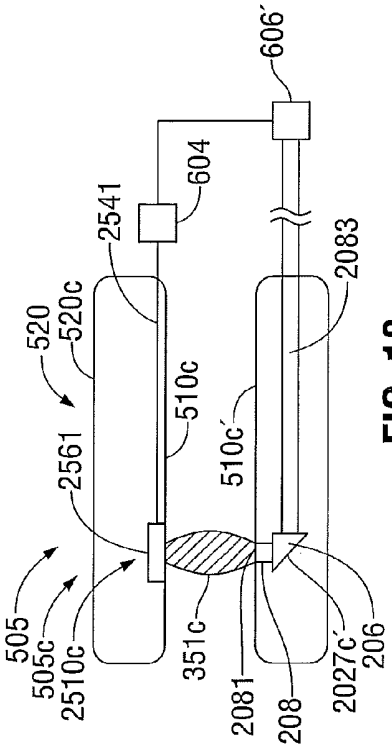

FIG. 18

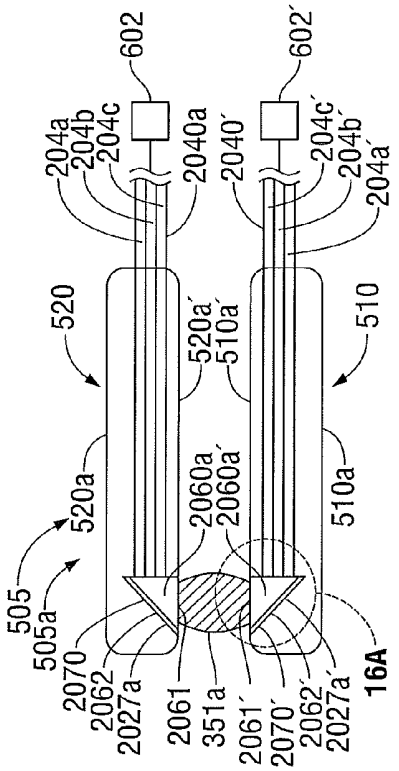

FIG. 16

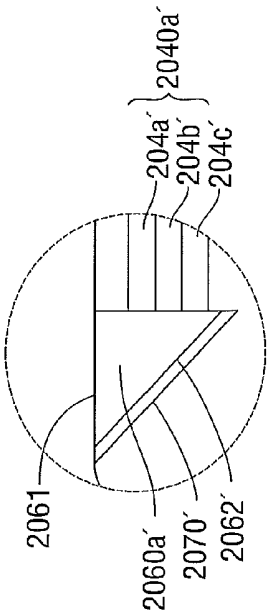

FIG. 16A

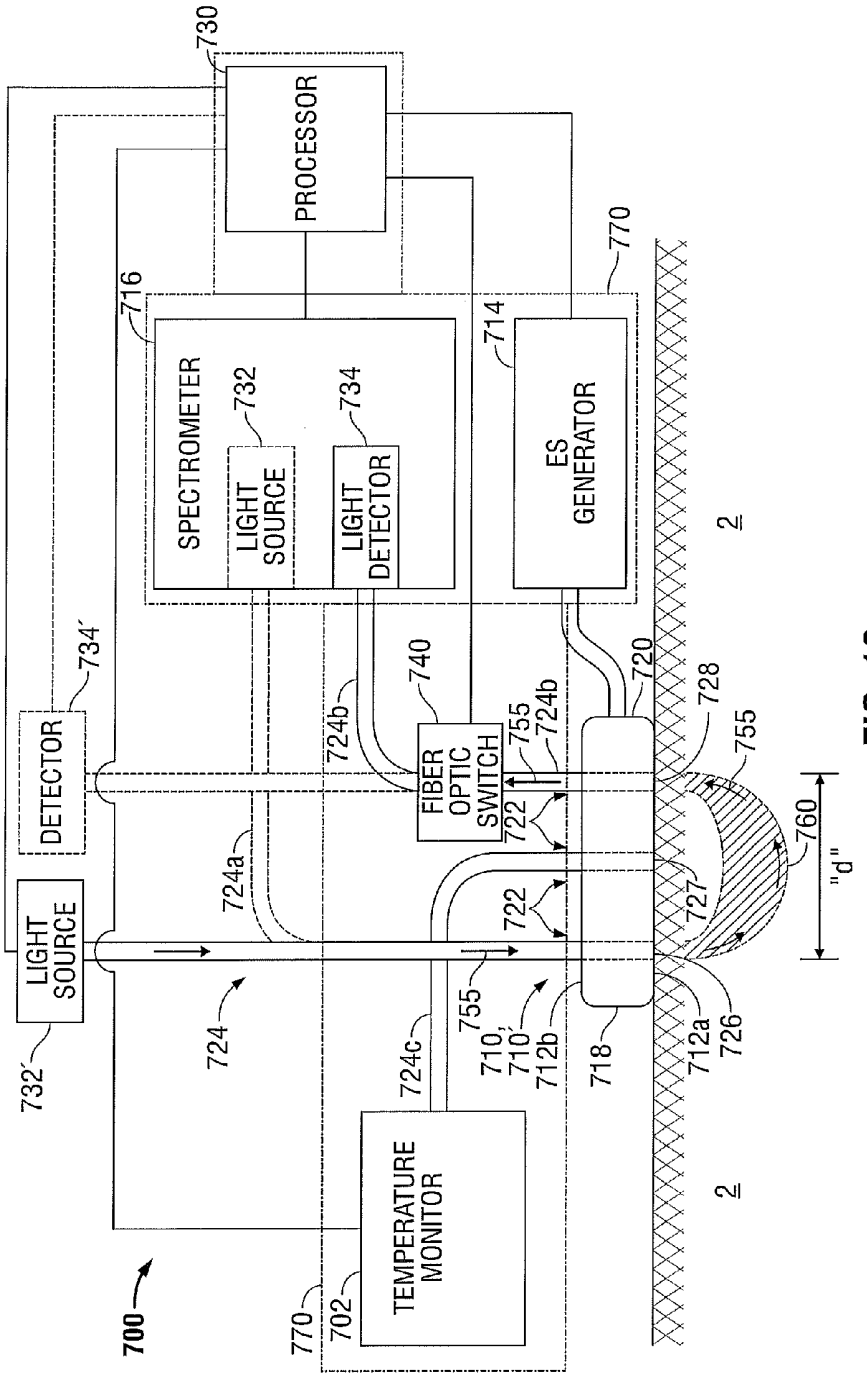
730
PROCESSOR
716
714
770
SPECTROMETER
732
LIGHT SOURCE
734
LIGHT DETECTOR
ES GENERATOR
2
734'
DETECTOR
740
724b
720
728
755
724b
FIBER OPTIC SWITCH
722
760
"d"
724a
722
727
LIGHT SOURCE
732'
724
755
710'
710
712b
718
712a
726
724c
TEMPERATURE MONITOR
702
770
700
2

FIG. 19

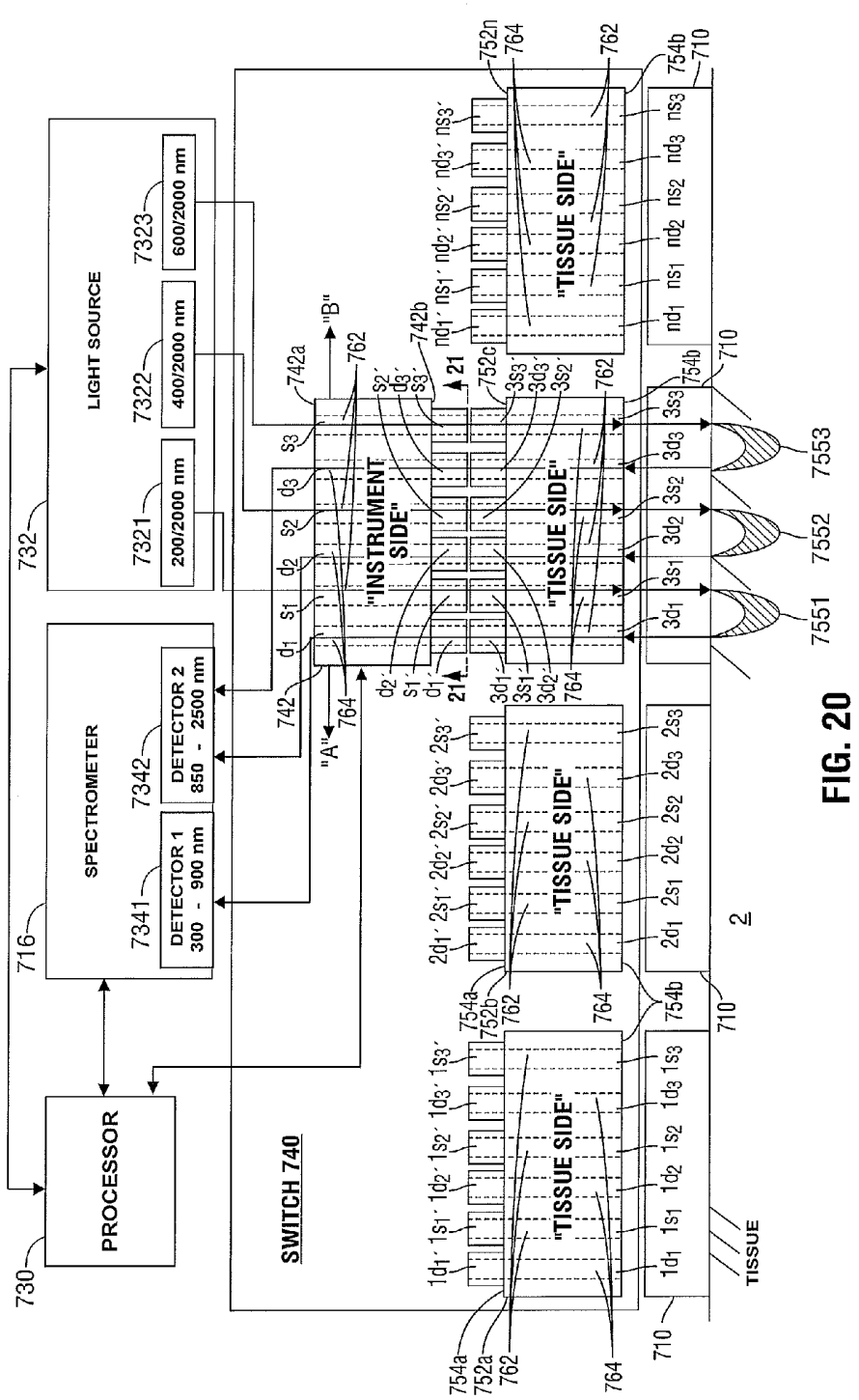
LIGHT SOURCE
7321
200/2000 nm
7322
400/2000 nm
7323
600/2000 nm
732
SPECTROMETER
7341
DETECTOR 1
300 - 900 nm
7342
DETECTOR 2
850 - 2500 nm
716
PROCESSOR
730
SWITCH 740
"INSTRUMENT SIDE"
"TISSUE SIDE"
"A"
"B"
21
214
742
742a
742b
752a
752b
752c
752n
754a
754b
762
764
710
TISSUE
2
7551
7552
7553

FIG. 20

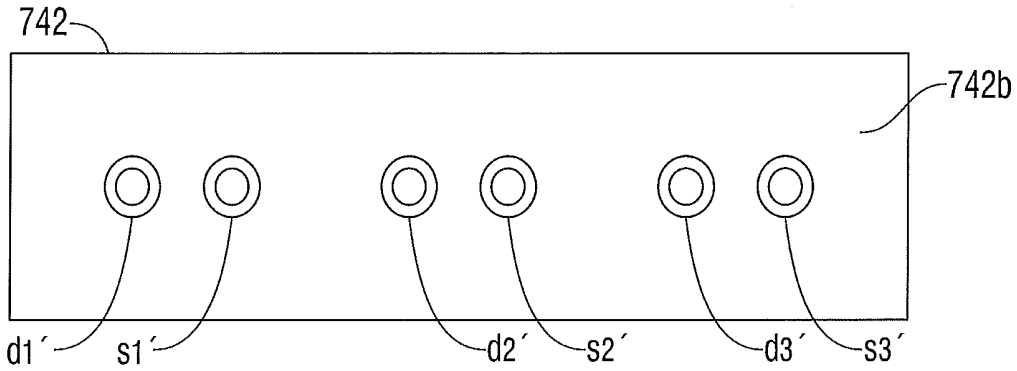

FIG. 21

OPTICAL HYDROLOGY ARRAYS AND SYSTEM AND METHOD FOR MONITORING WATER DISPLACEMENT DURING TREATMENT OF PATIENT TISSUE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application is a continuation application of U.S. patent application Ser. No. 12/757,340 filed on Apr. 9, 2010, the entire content of which is hereby incorporated by reference herein.

BACKGROUND

[0002] 1. Technical Field

[0003] This application relates to optical spectrometry systems and, more particularly, to optical spectrometry systems applied to patient tissue to measure tissue hydration levels and to detect a signal indicative of water content.

[0004] 2. Description of Related Art

[0005] Electrosurgical forceps utilize both mechanical clamping action and electrical energy to effect hemostasis by heating the tissue and blood vessels to coagulate, cauterize and/or seal tissue. As an alternative to open forceps for use with open surgical procedures, many modern surgeons use endoscopes and endoscopic instruments for remotely accessing organs through smaller, puncture-like incisions. As a direct result thereof, patients tend to benefit from less scarring and reduced healing time.

[0006] Endoscopic instruments are inserted into the patient through a cannula, or port, which has been made with a trocar. Typical sizes for cannulas range from three millimeters (mm) to twelve millimeters (mm). Smaller cannulas are usually preferred, which, as can be appreciated, ultimately presents a design challenge to instrument manufacturers who must find ways to make endoscopic instruments that fit through the smaller cannulas.

[0007] Many endoscopic surgical procedures require cutting or ligating blood vessels or vascular tissue. Due to the inherent spatial considerations of the surgical cavity, surgeons often have difficulty suturing vessels or performing other traditional methods of controlling bleeding, e.g., clamping and/or tying-off transected blood vessels. By utilizing an endoscopic electrosurgical forceps, a surgeon can either cauterize, coagulate/desiccate and/or simply reduce or slow bleeding simply by controlling the intensity, frequency and duration of the electrosurgical energy applied through the jaw members to the tissue. Most small blood vessels, i.e., in the range below two millimeters in diameter, can often be closed using standard electrosurgical instruments and techniques. However, if a larger vessel is ligated, it may be necessary for the surgeon to convert the endoscopic procedure into an open-surgical procedure and thereby abandon the benefits of endoscopic surgery. Alternatively, the surgeon can seal the larger vessel or tissue.

[0008] It is thought that the process of coagulating vessels is fundamentally different than electrosurgical vessel sealing. For the purposes herein, "coagulation" is defined as a process of desiccating tissue wherein the tissue cells are ruptured and dried. "Vessel sealing" or "tissue sealing" is defined as the process of liquefying the collagen in the tissue so that it reforms into a fused mass. Coagulation of small vessels is sufficient to permanently close them, while larger vessels need to be sealed to assure permanent closure.

[0009] Thus, medical devices that apply electro-thermal energy for vessel sealing, ablation, coagulation are known in the art. Tissue conductance and permittivity are significant factors in the therapeutic effect of such medical devices that apply the electro-thermal energy to patient tissue. Displacement of water is correlated with changes in tissue conductance and permittivity and lack of control over such changes in tissue conductance and permittivity can lead to overdessication during vessel sealing procedures.

SUMMARY

[0010] To advance the state of the art with respect to application of electro-thermal energy to patient tissue, the present disclosure relates to a system and a method for monitoring water displacement during treatment of patient tissue.

