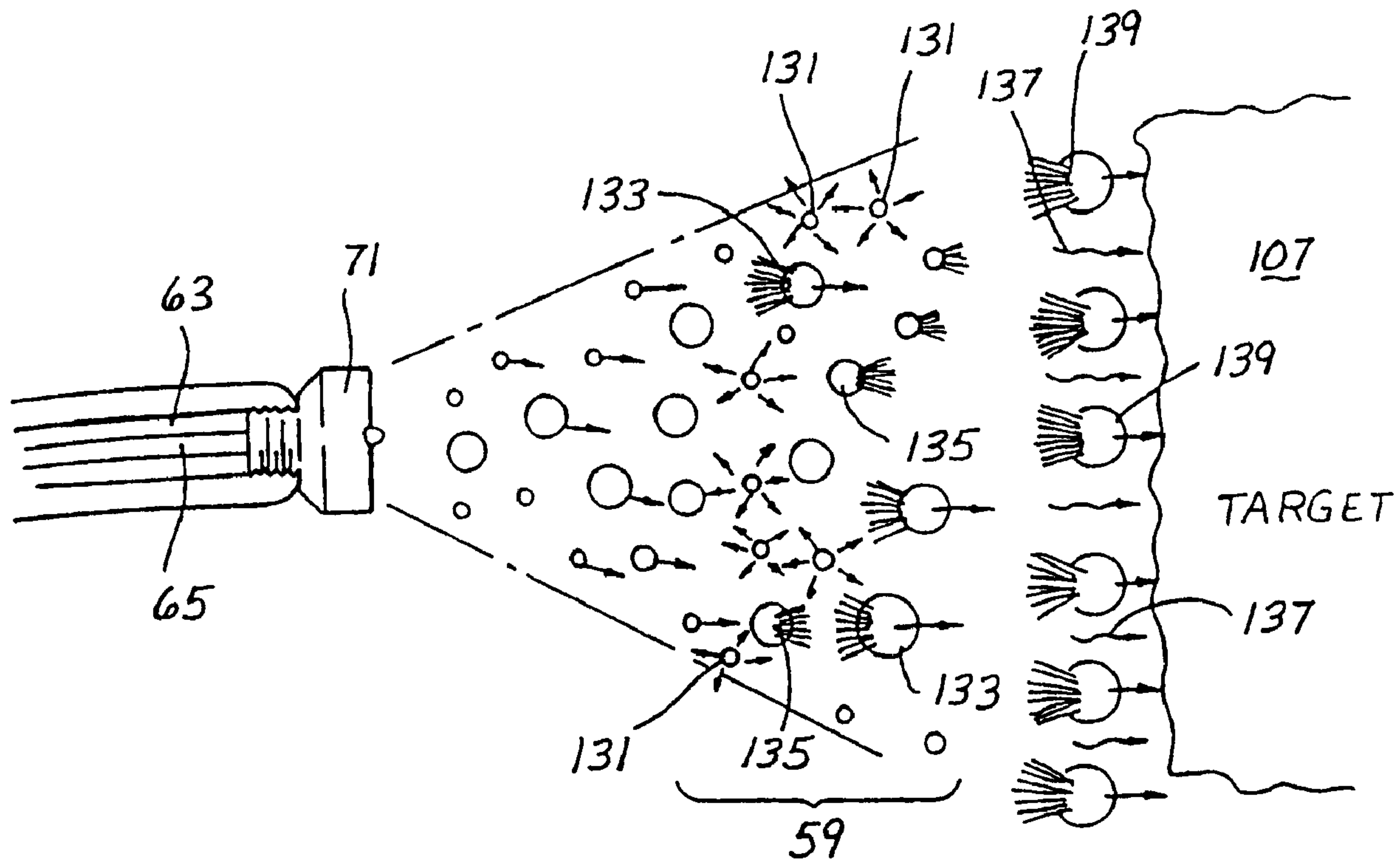




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 (54) Title: USER PROGRAMMABLE COMBINATION OF ATOMIZED PARTICLES FOR ELECTROMAGNETICALLY
 INDUCED CUTTING



(57) Abrégé/Abstract:

An electromagnetically induced cutting mechanism which can provide accurate cutting operations on both hard and soft materials is disclosed. The electromagnetically induced cutter is capable of providing extremely fine and smooth incisions, irrespective of the cutting surface. Additionally, a user programmable combination of atomized particles allows for user control of various cutting parameters. The various cutting parameters may also be controlled by changing spray nozzles and electromagnetic energy source parameters. A fluid conditioning system is adaptable to condition the water or air used in medical and dental cutting, irrigating,

(57) **Abrégé(suite)/Abstract(continued):**

evacuating, cleaning, and drilling operations, The air or water may be conditioned by adding flavor, scent, saline, medications, and disinfectants In addition to the direct benefits obtained from introduction of these agents, the laser cutting properties may be varied from the selective introduction of the various agents.

(57) Abstract

An electromagnetically induced cutting mechanism which can provide accurate cutting operations on both hard and soft materials is disclosed. The electromagnetically induced cutter is capable of providing extremely fine and smooth incisions, irrespective of the cutting surface. Additionally, a user programmable combination of atomized particles allows for user control of various cutting parameters. The various cutting parameters may also be controlled by changing spray nozzles and electromagnetic energy source parameters. A fluid conditioning system is adaptable to condition the water or air used in medical and dental cutting, irrigating, evacuating, cleaning, and drilling operations. The air or water may be conditioned by adding flavor, scent, saline, medications, and disinfectants. In addition to the direct benefits obtained from introduction of these agents, the laser cutting properties may be varied from the selective introduction of the various agents.

