



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : A61B 17/22	A2	(11) International Publication Number: WO 96/32895 (43) International Publication Date: 24 October 1996 (24.10.96)
--	-----------	--

(21) International Application Number: PCT/US96/04554

(22) International Filing Date: 3 April 1996 (03.04.96)

(30) Priority Data:
08/422,820 17 April 1995 (17.04.95) US

(71) Applicant (for all designated States except US): COHERENT, INC. [US/US]; 5100 Patrick Henry Drive, Santa Clara, CA 95056 (US).

(72) Inventors; and

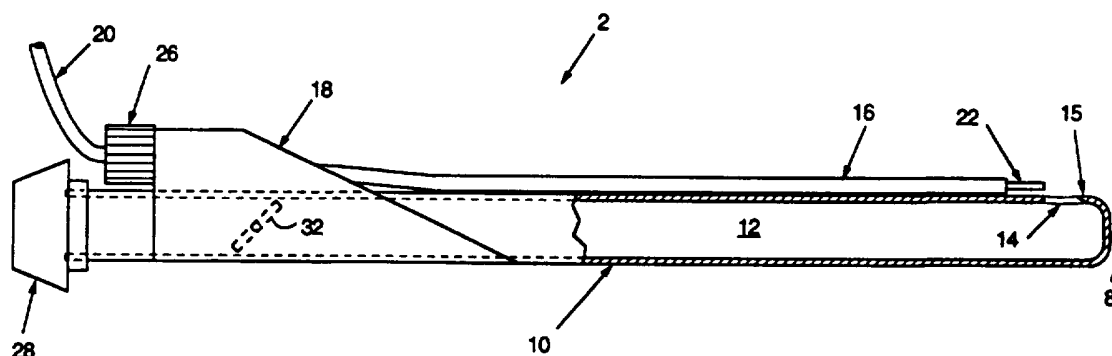
(75) Inventors/Applicants (for US only): MANOUKIAN, Nubar [US/US]; 10318 Brittany Court, Cupertino, CA 95014 (US). SOLTIS, Tim [US/US]; 801 Clara Drive, Palo Alto, CA 94303 (US). HMELAR, Michael [US/US]; 3144 Maddux Drive, Palo Alto, CA 94303 (US). MATHIS, Mark [US/US]; 42770 Castillejo, Fremont, CA 94539 (US).

(74) Agents: STALLMAN, Michael, A. et al.; Limbach & Limbach L.L.P., 2001 Ferry Building, San Francisco, CA 94111 (US).

(81) Designated States: JP, US, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published*Without international search report and to be republished upon receipt of that report.*

(54) Title: METHOD AND APPARATUS FOR MANIPULATING, CUTTING, ABLATING AND COAGULATING TARGETED TISSUE WITHIN A PATIENT



(57) Abstract

A probe device for removing targeted tissue from within a patient includes a probe assembly, a laser system, and a vacuum source. The probe assembly includes an elongated probe tube forming an aspiration channel therein, and an aspiration aperture near one end. An aspiration port is formed near the other end of the probe tube. An optical fiber is attached to the probe tube and terminates proximate to the aspiration aperture. The aspiration port is connected to a vacuum source whereby targeted tissue in the patient is drawn to the aspiration aperture. The optical fiber is connected to an infrared laser system such that the laser energy is directed out of the optical fiber into an area in and immediately above the aspiration aperture. The laser energy cuts and/or ablates the targeted tissue, which is immediately aspirated into the aspiration aperture and out of the patient through the aspiration channel. The infrared laser system creates moving vapor bubbles at the delivery end of the optical fiber to enhance the rate of ablation and aspiration of the targeted tissue.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia	GB	United Kingdom	MW	Malawi
AT	Austria	GE	Georgia	MX	Mexico
AU	Australia	GN	Guinea	NE	Niger
BB	Barbados	GR	Greece	NL	Netherlands
BE	Belgium	HU	Hungary	NO	Norway
BF	Burkina Faso	IE	Ireland	NZ	New Zealand
BG	Bulgaria	IT	Italy	PL	Poland
BJ	Benin	JP	Japan	PT	Portugal
BR	Brazil	KE	Kenya	RO	Romania
BY	Belarus	KG	Kyrgyzstan	RU	Russian Federation
CA	Canada	KP	Democratic People's Republic of Korea	SD	Sudan
CF	Central African Republic			SE	Sweden
CG	Congo	KR	Republic of Korea	SG	Singapore
CH	Switzerland	KZ	Kazakhstan	SI	Slovenia
CI	Côte d'Ivoire	LJ	Liechtenstein	SK	Slovakia
CM	Cameroon	LK	Sri Lanka	SN	Senegal
CN	China	LR	Liberia	SZ	Swaziland
CS	Czechoslovakia	LT	Lithuania	TD	Chad
CZ	Czech Republic	LU	Luxembourg	TG	Togo
DE	Germany	LV	Latvia	TJ	Tajikistan
DK	Denmark	MC	Monaco	TT	Trinidad and Tobago
EE	Estonia	MD	Republic of Moldova	UA	Ukraine
ES	Spain	MG	Madagascar	UG	Uganda
FI	Finland	ML	Mali	US	United States of America
FR	France	MN	Mongolia	UZ	Uzbekistan
GA	Gabon	MR	Mauritania	VN	Viet Nam

METHOD AND APPARATUS FOR MANIPULATING,
CUTTING, ABLATING AND COAGULATING
TARGETED TISSUE WITHIN A PATIENT

FIELD OF THE INVENTION

5 The present invention relates to medical probes, and in particular, to aspirating probes for efficient cutting and removal of body tissue from within a patient.

BACKGROUND OF THE INVENTION

10 There are numerous medical procedures that involve cutting and removing targeted tissue from within a patient. Examples of some of these procedures include transurethral resection of the prostate (TURP), stone removal, and phaco lensectomy.

15 Each of these procedures involves inserting a probe into the patient's body, where the targeted tissue is cut and then removed. The targeted tissue is usually irrigated during the tissue removal procedure. For optimal results, a tissue removing

20 probe should cut and remove the tissue accurately and efficiently. The probe should also be able to manipulate the targeted tissue, both towards the probe and also away from any sensitive or fragile non-targeted tissue. The probe should also provide a

25 clear field of view for the surgeon during the procedure, and should control excessive bleeding. The probes currently in use for tissue removal procedures, however, have enjoyed only moderate success in these areas.

30 The most widely used transurethral resection device is an electrocautery probe which uses a radio-frequency electric current passing through a loop to cut the targeted tissue. The loop is energized by either passing electrical current through it (bipolar

35 version), or by passing electrical current from the

loop, through the body, and out through a grounding pad attached to the body (monopolar version).

5 The electrocautery probe, however, does not efficiently remove the tissue once it is cut. As the tissue is cut, it is deposited in the bladder. Therefore, the surgeon must intermittently stop the cutting procedure and allow the cut tissue and irrigation fluid to drain from the bladder. Also the cutting loop can easily cut or nick tissue not
10 intended to be affected, which can cause severe complications. In addition, the electrocautery probe has no means for manipulating the targeted tissue. Further, there is no means for continually removing debris and cut tissue to provide a clear field of
15 view. Also, tissue cut by the loop bleeds excessively. The surgeon must spend a lot of operating time controlling the bleeding. Patients using anticoagulation medication cannot be candidates for this procedure. And, for those patients who are,
20 a catheter must be placed in the urethra following the procedure to control bleeding. Finally, the monopolar version cannot be used in conjunction with standard saline irrigation solutions because this fluid is electrically conductive. Therefore, a non-
25 conductive irrigation fluid must be used, which could disrupt the patient's electrolyte balance.

One solution to the excessive bleeding problem is the use of fiber optic probe, where laser light is directed by a fiber optic to the targeted tissue.
30 The tissue is cut, and the remaining tissue is coagulated, which prevents excessive bleeding during and after the tissue removal procedure.

A fiber optic probe has been used for visual laser ablation of the prostate, whereby laser light
35 from an Nd:Yag laser is focused onto the targeted tissue using an optical fiber. The laser energy

heats and kills the targeted tissue. The dead tissue cells eventually flush out of the patient through their urine over a period of several months.