[0011] In one embodiment, the system for monitoring water displacement in tissue during patient therapy includes a generator configured to supply electrosurgical energy to tissue, a spectrometer operably coupled to the generator, and a processor in operative communication with the generator and with the spectrometer. The spectrometer includes a light source for exposing tissue to light and a light sensor. The light sensor is configured to sense changes in light through tissue in response to tissue treatment and communicate such changes to the processor to determine tissue hydration levels. A plurality of optical fibers may be operably coupled to the generator and configured to communicate light between the generator and tissue. The plurality of optical fibers may be configured in an array. The spectrometer may be a near infrared spectrometer providing light in the near infrared wavelength range as the light source.

[0012] In one embodiment, the system may also include an optical temperature monitor. The optical temperature monitor may be in operative communication with the processor, and include at least one optical fiber operatively coupled to the optical temperature monitor. The one or more optical fibers are configured to enable the optical temperature monitor to monitor the temperature of the tissue where water displacement is optically monitored. The one or more optical fibers may be configured within a plurality of optical fibers wherein at least one optical fiber is operatively coupled to the light source to enable transmitting light towards the tissue and at least one optical fiber is configured to receive light reflected from the tissue and to transport the light to the light sensor. The plurality of optical fibers may be configured in an optical array. The plurality of optical fibers of the optical array may be configured to have an optic fiber distance between adjacent optical fibers. The optical fiber distance is within the range of about 0.25 millimeters (mm) to about 4.0 mm to optimize the transmission of light through tissue to determine hydration levels.

[0013] In one embodiment, the processor is configured to record and/or analyze changes in hydration of the tissue sensed by the spectrometer across the optic fiber distance. In addition, the processor may be configured to record and/or analyze changes in temperature of the tissue sensed by the optical temperature monitor. The sensed temperature may be used to calculate compensation for the temperature effect on hydration measured by the spectrometer.

[0014] In one embodiment, the system is incorporated in an electrosurgical pencil that includes a housing having proximal and distal ends, and a blade receptacle defined at a distal end of the housing for supporting an electrosurgical blade therein. The electrosurgical blade is disposed in optical com-

munication with the light source and light sensor for monitoring hydration levels in tissue during operation of the electrosurgical pencil.

[0015] In one embodiment, the system is incorporated in an electrosurgical forceps that includes a pair of first and second jaw members disposed in pivotal relationship with respect to one another and attached to a distal end of at least one shaft. Each jaw member supports an electrically conductive surface thereon, at least one of the jaw members is disposed in optical communication with the light source and the other of the jaw members is disposed in optical communication with the light sensor for monitoring hydration levels in tissue during operation of the electrosurgical forceps.

[0016] The present disclosure relates also to a method for monitoring water displacement in tissue during patient therapy. The method includes the steps of providing a spectrometer including a light source in operative communication with patient tissue, generating light from the light source, reflecting the light through the patient tissue; and receiving the light reflected through the patient tissue with a light sensor. The method may include supplying electrosurgical energy to patient or subject tissue utilizing an energy source, sensing changes in light through the tissue in response to tissue treatment, and determining changes in tissue hydration levels based on the sensed changes in light through the tissue. In addition, the method may include providing a processor for analyzing the sensed changes in light through the tissue, and determining the changes in hydration levels in the tissue based on the sensed changes in light through the tissue. The processor may operatively communicate with the spectrometer to regulate the supply of electrosurgical energy to the tissue. The method may also include configuring a plurality of optical fibers in an array, wherein the array enables at least one of the plurality of optical fibers operatively coupled to the light source and enables at least one optical fiber of the plurality of optical fibers to be configured to enable transporting light reflected from the tissue to be separated to effect an optic fiber distance within the tissue. That is, the processor may be operatively coupled to the spectrometer and/or the supply of electrosurgical energy.

[0017] In one embodiment, the method includes providing an optical temperature monitor, providing at least one optical fiber operatively coupled to the optical temperature monitor, and monitoring the temperature of the tissue where water displacement is optically monitored. Knowledge of the temperature of the tissue can be used to provide more accurate measurement of tissue hydration.

[0018] In one embodiment, the present disclosure relates to an electrically conductive member for use with an electrosurgical instrument. The electrically conductive member includes a surface configured to engage patient tissue and adapted to connect to a source of electrosurgical energy. The electrically conductive member also includes at least one optical transmitter that is configured to propagate light through patient tissue and at least one corresponding optical sensor configured to sense changes in reflected light propagating through patient tissue during operation of the electrosurgical instrument and relating the changes in reflected light through patient tissue to hydration levels in tissue.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Various embodiments are described herein with reference to the drawings:

[0020] FIG. **1** is a perspective view of an electrode assembly of an electrosurgical pencil according to the present disclosure illustrating one embodiment of an end effector assembly having an optical transmitter positioned to propagate light through patient tissue and optical sensors positioned to sense at least a portion of the light propagating through patient tissue for monitoring hydration levels in tissue during operation of the electrosurgical pencil;

[0021] FIG. **2**A is a perspective view an ES pencil blade of the end effector assembly of FIG. **1**;

[0022] FIG. **2**B is a cross-sectional view of the pencil blade of the end effector assembly taken along section line **2**B-**2**B of FIG. **2**A;

[0023] FIG. **2**C is a perspective view of another embodiment of the pencil blade of the electrocautery end effector assembly of FIG. **1** having an optical transmitter and an optical sensor;

[0024] FIG. **2**D is a cross-sectional view of the pencil blade of the electrocautery end effector assembly taken along section line **2**D-**2**D of FIG. **2**C

[0025] FIG. **3**A is a schematic view of one embodiment of an optical transmitter wherein light is reflected by a prism;

[0026] FIG. **3**B is a schematic view of one embodiment of an optical sensor wherein light is reflected by a prism;

[0027] FIG. **3**C is a schematic view of one embodiment of a dual-function optical transmitter and optical sensor wherein light is reflected by a prism;

[0028] FIG. **4**A is a schematic view of one embodiment of an optical transmitter wherein light is transmitted by a light emitting diode;

[0029] FIG. **4**B is a schematic view of one embodiment of an optical sensor wherein light is sensed by a light emitting diode;

[0030] FIG. **5**A is a perspective view of another embodiment of the pencil blade of the end effector assembly of FIG. **1** having an optical transmitter and an optical sensor;

[0031] FIG. **5**B is a cross-sectional view of the pencil blade of the end effector assembly taken along section line **5**B-**5**B of FIG. **5**A;

[0032] FIG. **6**A is a perspective view of another embodiment of the pencil blade of the end effector assembly of FIG. **1** having an optical transmitter and an optical sensor;

[0033] FIG. **6**B is a cross-sectional view of the pencil blade of the electrocautery end effector assembly taken along section line **6**B-**6**B of FIG. **6**A;

[0034] FIG. **7** is a schematic view of one embodiment of an electrically conductive member for use with an electrosurgical instrument according to the present disclosure in which one optical transmitter and two optical sources are disposed substantially linearly on a surface of the electrically conductive member;

[0035] FIG. **7**A is a schematic view of the electrically conductive member of FIG. **7** taken along section line **7**A-**7**A;

[0036] FIG. **8** is a schematic view of another embodiment of an electrically conductive member for use with an electrosurgical instrument according to the present disclosure in which one optical transmitter and two optical sources are disposed substantially linearly on a surface of the electrically conductive member;

[0037] FIG. **9** is a schematic view of yet another embodiment of an electrically conductive member for use with an

electrosurgical instrument according to the present disclosure having a circular array of optical sensors and an optical transmitter disposed on a surface of the electrically conductive member;

[0038] FIG. **10** is a schematic view of still another embodiment of an electrically conductive member for use with an electrosurgical instrument according to the present disclosure having a circular array of optical transmitters and an optical sensor disposed on a surface of the electrically conductive member;

[0039] FIG. **11** is a schematic view of another embodiment of an electrically conductive member for use with an electrosurgical instrument according to the present disclosure having two circular arrays of optical transmitters and optical sensors disposed on a surface of the electrically conductive member;

[0040] FIG. **12**A is a schematic view of a surface of an electrically conductive member for use with an electrosurgical instrument according to the present disclosure having an array of optical transmitters and optical sensors disposed in channels on the suface of the electrically conductive member;

[0041] FIG. **12**B is an end view of the electrically conductive member of FIG. **12**A for an electrosurgical pencil;

[0042] FIG. **12**B' is an end view of the electrically conductive member of FIG. **12**A for a bipolar electrosurgical forceps;

[0043] FIG. **12**C is a schematic view of the electrically conductive member of FIG. **12**B taken along section line **12**C-**12**C;

[0044] FIG. **12**C' is a view of the electrically conductive member of FIG. **12**B' taken along section line **12**C'-**12**C';

[0045] FIG. **13** is an enlarged view of an end of an optical fiber illustrated in FIG. **12**C';

[0046] FIG. **14** is a perspective view of a bipolar electrosurgical forceps according to the present disclosure illustrating one embodiment of an end effector assembly having an optical transmitter positioned to propagate light through patient tissue and optical sensors positioned to sense light propagating through patient tissue for monitoring hydration levels in tissue during operation of the bipolar forceps;

[0047] FIG. **14**A is an enlarged perspective view of the embodiment of the jaw members of the end effector assembly of FIG. **14**;

[0048] FIG. **14**B is a profile view of another embodiment of the jaw members of the end effector assembly of FIG. **14**;

[0049] FIG. **14**C is an enlarged perspective view of another embodiment of the jaw members of the end effector assembly of FIG. **14**;

[0050] FIG. **15**A is a schematic, side view of another embodiment of the jaw members of the end effector assembly of FIG. **14**;

[0051] FIG. **15**B is a schematic, view of the lower jaw member of the end effector assembly of FIG. **15**A taken along section line **15**B-**15**B;

[0052] FIG. **15**C is a schematic, side view of another embodiment of the jaw members of the end effector assembly of FIG. **14**;

[0053] FIG. **15**D is a schematic view of the lower jaw member of the end effector assembly of FIG. **15**C taken along section line **15**D-**15**D;

[0054] FIG. **16** is a schematic, side view of another embodiment of an end effector assembly according to the present disclosure for a parallel jaw type bipolar electrosurgical forceps assembly having an optical transmitter positioned to propagate light through patient tissue and optical sensors positioned to sense light propagating through patient tissue for monitoring hydration levels in tissue during operation of the bipolar forceps;

[0055] FIG. **16**A is an enlarged view of the area of detail **16**A illustrated in FIG. **16**;

[0056] FIG. **17** is a schematic, side view of another embodiment of the parallel jaw type bipolar electrosurgical forceps assembly of FIG. **16** having an optical transmitter positioned to propagate light through patient tissue and optical sensors positioned to sense light propagating through patient tissue for monitoring hydration levels in tissue during operation of the bipolar forceps;

[0057] FIG. **18** is a schematic, side view of yet another embodiment of the parallel jaw type bipolar electrosurgical forceps assembly of FIG. **16** having an optical transmitter positioned to propagate light through patient tissue and optical sensors positioned to sense light propagating through patient tissue for monitoring hydration levels in tissue during operation of the bipolar forceps;

[0058] FIG. **19** is a schematic view of a system for monitoring water displacement during treatment of patient tissue according to the present disclosure;

[0059] FIG. **20** is a schematic view of one embodiment of the mechanical-optical multiplexer switch included within the system for monitoring water displacement of FIG. **19** as configured with respect to the array of optical transmitters and optical sensors illustrated in FIG. **11**; and

[0060] FIG. **21** is a view of an optical alignment member included within the mechanical-optical multiplexer switch taken along section line **21**-**21** illustrated in FIG. **20**.

DETAILED DESCRIPTION

[0061] The present disclosure relates to a system and method for detecting water displacement and/or water hydration levels in tissue by arranging optic fibers in an array on the tissue contacting surfaces. Optic fibers are configured at one end to connect the fibers to a light source and at an opposite end to terminate in an array such that the light is transmitted into the tissue may be measured and/or monitored. Several light sensing optic fibers may also be included in the array and disposed in close proximity to the lens of the fiber optic that is the source. The end of the sensing optic fiber opposite the array is connected to a spectrometer. The configuration of the array can be designed into many different configurations and is not necessarily limited in this disclosure. The configuration may be dependent on the type of tissue and the geometry of the application. Applications include by are not limited to medical devices that use electro-thermal energy. The spacing and placement of the optical fiber elements of the optical array are specified such that discrete changes in hydration of the tissue over time can be recorded. These recorded discrete hydration changes together with the known array geometry can be analyzed (for example, by computer) to provide information on the displacement of water in the tissue. The source and detected wavelengths are selected to optimize the detection of water.

[0062] One application of this type of optical array is the placement of the array in close proximity to a thermal ablation probe. The displacement of water is correlated with changes in tissue conductance and permittivity. Tissue conductance and permittivity are significant factors in the therapeutic effect of medical devices that use electro-thermal energy.

[0063] A series of probes measures the hydration of a multitude of tissues. A probe or probes are placed in an array at a location where the sensors receiving the reflected signal are placed in the array so that changes in hydration can be monitored. Dynamic changes of hydration during energy treatment of tissue can be recorded, analyzed, and utilized to control delivery of electrosurgical energy during the course of tissue treatment.

[0064] Turning now to FIG. **1**, there is illustrated a partial view of electrosurgical pencil **100** that includes a housing **102** defining an open distal end **103***a* for selectively receiving proximal end **108** of electrocautery blade **106** therein. Open distal end **103***a* defines a blade receptacle **105** for blade **106**. (The proximal end **103***b* of the housing **103** is not entirely shown).

[0065] In one embodiment, electrocautery blade **106** is supported in a collar **120**. Collar **120** is positioned between distal end **110** and proximal end **108** of electrocautery blade **106**. Collar **120** has a shaped outer surface **120***a* configured and dimensioned to complement the inner profile of receptacle **105** of open distal end **103***a*. In one embodiment, the open distal end **103***a* of housing **102** defines a hexagonally-shaped inner profile of receptacle **105** and collar **120** defines a hexagonal outer surface **120***a*. The blade **106** and the collar **120** define an electrocautery end effector assembly **112** that is operatively connectable to the blade receptacle **105**.

[0066] Such an electrosurgical pencil is disclosed in commonly owned US Patent Application Publication No. 2006/0178667, U.S. patent application Ser. No. 11/337,990 by Sartor et al., entitled "ELECTROSURGICAL PENCIL WITH ADVANCED ES CONTROLS," the entire contents of which is incorporated by reference herein.

[0067] Blade receptacle **105** is defined at the distal end **103***a* of the housing for supporting the electrosurgical blade **106** therein. The electrosurgical blade **106** is configured to be connected to a source of electrosurgical energy, e.g., an electrosurgical generator, not shown.

[0068] Turning initially to FIGS. **3**A through **4**B, there are various illustrated embodiments of optical transmitters and optical sensors for use with end effector assembly **112**. As defined herein, an optical transmitter includes, but is not limited to, small diameter optical fibers, e.g., having a diameter ranging up to about 1 millimeter (mm); large diameter optical fibers, e.g. having a diameter ranging up to about 2 mm; prisms that reflect at least a portion of light propagating therethrough, optical fibers having at least one end with a tapered configuration to function as a prism, light-emitting electronic devices such as a light-emitting diodes (LED), or electrical cable s that transmit electrical signals that provide optical information from a light source. As defined herein, an electrical cable is capable of providing optical communication between a light source and a light-emitting electronic device. Photo-electric detectors convert photonic signals to electrical signals, and light-emitting electronic devices such as light-emitting diodes convert electrical signals to photonic signals.

[0069] Such optical transmitters may be configured as single members or in an assembly of one or more members of the same category in optical communication with one another or in an assembly of one or more members of different categories in optical communication with one another.