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USER PROGRAMMABLE COMBINATION OF ATOMIZED PARTICLES
FOR ELECTROMAGNETICALLY INDUCED CUTTING

Background of the Invention

The present invention relates generally to devices adapted for operating on hard and soft materials and, more particularly, to devices for combining
5 electromagnetic and hydro energies for cutting and removing both hard and soft tissues and to systems for introducing conditioned fluids into cutting, irrigating, evacuating, cleaning, and drilling systems.

A prior art dental/medical work station 6 is shown
10 in Figure 1a. A vacuum line 8 and an air supply line 10 supply negative and positive pressures, respectively. A water supply line 12 and an electrical outlet 14 supply water and power, respectively. The vacuum line 8, the
15 air supply line 10, the water supply line 12, and the power source 14 are all connected to the dental/medical unit 16.

The dental/medical unit 16 may comprise a dental seat or an operating table, a sink, an overhead light, and other conventional equipment used in dental and
20 medical procedures. The dental/medical unit 16 provides water, air, vacuum and/or power to the instruments 18. These instruments may include an electrocauterizer, an electromagnetic energy source, a mechanical drill, a mechanical saw, a canal finder, a syringe, and/or an
25 evacuator.

The electromagnetic energy source is typically a laser coupled with a delivery system. The laser 20a and delivery system 22a, both shown in phantom, as well as any of the above-mentioned instruments, may be connected

directly to the dental/ medical unit 16. Alternatively, the laser 20b and delivery system 22b, both shown in phantom, may be connected directly to the water supply 12, the air supply 10, and the electric outlet 14.

5 Other instruments 18 may be connected directly to any of the vacuum line 8, the air supply line 10, the water supply line 12, and/or the electrical outlet 14.

The laser 20 and delivery system 22 may typically comprise an electromagnetic cutter for dental use. A
10 conventional prior art electromagnetic cutter is shown in Figure 1b. According to this prior art apparatus, a fiber guide tube 5, a water line 7, an air line 9, and an air knife line 11 (which supplies pressurized air) are fed into the hand-held apparatus 13. A cap 15 fits
15 onto the hand-held apparatus 13 and is secured via threads 17. The fiber guide tube 5 abuts within a cylindrical metal piece 19. Another cylindrical metal piece 21 is a part of the cap 15.

When the cap 15 is threaded onto the hand-held
20 device 13, the two cylindrical metal tubes 19 and 21 are moved into very close proximity of one another. A gap of air, however, remains between these two cylindrical metal tubes 19 and 21. Thus, the laser within the fiber guide tube 5 must jump this air gap before it can travel
25 and exit through another fiber guide tube 23. Heat is dissipated as the laser jumps this air gap.

The pressurized air from the air knife line 11 surrounds and cools the laser as the laser bridges the gap between the two metal cylindrical objects 19 and 21.
30 Thus, a first problem in this prior art apparatus is that the interface between the two metal cylindrical objects 19 and 21 has a dissipation of heat which must be cooled by pressurized air from the air knife line 11. (Air from the air knife line 11 flows out of the two

exhausts 25 and 27 after cooling the interface between elements 19 and 21.) This inefficient interface between elements 19 and 21 results from the removability of the cap 15, since a perfect interface between elements 19 and 21 is not achieved.

The laser energy exits from the fiber guide tube 23 and is applied to a target surface within the patient's mouth, according to a predetermined surgical plan.

Water from the water line 7 and pressurized air from the air line 9 are forced into the mixing chamber 29. The air and water mixture is very turbulent in the mixing chamber 29, and exits this chamber through a mesh screen with small holes 31. The air and water mixture travels along the outside of the fiber guide tube 23, and then leaves the tube and contacts the area of surgery. This air and water spray coming from the tip of the fiber guide tube 23 helps to cool the target surface being cut and to remove cut materials by the laser. The need for cooling the patient surgical area being cut is another problem with the prior art.

Water is generally used in a variety of laser cutting operations in order to cool the target surface. Additionally, water is used in mechanical drilling operations for cooling the target surface and removing cut or drilled materials therefrom. Many prior art cutting or drilling systems use a combination of air and water, commonly combined to form a light mist, for cooling a target surface and/or removing cut materials from the target surface.

The use of water in these prior art systems has been somewhat successful for the limited purposes of cooling a target surface or removing debris therefrom. These prior art uses of water in cutting and drilling operations, however, have not allowed for versatility,

outside of the two functions of cooling and removing debris. In particular, during cutting or drilling operations, medication treatments, preventative measure applications, and aesthetically pleasing substances, such as flavors or aromas, have not been possible or used. A conventional drilling operation may benefit from the use of an anesthetic near the drilling operation, for example, but during this drilling operation only water and/or air has so far been used. In the case of a laser cutting operation, a disinfectant, such as iodine, could be applied to the target surface during drilling to guard against infection, but this additional disinfectant has not been applied during such laser cutting operations. In the case of an oral drilling or cutting operation, unpleasant tastes or odors may be generated, which may be unpleasing to the patient. The conventional use of only water during this oral procedure does not mask the undesirable taste or odor. A need has thus existed in the prior art for versatility of applications and of treatments during drilling and cutting procedures.