5 While this fiber optic probe does coagulate the treated tissue, there are several drawbacks to this procedure. Tissue removal is inefficient, as it takes several months to fully clear the dead tissue from the patient's system. Also, the procedure is not very accurate as there is no visual indication as
10 to what tissue has been sufficiently heated, and to what depth. The area and depth of tissue affected by the laser energy is highly dependent on the position of the delivery end of the optical fiber relative to the tissue. Further, there is no means for
15 manipulating the targeted tissue with respect to the probe. Lastly, there is no means for providing a clear field of view.

Fiber optic probes have also been used cut up stones formed in the body, or defective lenses in the
20 eye. Pulsed laser energy is directed out of the optical fiber to strike and break up stones or lenses, where they are then removed from the patient's body. Yet, the fiber optic probes cannot accurately and efficiently remove the targeted
25 tissue. The laser energy exiting the fiber tends to move the targeted tissue away from the delivery end of the fiber. Since stones in a stone removal procedure, or a lens in a phaco lensectomy, may not be attached to the surrounding tissue, they freely
30 move away from the fiber, decreasing accuracy and efficiency. Further, there is no means of manipulating the targeted tissue. Therefore, the stone or lens may move up against sensitive non-targeted tissue, or stray laser energy could
35 adversely affect vital non-targeted tissue. There is no way to manipulate the tissue to a safer area

before laser treatment, which would reduce the risk of damaging vital tissue. In addition, there is no means for providing a clear field of view.

5 There is a need for a tissue removal device that accurately and efficiently cuts and removes targeted tissue, provides a means for manipulating the targeted tissue, provides a clear field of view, and coagulates the cut tissue to control excessive bleeding. There is also a need for a tissue removal
10 device that is compatible with a balanced saline irrigation solution, provides immediate visible results for the surgeon during the procedure, safely removes a predictable amount of tissue in a manner less sensitive to the position of the delivery end of
15 the fiber relative to the targeted tissue, and does not repel the targeted tissue during the tissue removal procedure.

SUMMARY OF THE INVENTION

20 The present invention solves the aforementioned problems with an aspirating laser probe device and method that combines aspiration and laser energy to accurately and efficiently manipulate, cut, ablate, aspirate and coagulate the targeted tissue, while providing a clear field of view for the surgeon.

25 The probe device of the preferred embodiment includes an elongated probe tube including an aspiration channel therein and an aspiration aperture formed near or at one end of the probe tube. The other end of the probe tube connects the aspiration
30 channel to a vacuum source. An optical wave guide, such as an optical fiber, attaches to the probe tube. The delivery end of the optical fiber is located proximate to the aspiration aperture.

35 During operation, the vacuum in the aspiration channel manipulates the targeted tissue to the

aspiration aperture. The target tissue is held in place at the aspiration aperture. Loose target tissue can be moved to a safer area for treatment which reduces the chance of harming nearby vital tissues. The aspiration also provides a clear field of view by removing debris and fluids from the area.

Laser energy entering the input end of the wave guide is channeled by the wave guide and directed out the delivery end to the targeted tissue to cut, ablate and coagulate the tissue. The cut and ablated tissue is drawn into the aspiration channel and aspirated out of the patient's body. The coagulated tissue left behind minimizes bleeding.

To increase the cutting and ablating efficiency, the laser system produces pulsed infrared laser energy that is highly absorbed by fluids and tissue in the body. If the power density is high enough, vapor bubbles are created at the delivery end of the wave guide when the delivery end is in a fluid environment. The shock waves from the collapsing bubbles contribute to the removal of the targeted tissue. The turbulence of the shock waves is exploited by fixing the target tissue in place against the aspiration aperture with the vacuum in the aspiration channel.

Other aspects and features of the present invention will become apparent by a review of the specification, claims and appended figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view of the probe device of the present invention.

Fig. 2 is a side view of the probe assembly of the present invention.

Fig. 3a is a partial cross-sectional side view of the probe assembly illustrating tissue being drawn into the aspiration aperture.

5 **Fig. 3b** is a partial cross-sectional side view of the probe assembly illustrating the formation of the vapor bubble.

Fig. 3c is a partial cross-sectional side view of the probe assembly illustrating the vapor bubble extended out over the aspiration aperture.

10 **Fig. 4** is a partial top view of the probe assembly illustrating the dam and the teardrop shape of the aspiration aperture.

Fig. 5 is a cross-sectional view of a teardrop shaped probe tube.

15 **Fig. 6** is a partial perspective view of a second embodiment of the probe assembly of the present invention.

Fig. 7 is a partial side view of the probe assembly positioned inside a surgical sheath.

20 **Fig. 8a** is a partial side cross-sectional view of a third embodiment of the probe assembly of the present invention.

Fig. 8b is a partial side cross-sectional view of the third embodiment having a tapered end.

25 **Fig. 8c** is a partial side cross-sectional view of the third embodiment having an aspiration aperture of reduced size.

Fig. 8d is a partial side cross-sectional view of the third embodiment where the fiber optic is flush with the end of the probe tube.

30 **Fig. 8e** is a partial side cross-sectional view of the third embodiment having a teflon cover over the aspiration aperture.

Fig. 9 is a partial side cross-sectional view of a fourth embodiment of the probe assembly of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is an aspirating laser probe that combines aspiration and laser energy to accurately and efficiently manipulate, cut, ablate, aspirate and coagulate the targeted tissue, while providing a clear field of view for the surgeon.

A first embodiment of the present invention is an aspirating laser probe device for increased cutting efficiency and for removing tissue from within a patient, as illustrated in Figs. 1 and 2. The aspirating probe device includes an elongated probe assembly 2, a laser system 4, and a vacuum source 6.

The probe assembly 2 includes an aspiration probe tube 10 made of a rigid material such as stainless steel, which forms an aspiration channel 12 therein, and a tip end 8 insertable into a patient, as illustrated in Figs. 1 and 2. An aspiration aperture 14 is formed in the wall of the aspiration tube 10 near tip end 8. A fiber tube 16 is attached to the outside surface of the aspiration tube 10 and runs along the length thereof. The fiber tube 16 terminates on one end at or near the aspiration aperture 14, and on the other end in a fiber block 18. Fiber tube 16 bends away from aspiration tube 10 as it enters block 18.

The fiber tube 16 is dimensioned to receive the delivery end 22 of an optical wave guide, in this case an optical fiber 20. The optical fiber 20 is inserted through the fiber tube 16 until the delivery end 22 of the fiber 20 is positioned proximate to the aspiration aperture 14. A knob/O-ring assembly 26 clamps around optical fiber 20, thus securing the position of the fiber 20 in the fiber tube 16. The aspiration channel 12 terminates in an aspiration

port 28. A vacuum tube 30 from the vacuum source 6 connects to the aspiration port 28.

5 A valve 32 located in aspiration channel 12 extends out of block 18. The valve 32 selectively opens and closes aspiration channel 12.

10 The input end 24 of the optical fiber 20 is attached to the laser system 4, which can either be a continuous output or pulsed laser system. The vacuum tube 30 attaches to the vacuum source 6, which is a pump capable of creating a variable vacuum, preferably between 0-750 mmHg. The vacuum source 6 includes a tissue trap 34 to collect tissue and fluids aspirated from the patient.

15 To perform a tissue removal procedure, the tip end 8 of probe assembly 2 is inserted into a patient, for example into the urethra, the knee, the kidney, or the eye. These areas are usually irrigated with a saline solution during the tissue removal procedure. When the vacuum source 6 is activated and valve 32 is open, the vacuum in aspiration channel 12 draws any surrounding tissue, fluid or debris to the aspiration aperture 14. The vacuum in aspiration channel 12 firmly secures tissue masses too large to fit through the aspiration aperture 14 up against aperture 14. 20 For loose target tissue, such as stones or lenses, the aspiration action fixes the tissue to the probe assembly 2 so that it can be manipulated away from vital fragile tissues that could be adversely affected by the laser treatment. For fixed tissue, 25 the aspiration action puts the tissue in tension, which makes the tissue easier to cut and ablate with the laser energy. 30

35 When the laser system 4 is activated, the laser energy exiting the delivery end 22 of the optical fiber 20 is directed out into an area in and immediately outside of the aspiration aperture 14,

thereby cutting, ablating, and coagulating the tissue secured against the aspiration aperture 14. The cut and/or ablated tissue is immediately aspirated into aspiration aperture 14, through aspiration channel 12, and out the aspiration port 28 to the vacuum source 6. The remaining tissue in the body is coagulated, which controls excessive bleeding during and after the tissue removal procedure. A clearer field of view for the surgeon is created because debris and particulates created by the laser-tissue interaction are immediately aspirated into the aspiration aperture 14. By having the laser-tissue interaction area near or in the aspiration aperture 14, clogging of that aperture and the aspiration channel is reduced significantly.