[0070] As defined herein, an optical sensor includes, but is not limited to, small diameter optical fibers, e.g., having a diameter ranging up to about one (1) millimeter (mm); large diameter optical fibers, e.g. having a diameter ranging up to about two (2) mm; prisms that reflect at least a portion of light propagating therethrough, optical fibers having at least one end with a tapered configuration that functions as a prism, light-sensing electronic devices such a photo-electric detector or photosensor, or electrical cables that transmit electrical signals that provide optical information from a photo-electric detector. Such photoelectric detectors may be made from, for example, gallium arsenide (GaAs), indium phosphide (InP), gallium phosphide (GaP), indium gallium arsenide (InGaAs), silicon germanium (SiGe), germanium (Ge), germanium tin (GeSn), sulfur germanium tin (SGeSn) and the like. As defined herein, an electrical cable is capable of providing optical communication between a photo-electric detector and a light-emitting electronic device. Photo-electric detectors convert photonic signal to electrical signals, and light-emitting electronic devices such as light-emitting diodes convert the electrical signals to photonic signals.

[0071] Similarly, such optical sensors may be configured as single members or in an assembly of one or more members of the same category in optical communication with one another or in an assembly of one or more members of different categories in optical communication with one another.

[0072] Optical sensors include, but are not limited to, optical detectors that are mostly quantum devices in which an individual photon produces a discrete effect; photoresistors or light dependent resistors in which resistance is a function of light intensity; photodiodes operating in a photovoltaic mode or in a photoconductive mode; photovoltaic cells or solar cells producing a voltage and an electric current when illuminated; photomultiplier tubes containing a photocathode that emits electrons when illuminated and wherein the electrons may be amplified by a chain of dynodes; phototubes containing a photocathode that emits electrons when illuminated wherein the tube conducts a current proportional to the light intensity; light-emitting devices (LEDs) that are reverse-biased to act as photodiodes; phototransistors that function as amplifying photodiodes; optical detectors that function as thermometers converting heat of incoming radiation to an electrical current, such as pyroelectric detectors, Golay cells, thermocouples and thermistors

[0073] Additionally, as defined herein, an optical transmitter may also function alternately as an optical sensor to serve as a dual function optical transmitter and optical receiver. A dual function optical transmitter and optical receiver may include a multiplexer device.

[0074] Returning specifically to FIG. **3**A, optical transmitter **202** includes one or more optical fibers e.g., optical fibers **204***a*, **204***b*, and **204***c* and/or one or more light reflecting prisms **206** in optical communication with corresponding optical fibers **204***a*, **204***b* and/or **204***c*. The optical transmitter **202** may include a large diameter single optical fiber **208** in optical communication with patient tissue (not shown). The diameter of optical fiber **208** ranges up to about 3 mm. Light **10** is illustrated propagating through the optical fibers **204***a*, **204***b* and **204***c* to prism **206** wherein the light **10** is reflected by the prism **306** to a large diameter single optical fiber **208** propagates the light to patient tissue.

[0075] FIG. **3**B illustrates an optical sensor **202'** that also includes one or more optical fibers e.g., optical fibers **204***a*, **204***b*, and **204***c* and/or one or more light reflecting prisms **206** in optical communication with corresponding optical fibers **204***a'*, **204** *b'* and/or **204***c'*. The optical sensor **202** may include a large diameter single optical fiber **208** in optical

communication with patient tissue (not shown). Optical sensor **202'** differs from optical transmitter **202** in that light **10'** travels in the reverse direction as compared to light **10**. More particularly, light **10'** is illustrated propagating from the patient tissue (again not shown) through the large diameter optical fiber **208** to prism **206** wherein the light **10'** is reflected by the prism **206** to optical fibers **204***a'*, **204***b'* and **204***c'*. Additionally, optical fibers **204***a'*, **204***b'* and **204***c'* may have diameters which differ from one another so as to propagate differing wavelengths of light. The diameters of optical fibers **204***a'*, **204***b'* and **204***c'* may also differ from the diameters of optical fibers **204***a*, **204***b* and **204***c* of optical transmitter **202** described with respect to FIG. **3**A.

[0076] FIG. **3**C illustrates one embodiment of a dual function optical transmitter and optical sensor **202"** wherein light **10"** may propagate to patient tissue (again not shown) and alternately propagate from patient tissue. More particularly, dual-function optical transmitter and optical sensor **202"** is substantially identical to optical transmitter **202** and optical sensor **202'** except for the inclusion of optical multiplexer **210** in the path of optical fibers **204***a*, **204***b* and **204***c*. The optical multiplexer (MUX) **210** is in optical communication with proximal optical fibers **214***a*, **214***b* and **214***c* and with distal optical fibers **204***a*, **204***b* and **204***c*

[0077] In the transmission phase of operation, light **10"** propagates from the proximal side of MUX **210** through the proximal optical fibers **214***a*, **214***b* and **214***c* through the MUX **210** to the distal optical fibers **204***a*, **204***b* and **204***c*. As is the case for optical transmitter **202**, light **10"** is reflected by the prism **206** to propagate through the large optical fiber **208** to pass through patient tissue.

[0078] In the sensing phase of operation, light **10"** propagates from patient tissue where the light **10"** is detected by the large diameter optical fiber **208** and propagates to the prism **206** wherein the light **10"** is reflected by the prism **206** to distal optical fibers **204***a*, **204***b* and **204***c*. The light **10"** propagates to the MUX **210** where the light is selectively propagated by switching to at least one or more of the proximal optical fibers **214***a*, **214***b* and **214***c*.

[0079] FIG. **4**A illustrates an alternate embodiment of an optical transmitter **2510**. More particularly, optical transmitter **2510** includes electrical cable **2541** that is capable of providing optical communication between a light source (to be described below with respect to FIGS. **18-20**), and a light-emitting electronic device **2561** such as a light-emitting diode. A photo-electric detector (not shown) converts a photonic signal to an electrical signal. The light-emitting electronic device **256** converts the electrical signal to a photonic signal resulting in light **101** being emitted from the light-emitting electronic device **256** to propagate through large diameter optical fiber **208** to patient tissue (also not shown).

[0080] FIG. **4**B illustrates an alternate embodiment of an optical sensor **2520**. More particularly, optical sensor **2520** includes electrical cable **2542** that is capable of providing optical communication between photo-electric detector **2562** and a light detector (to be described below with respect to FIGS. **18-20**). Light **102** propagating through patient tissue (not shown) propagates to large diameter optical fiber **208** in contact with patient tissue. The photo-electric detector **2520** detects the light **102** propagating through the large diameter optical fiber **208** and converts the photonic signal to an electrical signal. The electrical signal communicates with the light detector (to be described below).

[0081] Returning to FIGS. **2**A and **2**B, one embodiment of electrocautery blade **106** is shown. More particularly, electrocautery blade **106***a* defines a proximal end **150***a* and a distal end **150***b*. The blade **106***a* has a substantially planar configuration having a generally convex lateral cross-section defining one or more peripheral edges **120** and one or more lateral surfaces, e.g., first surface **1301***a* and second surface **1301***b*. The blade **106***a* includes a cylindrical shaft **140** defining a hollow central region **140'** therewithin and extending to a proximal end **144** of substantially planar region **152** of the blade **106***a*. The hollow shaft **140** extends to the substantially planar region **152** to define a circumferential recess **142** around the outer surface of the hollow shaft **140**.

[0082] The electrosurgical blade **106***a* is configured with one or more optical transmitters **202** positioned to propagate light **10** through patient tissue and one or more optical sensors **202'** positioned to sense at least a portion of the light **10'** propagating through patient tissue for monitoring hydration levels in tissue during operation of the electrosurgical pencil **100**.

[0083] More particularly, the electrosurgical blade **106***a* is configured wherein optical transmitters **2021***a* and **2022***a* (shown partially) propagate light through patient tissue via the first lateral surface **1301***a* while optical transmitters **2021***b* (**2022***b*, not shown) propagate light through patient tissue via the second lateral surface **1301***b*. Optical transmitters **2021***a*, **2022***a*, **2021***b* (and **2022***b*, not shown) are configured with prism **206** and the optical fibers described with respect to optical transmitter **202** in FIG. **3**A.

[0084] Similarly, the electrosurgical blade **106***a* is configured wherein optical sensors **2021***a'* and **2022***a'* (shown partially) sense at least a portion of the light propagating through the patient tissue via the first lateral surface. **1301***a* while optical sensors **2021***b'* (and corresponding optical sensors not shown) sense at least a portion of the light propagating through the patient tissue via the second lateral surface **1301***b*. Optical sensors **2021***a'*, **2022***a'*, **2021***b'* (and corresponding optical sensors not shown) are also configured with prism **206** and the optical fibers described with respect to the optical sensor **202'** in FIG. **3**B. As indicated, the diameters of the sensing optical fibers **204***a'*, **204***b'*, **204***c'* may differ from one another. The optical sensors **2021***a'* and **2021***b'* may be positioned proximally on the electrosurgical blade **106***a* with respect to the optical transmitters **2021***a* and **2021***b*.

[0085] The transmission optical fibers **204***a*, **204***b*, **204***c* and the sensing optical fibers **204***a'*, **204***b'*, **204***c'* are routed through the hollow central region **140'** of the shaft **140** and further through the housing **102**.

[0086] Turning now to FIGS. **2**C and **2**D, there is illustrated another embodiment of electrocautery blade **106**. More particularly, electrocautery blade **106***b* again defines proximal end **150***a* and distal end **150***b*. The blade **106***b* has a substantially planar configuration having a generally convex lateral cross-section defining at least one peripheral edge **1202** and at least one lateral surface, e.g., first surface **1302***a* and second surface **1302***b* (not explicitly shown on the opposing side of first surface **1302***a*). The blade **106***b* includes cylindrical shaft **140** defining hollow central region **140'** therewithin and extending to proximal end **144** of substantially planar region **152** of the blade **106***b*. The hollow shaft **140** extends to the substantially planar region **152** to define a circumferential recess **142** around the outer surface of the hollow shaft **140**.

[0087] The electrosurgical blade **106***b* is again configured with at least one optical transmitter **202** positioned to propa-

gate light **10** through patient tissue and at least one optical sensor **202'** positioned to sense at least a portion of the light **10'** propagating through the patient tissue for monitoring hydration levels in tissue during operation of the electrosurgical pencil **100**.

[0088] More particularly, the electrosurgical blade **106***b* is configured wherein optical transmitters **2023***a* and **2023***b* propagate light through the patient tissue via first and second lateral portions **1202***a* and **1202***b*, respectively, of peripheral edge **1202**. Additionally, the electrosurgical blade **106***b* is configured wherein optical sensors **2023***a'* and **2023***b'* sense at least a portion of the light propagating through the patient tissue via first and second lateral portions **1202***a* and **1202***b*, respectively, of peripheral edge **1202**.

[0089] Optical transmitters **2023***a* and **2023***b* are configured with prism **206** and the optical fibers described with respect to optical transmitter **202** in FIG. **3**A. Optical sensors **2023***a'* and **2023***b'* are also configured with prism **206** and the optical fibers described with respect to the optical sensor **202'** in FIG. **3**B, except that large diameter single optical fiber **208** is replaced by more than one smaller diameter optical fibers similar to **204***a'*, **204***b'*, **204***c'*. As indicated, the diameters of the sensing optical fibers **204***a'*, **204***b'*, **204***c'* may differ from one another. The optical sensors **2023***a'* and **2023***b'* may be positioned on the electrosurgical blade **106***b* proximally with respect to optical transmitters **2023***a* and **2023***b*.

[0090] The transmission optical fibers **204***a*, **204***b*, **204***c* and the sensing optical fibers **204***a'*, **204***b'*, **204***c'* are routed through the hollow central region **140'** of the shaft **140** and further through the housing **102**.

[0091] Turning now to FIGS. **5**A and **5**B, there is illustrated still another embodiment of electrocautery blade **106**. More particularly, electrocautery blade **106***c* again defines proximal end **150***a* and distal end **150***b*. The blade **106***c* again has a substantially planar configuration having a generally convex lateral cross-section defining at least one peripheral edge **1203** and at least one lateral surface, e.g., first surface **1303***a* and a second surface not explicitly shown on the opposing side of first surface **1303***a*. The blade **106***c* again includes cylindrical shaft **140** defining hollow central region **140'** therewithin and extending to proximal end **144** of substantially planar region **152** of the blade **106***c*. The hollow shaft **140** extends to the substantially planar region **152** to define a circumferential recess **142** around the outer surface of the hollow shaft **140**.

[0092] In contrast to electrosurgical blades **106***a* and **106***b*, the electrosurgical blade **106***c* is configured with at least one optical transmitter **2510** positioned to propagate light **1001** through patient tissue, but, in a similar manner as with respect to electrosurgical blades **106***a* and **106***b*, with at least one optical sensor **202'** positioned to sense at least a portion of the light **10'** propagating through the patient tissue for monitoring hydration levels in tissue during operation of the electrosurgical pencil **100**.

[0093] More particularly, the electrosurgical blade **106***c* is configured wherein optical transmitters **2511***a* and **2511***b* propagate light through the patient tissue via first and second lateral portions **1203***a* and **1203***b*, respectively, of peripheral edge **1203**. Thus, the optical transmitters **2511***a* and **2511***b* include electrical cables **2541***a* and **2541***b* and light-emitting electronic devices **2561***a* and **2561***b* and large diameter optical fibers **2081***a* and **2081***b*, respectively, as described with respect to optical transmitter **2510** in FIG. **4**A. Additionally, the electrosurgical blade **106***c* is configured wherein optical sensors **2024***a'* and **2024***b'* sense at least a portion of the light propagating through the patient tissue via first and second lateral portions **1203***a* and **1203***b*, respectively, of peripheral edge **1203**.

[0094] Optical sensors **2024***a'* and **2024***b'* are also configured with prism **206** and the optical fibers described with respect to the optical sensor **202'** in FIG. **3**B, except that large diameter single optical fiber **208** is replaced by more than one smaller diameter optical fibers similar to **204***a'*, **204***b'*, **204***c'*. As indicated, the diameters of the sensing optical fibers **204***a'*, **204***b'*, **204***c'* may differ from one another.

[0095] The transmitting electrical cables **2541***a* and **2541***b* and the sensing optical fibers **204***a'*, **204***b'*, **204***c'* are again routed through the hollow central region **140'** of the shaft **140** and further through the housing **102**.

[0096] FIGS. **6**A and **6**B illustrate yet another embodiment of electrocautery blade **106**. More particularly, electrocautery blade **106***d* again defines proximal end **150***a* and distal end **150***b*. The blade **106***d* has a substantially planar configuration having a generally convex lateral cross-section defining at least one peripheral edge **1204** and at least one lateral surface, e.g., first surface **1304***a* and a second surface not explicitly shown on the opposing side of first surface **1304***a*. The blade **106***d* includes cylindrical shaft **140** defining hollow central region **140'** therewithin and extending to proximal end **144** of substantially planar region **152** of the blade **106***c*. The hollow shaft **140** extends to the substantially planar region **152** to define a circumferential recess **142** around the outer surface of the hollow shaft **140**.

[0097] In contrast to electrosurgical blades **106***a*, **106***b* or **106***c*, the electrosurgical blade **106***d* is configured with at least one optical transmitter **202** positioned to propagate light **10** through patient tissue, but, with at least one optical sensor **2520** positioned to sense at least a portion of the light **1002** propagating through the patient tissue for monitoring hydration levels in tissue during operation of the electrosurgical pencil **100**.

[0098] More particularly, the electrosurgical blade **106***d* is configured wherein optical transmitters **2025***a* and **2025***b* propagate light through the patient tissue via first and second lateral portions **1204***a* and **1204***b*, respectively, of peripheral edge **1204**. Thus, the optical transmitters **2025***a* and **2025***b* include large diameter optical fibers **2082***a* and **2082***b*, respectively, as described with respect to optical transmitter **202** in FIG. **3**A.

[0099] Optical sensors **2025***a* and **2025***b* are also configured with prism **206** and the optical fibers described with respect to the optical sensor **202'** in FIG. **3**A.