Compressed gases, pressurized air, and electrical motors are commonly used to provide the driving force for mechanical cutting instruments, such as drills, in dentistry and medicine. The compressed gases and pressurized water are subsequently ejected into the atmosphere in close proximity to or inside of the patient's mouth and/or nose. The same holds true for electrically driven turbines when a cooling spray (air and water) is typically ejected into the patient's mouth, as well. These ejected fluids commonly contain vaporous elements of burnt flesh or drilled tissue structure. This odor can be quite uncomfortable for the patient, and can increase trauma experienced by the

patient during the drilling or cutting procedure. In a such a drilling or cutting procedure, a mechanism for masking the smell and the odor generated from the cutting or drilling may be advantageous.

5 Another problem exists in the prior art with bacteria growth on surfaces within a dental operating room. The interior surfaces of air, vacuum, and water lines of the dental unit, for example, are subject to bacteria growth. Additionally, the air and water used
10 to cool the tissue being cut or drilled within the patient's mouth is often vaporized into the air to some degree. This vaporized air and water condensates on surfaces of the dental equipment within the dental operating room. These moist surfaces can also promote
15 bacteria growth, which is undesirable. A system for reducing the bacteria growth within air, vacuum, and water lines, and for reducing the bacteria growth resulting from condensation on exterior surfaces, is needed to reduce sources of contamination within a
20 dental operating room.

In addition to prior art systems which utilize laser light from a fiber guide tube 23, for example, to cut tissue and use water to cool this cut tissue, other prior art systems have been proposed. U.S. Patent No.
25 5,199,870 to Steiner et al., which issued on April 6, 1993, discloses an optical cutting system which utilizes the expansion of water to destroy and remove tooth material. This prior art approach requires a film of liquid having a thickness of between 10 and 200 mm.
30 Another prior art system is disclosed in U.S. Patent No. 5,267,856 to Wolbarsht et al., which issued on December 7, 1993. This cutting apparatus is similar to the Steiner et al. patent, since it relies on the absorption

of laser radiation into water to thereby achieve cutting.

Similarly to the Steiner et al. patent, the Wolbarsht et al. patent requires water to be deposited onto the tooth before laser light is irradiated thereon. Specifically, the Wolbarsht et al. patent requires water to be inserted into pores of the material to be cut. Since many materials, such as tooth enamel, are not very porous, and since a high level of difficulty is associated with inserting water into the "pores" of many materials, this cutting method is somewhat less than optimal. Even the Steiner et al. patent has met with limited success, since the precision and accuracy of the cut is highly dependent upon the precision and accuracy of the water film on the material to be cut. In many cases, a controllable water film cannot be consistently maintained on the surface to be cut. For example, when the targeted tissue to be cut resides on the upper pallet, a controllable water film cannot be maintained.

The above-mentioned prior art systems have all sought in vain to obtain "cleanness" of cutting. In several dental applications, for example, a need to excise small amounts of soft tissues and/or hard tissues with a great degree of precision has existed. These soft tissues may include gingiva, frenum, and lesions and, additionally, the hard tissues may include dentin, enamel, bone, and cartilage. The term "cleanness" of cutting refers to extremely fine, smooth incisions which provide ideal bonding surfaces for various biomaterials. Such biomaterials include cements, glass ionomers and other composites used in dentistry or other sciences to fill holes in structures such as teeth or bone where tooth decay or some other defect has been removed. Even when an extremely fine incision has been achieved, the

incision is often covered with a rough surface instead of the desired smooth surface required for ideal bonding.

5 One specific dental application, for example, which requires smooth and accurate cutting through both hard and soft tissues is implantology. According to the dental specialty of implantology, a dental implant can be installed in a person's mouth when that person has lost his or her teeth. The conventional implant
10 installation technique is to cut through the soft tissue above the bone where the tooth is missing, and then to drill a hole into the bone. The hole in the bone is then threaded with a low-speed motorized tap, and a titanium implant is then screwed into the person's jaw.
15 A synthetic tooth, for example, can be easily attached to the portion of the implant residing above the gum surface. One problem associated with the conventional technique occurs when the clinician drills into the patient's jaw to prepare the site for the implant. This
20 drilling procedure generates a great deal of heat, corresponding to friction from the drilling instrument. If the bone is heated too much, it will die. Additionally, since the drilling instrument is not very precise, severe trauma to the jaw occurs after the
25 drilling operation. The drilling operation creates large mechanical internal stress on the bone structure.

Summary of the Invention

The present invention discloses an
electromagnetically induced cutting mechanism, which can
30 provide accurate cutting operations on hard and soft tissues, and other materials, as well. The electromagnetically induced cutter is capable of providing extremely fine and smooth incisions,

irrespective of the cutting surface. Additionally, a user programmable combination of atomized particles allows for user control of various cutting parameters. The various cutting parameters may also be controlled by changing spray nozzles and electromagnetic energy source parameters. Applications for the present invention include medical, dental, industrial (etching, engraving, cutting and cleaning) and any other environments where an objective is to precisely remove surface materials without inducing thermal damage, uncontrolled cutting parameters, and/or rough surfaces inappropriate for ideal bonding. The present invention further does not require any films of water or any particularly porous surfaces to obtain very accurate and controllable cutting.

Drills, saws and osteotomes are standard mechanical instruments used in a variety of dental and medical applications. The limitations associated with these instruments include: temperature induced necrosis (bone death), aerosolized solid-particle release, limited access, lack of precision in cutting depth and large mechanical stress created on the tissue structure. The electromagnetically induced mechanical cutter of the present invention is uniquely suited for these dental and medical applications, such as, for example, implantology. In an implantology procedure the electromagnetically induced mechanical cutter is capable of accurately and efficiently cutting through both oral soft tissues overlaying the bone and also through portions of the jawbone itself. The electromagnetically induced mechanical cutter of the present invention does not induce thermal damage and does not create high internal structural stress on the patient's jaw, for example. After the patient's jaw is prepared with the

electromagnetically induced mechanical cutter,
traditional methods can be employed for threading the
hole in the patient's jaw and inserting the dental
implant. Similar techniques can be used for preparing
5 hard tissue structures for insertion of other types of
medical implants, such as pins, screws, wires, etc.