The operation of the aspiration source and laser system can vary or be coupled to create the desired effect. The laser could first be turned on, followed by the aspiration. This would ensure that any tissue aspirated into the aspiration channel 12 is ablated first. Alternately, the aspiration could be turned on first, followed by the laser power. This would draw the targeted tissue into and engage with the probe before ablation begins. Finally, the laser power and aspiration could be turned on and off simultaneously, to simplify the tissue removal procedure.

The cutting action of the probe device can be enhanced by outputting high energy pulses from optical fiber 20 which, with sufficient power density in a fluid environment, to form a vapor bubble 36 at the delivery end 22 of optical fiber 20 during each pulse. Before each pulse, tissue 35 is drawn into aspiration aperture 14, as shown in Fig. 3a. During each pulse, the vapor bubble 36 forms (Fig. 3b) and extends out over the aspiration aperture 14 (Fig.

3c). When the pulse ceases, the vapor bubble 36 collapses. The vapor bubble 36 acts as a conduit for the laser energy during the pulse. The cutting action on the targeted tissue is accomplished by both absorption of the laser energy by the tissue and the shock wave created by the collapsing vapor bubble 36, which combine to cut, ablate and coagulate any tissue in and immediately outside of the aspiration aperture 14. The turbulence from the vapor bubble shock waves softens the target tissue and/or shreds it into stringy tissue that is easily drawn into the aspiration aperture 14 and to be cut. This turbulence energy is harnessed by holding the tissue firmly in place (in the aspiration aperture by the vacuum in aspiration channel 12). If the tissue were not held in place by the probe assembly 2, and/or the optical fiber 20 was not held in place by the probe tube 10, the tissue and/or fiber 20 would move with the vapor bubble 36, which would minimize the effect of the vapor bubble shock waves on the targeted tissue.

In order to get the desired cutting action, an infrared laser source is used. Certain infrared wavelengths are highly absorbed by water, resulting in a low penetration depth into fluids and tissues in the body. For satisfactory results, the wavelength in a solid state laser should be between 2.0 and 3.0 μm . A Ho:Yag laser will generate light having a wavelength of 2.1 μm while an Er:Yag laser will generate light having a wavelength of 2.9 μm . The low penetration depth ensures the high power density in fluids to create the vapor bubble 36, and in the targeted tissue to quickly cut, ablate and coagulate that tissue. The high absorption and low penetration depth also ensures that tissues and/or fluids affected by the laser energy is limited to that area

in and immediately outside of the aspiration aperture 14. This small "laser-tissue interaction area" outside the aspiration aperture 14 not only results in high precision tissue ablation, but also results in efficient tissue aspiration from the body. As soon as the targeted tissue is ablated, it is immediately aspirated from the laser-tissue interaction area, whereby new tissue to be cut immediately takes its place.

The small laser-tissue interaction area also allows the surgeon to safely work near vital tissue with a reduced chance of damaging nearby non-targeted tissue. Only tissue held by the aspiration aperture is ablated. Further, any tissue that is cut, heated and/or ablated by the laser energy, or any heated irrigation fluid, is immediately aspirated from the patient, resulting in reduced debris and residual thermal effects on tissue and irrigation fluid remaining in the body.

The typical pulsed laser sources that have been found to produce adequate infrared radiation with sufficient power include erbium, holmium, and carbon dioxide laser systems.

Different laser sources can be combined to alternately or simultaneously feed the optical fiber 20 with different wavelengths of laser energy. For example, the longer wavelength produced by an erbium laser system have higher absorption in water than the shorter wavelength produced by a holmium laser system. Therefore, the erbium laser energy would be more precise, but have a lesser coagulative effect. By combining these laser outputs, precise ablation with improved coagulation can be achieved. Other types of laser systems that can be incorporated into such a combination include Nd:Yag and Carbon dioxide laser systems. Also, multiple optical fibers can be

attached to the probe assembly to deliver different wavelengths of laser energy and/or deliver the laser energy from different angles. In addition, the laser output power, the laser repetition rate and the amount of vacuum in the aspiration channel 12 can be set to optimally remove different predetermined amounts of tissue or different tissue types, and/or adjust the depth of tissue interaction.

The cutting action of the probe device can be further enhanced by sharpening the edges 15 of the aspiration aperture 14. The expanding and collapsing vapor bubbles 36 force tissue up against the sides of the aspiration aperture 14, where the sharpened edges 15 cut the moving tissue.

The dimensions of the aspiration aperture 14 can be changed to optimize tissue removal for different tissue types. For example, the aspiration aperture 14 can have a tear drop shape, as shown in Fig. 4, to exploit the diverging characteristics of the laser energy exiting the optical fiber 20, and match the shape of the vapor bubble 36. A raised dam 38 can be formed near the aspiration aperture 14 creating a funnel action that enhances the cutting action of the probe assembly 2. The high profile of the dam 38 would also protect tissue from the delivery end of the fiber and the aspiration aperture during insertion and removal of the probe device inside the patient.

The dimensions of the probe tube can be changed to minimize abrading the adjacent tissue and maximize ablation efficiency. The cross-section of the probe tube 10 can be elliptical or teardrop shaped, as shown in Fig. 5. The fiber tube 16 and the optical fiber 20 are positioned at the apex of the teardrop shape of the probe tube 10. This configuration minimizes the amount of probe tube surface in contact

with the tissue that will be treated by the laser energy.

The optical fiber 20 can be removed from the probe assembly 2 to be recleaved or replaced. The probe assembly 2 itself can be separately sterilized for repeated use. Alternately, the optical fiber 20 can be glued or otherwise permanently affixed to the probe assembly 2.

The probe device is ideal for transurethral resection of the prostate. The suction action caused by opening valve 32 secures the probe assembly 2 against the targeted tissue surface. By activating the laser and drawing the probe assembly 2 along the tissue surface, a predetermined amount of tissue is efficiently removed from the tissue surface, leaving a trench like incision. The positive probe contact with the targeted tissue surface simplifies probe placement, so there is no reliance on the surgeon's skills to hold the probe assembly 2 above the tissue surface. By repeating the process over the entire surface of the urethra, the urethra cross-section is efficiently enlarged to the desired amount while coagulating the remaining tissue to reduce bleeding and reducing the need for catheterization. The probe assembly 2 leaves a visible effect on the remaining tissue so the surgeon can see how much tissue has been removed. Lastly, conventional saline irrigation can be used, because no electrical currents are used in the cutting process.

In the preferred embodiment, as shown in Figs. 1-3, the aspiration aperture 14 is located in the longitudinal wall of the probe tube 10. The optical fiber 20 is located on the outside of the probe tube 10, with the delivery end 22 of the optical fiber 20 being adjacent to the aspiration aperture 14. This configuration has several advantages. First, any

tissue in or adjacent to the aspiration aperture 14 is immediately ablated and aspirated into the aspiration channel 12. This prevents clogging of the aspiration aperture 14. Secondly, targeted tissue is easier to access with the probe device because the laser-tissue interaction area is outside of the aspiration aperture 14. Lastly, since ablated and cut tissue is immediately aspirated from the laser-tissue interaction area, the probe device can efficiently remove high volumes of tissue thus reducing the time required to perform the tissue removal procedure.

The applicant has developed an aspirating probe for use with a holmium laser system outputting pulsed laser energy at 2.1 um at a repetition rate of 20-50 Hz, and having an energy of 2-3 joules per pulse. The vacuum in the aspiration channel is preferably between 200-650 mmHg.

While the above described probe assembly 2 is ideal for transurethral resection of the prostate, it can be used for other medical procedures that cut tissue masses for removal from the body, such as latching onto and breaking up stones or tumors.

The probe device can also treat tissue with laser light without cutting or aspirating such tissue. With lower laser powers and aspiration rates, the suction action at the aspiration aperture 14 secures targeted tissue against the delivery end 22 of fiber 20, whereby the laser energy can properly treat it. Alternatively, the fiber 20 can be extended through the fiber tube 16 beyond the end of the probe assembly 2 for treatment of tissue with laser energy without the effects of aspiration.