[0100] Additionally, the electrosurgical blade **106***d* is configured wherein optical sensors **2521***a'* and **2521***b'* sense at least a portion of the light propagating through the patient tissue also via first and second lateral portions **1204***a* and **1204***b*, respectively, of peripheral edge **1204**. The optical sensors **2521***a'* and **2521***b'* include the electrical cables **2542***a'* and **2542***b'* and photo-electric detectors **2562***a'* and **2562***b'* and each with a plurality of optical fibers similar to optical fibers **204***a'*, **204***b'* and **204***c'* on the first and second portions **1204***a* and **1204***b*, respectively, of the lateral edge **1204**. as described with respect to optical sensor **2520** in FIG. **4**B, thereby sensing at least a portion of the light propagating through the patient tissue.

[0101] Additionally, the electrosurgical blade **106***d* is configured wherein optical sensors **2521***a'* and **2521***b'* may be

positioned proximally on the electrosurgical blade **106***d* with respect to the optical transmitters **2025***a* and **2025***b*.

[0102] The transmitting optical fibers **204***a*, **204***b*, **204***c* and the sensing electrical cables **2542***a* and **2542***b* are routed through the hollow central region **140'** of the shaft **140** and further through the housing **102**.

[0103] FIGS. **7-11** and **12**A, **12**B, **12**C and **13** illustrate various embodiments of an electrically conductive member **300** for use with an electrosurgical instrument. The electrically conductive member **300** has a surface **302** that is configured to be in contact with patient tissue (not shown) and to be connected to a source of electrosurgical energy (not shown),

[0104] As described in more detail below, the electrically conductive member **300** is configured with one or more optical transmitters positioned in an array to propagate light through patient tissue and one or more optical sensors positioned in an array to sense via reflectance by the patient tissue at least a portion of the light propagating through the patient tissue for monitoring hydration levels in tissue during operation of the electrosurgical pencil.

[0105] Turning particularly to FIGS. **7** and **7**A, and in conjunction with FIGS. **4**A and **4**B, electrically conductive member **300***a* has surface **302***a* that is configured to be in contact with, or to engage with, patient tissue (not shown) and adapted to connect to a source of electrosurgical energy (not shown), The surface **302***a* is configured with one more optical transmitters **2512** positioned in an array to propagate light through patient tissue and at least one optical sensor, e.g., two optical sensors **2522** and **2523** positioned in an array, configured to sense changes in reflected light, e.g., via reflectance by the patient tissue, at least a portion of the light propagating through the patient tissue during operation of the electrosurgical instrument and relating the changes in reflected light to hydration levels in tissue during operation of the electrosurgical pencil.

[0106] The optical sensors **2522'** and **2523'** may include first optical fibers **2522***a'* and **2523***a'*, second optical fibers **2522***b'* and **2523***b'*, and third optical fibers **2522***c'* and **2523***c'*, respectively, wherein the diameter of the first optical fibers **2522***a'* and **2523***a'* differs from the diameter of the second optical fibers **2522***b'* and **2523***b'*, and the diameter of the third optical fibers **2522***c'* and **2523***c'* differs from the diameters of the first and second optical fibers.

[0107] The optical transmitters **2512** are disposed substantially linearly to form on the surface a single line of optical fibers **2512***a* that is disposed distally from the two optical sensors **2522'** and **2523**. The optical fibers of optical sensors **2522'** and **2523'** are disposed substantially linearly to form first and second lines of optical fibers **2522***a'*, **2522***b'*, **2522***c'* and **2523***a'*, **2523***b'*, **2523***c'*, respectively. The optical transmitters **2512** may be disposed substantially linearly relative to one another along an axis "A" defined through the electrically conductive member **300***a* from a proximal end to a distal end thereof. The optical transmitters **2512** may be disposed distally relative to the optical sensors **2522'** and **2523'**. The optical sensors **2522'** and **2523'** may correspond to the optical transmitters **2512**.

[0108] As illustrated in FIG. **7**A, in a similar manner as with respect to the optical transmitter **2510** described with respect to FIG. **4**A, the optical transmitter **2512** includes electrical cable **2541**, light-emitting electronic device **2561** and the single line of optical fibers **2512***a*. In addition, in a similar manner as with respect to the optical sensor **2520** described with respect to FIG. **4**B, optical sensors **2522'** and **2523'** include electrical cables **2542'** and **2543'**, photo-electric detector **2562'** and **2563'**, and the optical fibers **2522***a'*, **2522***b'*, **2522***c'* and **2523***a'*, **2523***b'*, **2523***c'*, respectively.

[0109] Upon emission of light from the light-emitting electronic device **2561**, light path **301** propagates from the single line of optical fibers **2512***a* to first line of optical fibers **2522***a'*, **2522***b'*, **2522***c'* of first optical sensor **2522'**. Similarly, light path **311** propagates from the single line of optical fibers **2512***a* to second line of optical fibers **2523***a'*, **2523***b'*, **2523***c'* of second optical sensor **2523'**.

[0110] As explained below in more detail with respect to FIGS. **19-20**, the different diameters of the optical fibers of the optical sensors **2522'** and **2523'** enable monitoring of water motility within the patient tissue during the electrosurgical procedure.

[0111] FIG. **8** illustrates an alternate embodiment of the electrically conductive member **300** having surface **302**. More particularly, electrically conductive member **300***b* is an alternate embodiment of the electrically conductive member **300***a* described above with respect to FIGS. **7** and **7**A. Again, the electrically conductive member **300***b* includes the at least two optical sensors **2522'** and **2523'**. The optical fibers **2522***a'*, **2522***b'*, **2522***c'* and **2523***a'*, **2523***b'* **2523***c'* of the optical sensors **2522'** and **2523'**, respectively are disposed substantially linearly to form on surface **302***b* first and second lines. The first line **2522'** is distal from the second line **2523'**.

[0112] Electrically conductive member **300***b* differs from electrically conductive member **300***a* in that the optical fibers **2512***a* of the optical transmitter **2512** are disposed substantially linearly to form a single line disposed between the first and second lines of the two or more optical sensors **2522'** and **2523'**. That is, the plurality of optical sensors **2522'** and **2523'** may be disposed substantially linearly along an axis "B" defined through the electrically conductive member **300***b*. The optical sensors **2522'** and **2523'** may be disposed substantially linearly relative to one another to form first and second lines of optical sensors on the surface **302***b*. The second line of optical sensors **2522'** may be distal from the first line of optical sensors **2523'**.

[0113] As illustrated in FIG. **7**A, the optical transmitter **2512** forms a first light path in patient tissue. The first light propagates by reflectance in the patient tissue to the first optical sensor **2522'** while the optical transmitter **2512** also forms a second light path in patient tissue, wherein the second light path propagates by reflectance in the patient tissue to the second optical sensor **2523'**. The diameters of the optical fibers **2522***a'*, **2522***b'*, **2522***c'* may differ from one another. Similarly, the diameters of the optical fibers **2523***a'*, **2523***b'*, **2523***c'* may differ from one another to allow propagation of light of differing wavelengths.

[0114] The optical transmitter **2512** may also include the light-emitting electronic device **2561** and electrical cable **2541** described previously with respect to FIG. **4**A while the optical sensors **2522'**, **2523'** include the photo-electric detector **2562** and electrical cable **2542** described previously with respect to FIG. **4**B.

[0115] FIG. **9** illustrates yet another embodiment of the electrically conductive member **300** having surface **302**. More particularly, electrically conductive member **300***c* includes one or more optical transmitters **2513** and two or more optical sensors, e.g., first optical sensor **2524'** and second optical sensor **2525'**. The optical transmitter **2513** and the first and second optical sensors **2524'**, **2525'** are disposed in a

pattern on surface **302***c* that includes at least a first plurality of optical fibers **2524***a*', **2524***b*', **2524***c*' of optical sensor **2524**' in a circumferential arrangement and a second plurality of optical fibers **2525***a*', **2525***b*', **2525***c*' of optical sensor **2525**' in a circumferentially substantially concentric arrangement with respect to the first plurality of optical fibers **2524***a*', **2524***b*', **2524***c*' of optical sensor **2524**'. That is, the first plurality of optical sensors **2524**' may be disposed in a first circumferential pattern on the surface **302***c* and the second plurality of optical sensors **2525**' may be disposed in a second circumferential pattern on the surface **302***c* that is concentric to the first circumferential pattern of the first plurality of optical sensors **2524**'.

[0116] Optical fibers **2513***a*, **2513***b*, **2513***c*, **2513***c*, **2513***d*, **2513***e* of optical transmitter **2513** are disposed substantially at the center of the substantially concentric arrangement of the first and second plurality of optical fibers **2524***a*', **2524***b*', **2524***c*' and **2525***a*', **2525***b*', **2525***c*' of the optical sensors **2524**' and **2525**', respectively. That is, the optical transmitter **2513** may be disposed substantially at the center of the concentric arrangement of the first and second circumferential patterns of the optical sensors **2524**' and **2525**', respectively.

[0117] In view of the light paths **301** and **311** illustrated in FIG. **7**A, the optical transmitter **2513** forms multiple light paths in patient tissue distributed substantially radially away from the optical fibers **2513***a*, **2513***b*, **2513***c*, **2513***c*, **2513***d*, **2513***e*. The light propagates by reflectance in the patient tissue to the substantially concentric arrangement of the first and second plurality of optical fibers **2524***a*', **2524***b*', **2524***c*' and **2525***a*', **2525***b*', **2525***c*' of the optical sensors **2524**' and **2525**', respectively. The diameters of the plurality of optical fibers **2524***a*', **2524***b*', **2524***c*' and **2525***a*', **2525***b*', **2525***c*' may again differ from one another as explained above

[0118] In addition, the optical transmitter **2513** may include the light-emitting electronic device **2561** and electrical cable **2541** described previously with respect to FIG. **4**A while the optical sensors **2524**', **2525**' include the photoelectric detector **2562** and electrical cable **2542** described previously with respect to FIG. **4**B.

[0119] FIG. **10** illustrates still another embodiment of the electrically conductive member **300** having surface **302**. More particularly, electrically conductive member **300***d* includes two or more optical transmitters, e.g., first optical transmitter **2514** and second optical transmitter **2515**. The optical transmitters **2514**, **2515** are disposed in a pattern on surface **302***d* that includes at least a first plurality of optical fibers **2514***a*, **2514***b* . . . **2514***n* of optical transmitter **2514** in a circumferential arrangement and a second plurality of optical fibers **2515***a*, **2515***b* . . . **2515***n* of optical transmitter **2515** in a circumferential substantially concentric arrangement with respect to the first plurality of optical fibers **2514***a*, **2514***b* . . . **2514***n*. That is, the first plurality of optical transmitters **2514** may be disposed in a first circumferential pattern on the surface **302***d* and the second plurality of optical transmitters **2515** may be disposed in a second circumferential pattern on the surface **302***d* that is concentric to the first circumferential pattern of the first plurality of optical transmitters **2514**.

[0120] Optical fibers **2526***a*' and **2526***b*' and **2526***c*' of one or more optical sensors **2526**' are disposed substantially at the center of the substantially concentric arrangement of the first and second plurality of optical fibers **2514***a*, **2514***b* . . . **2514***n* and **2515***a*, **2515***b* . . . **2515***n* of optical transmitters **2514** and **2515**, respectively. That is, the optical sensor **2526**' may be disposed substantially at the center of the concentric arrangement of the first and second circumferential patterns of the optical transmitters **2514** and **2515**, respectively.

[0121] In view of the light paths **301** and **311** illustrated in FIG. **7**A, the optical transmitters **2514**, **2515** form multiple light paths in patient tissue distributed substantially radially towards the optical fibers **2526***a*', **2526***b*', **2526***c*' of optical sensor **2526**'. The light propagates by reflectance in the patient tissue from the substantially concentric arrangement of the first and second plurality of optical fibers **2514***a*, **2514***b* . . . **2514***n* and **2515***a*, **2515***b* . . . **2515***n* of optical transmitters **2514** and **2515**, respectively. The diameters of the optical fibers **2526***a*', **2526***b*', **2526***c*' of optical sensor **2526**' may again differ from one another to allow propagation and sensing of light of different wavelengths. The light-emitting electronic devices and photo-electric detectors and electrical cables may be configured as described previously with respect to FIGS. **4**A and **4**B.

[0122] FIG. **11** illustrates yet another embodiment of the electrically conductive member **300** having surface **302**. More particularly, electrically conductive member **300***e* includes two or more optical transmitters, e.g., first optical transmitter **2516** and second optical transmitter **2517**, and two or more optical sensors, e.g., first optical sensor **2527**' and second optical sensor **2528**'. The optical transmitters **2516**, **2517** and the optical sensors **2527**', **2528**' are disposed in a pattern on surface **302***e*. At least a first plurality of optical fibers **2516***a*, **2516***b* . . . **2516***n* and **2517***a*, **2517***b* . . . **2517***n* form at least a portion of the optical transmitters **2516** and **2517**, respectively, and are disposed in a substantially circumferential arrangement.

[0123] At least a first plurality of optical fibers **2527***a*', **2527***b*', **2527***c*' and at least a second plurality of optical fibers **2528***a*', **2528***b*', **2528***c*' form at least a portion of the optical sensors **2527**' and **2528**', respectively. The first and second plurality of optical fibers **2527***a*', **2527***b*', **2527***c*' and **2528***a*', **2528***b*', **2528***c*' of optical sensors **2527**' and **2528**', respectively, are disposed substantially at the center of the substantially circumferential arrangement of the first and second plurality of optical fibers **2516***a*, **2516***b* . . . **2516***n* and **2517***a*, **2517***b* . . . **2517***n* that form at least a portion of the optical transmitters **2516** and **2517**, respectively, to form a first array of optical transmitting and sensing fibers. The first array of optical transmitter **2516** and optical sensor **2527**' is disposed distally with respect to the second array of optical transmitter **2517** and optical sensor **2528**'. That is, the first optical sensor **2527**' may include fibers **2527***a*', **2527***b*', **2527***c*' that form a first circumferential arrangement and the first optical transmitter **2516** may be disposed substantially at the center of the first circumferential arrangement of the fibers **2527***a*', **2527***b*', **2527***c*'. The second optical sensor **2528**' may include fibers **2528***a*', **2528***b*', **2528***c*' that form a second circumferential arrangement and the second optical transmitter **2517** may be disposed substantially at the center of the second circumferential arrangement of the fibers **2528***a*', **2528***b*', **2528***c*'. The second circumferential arrangement may be disposed distally relative to the first circumferential arrangement, along an axis "C" defined through the electrically conductive member **302***e*.

[0124] In view of the light paths **301** and **311** illustrated in FIG. **7**A, the optical transmitters **2516**, **2517** form multiple light paths in patient tissue distributed substantially radially towards the respective optical fibers **2527***a*', **2527***b*', **2527***c*' of optical sensor **2527**' and **2528***a*', **2528***b*', **2528***c*' of optical

sensor **2528'** in the first and second arrays, respectively. Again, the light propagates by reflectance in the patient tissue. The diameters of the optical fibers **2527***a*', **2527***b*', **2527***c*' of optical sensor **2527'** and of optical fibers **2528***a*', **2528***b*', **2528***c*' of optical sensor **2528'** may again differ from one another to allow propagation and sensing of light of different wavelengths.

[0125] First and second arrays of optical transmitters and optical sensors may also be formed by replacing the concentrically arranged optical fibers **2516***a*, **2516***b* . . . **2516***n* and **2517***a*, **2517***b* . . . **2517***n* of optical transmitters **2516** and **2517**, respectively, with optical sensors and by replacing the first and second plurality of optical fibers **2527***a*', **2527***b*', **2527***c*' and **2528***a*', **2528***b*', **2528***c*' of optical sensors **2527'** and **2528'**, respectively, that are disposed substantially at the center of the substantially circumferential arrangement of the first and second plurality of optical fibers **2516***a*, **2516***b* . . . **2516***n* and **2517***a*, **2517***b* . . . **2517***n* with optical transmitters.

[0126] FIGS. **12**A, **12**B, **12**B', **12**C, **12**C' and **13** illustrate different embodiments of yet another electrically conductive member **300** for use with an electrosurgical instrument having a surface **302** according to the present disclosure. More particularly, FIGS. **12**A, **12**B, **12**C and **13** illustrate an electrically conductive member **300***f* having at least a first lateral surface **3021***f* and a second lateral surface **3022***f* on an opposing side of the electrically conductive member **300***f*.