The electromagnetically induced mechanical cutter
of the present invention includes an electromagnetic
energy source, which focuses electromagnetic energy into
10 a volume of air adjacent to a target surface. The
target surface may be a tooth, for example. A user
input device specifies whether either a high resolution
or a low resolution cut is needed, and further specifies
whether a deep penetration cut or a shallow penetration
15 cut is needed. An atomizer generates a combination of
atomized fluid particles, according to information from
the user input device. The atomizer places the
combination of atomized fluid particles into the volume
of air adjacent to the target surface. The
20 electromagnetic energy, which is focused into the volume
of air adjacent to the target surface, is selected to
have a wavelength suitable for the fluid particles. In
particular, the wavelength of the electromagnetic energy
should be substantially absorbed by the atomized fluid
25 particles in the volume of air adjacent to the target
surface to thereby explode the atomized fluid particles.
Explosion of the atomized fluid particles imparts
mechanical cutting forces onto the target surface.

The user input device may incorporate only a single
30 dial for controlling the cutting efficiency, or may
include a number of dials for controlling the fluid
particle size, fluid particle velocity, spray cone
angle, average laser power, laser repetition rate,
fiberoptic diameter, etc. According to one feature of

the present invention, the atomizer generates relatively small fluid particles when the user input specifies a high resolution cut, and generates relatively large fluid particles when the user input specifies a low resolution cut. The atomizer generates a relatively low density distribution of fluid particles when the user input specifies a deep penetration cut, and generates a relatively high density distribution of fluid particles when the user input specifies a shallow penetration cut. A relatively small fluid particle may have a diameter less than the wavelength of the electromagnetic energy and, similarly, a relatively large fluid particle may have a diameter which is greater than the wavelength of the electromagnetic energy.

The electromagnetic energy source preferably is an erbium, chromium, yttrium, scandium, gallium garnet (Er, Cr:YSGG) solid state laser, which generates electromagnetic energy having a wavelength in a range of 2.70 to 2.80 microns. According to other embodiments of the present invention, the electromagnetic energy source may be an erbium, yttrium, scandium, gallium garnet (Er:YSGG) solid state laser, which generates electromagnetic energy having a wavelength in a range of 2.70 to 2.80 microns; an erbium, yttrium, aluminum garnet (Er:YAG) solid state laser, which generates electromagnetic energy having a wavelength of 2.94 microns; chromium, thulium, erbium, yttrium, aluminum garnet (CTE:YAG) solid state laser, which generates electromagnetic energy having a wavelength of 2.69 microns; erbium, yttrium orthoaluminate (Er:YALO3) solid state laser, which generates electromagnetic energy having a wavelength in a range of 2.71 to 2.86 microns; holmium, yttrium, aluminum garnet (Ho:YAG) solid state laser, which generates electromagnetic energy having a

wavelength of 2.10 microns; quadrupled neodymium, yttrium, aluminum garnet (quadrupled Nd:YAG) solid state laser, which generates electromagnetic energy having a wavelength of 266 nanometers; argon fluoride (ArF) excimer laser, which generates electromagnetic energy having a wavelength of 193 nanometers; xenon chloride (XeCl) excimer laser, which generates electromagnetic energy having a wavelength of 308 nanometers; krypton fluoride (KrF) excimer laser, which generates electromagnetic energy having a wavelength of 248 nanometers; and carbon dioxide (CO₂), which generates electromagnetic energy having a wavelength in a range of 9.0 to 10.6 microns.

When the electromagnetic energy source is configured according to the preferred embodiment, the repetition rate is greater than 1 Hz, the pulse duration range is between 1 picosecond and 1000 microseconds, and the energy is greater than 1 milliJoule per pulse. According to one preferred operating mode of the present invention, the electromagnetic energy source has a wavelength of approximately 2.78 microns, a repetition rate of 20 Hz, a pulse duration of 140 microseconds, and an energy between 1 and 300 milliJoules per pulse. The atomized fluid particles provide the mechanical cutting forces when they absorb the electromagnetic energy within the interaction zone. These atomized fluid particles, however, provide a second function of cleaning and cooling the fiberoptic guide from which the electromagnetic energy is output.

The optical cutter of the present invention combats the problem of poor coupling between the two laser fiberoptics of Figure 1b. The optical cutter of the present invention provides a focusing optic for efficiently directing the energy from the first

fiberoptic guide to the second fiberoptic guide, to
thereby reduce dissipation of laser energy between the
first fiberoptic guide and the second fiberoptic guide.
This optical cutter includes a housing having a lower
5 portion, an upper portion, and an interfacing portion.
The first fiberoptic tube is surrounded at its upper
portion by a first abutting member, and the second
fiberoptic tube is surrounded at its proximal end by a
second abutting member. A cap is placed over the second
10 fiberoptic tube and the second abutting member. Either
fiberoptic tube may be formed of calcium fluoride (CaF),
calcium oxide (CaO₂), zirconium oxide (ZrO₂), zirconium
fluoride (ZrF), sapphire, hollow waveguide, liquid core,
TeX glass, quartz silica, germanium sulfide, arsenic
15 sulfide, and germanium oxide (GeO₂).