A second embodiment of the present invention is shown in Fig. 6. The fiber tube 16 is integrally formed into the longitudinal wall of the aspiration

tube 10 and terminates at the aspiration aperture 14. The optical fiber 20 is inserted into the fiber tube 16 until it nears or extends into the aspiration aperture 14. The integrally formed fiber tube 16 into the aspiration tube wall slightly lowers the laser-tissue interaction area into the aspiration aperture 14, which makes better use of the sharpened edges 15 of the aspiration aperture 14 and reduces clogging for some tissue types.

For improved probe mobility and irrigation, the probe assembly 2 can operate inside a surgical sheath 40, as illustrated in Fig. 7. Sheath 40 is a hollow tube with open ends 42 and 44. Sheath end 42 has a seal 46 engageable with the probe assembly 2. Sheath end 44 is insertable into the patient. An irrigation port 48 is formed near sheath end 42, and is connectable to an irrigation source 50 by an irrigation tube 52.

The probe assembly 2 inserts into the sheath 40 through seal 46, to form an annular irrigation channel 54 therebetween. The seal 46 prevents any fluid from leaking out the back end of the irrigation channel 54. During the tissue removal procedure, the irrigation source 50 provides an irrigation solution, such as a saline solution, to the targeted tissue via the irrigation channel 54.

Probe assembly 2 is moved back and forth inside the patient during the tissue removal procedure to access different targeted tissues. It is easier to move the probe assembly 2 back and forth inside the sheath 40 rather than directly through the tissue or passageway used for entry into the patient. Further, there is less abrasion to that tissue or passageway. Lastly, the sheath 40 provides irrigation directly to the laser-tissue interaction area while the targeted tissue is being treated.

To simplify the operation of probe device, valve 32 could also operate the output of laser 4 and/or flow of irrigation fluid from irrigation source 50. Alternately, a single device, such as a foot-switch, could simultaneously trigger a combination of the aspiration, the laser output, and the irrigation fluid flow.

A third embodiment of the present invention is shown in Figs. 8a-8e. An optical fiber 20 is situated inside an aspiration tube 62 which has an open end 64. The delivery end 22 of the optical fiber 20 is recessed inside the open end 64 of aspiration tube 62 by a predetermined amount L, forming an open chamber 66, as shown in Fig. 8a. An annular channel 68 is formed between the probe tube 62 and the fiber 20 for aspiration. The delivery end 22 of the fiber 20 and the aspiration tube 62 define an annular aperture 70.

The suction caused by aspiration through channel 68 draws targeted tissue, fluid and debris into the chamber 66, where the laser energy cuts, ablates and coagulates the target tissue therein for aspiration through the aspiration channel 68. Larger tissue masses are securely fixed against the open end 64 of aspiration tube 62, where they can be manipulated to a safer area within the body before the laser energy is used to break up the tissue mass for aspiration through aperture 70. For example, in a lensectomy, the lens can be pulled to the middle of the lens sack before the laser power ablates the lens. This reduces the risk that the lens would puncture the wall or that stray laser energy would adversely impact the wall. Also, kidney or gall bladder stones can be manipulated away from vital tissues before laser ablation and aspiration.

Laser light exiting the delivery end 22 of the optical fiber 20 is divergent and is partially directed out toward the annular aperture 70 to break up larger tissue masses that could clog the aperture 70. The high absorption and low penetration depth of infrared laser energy limits the laser-tissue interaction area to that area in and immediately outside of chamber 66.

The advantage of the open ended chamber 66 is that targeted tissue or tissue strands cannot pass through chamber 66 and into aperture 70 without being cut or ablated by the laser energy. This prevents the probe from engaging and aspirating targeted tissue that is still connected to vital tissue and introducing unwanted traction to non-targeted tissue. Further, such tissue can be drawn into chamber 66 only to a depth of L, which also prevents unwanted traction.

The shape of the chamber walls can be varied to maximize the safe aspiration of different types of tissue, as illustrated in Figs. 8a-8d. The shape of the open end 64 can be straight (Fig. 8a), or can be curved to a reduced size (Fig. 8b), or can be sharply angled to a reduced size (Fig. 8c). The particular end shape can be selected based upon the type of tissue to be ablated. Additionally, the fiber can be extended to be flush with the open end 64, as shown in Fig. 8d.

Additional protection from engaging tissue before it is ablated can be provided by a teflon shield 72 that covers the open end 64 of chamber 66, as shown in Fig. 8e. The teflon shield 72 has a plurality of small holes 74 for ablated tissue to pass through. The infrared laser energy passes through the teflon shield 72 and ablates tissue outside the chamber 66. Only ablated tissue passes

through the plurality of holes 74 for aspiration through aperture 70, thus preventing unwanted tension being placed on tissue still attached to non-targeted tissue.

5 A fourth embodiment of the present invention is shown in Fig. 9. An aspirating tube 80 terminates in a chamber 82. A plurality of slots 84 are formed in the chamber walls. The optical fiber 20 and aspirating tube 80 form the aspiration channel 88.
10 The laser-tissue interaction area is limited to the inside of chamber 82. This configuration is ideal for precise trimming of stringy tissues, as it prevents this stringy tissue from passing the laser-tissue interaction area without being cut and
15 ablated, thus preventing unwanted traction to vital non-targeted tissue.

 To prevent the laser energy from degrading the tip of the probe device, the walls of the aspiration tube 10 or 62 can be coated with a reflective
20 coating. The coating can be formed from a metallic material, such as gold. The coating will reflect laser energy that would otherwise be absorbed by the aspiration tube walls, especially around the aspiration aperture 14 or open end 64. The reflected
25 energy can be used for tissue cutting and/or ablation.

 To add visibility and efficiency, the probe device can be constructed of a transparent material, such as glass. The surgeon can view through the
30 transparent aspiration tube 10 or 62 during the tissue removal procedure. Further, laser energy can pass through the transparent material to cut adjacent tissue.

 Throughout the description of the preferred
35 embodiments, the laser energy is carried by an optical fiber 20 to the targeted tissue. It should

be noted, however, that any wave guide capable of carrying the laser energy to the targeted tissue can be used in place of the optical fiber 20. For example, it would be possible to use a well known hollow wave guide (air fiber) having a reflective inner surface.

It is to be understood that the present invention is not limited to the embodiments described above and illustrated herein, but encompasses any and all variations falling within the scope of the appended claims.

CLAIMS

What is claimed is:

1. A surgical assembly for removing targeted body tissue from within a patient, comprising:

5 an elongated probe tube including an aspiration channel therein, said probe tube having an aspiration aperture formed adjacent to one end of said probe tube, the other end of said probe tube for connecting said aspiration channel to a vacuum source;

10 an optical wave guide attached to said probe tube, said optical wave guide having an input end and a delivery end, said delivery end being located proximate to said aspiration aperture, a laser system means attached to said input end of said wave guide for producing pulsed infrared laser energy of
15 sufficient magnitude to produce a power density at said delivery end of said wave guide high enough to create vapor bubbles when said delivery end is in a fluid environment, and

20 wherein during operation, aspiration caused by a vacuum in said aspiration channel from said vacuum source manipulates targeted tissue to said aspiration aperture, and laser energy entering said input end is channeled by said wave guide and directed out said
25 delivery end to the targeted tissue such that said laser energy in combination with shock waves created by the vapor bubbles functions to efficiently cut, ablate and coagulate the tissue and wherein the cut and ablated tissue is drawn into said aspiration
30 channel.

2. The surgical assembly of claim 1 wherein said laser system means includes at least one of a holmium laser system, an erbium laser system, and a carbon dioxide laser system.

3. The surgical assembly of claim 1 wherein said laser system means includes a combination of at least two different types of infrared laser systems.

5 4. The surgical assembly of claim 1 wherein the vacuum in said aspiration channel secures the targeted tissue against the aspiration aperture.

5. The surgical assembly of claim 4 further comprising:

10 means for simultaneously controlling the output of said laser system means and the vacuum inside said aspiration channel caused by said vacuum source.

6. The surgical assembly of claim 4 wherein the periphery of said aspiration aperture is shaped to define a cutting edge.

15 7. The surgical assembly of claim 4 wherein said aspiration aperture is teardrop shaped.

8. The surgical assembly of claim 4 further comprising:

20 a raised dam attached to said probe tube adjacent to said aspiration aperture, said dam dimensioned to increase the funnel action of tissue being aspirated through said aspiration aperture and to soften the profile of said probe tube.