[0127] The electrically conductive member **300***f* includes on first and second lateral surfaces **3021***f* and **3022***f* one or more optical transmitters, e.g., optical transmitters **3011***a*, **3011***b*, **3011***c*, **3011***d* and **3012***a*, **3012***b*, **3012***c*, **3012***d*. The electrically conductive member **300***f* also includes on first and second lateral surfaces **3021***f* and **3022***f* one or more optical sensors, e.g., optical sensors **3011***a*', **3011***b*', **3011***c*' and **3012***a*', **3012***b*', **3012***c*'. The optical transmitters **3011***a*, **3011***b*, **3011***c*, **3011***d* and **3012***a*, **3012***b*, **3012***c*, **3012***d* and optical sensors **3011***a*', **3011***b*', **3011***c*' and **3012***a*', **3012***b*', **3012***c*' each may include an optical fiber having at least one end **3010** with a tapered configuration to function as a prism. That is, the optical transmitters **3011***a*, **3011***b*, **3011***c*, **3011***d* and **3012***a*, **3012***b*, **3012***c*, **3012***d* may each have tapered end **3010** that forms a prism.

[0128] As illustrated in FIGS. **12**B and **12**C, the optical sensors **3011***a*', **3011***b*', **3011***c*' and **3012***a*', **3012***b*', **3012***c*' are each positioned in channels (for simplicity, the channels are not separately numbered) in the respective surfaces **3021***f* and **3022***f* having a depth within the electrically conductive member **300***f* that is greater than the depth of channels (for simplicity, the channels are not separately numbered) within which optical transmitters **3011***a*, **3011***b*, **3011***c*, **3011***d* and **3012***a*, **3012***b*, **3012***c*, **3012***d* are positioned.

[0129] The tapered configuration ends **3010** of the optical transmitters **3011***a*, **3011***b*, **3011***c*, **3011***d* and **3012***a*, **3012***b*, **3012***c*, **3012***d* are positioned within the respective surfaces **3021***f* and **3022***f* to transmit light through patient tissue via the tapered configuration ends **3010**. Similarly, the tapered configuration ends **3010** of the optical sensors **3011***a*', **3011***b*', **3011***c*' and **3012***a*', **3012***b*', **3012***c*' are positioned within the respective surfaces **3021***f* and **3022***f* to sense light propagating by reflectance, through patient tissue via the tapered configuration ends **3010**. For simplicity, light **321** is identified in FIG. **13** as reflecting in either direction to represent the two different functions of transmission into the patient tissue and sensing by reflectance from the patient tissue. The light **321** propagates and reflects through patient tissue. The first and second lateral surfaces **3021***f*, **3022***f* may each include translucent heat-insulating layers **3031***f* and **3032***f* to cover the respective channels and the optical fibers positioned therewithin.

[0130] The electrically conductive member **300***f* illustrated in FIGS. **12**A, **12**B, **12**C and **13**, which includes the optical transmitters and optical sensors in both the first and second lateral surfaces **3021***f*, **3022***f* may be adapted as a blade for an electrosurgical pencil in a similar manner as described previously with respect to FIGS. **1** through **6***b*.

[0131] The electrically conductive member **300***f* illustrated in FIGS. **12**A, **12**B', **12**C' and **13** is configured identically to the electrically conductive member **300***f* except that only the optical transmitters **3012***a*, **3012***b*, **3012***c*, **3012***d* and optical sensors **3012***a*', **3012***b*', **3012***c*' associated with second lateral surface **3022***f* and their respective channels (again not numbered for simplicity) are illustrated. The electrically conductive member **300***f*' may be adapted as a jaw member of a bipolar electrosurgical forceps, as described in more detail below with respect to FIG. **14**.

[0132] FIG. **14** illustrates a bipolar electrosurgical forceps **400** according to the present disclosure illustrating one embodiment of an end effector assembly **405** having an optical transmitter positioned to propagate light through patient tissue and optical sensors positioned to sense at least a portion of the light propagating through the patient tissue for monitoring hydration levels in tissue during operation of the bipolar forceps.

[0133] One embodiment of a bipolar forceps **400** is shown for use with various surgical procedures and generally includes a housing **402**, a handle assembly **430**, a rotating assembly **480**, a trigger assembly **470** and an end effector assembly **405** which mutually cooperate to grasp, seal and divide tubular vessels and vascular tissue.

[0134] End effector assembly **405** is attached to distal end **414** of shaft **412** and includes a pair of opposing jaw members **410** and **420**. Movable handle **440** of handle assembly **430** is ultimately connected to a drive rod (not shown) disposed within the shaft **412** which, together, mechanically cooperate to impart movement of the jaw members **410** and **420** from an open position wherein the jaw members **410** and **420** are disposed in spaced relation relative to one another, to a clamping or closed position wherein the jaw members **410** and **420** cooperate to grasp tissue.

[0135] Forceps **400** also includes an electrical interface or plug **450** which connects the forceps **400** to a source of electrosurgical energy, e.g., a generator (not shown). Plug **450** includes a pair of prong members **452***a* and **452***b* that are dimensioned to mechanically and electrically connect the forceps **400** to the source of electrosurgical energy. An electrical cable **455** extends from the plug **450** to a sleeve **456** which securely connects the cable **455** to the forceps **400**.

[0136] The first and second jaw members **410** and **420** each have respective inwardly facing surfaces **410'** and **420'** associated therewith. As defined herein, the inwardly facing surfaces **410'** and **420'** may be formed partially of an electrically conductive material and partially of an electrically insulating material. The electrically conductive material is in electrical communication with the source of electrosurgical energy. Consequently, the inwardly facing surfaces **410'** and **420'** may be referred to as electrically conductive surfaces **410'**, **420'** and as electrically insulating surfaces **410'**, **420'**.

[0137] The first and second jaw members **410** and **420** respectively are each adapted for relative movement between

an open position to receive tissue and a closed position engaging tissue between the inwardly facing surfaces **410'** and **410'**. That is, first and second jaw members **410** and **420** are disposed in pivotal relationship with respect to one another and attached to distal end **414** of at least one shaft, e.g., shaft **412**. Each jaw member **410** and **420** supports an electrically conductive surface **410'** and **420'**, respectively, thereon. Jaw member **410** and/or jaw member **420** is configured to be connected to the source of electrosurgical energy (via the plug **450**), One of the jaw members, e.g., lower jaw member **410**, may be in a fixed position with respect to the shaft **412**. The jaw members **410** and **420** of end effector assembly **405** are configured to effect optical transmission of light through patient tissue.

[0138] FIG. **14**A illustrates one embodiment of end effector assembly **405**. More particularly, end effector assembly **405***a* includes one of the jaw members **410** and/or **420**, e.g., upper jaw member **420***a*, configured with one or more optical transmitters, e.g., optical transmitter **2510**, as described previously with respect to FIG. **4**A, that is positioned in the surface **420'** to propagate light through patient tissue.

[0139] One or both of the jaw members, e.g., lower jaw member **410***a*, may be configured with one or more optical sensors, e.g., optical sensor **202'**, as described previously with respect to FIG. **2**B with the exception that the large diameter single optical fiber **208** is replaced by a plurality of optical fibers such as optical fibers **204***a'*, **204***b'*, **204***c'* having diameters that differ from one another. Optical sensor **202'** is positioned to sense at least a portion of the light (not shown) propagating through the patient tissue. The light is transmitted by the optical transmitter **2510** positioned in the upper jaw member **420***a*, for monitoring hydration levels in the patient tissue during operation of the electrosurgical forceps **400**.

[0140] As described below with respect to FIGS. **19-20**, one or both of the jaw members **410** and **420** is disposed in optical communication with a light source **7321**, **7322** and/or **7323** and the other of the jaw members **410** and **420** is disposed in optical communication with a light sensor **7341** and/or **7342** for monitoring hydration levels in the tissue **2** during operation of the electrosurgical forceps **400**.

[0141] FIG. **14**B illustrates another embodiment of the end effector assembly **405** of FIG. **14**. More particularly, end effector assembly **405***b* includes one of the jaw members **410** and/or **420**, e.g., upper jaw member **420***b*, configured with one or more optical transmitters, e.g., optical transmitter **2510** that includes a light-emitting electronic device (as described previously with respect to FIG. **4**A) that is positioned in the surface **420'** to propagate light through patient tissue.

[0142] One or both of the jaw members, e.g., lower jaw member **410***b*, is configured with one or more optical sensors, e.g., optical sensor **2520** that includes a photo-electric detector (as described previously with respect to FIG. **4**B) that is positioned to sense at least a portion of light **331** propagating through the patient tissue. The light **331** is transmitted by the optical transmitter **2510** positioned in the upper jaw member **420**, for monitoring hydration levels in the patient tissue during operation of the electrosurgical forceps **400**.

[0143] As described below with respect to FIGS. **19-20**, one or both of the jaw members **410** and **420** is disposed in optical communication with a light source **7321**, **7322** and/or **7323** and the other of the jaw members **410** and **420** is disposed in optical communication with a light sensor **7341** and/or **7342** for monitoring hydration levels in the tissue **2** during operation of the electrosurgical forceps **400**.

[0144] FIG. **14**C illustrates still another embodiment of the end effector assembly **405** of FIG. **14**. More particularly, end effector assembly **405***c* includes one or more jaw members **410** and/or **420**, e.g., upper jaw member **420***c*, configured with one or more optical transmitters, e.g., optical transmitter **202**, as described previously with respect to FIG. **4**A with the exception that the large diameter single optical fiber **208** is replaced by a plurality of optical fibers such as optical fibers **204***a*, **204***b*, **204***c* having diameters that differ from one another. The optical transmitter **202** is positioned in the surface **420'** to propagate light through patient tissue.

[0145] One or both of the jaw members, e.g., lower jaw member **410***b*, is configured with one or more optical sensors, e.g., optical sensor **202'**, as described previously with respect to FIG. **3**B with the exception that the large diameter single optical fiber **208** is replaced by a plurality of optical fibers such as optical fibers **204***a'*, **204***b'*, **204***c'* having diameters that differ from one another. The optical sensor **202'** is positioned to sense at least a portion of light propagating through the patient tissue. The light has been transmitted by the optical transmitter **202** positioned in the upper jaw member **420**, for monitoring hydration levels in the patient tissue during operation of the electrosurgical forceps **400**.

[0146] Again, as described below with respect to FIGS. **19-20**, at least one of the jaw members **410** and **420** is disposed in optical communication with a light source **7321**, **7322** and/or **7323** and the other of the jaw members **410** and **420** is disposed in optical communication with a light sensor **7341** and/or **7342** for monitoring hydration levels in the tissue **2** during operation of the electrosurgical forceps **400**.

[0147] FIGS. **15**A and **15**B illustrate yet another embodiment of the end effector assembly **405** of FIG. **14**. More particularly, end effector assembly **405***d* includes the jaw members **410** and/or **420**, e.g., upper jaw member **420***d*, configured with one or more optical transmitters **2026**, e.g., optical transmitter **202**, as described previously with respect to FIG. **3**A with the exception that the large diameter single optical fiber **208** is omitted and one surface **2061** of prism **206** is exposed directly on inwardly facing surface **420'** to reflect light from a common light source **1220** via the prism **206** to patient tissue (not shown). Thus, optical transmitter **2026** is positioned in the inwardly facing surface **420'** to propagate light in different paths, e.g., light paths **341***a*, **341***b*, **341***c*, through patient tissue.

[0148] One or both of the jaw members, e.g., lower jaw member **410***d*, is configured with one or more optical sensors, e.g., first, second and third optical sensors **2026***a'*, **2026***b'*, **2026***c'*, respectively, that are similar to optical sensor **202'**, as described previously with respect to FIG. **3**B with the exception that the large diameter single optical fiber **208** is again omitted and one surface **2061***a'*, **2061***b'*, **2061***c'* of prisms **206***a'*, **206***b'*, **206***c'*, respectively, is exposed directly on inwardly facing surface **410'** to reflect light via the prism **206** from patient tissue (not shown) through a plurality of optical fibers **204***a'*, **204***b'*, **204***c'* that are routed through individual channels in channel groups **2040***a'*, **2040***b'*, **2040***c'*, respectively.

[0149] The optical sensors **2026***a'*, **2026***b'*, **2026***c'* are each positioned to sense at least a portion of the light propagating in light paths **341***a*, **341***b*, **341***c*, respectively, through the patient tissue. The light is transmitted by the optical transmitter **2026** positioned in the upper jaw member **420**, for monitoring hydration levels in the patient tissue during operation of the electrosurgical forceps **400**. To enable routing of the

optical fibers **204***a*', **204***b*', **204***c*' in channel groups **2040***a*', **2040***b*', **2040***c*', the channel groups **2040***a*', **2040***b*', **2040***c*' are formed laterally offset from one another within the lower jaw member **410***d*. More particularly, as indicated above, the first, second and third optical sensors **2026***a*', **2026***b*', **2026***c*' each have a prism associated therewith, e.g., prisms **206***a*', **206***b*', **206***c*', respectively, mounted on the fixed jaw member **410***d*. The first prism **206***a*' is mounted distally of the second prism **206***b*' and the second prism **206***b*' is mounted distally of the third prism **206***c*'. The first prism **206***a*' is mounted proximal to first lateral edge **430***a* of the surface **410***d*. The second prism **206***b*' is laterally offset with respect to the first prism **206***a*' and is further laterally offset with respect to the lateral edge **430***a*. The third prism **206***c*' is laterally offset with respect to both first and second prisms **206***a*' and **206***b*', respectively, and may be proximal to second lateral edge **430***b* of the surface **410***d*.

[0150] Correspondingly, the first channel group **2040***a*' is laterally offset from the second channel group **2040***b*' and both the first and second channel groups **2040***a*' and **2040***b* are laterally offset from third channel group **2040***c'*.

[0151] As described below with respect to FIGS. **19-20**, one or both of the jaw members **410** and **420** may be disposed in optical communication with a light source **7321**, **7322** and/or **7323** and the other of the jaw members **410** and **420** may be disposed in optical communication with a light sensor **7341** and/or **7342** for monitoring hydration levels in the tissue **2** during operation of the electrosurgical forceps **400**.

[0152] FIGS. **15**C and **15**D illustrate yet another embodiment of the end effector assembly **405** of FIG. **14** having lower and upper jaw members **410** and **420**, respectively. More particularly, end effector assembly **405***e* includes upper jaw member **420***e* that is identical to upper jaw member **420***d* as described above with respect to FIGS. **15**A and **15**D. The jaw members, e.g., lower jaw member **410***e*, may be substantially identical to lower jaw member **410***d* described above with respect to FIGS. **15**A and **15**B. Lower jaw member **410***e* is also configured with one or more optical sensors, e.g., first, second and third optical sensors **2026***a*', **2026***b*', **2026***c*', respectively, that are again similar to optical sensor **202**', as described previously with respect to FIG. **4**B with the exception that the large diameter single optical fiber **208** is now included.

[0153] As illustrated in FIGS. **15**C and **15**D, one end **2080***a*, **2080***b*, **2080***c* of each large diameter single optical fiber **208***a*, **208***b*, **208***c*, respectively, is exposed directly on inwardly facing surface **410**' to sense light propagating in light paths **341***a*, **341***b*, **341***c*, respectively, from patient tissue (not shown) and to communicate the light to be reflected via the respective prisms **206***a*', **206***b*', **206***c*' again through a plurality of optical fibers **204***a*', **204***b*', **204***c*' that are routed through individual channels in channel groups **2040***a*', **2040***b*', **2040***c*', respectively.