The electromagnetically induced mechanical cutter
of the present invention efficiently and accurately cuts
both hard and soft tissue. This hard tissue may include
tooth enamel, tooth dentin, tooth cementum, bone, and
20 cartilage, and the soft tissues may include skin,
mucosa, gingiva, muscle, heart, liver, kidney, brain,
eye, and vessels.

The laser delivery system of the present invention
provides several mechanisms for combating heat
25 generation. Heat resistant ferrules, concentric
crystalline fibers, and air paths directed around these
fibers are provided. The present invention further
provides added strength to the laser fiber guide, by
enclosing the laser fiber guide in concentric tubular
30 members. Additionally, the handpiece of the laser
delivery system of the present invention is configured
into an outer sleeve component and an inner shaft
component for enhanced operability and sterility. Bent
crystalline fibers are used in conjunction with the

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laser delivery system of the present invention for delivering energy to a target. Additionally, an illumination line adapted for emitting coherent and non-coherent light is provided within the housing for
5 illuminating a target, and a medication line for delivering medications to a target is also provided within the housing.

According to one aspect of the present invention, there is provided an apparatus comprising: a plurality of fluid outputs carrying a fluid during use and being
10 constructed to direct the fluid to a first vicinity relative to the plurality of fluid outputs; and an electromagnetic energy source for supplying electromagnetic energy to a second vicinity; the first vicinity and the second vicinity being disposed at respective locations relative to the
15 plurality of fluid outputs and intersecting in a volume relative to the plurality of fluid outputs, said plurality of fluid outputs operable to place a combination of fluid particles into said volume; said electromagnetic energy source comprising a specifically configured electromagnetic
20 energy source that is arranged, when said apparatus is in use, to supply electromagnetic energy of a wavelength which is substantially absorbed by said combination of fluid particles and to direct a concentration of said electromagnetic energy into said volume to be substantially
25 absorbed by at least a portion of said combination of fluid particles wherein disruptive forces are imparted to a target.

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According to another aspect of the present invention, there is provided a non therapeutic method comprising the following steps: supplying fluid to a first vicinity in relation to a target; and supplying
5 electromagnetic energy to a second vicinity in relation to the target; the first vicinity and the second vicinity intersecting in a volume relative to the target; said step of supplying fluid comprising using a plurality of fluid outputs to generate a combination of fluid particles and
10 placing said combination of fluid particles into said volume relative to the target; said step of supplying electromagnetic energy comprising directing a concentration of electromagnetic energy, which has a wavelength that is substantially absorbed by said fluid, into said volume so as
15 to be absorbed by at least a portion of said fluid particles wherein particles of the portion of fluid particles expand, and wherein disruptive forces are imparted to said target.

According to another aspect of the present invention, a medical handpiece includes a housing having a
20 proximal end and a radiation delivery end. A first fiber guide for conducting laser radiation from an external source toward the radiation delivery end of the housing is disposed within the housing, and a first ferrule formed of a ceramic or crystalline material (such as sapphire) is secured to an
25 output end of the first fiber guide. A second fiber guide has a receiving end, which is adapted for receiving laser radiation from the output end of the first fiber guide, and a second ferrule secures the second fiber guide to the housing so that the receiving end of the second fiber guide
30 faces the output end of the first fiber guide. The second ferrule is formed of a ceramic or crystalline material (such

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13b

as sapphire). The first ferrule and the second ferrule together form a gas flow path in a direction from the first fiber guide toward the receiving end of the second fiber guide.

5 According to another aspect of the present invention, an electromagnetic energy conducting apparatus includes a housing and an inner electromagnetic energy guide disposed within the housing. The inner electromagnetic energy guide has a proximal end, a distal end, and an axis
10 extending between the proximal end and the distal end. The electromagnetic energy conducting apparatus further includes an outer electromagnetic energy guide, which

surrounds and contacts the inner electromagnetic energy guide. The outer electromagnetic energy guide has an axis that is substantially co-linear with the axis of the inner electromagnetic energy guide. Both the outer
5 electromagnetic energy guide and the inner electromagnetic energy guide may be disposed within a ferrule, or the outer electromagnetic energy guide may be a ferrule. Both electromagnetic energy guides preferably are made of a crystalline material, such as
10 sapphire. The electromagnetic energy conducting apparatus may further include a source electromagnetic energy guide, which has a diameter that is substantially larger than a diameter of the inner electromagnetic energy guide.

15 According to another aspect of the present invention, an optical energy conducting apparatus includes a housing and a crystalline fiber disposed within the housing. The crystalline fiber is adapted for conducting optical energy therethrough. A gas flow
20 path is disposed within the housing, as well. The gas flow path envelops the crystalline fiber and extends from a proximal end of the crystalline fiber to a distal end of the crystalline fiber.

The crystalline fiber may be bent according to
25 another aspect of the present invention. The angle formed by the bend of the crystalline fiber is preferably 90 degrees. The bent crystalline fiber of the present invention is suited for conducting coherent light. The coherent light preferably has a wavelength
30 on an order of approximately 3 microns.

According to another aspect of the present invention, a medical handpiece includes a housing and a source of electromagnetic energy disposed within the housing and adapted for emitting electromagnetic energy

from a distal end of the housing. An illumination source is disposed within the housing for projecting light from the distal end of the housing onto a target surface. The illumination source may include a
5 fiberoptic bundle. A medication line may also be disposed within the housing for outputting medication through a distal end of the housing onto a target surface.