25 9. The surgical assembly of claim 4 further comprising:

irrigation means attached to said probe tube for providing irrigation fluid to the targeted tissue.

10. The surgical assembly of claim 9 wherein said irrigation means is a sheath engaged around said

probe tube, said probe tube slidably within said sheath.

5 11. The surgical assembly of claim 4 wherein said probe tube having one of an elliptical and a teardrop cross-sectional shape.

12. A surgical assembly for removing targeted body tissue from within a patient, comprising:

10 an elongated probe tube including an aspiration channel therein, said probe tube having an aspiration aperture formed adjacent to one end of said probe tube, the other end of said probe tube for connecting said aspiration channel to a vacuum source; and

15 a wave guide mounted to the periphery of said probe tube, said wave guide having an input end and a delivery end, said delivery end being located proximate to said aspiration aperture whereby in operation, aspiration caused by a vacuum in said aspiration channel from said vacuum source manipulates targeted tissue to said aspiration
20 aperture and laser energy entering said input end is channeled by said wave guide and directed out said delivery end to the targeted tissue to cut and ablate the tissue and wherein the ablated tissue is drawn into said aspiration aperture and out of the
25 patient's body through said aspiration channel.

13. The surgical assembly of claim 12 further comprising:

30 a wave guide tube attached to the outside surface of said probe tube, said wave guide tube dimensioned to receive said wave guide therein.

14. The surgical assembly of claim 12 further comprising:

a wave guide tube integrally formed in the wall of said probe tube, said wave guide tube dimensioned to receive said wave guide therein.

5 15. The surgical assembly of claim 12 further comprising:

a laser system means attached to the input end of said optical wave guide for producing a pulsed infrared output beam at said delivery end of said wave guide.

10 16. The surgical assembly of claim 15 wherein said laser system creates vapor bubbles at said delivery end of said optical wave guide that extend out over said aspiration opening when said delivery end is in a fluid environment.

15 17. The surgical assembly of claim 16 wherein said laser system means includes at least one of a holmium laser system, an erbium laser system, and a carbon dioxide laser system.

20 18. The surgical assembly of claim 16 wherein said laser system means includes a combination of at least two different types of infrared laser systems.

19. The surgical assembly of claim 15 wherein the vacuum in said aspiration channel secures the targeted tissue against the aspiration aperture.

25 20. The surgical assembly of claim 15 further comprising:

means for simultaneously controlling the output of said laser system means and the vacuum inside said aspiration channel caused by said vacuum source.

21. The surgical assembly of claim 15 wherein the periphery of said aspiration aperture is shaped to define a cutting edge.

5 22. The surgical assembly of claim 15 wherein said aspiration aperture is teardrop shaped.

23. The surgical assembly of claim 15 further comprising:

10 a raised dam attached to said probe tube adjacent to said aspiration aperture, said dam dimensioned to increase the funnel action of tissue being aspirated through said aspiration aperture and to soften the profile of said probe tube.

24. The surgical assembly of claim 15 further comprising:

15 irrigation means attached to said probe tube for providing irrigation fluid to the targeted tissue.

20 25. The surgical assembly of claim 24 wherein said irrigation means is a sheath engaged around said probe tube, said probe tube slidably within said sheath.

26. The surgical assembly of claim 15 wherein said probe tube having one of an elliptical and a teardrop cross-sectional shape.

25 27. The surgical assembly of claim 13 wherein said aspiration aperture is formed in the side wall of said probe tube.

28. The surgical assembly of claim 27 wherein the delivery end is oriented to direct the laser

energy along the longitudinal axis of the probe tube and past the aspiration aperture.

5 29. The surgical assembly of claim 14 wherein said aspiration aperture is formed in the side wall of said probe tube.

 30. The surgical assembly of claim 29 wherein the delivery end is oriented to direct the laser energy along the longitudinal axis of the probe tube and through the aspiration aperture.

10 31. The surgical assembly of claim 12 wherein a reflective coating is formed on said probe tube.

 32. The surgical assembly of claim 31 wherein said reflective coating is formed from a metal.

15 33. The surgical assembly of claim 12 wherein said probe tube is made from a transparent material.

 34. A surgical assembly for delivering laser energy to a targeted body tissue, comprising:

20 an elongated probe tube having a distal end and a proximal end and having an internal channel therein, the proximal end being connectable to a vacuum source;

25 a wave guide disposed inside said internal channel, said wave guide and said probe tube forming an annular aspiration channel therebetween, said wave guide having an input end and a delivery end, said delivery end being located proximate to the distal end of the probe tube; and

30 a shield formed in the end of said probe tube, said shield being transparent to laser energy, said shield including a plurality of aspiration holes

therein, whereby in operation, aspiration caused by a vacuum in said aspiration channel from said vacuum source manipulates targeted tissue towards said shield, and laser energy entering said input end is
5 channeled by said wave guide and directed out said delivery end and through said shield to the targeted tissue to cut, ablate and coagulate the tissue and wherein the cut and ablated tissue is drawn into said aspiration channel through said holes in said shield.

10 35. The surgical assembly of claim 34 wherein said shield is made of teflon.

36. The surgical assembly of claim 34 wherein said delivery end of said wave guide is recessed from said shield.

15 37. The surgical assembly of claim 34 wherein the vacuum in said aspiration channel secures the targeted tissue against the shield.

38. The surgical assembly of claim 34 further comprising:

20 means for simultaneously controlling the output of said laser system means and the vacuum inside said aspiration channel caused by said vacuum source.

39. A surgical assembly for delivering laser energy to a targeted body tissue, comprising:

25 an elongated probe tube defining an internal channel therein, said internal channel terminating in an enclosed aspiration chamber formed at one end of said probe tube, the other end of said probe tube for connecting said internal channel to a vacuum source,
30 with said one end of the probe tube including a plurality of slots; and

a wave guide disposed inside said internal channel, said wave guide and said probe tube defining an annular aspiration channel therebetween, said wave guide having an input end and a delivery end, said delivery end being located proximate to said chamber whereby in operation, aspiration caused by a vacuum in said aspiration channel from said vacuum source manipulates targeted tissue towards said aspiration aperture and into said chamber through said slots and laser energy entering said input end is channeled by said wave guide and directed out said delivery end to the tissue that has been drawn into said chamber to cut and ablate the tissue and wherein the ablated tissue is drawn into said aspiration channel and out of the patient's body.

40. The surgical assembly of claim 39 further comprising:

a laser system means attached to the input end of said optical wave guide for producing a pulsed infrared output beam at said delivery end of said wave guide.

41. The surgical assembly of claim 40 wherein said laser system means includes at least one of a holmium laser system, an erbium laser system, and a carbon dioxide laser system.

42. The surgical assembly of claim 41 wherein said laser system means includes a combination of at least two different types of infrared laser systems.

43. The surgical assembly of claim 40 wherein the vacuum in said aspiration channel secures the targeted tissue against said slots.

44. The surgical assembly of claim 40 further comprising:

means for simultaneously controlling the output of said laser system means and the vacuum inside said aspiration channel caused by said vacuum source.

45. A method of removing tissue in a liquid field from within a patient using a probe assembly having an elongated probe tube including an aspiration channel therein, said probe tube having an aspiration aperture formed adjacent to one end of said probe tube, the other end of said probe tube for connecting said aspiration channel to a vacuum source, a wave guide is attached to said probe tube, said wave guide having an input end and a delivery end, said delivery end being located proximate to said aspiration aperture, said input end connected to a laser source that produces pulsed laser energy having a wavelength and energy selected to generate vapor bubbles in the liquid medium, comprising the steps of:

inserting the probe assembly into a patient's body adjacent to the tissue to be removed;

activating the vacuum source to draw targeted tissue to the aspiration aperture;

activating the pulsed laser source in a manner such that said laser energy in combination with shock waves created by the vapor bubbles functions to efficiently cut and ablate the tissue;

aspirating said cut and ablated tissue out of the patient's body through the probe tube.

46. The method of claim 45 further comprising the steps of:

adjusting the repetition rate and output power of the laser system to maximize cutting efficiency of the probe assembly; and

5 adjusting the vacuum created by the vacuum source to maximize tissue removal from the patient's body.

47. The method of claim 46 further comprising the steps of:

10 inserting the probe assembly into a surgical sheath before insertion of the probe assembly into the patient's body;

supplying irrigation fluid to the delivery end of the wave guide through the surgical sheath.