[0154] In a similar manner as with respect to end effector assembly **405***d* described with respect to FIGS. **15**A and **15**C, the optical sensors **2026***a*', **2026***b*', **2026***c*' are each positioned to sense at least a portion of the light propagating in light paths **341***a*, **341***b*, **341***c*, respectively, through the patient tissue. The light is transmitted by the optical transmitter **2026** positioned in the upper jaw member **420**, for monitoring hydration levels in the patient tissue during operation of the electrosurgical forceps **400**. To enable routing of the optical fibers **204***a*', **204***b*', **204***c*' in channel groups **2040***a*', **2040***b*', **2040***c*', the channel groups **2040***a*', **2040***b*', **2040***c*' are formed laterally offset from one another within the lower jaw member **410***d*. More particularly, as indicated above, the first, second and third optical sensors **2026***a*', **2026***b*', **2026***c*' each have a large diameter single optical fiber **208***a*, **208***b*, **208***c* associated with prisms **206***a*', **206***b*', **206***c*', respectively, that are mounted within the fixed jaw member **410***e*. The first large diameter single optical fiber **208***a* and associated prism **206***a*' are mounted distally of the second large diameter single optical fiber **208***b* and associated second prism **206***b*', and the second large diameter single optical fiber **208***b* and associated second prism **206***b*' are mounted distally of the third large diameter single optical fiber **208***c* and associated prism **206***c'*.

[0155] The first optical fiber **208***a* and associated first prism **206***a*' may be mounted in proximity to first lateral edge **440***a* of the surface **410***e*. The second optical fiber **208***b* and associated first prism **206***b*' may be laterally offset with respect to the first optical fiber **208***a* and associated first prism **206***a*' and may be further laterally offset with respect to the first lateral edge **440***a*. The third optical fiber **208***c* and associated third prism **206***c*' may be laterally offset with respect to both first and second optical fiber **208***a*, **208***b* and associated prisms **206***a*' and **206***b*', respectively, and may be in proximity to second lateral edge **440***b* of the surface **410***e*.

[0156] Correspondingly, the first channel group **2040***a*' is laterally offset from the second channel group **2040***b*' and both the first and second channel groups **2040***a*' and **2040***b* are laterally offset from third channel group **2040***c'*.

[0157] The first jaw member **410***e* is thus a compound jaw member in which the first, second and third optical fibers **208***a*, **208***b*, **208***c*, respectively, extend partially into a secondary region **410***e*' defined within the first jaw member **410***e* away from the surface **410**'. Additionally, the first, second and third prisms **206***a*', **206***b*', **206***c*' and the optical fibers **204***a*', **204***b*', **204***c*' and channel groups **2040***a*', **2040***b*', **2040***c*' are mounted predominantly, if not entirely, within the secondary region **410***e'*.

[0158] FIGS. **16**, **16**A, **17** and **18** illustrate various embodiments of an end effector assembly **505** according to the present disclosure for a parallel jaw type bipolar electrosurgical forceps (not shown) having first and second jaw members **510** and **520** having one or more optical transmitters positioned to propagate light through patient tissue and one or more optical sensors positioned to sense at least a portion of the light propagating through the patient tissue for monitoring hydration levels in tissue during operation of the bipolar forceps. The end effector assembly **505** ay be configured such that the jaw members **510** and **520** remain substantially parallel to one another during the relative movement between the open position to the closed position and vice versa. One of the jaw members **510** or **520** may be in a fixed position with respect to a shaft (not shown). Alternatively, both of the jaw members **510** and **520** may be movable with respect to a shaft (not shown).

[0159] More particularly, referring first to FIGS. **16** and **16**A, end effector assembly **505***a* includes first jaw member **510***a* and second jaw member **520***a* having respective inwardly facing surfaces **510***a*' and **520***a*' associated therewith. The jaw members **510***a* and **520***a* are adapted for relative movement between an open position to receive tissue and a closed position engaging tissue between the inwardly facing surfaces **510***a*' and **520***a'*.

[0160] In a similar manner as with respect to jaw members **410** and **420** discussed previously with respect to FIGS. **14**A to **15**D, the inwardly facing surfaces **510***a*' and **520***a*' of each

jaw member **510***a* and **520***a*, respectively, is formed partially of an electrically conductive surface and of an electrically insulating surface. One or both of the jaw members **510***a* and/or **520***a* is configured to be connected to a source of electrosurgical energy (not shown). One of the jaw members may be in a fixed position with respect to a shaft (not shown).

[0161] One or both of the jaw members, e.g., jaw member **520***a*, may be configured with one or more optical transmitters, e.g., optical transmitter **2027***a* that is similar to optical transmitter **202** described previously with respect to FIG. **3**A, except that optical transmitter **2027***a* does not include large diameter optical fiber **208**. The optical transmitter **2027***a* includes prism **2060***a* having surface **2061** that is exposed on inwardly facing surface **520***a*'. The optical transmitter **2027** and associated prism **2060***a* and surface **2061** are positioned to propagate light through patient tissue (not shown) in a light path **351***a*.

[0162] Similarly, one of the jaw members, e.g., jaw member **510***a*, may be configured with one or more optical sensors, e.g., optical sensor **2027***a*' that is similar to optical sensor **202**' described previously with respect to FIG. **3**B, except that optical sensor **2027***a*' also does not include large diameter optical fiber **208**. The optical sensor **2027***a*' includes prism **2060***a*' having surface **2061**' that is exposed on inwardly facing surface **510***a*'. The optical sensor **2027***a*' and associated prism **2060***a*' and surface **2061**' are positioned to sense at least a portion of the light propagating via light path **351***a* through the patient tissue for monitoring hydration levels in tissue during operation of the electrosurgical forceps.

[0163] The light reflected via the respective prisms **2027***a* and **2027***a*' propagates through plurality of optical fibers **204***a*, **204***b*, **204***c* and **204***a*', **204***b*', **204***c*' that are routed through individual channels in channel groups **2040***a* and **2040***a*' in jaw members **520***a* and **510***a*, respectively. The optical fibers **204***a*, **204***b*, **204***c* and **204***a*', **204***b*', **204***c*' again have diameters that differ from one another. The optical fibers **204***a*, **204***b*, **204***c* and **204***a*', **204***b*', **204***c*' are routed in individual channels to reduce interference between one another.

[0164] The optical transmitter **2027***a* receives light propagating through channel group **2040***a* from a light source **602** that is in optical-electrical communication therewith, while optical sensor **2027***a*' propagates light through channel group **2040***a*' that is in optical-electrical communication with a light detector **602**'.

[0165] As illustrated in more detail in FIG. **16**A, the prisms **2027***a* and **2027***a*' may include angled surfaces **2062** and **2062**' with reflective coatings **2070** and **2070**', respectively, to increase the efficiency of the reflection of light via the prisms.

[0166] FIG. **17** illustrates another embodiment of end effector assembly **505** according to the present disclosure for a parallel jaw type bipolar electrosurgical forceps (not shown) having first and second jaw members **510** and **520**.

[0167] In a similar manner as with respect to end effector assembly **505***a* described above with respect to FIGS. **16** and **16**A, jaw members **510***b* and **520***b* of end effector assembly **505***b* include, respectively, inwardly facing surfaces **510***b*' and **520***b*'.

[0168] Jaw members **510***b* and **520***b* differ from jaw members **510***a* and **520***a* in that in place of optical transmitter **2027***a* and optical sensor **2027***a*, respectively, second jaw member **520***b* includes optical transmitter **2510***b* that is similar to optical transmitter **2510** having light-emitting electronic device **2561** and electric cable **2541** described above with respect to FIG. **4**A, except that optical transmitter **2510***b* does not include large diameter optical fiber **208**. Optical transmitter **2027***b* is in electrical communication with a processor **600**.

[0169] Similarly, first jaw member **510***b* includes optical sensor **2520***b* that is similar to optical sensor **2520** having photo-electric detector **2562** and electrical cable **2542** described above with respect to FIG. **4**B, except that optical sensor **2520***b* also does not include large diameter optical fiber **208**.

[0170] The optical transmitter **2510***b* and optical sensor **2520***b* are in electrical communication, via electrical cables **2541** and **2542**, respectively, with a processor **604**.

[0171] Optical transmitter **2027***b* may propagate light from second surface **520***b*' in a path **351***b* through patient tissue (not shown) to optical sensor **2027***b*' and that the propagation and intensity of the light may be controlled by the processor **604**.

[0172] FIG. **18** illustrates yet another embodiment of end effector assembly **505** according to the present disclosure for a parallel jaw type bipolar electrosurgical forceps (not shown) having first and second jaw members **510** and **520**.

[0173] In a similar manner as with respect to end effector assemblies **505***a* and **505***b* described above with respect to FIGS. **16**, **16**A and **17**, jaw members **510***c* and **520***c* of end effector assembly **505***c* include, respectively, inwardly facing surfaces **510***c*' and **520***c*'. Second jaw member **520***c* includes optical transmitter **2510***c* that is identical to optical transmitter **2510***b* illustrated in FIG. **17** and includes light-emitting electronic device **2561** and electrical cable **2541**.

[0174] However, in contrast to first jaw member **510***b* illustrated in FIG. **16**, first jaw member **510***c* includes optical sensor **2027***c*' which is similar to optical sensor **202**' described above with respect to FIG. **3**B, and which includes large diameter optical fiber **208** having one end **2081** exposed on surface **510***c*' and which is in optical communication with prism **206** that is included in optical sensor **2027***c*'. Additionally, optical sensor **2027***c*' differs from optical sensor **2027***a*' illustrated in FIGS. **16** and **16**A in that in place of the plurality of optical fibers **204***a*', **204***b*', **204***c*' in optical communication with the prism **2060***a*', optical sensor **2027***c*' includes a large diameter optical fiber **2083** that is in optical communication with the prism **206** such that light emitted by optical transmitter **2510***c* propagates in light path **351***c* to be sensed at end **2081** of optical fiber **208** exposed on surface **510***c*'. The light propagates in light path **351***c* through large diameter optical fiber **208** to prism **206** where it is reflected to propagate through large diameter optical fiber **2083** to a photo-detector **606**'.

[0175] The photo-detector **606**' is in communication with the processor **604**. Similarly, the processor **604** is in communication with the light-emitting electronic device **2510***c* of optical transmitter **2510***c* via the electrical cable **2541**. Optical transmitter **2510***c* may propagate light from second surface **520***c*' in path **351***c* through patient tissue (not shown) to optical sensor **2520***b* and that the propagation and intensity of the light may be controlled by the processor **604**.

[0176] Turning now to FIGS. **19**-**20**, there is illustrated one embodiment of an optical hydrology system **700** according to the present disclosure that includes schematically an exemplary embodiment of an optical hydrology array **710** according to the present disclosure. Optical hydrology array **710** is formed, in one embodiment, in a flat rectangular plate type arrangement. The array **710** includes a first or lower surface **712***a* that is configured in a generally flat shape suitable to be disposed in proximity to patient tissue **2** (see FIG. **19**). A

second or upper surface **712***b* is disposed in a position opposite to the first or lower surface **712***a*. First and second side walls **718** and **720**, respectively, straddle between the first and second surfaces **712***a* and **712***b*, respectively to form the generally box-like flat rectangular plate type configuration of the array **710** for housing the optical components therein.

[0177] The array **710** further includes a plurality of apertures **722** that extend from the first surface **712***a* to the second surface **712***b*. The plurality of apertures **722** penetrate through the first and second surfaces **712***a* and **712***b*, respectively, and are configured in a matrix-like arrangement. The optical hydrology system **700** further includes a plurality of optical fibers **724** disposed in a corresponding number of apertures **722** disposed in the first and second surfaces **712***a* and **712***b*, respectively.

[0178] In one embodiment, the system **700** includes a generator **714** that is configured to supply electrosurgical energy to patient tissue **2**. An optical spectrometer **716** is operably coupled to the generator **714**. The electrosurgical generator **710** is operably coupled to the hydrology array **710**. In addition, a processor **730** is disposed in operative communication with the generator **714** and with the spectrometer **716**. The spectrometer **720** may include a light source **732** for transmitting light to expose the tissue **2** to light; and a light detector **734**. The light detector **734** is configured to sense changes in light through the tissue **2** in response to tissue treatment and communicate such changes to the processor **730** to determine tissue hydration levels.

[0179] The plurality of optical fibers **724** are operably coupled to the generator **714** and are configured to communicate light between the generator **714** and the tissue **2**. In one embodiment, the spectrometer **716** is a near infra-red spectrometer providing light in the near infrared wavelength range as the light source **722**. More particularly, at least one of the optical fibers **724***a* of the array **710** is configured to operatively communicate light **755** originating from the light source **732** to enable transmitting the light **755** towards the tissue **2**. In addition, one or more of the optical fibers **724***b* of the array **710** is configured to receive light reflected from the tissue **2** and to transport the light **755** to the light detector **734**.

[0180] The light **755**, originating from the light source **732**, travels in a generally U-shaped path **760** from ends **726** of the optical fibers **724***a* to ends **728** of optical fibers **724***b* and then to the light detector **734**. Thus, an optic fiber distance d is defined between adjacent optical fibers **724** and particularly between ends **726** of the optical fibers **724***a* to ends **728** of optical fibers **724***b*. The optical fiber distance d is within a range of about four (4) mm to about ten (10) mm to optimize and/or enable the transmission of light **755** through the tissue **2** to determine hydration levels in the tissue **2**. In one embodiment, range of the distance d extends from about three (3) mm to about twelve (12) mm. The processor **730** is configured to at least record and/or analyze changes in hydration of the tissue **2** sensed by the spectrometer **716** across the optic fiber distance d. The "banana-shaped" path of light **755** is that portion of the light emitted at the end **726** of optical fiber **724***a* that can be detected by the end **728** of the optical fiber **724***b* and does not define the limits of the light distribution within the tissue **2**.

[0181] In one embodiment, the system **700** includes a temperature monitor **702**. The temperature monitor **702** may be an optical temperature monitor and operatively communicates with the processor **730** and may be operably coupled to one or more fibers **724***c*. The temperature monitor **702** is described as an optical temperature monitor although other type of temperature monitors such as thermo-electrical or chemical or thermo-mechanical monitors may be used. The optical fiber(s) **724***c* is/are configured to enable the temperature monitor **702** to monitor the temperature of the light **755** reflected through the tissue **2** originating from the light source **732**. End **727** of the optical fiber **724***c* that is configured to enable the temperature monitor **702** to monitor the temperature of the light **755** is positioned in interfacing relationship with the generally U-shaped path **760** of the light **755** that travels from the end **726** of the optical fiber **724***a* to end **728** of optical fiber **724***b*. The processor **730** is configured to record and/or analyze changes in temperature of the tissue **2** sensed by the temperature monitor **702**.

[0182] In one embodiment, the system **700** may include a light source **732'** that is independent of the spectrometer **716**. The independent light source **732'** is in optical communication with the optical fiber **724***a* to propagate light **755** through the optical hydrology array and with the processor **730**. Additionally, a mechanical-optical multiplexer switch **740** may be included in the path of optical fiber **724***b* to enable the light **755** propagating through optical fiber **724***b* to be transferred from the light detector **734** housed in the spectrometer **716** to the independent detector **734'**.

[0183] FIG. **20** is a schematic view of one embodiment of the mechanical-optical multiplexer switch **740** included within the system **700** for monitoring water displacement of FIG. **19** as configured with respect to the array of optical transmitters and optical sensors illustrated in FIG. **11**.

[0184] FIG. **21** is a view of optical alignment member **742** included within the mechanical-optical multiplexer switch **742**.

[0185] The multiplexer switch **742** provides mechanical-optical alignment between one or more light sources **732**, e.g., light source **7321** emitting in a wavelength range of about 200 nanometers (nm) to about 2000 nm, light source **7322** emitting in a wavelength range of about 400 nm to about 2000 nm, and light source **7323** emitting in a wavelength range of about 600 nm to about 2000 nm and patient tissue **2** (see also FIG. **19**) and between patient tissue **2** and one or more light detectors, e.g., light detector **7341** detecting in a wavelength range of about 300 nm to about 900 nm and light detector **7342** detecting in a wavelength range of about 850 nm to about 2500 nm. The wavelength ranges disclosed herein represent exemplary embodiments of the present disclosure and are not intended to be limiting.