According to another aspect of the present
10 invention, a medical handpiece delivery system includes a housing, a fiber guide, and a ferrule disposed around a distal end of the fiber guide. A proximal end and an intermediate portion of the fiber guide are surrounded by an inner protective tube. An outer protective tube
15 is disposed around the inner protective tube. The outer protective tube is slidably disposed over the inner protective tube. The fiber guide may also include a tubular jacket, which is disposed on an outer surface of the fiber guide and within the inner protective tube.
20 Other protective tubes may be disposed around the outer protective tube.

The ferrule includes a proximal end and a distal end, the inner protective tube includes a proximal end and a distal end, and the outer protective tube includes
25 a proximal end and a distal end. The proximal end of the inner protective tube and the proximal end of the outer protective tube are disposed near an SMA connector, which surrounds a proximal end of the fiber guide. The SMA connector has a proximal end and a
30 distal end, and the fiber guide spans a distance between the proximal end of the ferrule and the distal end of the SMA connector. The lengths of the inner protective tube and the outer protective tube between the proximal end of the ferrule and the distal end of the SMA

connector, however, are less than the length of the fiber guide between these two items. Both the inner protective tube and the outer protective tube preferably include a flexible plastic material. These two tubes
5 may be surrounded by a metal tube near the SMA connector and, additionally, the metal tube may be surrounded by another plastic tube near the SMA connector.

According to another aspect of the present invention, a medical handpiece includes a sleeve housing and a shaft assembly adapted for being removably
10 disposed within the sleeve housing. The sleeve housing is preferably autoclavable, is adapted to be held by a hand of a user, and includes a proximal sleeve housing end, an intermediate sleeve housing portion, a radiation
15 delivery end, and an elongate aperture extending within the sleeve housing from the proximal sleeve housing end to the intermediate sleeve housing portion. The sleeve housing includes a delivery fiber guide, which extends
20 between the intermediate sleeve housing portion and the radiation delivery end. The shaft assembly fits within the elongate aperture, and includes a source fiber guide, which is adapted for supplying electromagnetic energy to the intermediate sleeve housing portion. A
25 collar fits around the proximal sleeve housing end when the shaft assembly is disposed with the sleeve housing. The collar applies a radially inwardly directed pressure onto the proximal sleeve housing end, to thereby
frictionally hold the shaft assembly within the elongate aperture of the sleeve housing. The distal end of the
30 source fiber guide is surrounded by a first ferrule, the proximal end of the delivery fiber guide is surrounded by a second ferrule, and a third ferrule surrounds a portion of the delivery fiber guide near the radiation delivery end of the sleeve housing. The shaft assembly

includes an air supply line, which is disposed around the source fiber guide, and the sleeve housing includes an air line, a water line, an illumination line, and a medication line.

5 The fluid conditioning system of the present invention is adaptable to most existing medical and dental cutting, irrigating, evacuating, cleaning, and drilling apparatuses. Flavored fluid is used in place of regular tap water during drilling operations. In the
10 case of a laser surgical operation, electromagnetic energy is focused in a direction of the tissue to be cut, and a fluid router routes flavored fluid in the same direction. The flavored fluid may appeal to the taste buds of the patient undergoing the surgical
15 procedure, and may include any of a variety of flavors, such as a fruit flavor or a mint flavor. In the case of a mist or air spray, scented air may be used to mask the smell of burnt or drilled tissue. The scent may function as an air freshener, even for operations
20 outside of dental applications.

 The fluids used for cooling a surgical site and/or removing tissue may further include an ionized solution, such as a biocompatible saline solution, and may further include fluids having predetermined densities, specific
25 gravities, pH levels, viscosities, or temperatures, relative to conventional tap water. Additionally, the fluids may include a medication, such as an antibiotic, a steroid, an anesthetic, an anti-inflammatory, an antiseptic or disinfectant, adrenaline, epinephrine, or
30 an astringent. The fluid may also include vitamins, herbs, or minerals.

 Introduction of any of the above-mentioned conditioning agents to the conventional water of a cutting or drilling operation may be controlled by a

user input. Thus, for example, a user may adjust a knob or apply pressure to a foot pedal in order to introduce iodine into the water after a cutting operation has been performed. The amount of conditioning applied to the
5 air, water, or mist may be a function of the position of the foot pedal, for example.

According to one broad aspect of the present invention, a mist of atomized particles is placed into a volume of air above the tissue to be cut, and a source
10 of electromagnetic energy, such as a laser, is focused into the volume of air. The electromagnetic energy has a wavelength, which is substantially absorbed by the atomized particles in the volume air. This absorption of the electromagnetic energy by the atomized particles
15 causes the atomized particles to explode and impart mechanical cutting forces onto the tissue. According to this feature, the electromagnetic energy source does not directly cut the tissue but; rather, the exploded fluid particles are used to cut the tissue. These fluid
20 particles may be conditioned with flavors, scents, ionization, medications, disinfectants, and other agents, as previously mentioned.

Since the electromagnetic energy is focused directly on the atomized, conditioned fluid particles,
25 the cutting forces are changed, depending upon the conditioning of the atomized fluid particles. The mechanical cutting efficiency is proportional (related) to the absorption of the electromagnetic energy by the fluid spray. The absorption characteristic can be
30 modified by changing the fluid composition. For example, introduction of a salt into the water before atomization, resulting in an ionized solution, will exhibit slower cutting properties than does regular water. This slower cutting may be desirable, or the

laser power may be increased to compensate for the ionized, atomized fluid particles. Additionally, the atomized fluid particles may be pigmented to either enhance or retard absorption of the electromagnetic energy, to thereby additionally control the cutting power of the system. Two sources of fluid may be used, with one of the sources having a pigment and the other not having a pigment.