1/8

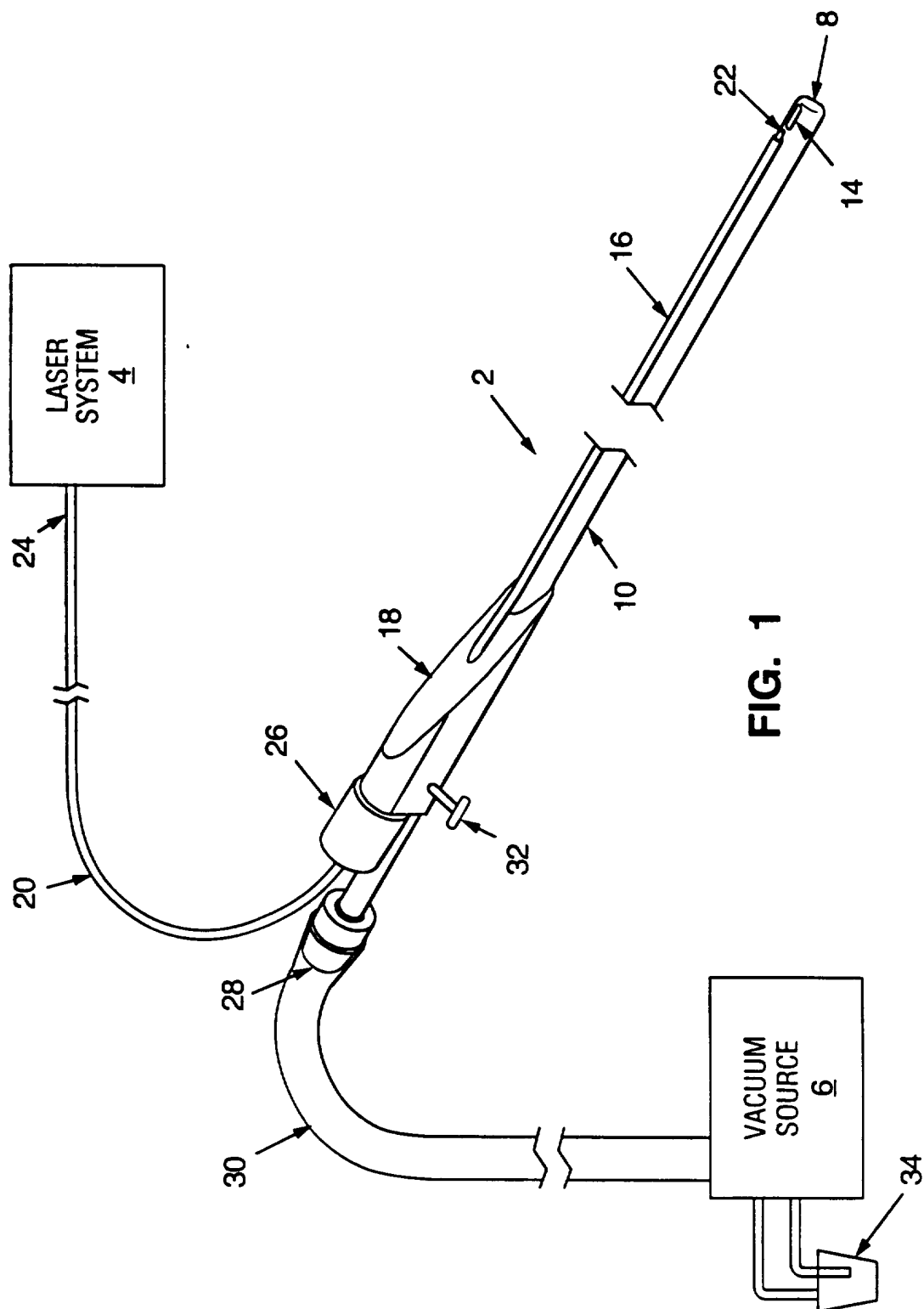


FIG. 1

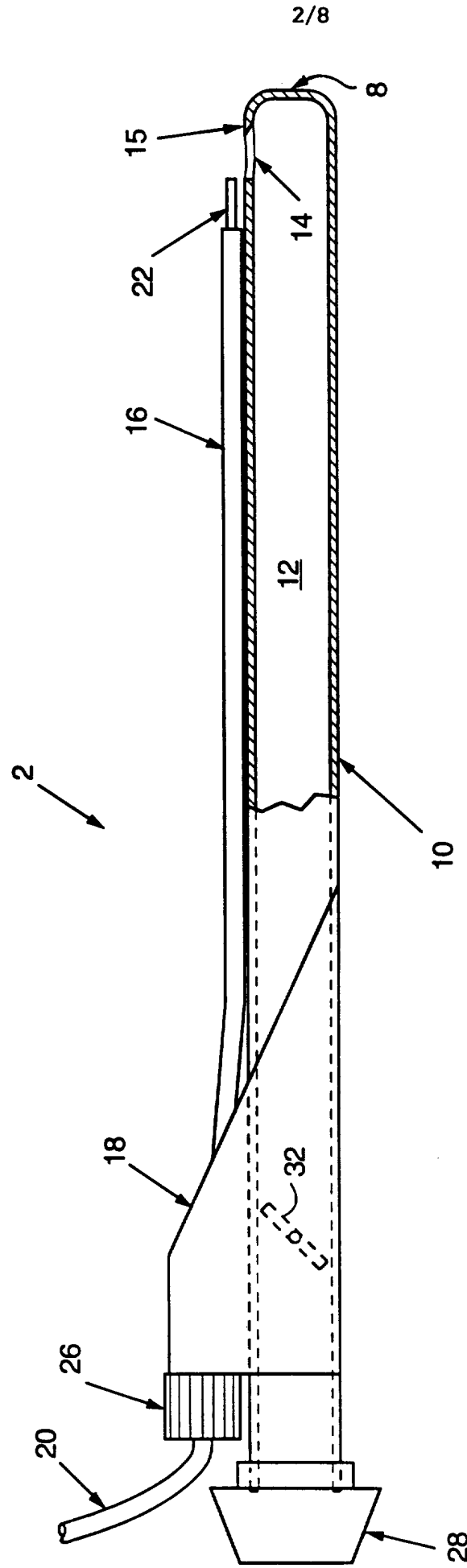
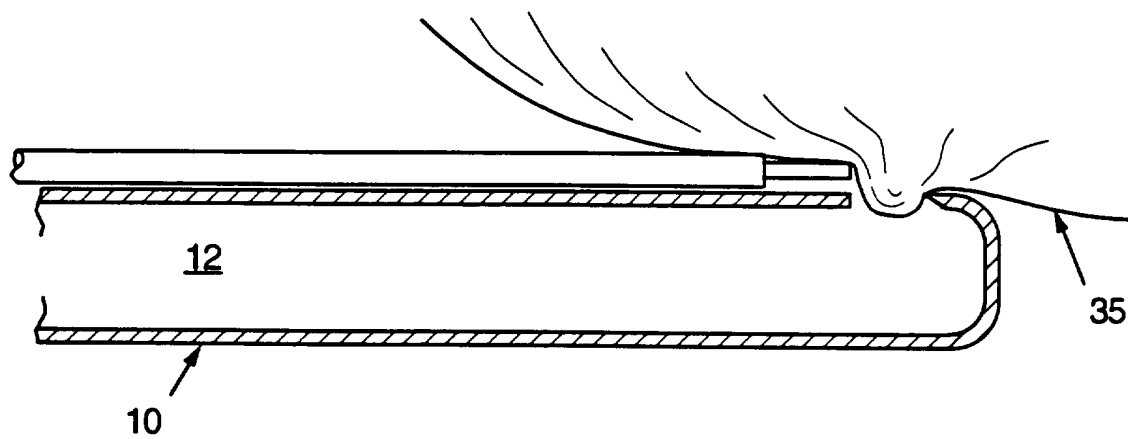
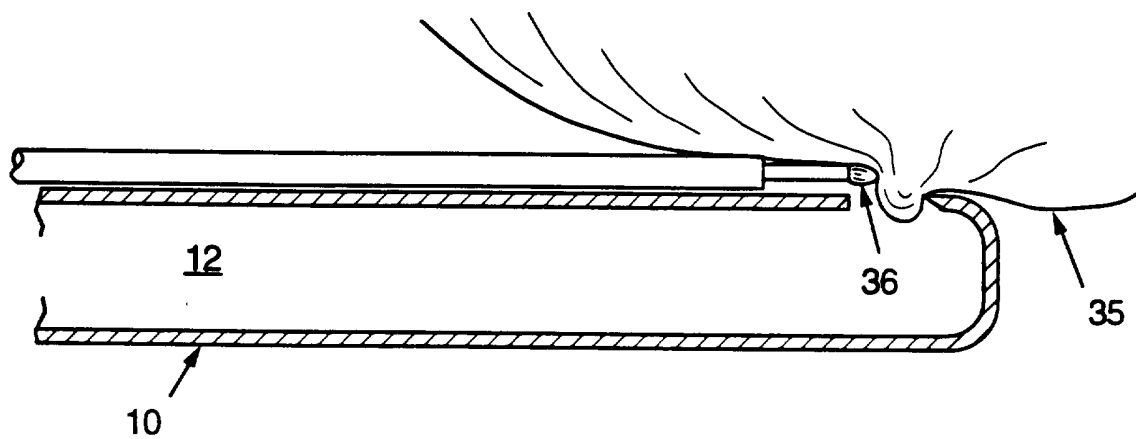
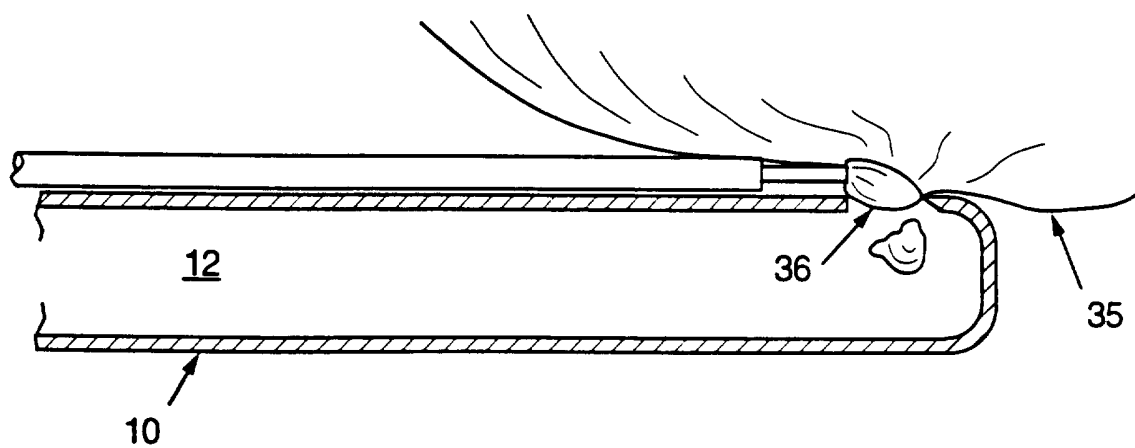