[0186] The switch **740** includes a first optical fiber alignment member **742** (an "instrument side" optical alignment member) that is configured with at least first and second surfaces **742***a* and **742***b*, respectively, on opposing sides of the alignment member **742**. The first and second surfaces **742***a* and **742***b* each include a plurality of ports disposed thereupon, e.g., ports d1, s1, d2, s2, d3, s3 on first surface **742***a* and ports d1', s1', d2', s2', d3', s3' on second surface **742***b*.

[0187] Two or more corresponding ports on the first surface, e.g., ports s1, s2, s3 on first surface **742***a*, are configured to enable optical communication between one or more light sources, e.g., first light source **7321**, second light source **7322**, and third light source **7323**, and the optical alignment member **742**.

[0188] Additionally, two or more corresponding ports on the first surface, e.g., ports d1, d2, d3 on first surface **742***a* are configured to enable optical communication between the

optical alignment member **742** and one or more light detectors, e.g., light detector **7341** and light detector **7342**.

[0189] Two or more corresponding ports on the second surface, e.g., ports s1', s2', s3' on surface **742***b*, are configured to enable optical communication between two or more corresponding ports on the first surface, e.g., ports s1, s2, s3, respectively, that are configured to enable optical communication between the one or more light sources, e.g., first light source **7321**, second light source **7322**, and third light source **7323**, and the optical alignment member **742** via corresponding channels **762** disposed therebetween,

[0190] Similarly, two or more corresponding ports on the second surface, e.g., ports d1', d2', d3', are configured to enable optical communication between two or more corresponding ports on the first surface, e.g., ports d1, d2, d3, respectively, that are configured to enable optical communication between the optical alignment member **742** and at least one light detector, e.g., light detector **7341** and light detector **7342**, via corresponding channels **764** disposed therebetween.

[0191] As indicated in FIG. **20**, ports s1 and s1' are aligned with first light source **7321**, ports s2 and s2' are aligned with second light source **7322** and ports s3 and s3' are aligned with light source **7323**. Ports d1 and d1' are aligned with first light detector **7341** and ports d2 and d2' and d3 and d3' are aligned with the second light detector **7342**.

[0192] The switch **740** also includes a second optical fiber alignment member **752***a* (a first "tissue-side" optical alignment member) configured with the first and second surfaces **754***a* and **754***b*, respectively. In a similar manner, the first and second surfaces **754***a* and **754***b* each include a plurality of ports 1d1', 1s1', 1d2', 1s2', 1d3', 1s3' and 1d1, 1s1, 1d2, 1s2, 1d3, 1s3, respectively, disposed thereupon,

[0193] Two or more corresponding ports on the first surface, e.g., ports 1s1', 1s2', 1s3', are configured to enable optical communication between corresponding optical ports on the optical member **752**, e.g., ports s1', s2', s3' on the surface **742***b* of the first optical member **742**, via corresponding channels **762** disposed therebetween,

[0194] Two or more corresponding ports on the second surface, e.g., ports 1d1, 1d2, 1d3, of the second optical alignment member **752** are configured to enable optical communication between corresponding optical ports 1d1', 1d2', 1d3' on the first surface **752***a* of the second optical alignment member **752***a* via corresponding channels **764** disposed therebetween and patient tissue **2**.

[0195] Similarly, at least a third optical fiber alignment member, e.g., optical alignment members **752***b*, **752***c* . . . **752***n* (or second, third . . . nth "tissue-side" optical alignment members) are also configured with at least the first and second surfaces **754***a* and **754***b*, respectively. Again, the first and second surfaces **754***a* and **754***b* each include a plurality of ports 1 disposed thereupon, e.g., ports 2s1', 2s2', 2s3', 2d1', 2d2', 2d3' and 2s1, 2s2, 2s3, 2d1, 2d2, 2d3 on surfaces **752***a* and **752***b* of third optical alignment member **752***b*, ports 3s1', 3s2', 3s3', 3d1', 3d2', 3d3' and 3s1, 3s2, 3s3, 3d1, 3d2, 3d3 on surfaces **754***a* and **754***b* of fourth optical alignment member **752***c*, up through ports ns1', ns2', ns3', nd1', nd2', nd3' and ns1, ns2, ns3, nd1, nd2, nd3 on surfaces **754***a* and **754***b* of nth optical alignment member **752***n*, respectively.

[0196] In view of the foregoing description of optical alignment members **742** and **752***a*, optical alignment is provided via the channels **762** and **764** and aforementioned ports of the third through nth optical alignment members **752***b* through **754***n*. As defined herein, the nth optical alignment member represents at least the third optical alignment member and may include a greater number within the limits of practicality.

[0197] As illustrated in FIG. **20**, the first optical alignment member **742** is movable, as indicated via the arrows "A" and "B" in a linear direction, with respect to the second and at least the third optical alignment members, e.g., **752***a*, **752***b*, **752***c* . . . **752***n* to enable the optical alignment between the light sources **7321**, **7322** and **7323** and patient tissue **2** and between patient tissue **2** and the light detectors **7341** and **7342**.

[0198] The optical alignment occurs when the first optical alignment member **742** has been moved to a position with respect to, for example, fourth optical alignment member **752***c* such that ports s1', s2', s3' on the second surface **742***b* of the first optical alignment member **742** are aligned with the ports 3s1', 3s2', 3s3', respectively, on the first surface **754***a* of the fourth optical alignment member **752***c*, and when the ports d1', d2', d3' on the second surface **742***b* of the first optical alignment member **742** are aligned with the ports 3d1', 3d2', 3d3' of the fourth optical alignment member **752***c*.

[0199] For clarity, optical fibers are not shown in the channels **762** and **764** or separately numbered. The result of the optical alignment is that light from first light source **7321** propagates through the optical fibers in the first optical alignment member **742** ("instrument side") to interface with the corresponding optical fibers in the fourth optical alignment member **752***c* ("tissue side") to form a first light path **7551** in patient tissue **2** between first light source **7321** emitting at a wavelength of about 200 nm to 2000 nm to first light detector **7341** detecting at wavelengths of about 300 nm to about 900 nm.

[0200] Similarly, light from second light source **7322** propagates through the optical fibers in the first optical alignment member **742** ("instrument side") to interface with the corresponding optical fibers in the fourth optical alignment member **752***c* ("tissue side") to form a second light path **7552** in patient tissue **2** between second light source **7322** emitting at a wavelength of about 400 nm to 2000 nm to second light detector **7342** detecting at wavelengths of about 850 nm to about 2500 nm.

[0201] Additionally, light from third light source **7323** propagates through the optical fibers in the first optical alignment member **742** ("instrument side") to interface with the corresponding optical fibers in the fourth optical alignment member **752***c* ("tissue side") to form a third light path **7553** in patient tissue **2** between third light source **7323** emitting at a wavelength of about 600 nm to 2000 nm to second light detector **7342** detecting at wavelengths of about 850 nm to about 2500 nm.

[0202] For simplicity, the same optical hydrology array **710** illustrated in FIG. **19** is positioned between the "tissue-side" optical alignment members **752***a* . . . **752***n* and the patient tissue **2**. It should be noted that the same optical hydrology array **710** is associated with the differing "tissue-side" optical alignment members **752***a* . . . **752***n*. That is, different groups of the optical fibers associated with the optical hydrology array **710** are routed to and from through the array **10** and separate to be associated with corresponding "tissue-side" optical alignment members **752***a* . . . **752***n* to provide differing details of water motility information with respect to the patient tissue **2**.

[0203] Although FIG. **20** is a schematic view of one embodiment of the mechanical-optical multiplexer switch

740 included within the system **700** for monitoring water displacement of FIG. **19** as configured with respect to the array of optical transmitters and optical sensors illustrated in FIG. **11**, that is, the switch **740** is configured wherein one sensing (detecting) optical fiber is associated with a corresponding transmitting (source or emitting) optical fiber, system **700** may further be modified to include optical splitters (not shown) in the paths between the patient tissue **2** and the "tissue-side" optical alignment members **752***a*, **752***b* to **752***n* to accommodate situations where there is a mis-match in the number of transmitting or source fibers with respect to the number of sensing or detecting fibers.

[0204] Similarly, system **700** may further be modified to include optical splitters (not shown) in the paths between the "instrument side" optical alignment member **742** and the light sources **7321**, **7322**, **7323** and light detectors **7341**, **7342** also to accommodate situations where there is a mismatch in the number of transmitting or source fibers with respect to the number of sensing or detecting fibers.

[0205] The "instrument-side" optical alignment member **742** and the "tissue-side" optical alignment members **752***a* . . . **752***n* may be configured to be substantially identical, and are illustrated as mirror images of one another. Also, the number of ports d1, s1, d2, s2, d3, s3 and d1', s1', d2', s2', d3', s3' etc. and channels **762** and **764** may be varied as necessary or advantageous. Additionally, the mechanical-optical multiplexer switch **740** may be configured wherein the second and at least a third optical alignment members **752***a* . . . **752***n* ("tissue-side" members) are movable with respect to the first optical alignment member **742** ("instrument-side" member) to enable the optical alignment between the at least one light source, e.g., light sources **7321**, **7322**, **7323**, and patient tissue **2** and between patient tissue **2** and the at least one light detector, e.g., light detectors **7341**, **7342**. Although such motion would also be linear as indicated by the arrows "A" and "B", other configurations of the "tissue-side" optical alignment members **752***a* . . . **752***n* may be devised, such as wherein the optical alignment member **742** rotates around the optical alignment members **752***a* . . . **752***b* or vice versa. The embodiments are not limited with respect to the direction and type of motion of the optical alignment members.

[0206] The mechanical-optical multiplexer switch **740** has been described with respect to the electrically conductive member **300***d* illustrated in FIG. **11**, which in FIGS. **19-20** is equivalent to the optical hydrology array **710**. The mechanical-optical multiplexer switch **740** is configured for the embodiment of FIG. **11** wherein the optical fibers are routed entirely to and from the patient tissue **2** as opposed to electrically conductive member **300***a* illustrated in FIGS. **7** and **7A** wherein light-emitting electronic devices **2561'** and photo-electric detectors **2562'** and **2563'** and associated electrical cables **2541** and **2542** are employed.

[0207] The mechanical-optical multiplexer switch **740** may be made from an opaque material such as a metal or metal alloy, a plastic or a ceramic or suitable combinations thereof to prevent interference by light transmission between the optical fibers in the various channels **762** and **764**. Dashed box **770** represents a common housing within which the processor **730**, spectrometer **716**, and the generator **714** may be incorporated therein. Additionally, temperature monitor **702** may be incorporated within the housing **770** or may be located elsewhere such as on or in the electrosurgical instrument. Supporting structure (not shown) for the optical alignment members **742** and **752***a* . . . **752***n* may be provided by the switch housing. Also, the motion of the optical alignment members **742** and **752***a* . . . **752***n* with respect to each other may be effected by electrical, mechanical, chemical, pneumatic or other movers suitable for the application.

[0208] In view of the previous descriptions of electrosurgical pencil blades **106***a* to **106***d* described with respect to FIGS. **1-6**B, of electrically conductive members **300***a* to **300***f* and **300***f'* described with respect to FIGS. **7** to **13**, of end effector assemblies **405***a* to **405***e* described with respect to FIGS. **14** to **15**D, and of end effector assemblies **505***a* to **505***c* described with respect to FIGS. **16** to **18**, the electrosurgical pencil blades **106***a* to **106***d*, the electrically conductive members **300***a* to **300***f* and **300***f'*, the end effector assemblies **405***a* to **405***e*, and the end effector assemblies **505***a* to **505***c* may be substituted for the optical hydrology array **710** in FIG. **19** for either light reflectance or light transmission applications, as applicable to the particular blade or assembly.

[0209] Referring to FIG. **19**, the near Infrared (IR) wavelength optical spectrometer **716** and optical fibers **724** sense changes across the array **710** and correlate the changes with movement of water through the tissue. Light reflected by the tissue enables detecting water content and transmitted light.

[0210] As described above with respect to FIG. **20**, first light source **7321** emits light at a wavelength of about 200 nm to 2000 nm to first light detector **7341** detecting at wavelengths of about 300 nm to about 900 nm. Second light source **7322** emits light at a wavelength of about 400 nm to 2000 nm to second light detector **7342** detecting at wavelengths of about 850 nm to about 2500 nm. Additionally, third light source **7323** emits light at a wavelength of about 600 nm to 2000 nm to second light detector **7342** detecting at wavelengths of about 850 nm to about 2500 nm.

[0211] The values of the electrical, thermal and hydraulic conductivities of the tissue all depend on the quantity and location of the water content within the tissue. The analysis of the quantity and location of the water content within the tissue may be determined by comparing intensities of the light passing through the patient tissue both spatially and temporally, that is by comparing the measured intensities to the spatial location and to the time at which the measurements have been made.

[0212] First, a reference wavelength λr may be defined as a measured wavelength of light that is insensitive to the moisture content of the tissue. Reference wavelength λr is a function of x, y and t, where x and y define a two-dimensional location of the measurement within the patient tissue with respect to a reference set of x-y coordinate axes and t defines the time of the measurement. For any given tissue, there are multiple wavelengths λr that are insensitive to the moisture content of the tissue. The reference wavelength λr is then defined as follows:

$$\lambda r = f(x,y,t) \quad \text{Eq. 1}$$

[0213] A reference intensity Ir may be defined as the intensity of light passing through patient tissue as measured at a selected particular reference wavelength λr that is a measured wavelength of light that is insensitive to the moisture content of the tissue. Since λr is a function of x, y and t, then Ir is also a function of λr, x, y and t, as follows:

$$Ir = f[\lambda r(x,y,t)] \quad \text{Eq. 2}$$

[0214] Reference intensity Ir is measured at a wavelength that is known not to be sensitive to the presence of water.

[0215] Next, hydration wavelength λh may be defined as a measured wavelength of light at which the intensity of light

passing through the tissue varies depending on the moisture content of the tissue. Hydration wavelength λh is a function of x, y and t, where x and y define a two-dimensional location of the measurement within the patient tissue with respect to a reference set of x-y coordinate axes and t defines the time of the measurement. The hydration wavelength λh is then defined as follows:

$$\lambda h = f(x,y,t) \quad \text{Eq. 3}$$

[0216] For any given tissue sample, there are a range of multiple, discrete hydration wavelengths λh at which the intensity of light passing through patient tissue is sensitive to the moisture content of the tissue. The particular hydration wavelength λh at which the intensity of the light passing through patient tissue is measured during the electrosurgical procedure may be selected as that wavelength that exhibits the greatest level of gain with respect to the moisture content of the tissue.

[0217] A hydration intensity Ih may be defined as a function of λh, x, y and t, where Ah defines the measured wavelength of light that is dependent on the moisture content of the tissue, x and y define a two-dimensional location of the measurement within the patient tissue with respect to a reference set of x-y coordinate axes and t defines the time of the measurement. Therefore, the hydration intensity Ih is defined as follows:

$$Ih = f[\lambda h(x,y,t)] \quad \text{Eq. 4}$$

[0218] The intensities Ir and Ih may be measured in counts of photon emissions per unit of time. Alternatively, other units of measurement may be applied such as the candela (cd, the Standards International SI unit of measurement for light intensity) or the lumen (Im, the SI unit for measuring the flux of light being produced by a light source or received by a surface) or the lumen hour (Im h, the SI unit for a quantity of light, equal to one lumen of light flux continued for one hour). The analysis of the moisture content is performed by calculating the ratio R of the hydration intensity Ih to the reference intensity Ir as follows:

$$R = \{Ih[\lambda h(x,y,t)]/Ir[\lambda r(x,y,t)]\} \quad \text{Eq. 5}$$

[0219] At location x1, y1 at time t1, Ir is determined as a function of [λr(x1, y1, t1)]. Ih is determined as a function of [λh (x1, y1, t1)]. The ratio R is then calculated:

$$R(111/111) = \{Ih[\lambda h(x1,y1,t1)]/Ir[\lambda r(x1,y1,t1)]\} \quad \text{Eq. 6}$$

[0220] where λh(x1, y1, t1) is the hydration wavelength measured at location x1, y1 at time t1 and λr(x1, y1, t1) is the reference wavelength measured at location x1, y1 at time t1.