Another feature of the present invention places a disinfectant in the air, mist, or water used for dental applications. This disinfectant can be periodically routed through the air, mist, or water lines to disinfect the interior surfaces of these lines. This routing of disinfectant can be performed between patients, daily, or at any other predetermined intervals. A mouthwash may be used, for example, at the end of each procedure to both clean the patient's mouth and clean the air and water tubes.

According to another feature of the present invention, when disinfectant is routed through the lines during a medical procedure, the disinfectant stays with the water or mist, as the water or mist becomes airborne and settles on surrounding surfaces within the dental operating room. Bacteria growth within the lines, and from the condensation, is significantly attenuated, since the disinfectant retards bacteria growth on the moist surfaces.

The invention, together with additional features and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying illustrative drawings.

Brief Description of the Drawings

Figure 1a illustrates a conventional dental/medical work station;

5 Figure 1b is a conventional optical cutter apparatus;

Figure 2 is an optical cutter with the focusing optic of the present invention;

10 Figure 3 is a schematic block diagram illustrating the electromagnetically induced mechanical cutter of the present invention;

Figure 4 illustrates one embodiment of the electromagnetically induced mechanical cutter of the present invention;

15 Figure 5 illustrates the present preferred embodiment of the electromagnetically induced mechanical cutter of the present invention;

Figure 6 illustrates a control panel for programming the combination of atomized fluid particles according to the presently preferred embodiment;

20 Figure 7 is a plot of particle size versus fluid pressure;

Figure 8 is a plot of particle velocity versus fluid pressure;

25 Figure 9 is a schematic diagram illustrating a fluid particle, a source of electromagnetic energy, and a target surface according to the present invention;

Figure 10 is a schematic diagram illustrating the "grenade" effect of the present invention;

30 Figure 11 is a schematic diagram illustrating the "explosive ejection" effect of the present invention;

Figure 12 is a schematic diagram illustrating the "explosive propulsion" effect of the present invention;

Figure 13 is a schematic diagram illustrating a combination of Figures 10-12;

Figure 14 is a schematic diagram illustrating the "cleanness" of cut obtained by the present invention;

Figure 15 is a schematic diagram illustrating the roughness of cut obtained by prior art systems;

5 Figure 16 is a cross-sectional view of the laser delivery system of a presently preferred embodiment;

Figures 17 and 17b illustrate a partially disassembled state of the laser delivery system of a presently preferred embodiment;

10 Figure 18 illustrates a bent crystalline fiber according to the present invention;

Figure 19 illustrates a portion of the laser delivery system adapted for being connected to a laser source, according to a presently preferred embodiment;

15 Figure 20 illustrates a dental/medical work station according to the present invention;

Figure 21 is a schematic block diagram illustrating an electromagnetic cutter using conditioned fluid, according to one embodiment of the present invention;

20 Figure 22a illustrates a mechanical drilling apparatus according to the present invention;

Figure 22b illustrates a syringe according to the present invention;

25 Figure 23 illustrates the fluid conditioning system of the present invention;

Figure 24 illustrates one embodiment of the fluid conditioning unit of the present invention; and

Figure 25 illustrates the air conditioning unit of the present invention.

30 Description of the Presently Preferred Embodiments

Figure 2 shows an optical cutter according to the present invention. The optical cutter 13 comprises many of the conventional elements shown in Figure 1b. A

focusing optic 35 is placed between the two metal cylindrical objects 19 and 21. The focusing optic 35 prevents undesired dissipation of laser energy from the fiber guide tube 5. Specifically, energy from the fiber guide tube 5 dissipates slightly before being focused by the focusing optic 35. The focusing optic 35 focuses energy from the fiber guide tube 5 into the fiber guide tube 23. The efficient transfer of laser energy from the fiber guide tube 5 to the fiber guide tube 23 vitiates any need for the conventional air knife cooling system 11 (Figure 1b), since little laser energy is dissipated. The first fiber guide tube 5 comprises a trunk fiberoptic, which comprises one of calcium fluoride (CaF), calcium oxide (CaO₂), zirconium oxide (ZrO₂), zirconium fluoride (ZrF), sapphire, hollow waveguide, liquid core, TeX glass, quartz silica, germanium sulfide, arsenic sulfide, and germanium oxide (GeO₂).

Figure 3 is a block diagram illustrating the electromagnetically induced mechanical cutter of the present invention. An electromagnetic energy source 51 is coupled to both a controller 53 and a delivery system 55. The delivery system 55 imparts mechanical forces onto the target surface 57. As presently embodied, the delivery system 55 comprises a fiberoptic guide for routing the laser 51 into an interaction zone 59, located above the target surface 57. The delivery system 55 further comprises an atomizer for delivering user-specified combinations of atomized fluid particles into the interaction zone 59. The controller 53 controls various operating parameters of the laser 51, and further controls specific characteristics of the user-specified combination of atomized fluid particles output from the delivery system 55.

Figure 4 shows a simple embodiment of the electromagnetically induced mechanical cutter of the present invention, in which a fiberoptic guide 61, an air tube 63, and a water tube 65 are placed within a hand-held housing 67. The water tube 65 is preferably operated under a relatively low pressure, and the air tube 63 is preferably operated under a relatively high pressure. The laser energy from the fiberoptic guide 61 focuses onto a combination of air and water, from the air tube 63 and the water tube 65, at the interaction zone 59. Atomized fluid particles in the air and water mixture absorb energy from the laser energy of the fiberoptic tube 61, and explode. The explosive forces from these atomized fluid particles impart mechanical cutting forces onto the target 57.