FIG. 2

3/8

**FIG. 3A****FIG. 3B****FIG. 3C**

4/8

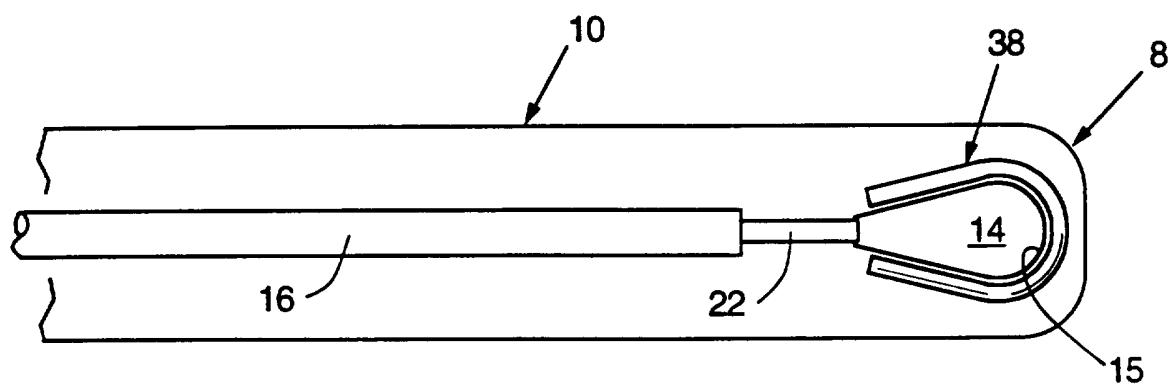


FIG. 4

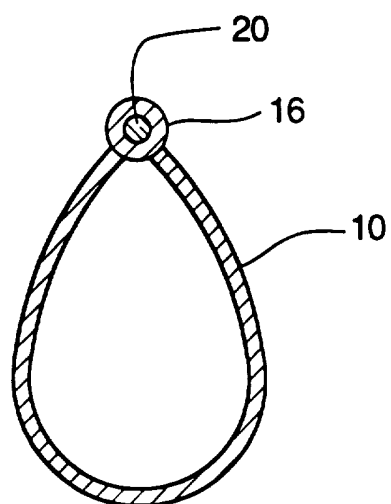


FIG. 5

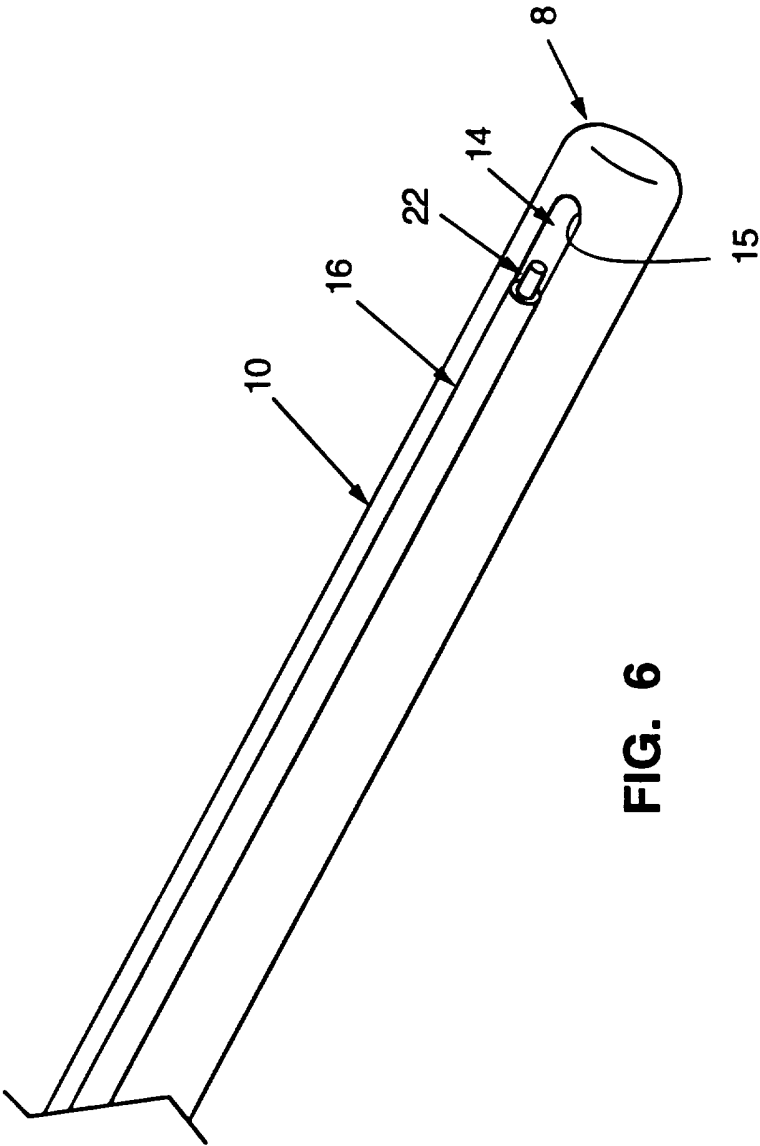


FIG. 6

6/8

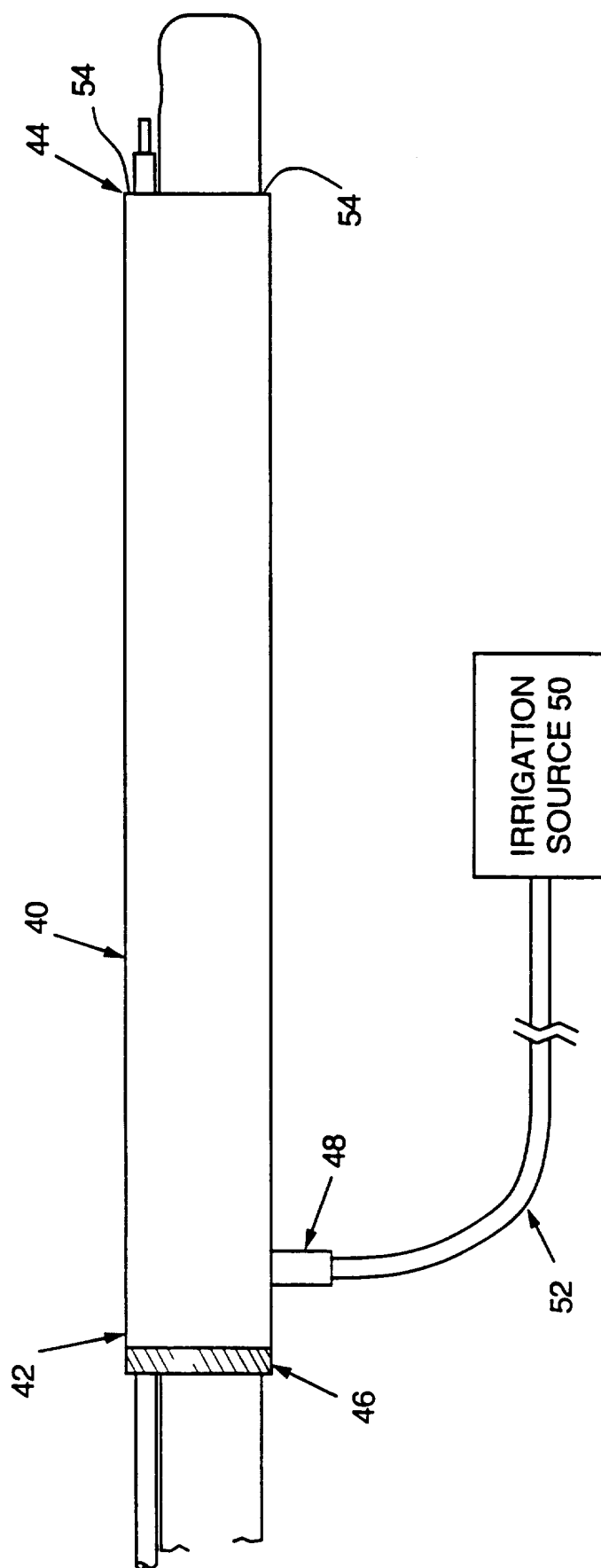


FIG. 7

7/8

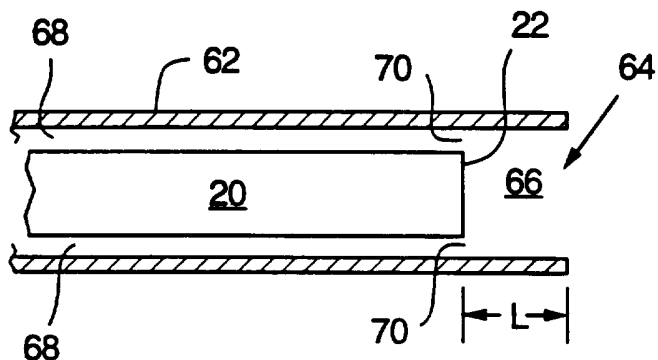