[0221] A subsequent measurement of the reference wavelength λr, reference intensity Ir, hydration wavelength λh and hydration intensity Ih may be taken at the same location but at a different time and a new ratio of intensities calculated as follows:

$$R(112/112) = \{Ih[\lambda h(x1,y1,t2)]/Ir[\lambda r(x1,y1,t12]\} \quad \text{Eq. 7}$$

where λh(x1, y1, t2) is the hydration wavelength measured at location x1, y1 at time t2 and λr(x1, y1, t2) is the reference wavelength measured at location x1, y1 at time t2.

[0222] Alternatively, another measurement of the reference wavelength λr, reference intensity Ir, hydration wavelength λh and hydration intensity Ih may be taken at a different location but at the same time and another ratio of intensities calculated as follows:

$$R(221/221) = \{Ih[\lambda h(x2,y2,t1)]/Ir[\lambda r(x2,y2,t1]\} \quad \text{Eq. 8}$$

where λh(x2, y2, t1) is the hydration wavelength measured at location x2, y2 at time t1 and λr(x2, y2, t1) is the reference wavelength measured at location x2, y2 at time t1.

[0223] Yet another measurement of the reference wavelength λr, reference intensity Ir, hydration wavelength λh and hydration intensity Ih may be taken at a different location and a different time as follows:

$$R(222/222) = \{Ih[\lambda h(x2,y2,t2)]/Ir[\lambda r(x2,y2,t2]\} \quad \text{Eq. 9}$$

where λh(x2, y2, t2) is the hydration wavelength measured at location x2, y2 at time t2 and λr(x2, y2, t2) is the reference wavelength measured at location x2, y2 at time t2.

[0224] As can be understood from the foregoing, the ratio R may be calculated at numerous desired locations and times. The location and time of the reference wavelength λr and reference intensity Ir need not correspond to the location and time of the hydration wavelength λh and hydration intensity Ih. In such an exemplary case, the ratio R may be calculated as follows:

$$R(221/112) = \{Ih[\lambda h(x2,y2,t1)]/Ir[\lambda r(x1,y1,t12]\} \quad \text{Eq. 10}$$

where λh(x2, y2, t1) is the hydration wavelength measured at location x2, y2 at time t1 and λr(x1, y1, t2) is the reference wavelength measured at location x1, y1 at time t2.

[0225] The ratio R corrects for inconsistencies not related to the hydration level of the tissue. Such inconsistencies may include variation of the intensity of the light source or variations in the tissue that are not related to hydration content. The numerical values of the ratio R are dependent on the particular tissue undergoing the electrosurgical procedure and on the particular spectrometer. Wavelengths in the range of about 900 nm generally represent wavelengths at which the light intensity is generally not sensitive to hydration content and thus does not vary with hydration content. Such wavelengths may be selected as reference wavelengths λr. Wavelengths in the range of about 1500 nm generally represent wavelengths at which the light intensity is sensitive to hydration content, and thus do vary with hydration content. Such wavelengths may be selected as hydration wavelengths λh.

[0226] While the measurements of the ratio R may be calculated at a fixed value of the hydration wavelength λh during an electrosurgical procedure, for further validation of the results, the measurements of the ratio R may be calculated at one or more other values of the hydration wavelength λh during the electrosurgical procedure.

[0227] A refinement of the intensity measurements may be performed to further remove spurious factors to give a more accurate reading of tissue moisture content by various mathematical operations such as addition, subtraction, multiplication and division as follows:

$$\text{Addition: } R(111/111)+R(221/221) \quad \text{Eq. 11}$$

or

$$\text{Subtraction: } R(112/112)-R(111/111) \quad \text{Eq. 12}$$

or

$$\text{Multiplication: } R(111/221)*R(212/211) \quad \text{Eq. 13}$$

or

$$\text{Division: } R(222/212)/R(221/112),\text{etc.} \quad \text{Eq. 14}$$

[0228] If determined to be advantageous, the above calculated ratio values of intensities may also be raised exponentially, for example, as follows:

$$\text{Multiplication: } R(111/221)^{n} * R(221/112)^{n}, \quad \text{Eq. 15}$$

where n is a positive or negative number other than zero (and which may differ for each ratio reading such as R(111/221) or R(221/112), etc.)

[0229] The mechanical-optical multiplexer switch **740** in FIGS. **19-20** allows different wavelength intensities to be measured with respect to space and time, e.g., with respect to x-y coordinates and with respect to time t.

[0230] The array **710** provides a differential in water content and in water movement. Water movement could be in an elliptical pattern rather than a circular pattern. Based on any of the foregoing measurements, either with intensity ratio measurements alone or further refined by additional mathematical operations such as addition, subtraction, multiplication, division, etc., a Monte-Carlo analysis may be performed to determine the most probable location of the greatest moisture content within the tissue.

[0231] Movement of the mechanical-optical multiplexer switch **740** during the electrosurgical process enables acquisition of numerous intensity measurements at different locations and at different times from various locations within the array **710**.

[0232] In view of the foregoing description of the optical hydrology array monitoring system **700** and electrosurgical pencil **100** and electrosurgical forceps **400**, the present disclosure relates also to a method for monitoring water displacement in tissue during patient therapy. The method includes providing a spectrometer, e.g., spectrometer **716** that includes light source **732** and light detector **734**. The method includes generating light **755** from the light source **732** that is reflected through the patient or subject tissue **2** and receiving the light **755** reflected through the tissue **2** wherein the light **755** reflected through the tissue **2** is received by the light detector **734**.

[0233] The method may further include supplying electrosurgical energy to the tissue **2**, e.g., via the electrosurgical generator **714** utilizing an energy source (not shown), sensing changes in light through the tissue **2** in response to tissue treatment, e.g. via the optical array **710**, and determining changes in tissue hydration levels based on the sensed changes in light **755** through the tissue **2**, e.g., via the optical spectrometer **716**. The method may also include providing a processor such as the processor **730** to which the sensed changes in light **755** through the tissue **2** are communicated wherein the processor **730** determines the changes in tissue hydration levels based on the sensed changes in light **755** through the tissue **2**. The processor **730** is operably coupled to the spectrometer **716** and/or the electrosurgical generator **714** and/or the energy source.

[0234] Additionally, in one embodiment, the method includes providing a plurality of optical fibers **724** arranged wherein at least one of the optical fibers **724***a* is configured to operatively communicate light **755** originating from the light source **732** to enable transmitting light towards the tissue **2** and at least one of the optical fibers **724***b* is configured to enable transporting light **755** reflected from the tissue **2**.

[0235] The method may also include interfacing the one or more optical fibers **724***a* to the light source **732** and the one or more optical fibers **724***b* to the light detector **734**. The method may also include configuring the plurality of optical fibers **724** in the array **710** to be separated to effect an optimal optic fiber distance d within the tissue **2**, as described above.

[0236] In one embodiment, the method further includes providing light **755** in the near infrared wavelength range as the light source **732**. Additionally, the method may be implemented by further including the steps of providing optical temperature monitor **702**, providing one or more optical fibers **724***c* that operatively couple to the optical temperature monitor **702**, and monitoring the temperature of light **755** reflected through the tissue **2** originating from the light source **732**.

[0237] The method may be implemented wherein the one or more optical fibers **724***c* operatively coupled to the optical temperature monitor **702** is configured within the array **710**.

[0238] In one embodiment, the method is implemented via a processor such as the processor **730** for recording and/or analyzing changes in hydration of the tissue **2** in time and/or space sensed by the spectrometer **716** based on the fiber optic distance d. Additionally, the method may be implemented wherein the processor **730** records and/or analyzes changes in temperature of the tissue **2** sensed by the optical temperature monitor **702**.

[0239] Referring again to FIG. **1** and FIG. **19**, the method is implemented wherein the array **710** and/or system **700** is incorporated in the electrosurgical pencil **100** including the housing **102** having proximal and distal ends **108** and **110**, respectively, and the blade receptacle **105** defined at the distal end **110** of the housing **102** for supporting the electrosurgical blade **106** therein. The electrosurgical blade **106** is disposed in optical communication with the light source **732** and the light detector **734** and the method includes monitoring hydration levels in the tissue **2** during operation of the electrosurgical pencil **100**.

[0240] Referring again to FIG. **14**, the method is implemented wherein the arrays **710** and **710'** are incorporated in the electrosurgical forceps **400** including the pair of first and second jaw members **410** and **420**, respectively, disposed in pivotal relationship with respect to one another and attached to the distal end **414** of at least one shaft **412**. Each jaw member **410** and **420** supports the electrically conductive surfaces **410'** and **420'**, respectively, thereon. At least one of the jaw members **410** and/or **420** is disposed in optical communication with the light source **732**, via the optical fibers **724** of the respective arrays **710** and/or **710'**, and the other of the jaw members **420** and/or **410**, respectively being disposed in optical communication with the light detector **734**, also via the optical fibers **724** of the respective arrays **710** and/or **710'**. The method includes monitoring hydration levels in tissue **2** during operation of the electrosurgical forceps **400**.

[0241] Again, the near Infrared (IR) wavelength optical spectrometer **716** and optical fibers **724** sense changes across the array **710** and correlate the changes with movement of water through the tissue. Light reflected by the tissue enables detecting water content and transmitted light.

[0242] Whether the optical hydrology system with the array is applied to RF therapy or to microwave therapy, the water content is a solvent. The dissolved ions travel through the solvent and their optical characteristics enable the spectrometer to sense the presence and movement of water in the tissue. The electrosurgical generator thus may be driven to control the flow of water through the tissue to optimize the delivery of energy to the tissue and thus to enhance the therapeutic effect of the particular energy treatment being applied.

[0243] As described previously, such as with respect to FIGS. **7** to **13**, the array of optical fibers may be arranged in various geometries to track the motility of water through the tissue. During tissue dessication, water must be displaced to other locations within the tissue. The system array can track movement of water and then control algorithms can optimize energy induction. Again, the near Infrared (IR) wavelength optical spectrometer **716** and optical fibers **724** sense changes across the array **710** and/or **710'** and correlate the changes with movement of water through the tissue. Light reflected by the tissue enables detecting water content and transmitted light.

[0244] Differences in fiber optic geometries enable detection and tracking of the manner in which water is moving through the tissue. The induction of energy can be slowly ramped up or the induction can be applied to immediately reach a steady peak value. Alternatively, the induction of energy can be applied in pulses. The energy induction process can be applied to force water out of tissue and control pulsing time and operation can be controlled to effect such forcing of water out of patient tissue.

[0245] Although the subject disclosure has been described with respect to exemplary embodiments, it will be readily apparent to those having ordinary skill in the art to which it appertains that changes and modifications may be made thereto without departing from the spirit or scope of the subject disclosure as defined by the appended claims.

1-10. (canceled)

11. A system for monitoring water displacement in tissue during tissue treatment, comprising:
- a generator configured to supply electrosurgical energy to tissue;
- a spectrometer operably coupled to the generator; and
- a processor in operative communication with the generator and with the spectrometer, the spectrometer including:
  - at least one light source configured to expose tissue to light; and
  - at least one light sensor configured to sense changes in light through tissue in response to tissue treatment and communicate such changes to the processor to determine tissue hydration levels.

12. The system according to claim **11**, further comprising:
- a plurality of optical fibers operably coupled to the generator and configured to communicate light between the spectrometer and tissue.

13. The system according to claim **12**, wherein the plurality of optical fibers are configured in an array.

14. (canceled)

15. A method for monitoring water displacement in tissue during tissue treatment, comprising:
- providing a spectrometer including a light source in operative communication with patient tissue;
- generating light from the light source;
- reflecting the light through patient tissue; and
- receiving the light reflected through the patient tissue with a light sensor.

16. The method according to claim **15**, further comprising:
- supplying electrosurgical energy to patient tissue utilizing an energy source;
- sensing changes in light through the patient tissue with the light sensor in response to patient tissue treatment; and
- determining changes in patient tissue hydration levels based on the sensed changes in light through the patient tissue.

17. The method according to claim **16**, further comprising:
- providing a processor operatively coupled to at least one of the spectrometer and energy source for analyzing the sensed changes in light through the patient tissue.

18. The method according to claim **17**, wherein the processor operatively communicates with the spectrometer and the method further comprises regulating the supply of electrosurgical energy to the patient tissue based on the sensed changes in light through the patient tissue.

19. (canceled)

20. A system for determining tissue hydration in patient tissue during tissue treatment, comprising:
- a generator configured to supply electrosurgical energy to patient tissue;
- a processor in operatively coupled to the generator;
- a first light source operatively coupled to the processor and configured to expose patient tissue to light at a reference wavelength insensitive to the moisture content of patient tissue;
- a second light source operatively coupled to the processor and configured to expose patient tissue to light at a hydration wavelength sensitive to the moisture content of patient tissue;
- a first light sensor operatively coupled to the processor and configured to sense changes in light at the reference wavelength in response to tissue treatment; and
- a second light sensor operatively coupled to the processor and configured to sense changes in light at the hydration wavelength in response to tissue treatment.

21. The system for determining tissue hydration in accordance with claim **20**, wherein the processor is configured to:
- receive sensed changes in light at the reference wavelength;
- receive sensed changes in light at the hydration wavelength; and
- computing tissue hydration based at least in part upon the sensed changes in light at the reference wavelength and the sensed changes in light at the hydration wavelength.

22. The system for determining tissue hydration in accordance with claim **21**, wherein the processor is configured to determine the electrosurgical energy supplied to tissue by the generator.

23. The system for determining tissue hydration in accordance with claim **21**, wherein the processor is configured to determine the electrosurgical energy supplied to tissue by the generator based at least in part upon the computed tissue hydration.

24. The system for determining tissue hydration in accordance with claim **20**, wherein at least one of the first light sensor and the second light sensor are configured to sense light reflected from patient tissue.

25. The system for determining tissue hydration in accordance with claim **20**, wherein at least one of the first light sensor and the second light sensor are configured to sense light transmitted through patient tissue.

26. A method for determining tissue hydration, comprising:
- exposing tissue to light at a reference wavelength insensitive to the moisture content of tissue;
- exposing tissue to light at a hydration wavelength sensitive to the moisture content of tissue;
- sensing changes in light at the reference wavelength;
- sensing changes in light at the hydration wavelength; and

comparing the sensed changes in light at the reference wavelength to the sensed changes in light at the hydration wavelength to determine tissue hydration.

27. The method for determining tissue hydration in accordance with claim **26**, further comprising applying electrosurgical energy to tissue.

28. The method for determining tissue hydration in accordance with claim **27**, further comprising modifying the electrosurgical energy in response to the determined tissue hydration.

29. The method for determining tissue hydration in accordance with claim **26**, wherein sensing changes in light includes sensing changes in light reflected from tissue.

30. The method for determining tissue hydration in accordance with claim **26**, wherein sensing changes in light includes sensing changes in light transmitted through tissue.

31. The method for determining tissue hydration in accordance with claim **26**, wherein sensing changes in light includes sensing changes in light absorbed by tissue.

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[标]发明人	HOARAU CARINE PODHAJSKY RONALD J		
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摘要(译)

在患者治疗期间监测组织中的水位移的系统包括向组织提供电外科能量的发生器，可操作地耦合到发生器的光谱仪，以及与发生器通信的处理器以及具有用于将组织暴露于光的光源的光谱仪和光传感器。光传感器被配置为响应于组织治疗来感测穿过组织的光的变化，并将变化传达给处理器以确定组织水合水平和运动性。多个光纤可以配置成阵列，以在发生器和组织之间传递光。光学温度监测器可以与处理器通信并且耦合到光纤。光纤可以在相邻光纤之间具有光纤距离。该系统可以结合在电外科手术笔或钳子中。还公开了一种检测水合作用的相应方法。