FIG. 8A

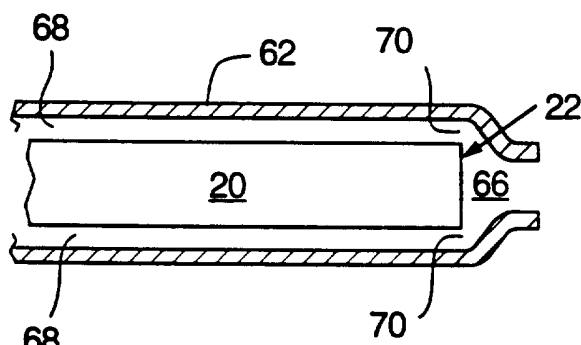


FIG. 8B

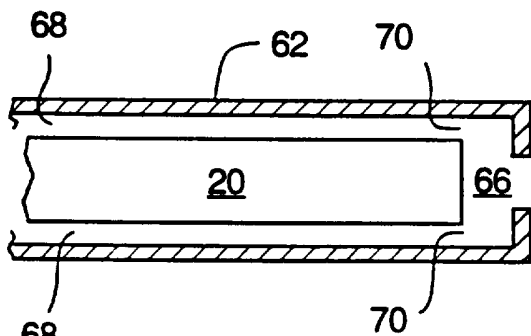


FIG. 8C

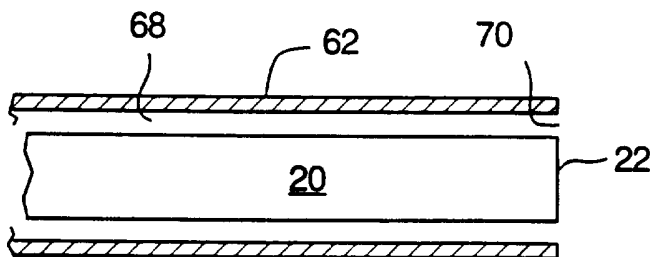


FIG. 8D

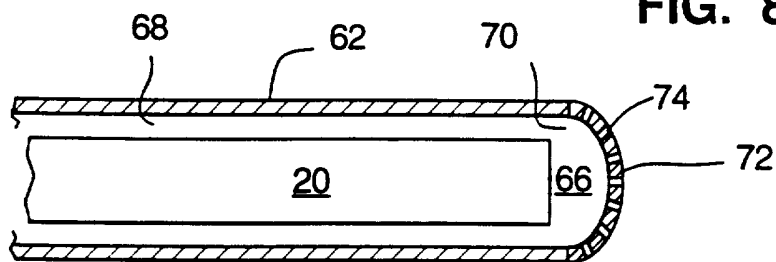


FIG. 8E

8/8

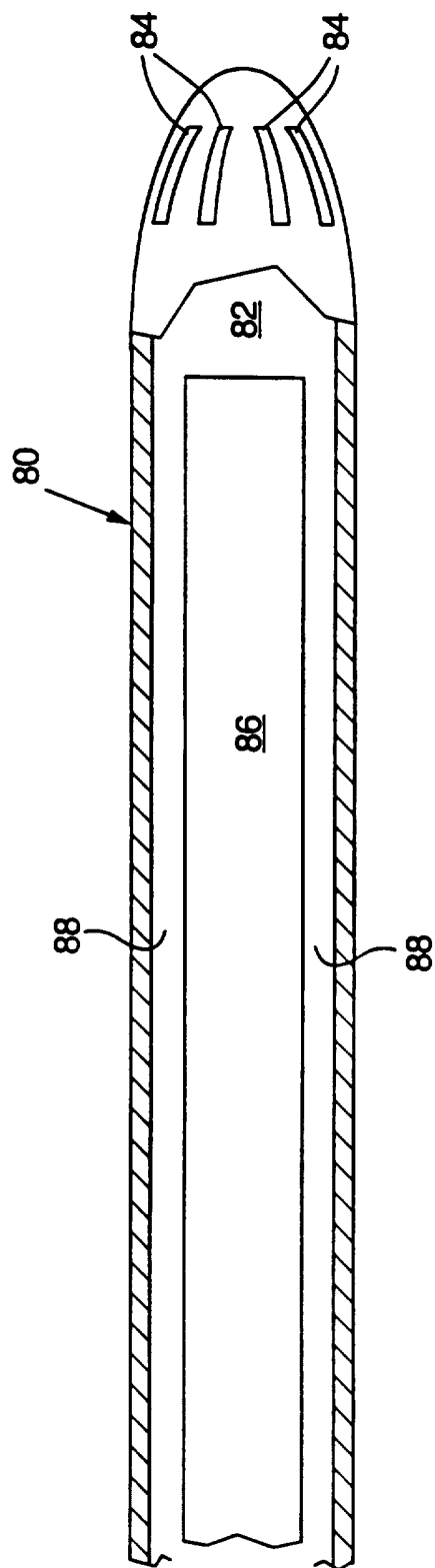


FIG. 9