Turning back to Figure 1b, the prior art optical cutter focuses laser energy on a target surface at an area A, for example, and the electromagnetically induced mechanical cutter of the present invention focuses laser energy into an interaction zone B, for example. The prior art optical cutter uses the laser energy directly to cut tissue, and the electromagnetically induced mechanical cutter of the present invention uses the laser energy to expand atomized fluid particles to thus impart mechanical cutting forces onto the target surface. The prior art optic cutter must use a large amount of laser energy to cut the area of interest, and also must use a large amount of water to both cool this area of interest and remove cut tissue.

In contrast, the electromagnetically induced mechanical cutter of the present invention uses a relatively small amount of water and, further, uses only a small amount of laser energy to expand atomized fluid particles generated from the water. According to the

electromagnetically induced mechanical cutter of the present invention, water is not needed to cool the area of surgery, since the exploded atomized fluid particles are cooled by exothermic reactions before they contact the target surface. Thus, atomized fluid particles of the present invention are heated, expanded, and cooled before contacting the target surface. The electromagnetically induced mechanical cutter of the present invention is thus capable of cutting without charring or discoloration.

Figure 5 illustrates the presently preferred embodiment of the electromagnetically induced mechanical cutter. The atomizer for generating atomized fluid particles comprises a nozzle 71, which may be interchanged with other nozzles (not shown) for obtaining various spatial distributions of the atomized fluid particles, according to the type of cut desired. A second nozzle 72, shown in phantom lines, may also be used. The cutting power of the electromagnetically induced mechanical cutter is further controlled by the user control 75. In a simple embodiment, the user control 75 controls the air and water pressure entering into the nozzle 71. The nozzle 71 is thus capable of generating many different user-specified combinations of atomized fluid particles and aerosolized sprays.

Intense energy is emitted from the fiberoptic guide 23. This intense energy is preferably generated from a coherent source, such as a laser. In the presently preferred embodiment, the laser comprises an erbium, chromium, yttrium, scandium, gallium garnet (Er, Cr:YSGG) solid state laser, which generates light having a wavelength in a range of 2.70 to 2.80 microns. As presently preferred, this laser has a wavelength of approximately 2.78 microns. Although the fluid emitted

from the nozzle 71 preferably comprises water, other fluids may be used and appropriate wavelengths of the electromagnetic energy source may be selected to allow for high absorption by the fluid.

5 When fluids besides mere water are used, the absorption of the light energy changes and cutting efficiency is thus affected. Alternataively, when using certain fluids containing pigments or dyes, laser systems of different wavelengths such as Neodymium
10 yttrium aluminum garnet-Nd:YAG wavelengths may be selected to allow for high absorption by the fluid.

Other possible laser systems include an erbium, yttrium, scandium, gallium garnet (Er:YSGG) solid state laser, which generates electromagnetic energy having a
15 wavelength in a range of 2.70 to 2.80 microns; an erbium, yttrium, aluminum garnet (Er:YAG) solid state laser, which generates electromagnetic energy having a wavelength of 2.94 microns; chromium, thulium, erbium, yttrium, aluminum garnet (CTE:YAG) solid state laser,
20 which generates electromagnetic energy having a wavelength of 2.69 microns; erbium, yttrium orthoaluminate (Er:YALO3) solid state laser, which generates electromagnetic energy having a wavelength in a range of 2.71 to 2.86 microns; holmium, yttrium,
25 aluminum garnet (Ho:YAG) solid state laser, which generates electromagnetic energy having a wavelength of 2.10 microns; quadrupled neodymium, yttrium, aluminum garnet (quadrupled Nd:YAG) solid state laser, which generates electromagnetic energy having a wavelength of
30 266 nanometers; argon fluoride (ArF) excimer laser, which generates electromagnetic energy having a wavelength of 193 nanometers; xenon chloride (XeCl) excimer laser, which generates electromagnetic energy having a wavelength of 308 nanometers; krypton fluoride

(KrF) excimer laser, which generates electromagnetic energy having a wavelength of 248 nanometers; and carbon dioxide (CO₂), which generates electromagnetic energy having a wavelength in a range of 9.0 to 10.6 microns. Water is chosen as the preferred fluid because of its biocompatibility, abundance, and low cost. The actual fluid used may vary as long as it is properly matched (meaning it is highly absorbed) to the selected electromagnetic energy source (i.e. laser) wavelength.

The delivery system of the presently preferred embodiment for delivering the electromagnetic energy includes a fiberoptic energy guide or equivalent which attaches to the laser system and travels to the desired work site. Fiberoptics or waveguides are typically long, thin and lightweight, and are easily manipulated. Fiberoptics can be made of calcium fluoride (CaF₂), calcium oxide (CaO), zirconium oxide (ZrO₂), zirconium fluoride (ZrF₄), sapphire, hollow waveguide, liquid core, TeX glass, quartz silica, germanium sulfide, arsenic sulfide, germanium oxide (GeO₂), and other materials. Other delivery systems can include devices comprising mirrors, lenses and other optical components where the energy travels through a cavity, is directed by various mirrors, and is focused onto the targeted cutting site with specific lenses. As will be discussed later with reference to Figures 16-19, the presently preferred embodiment of light delivery for medical applications of the present invention is through a fiberoptic conductor, because of its light weight, lower cost, and ability to be packaged inside of a handpiece of familiar size and weight to the surgeon, dentist, or clinician. In industrial applications, for example, non-fiberoptic systems may be more particularly suited for delivering electromagnetic energy to the targeted cutting site. The various above-mentioned delivery systems may be

interchanged according to preference and desired results.

The nozzle 71 is employed to create an engineered combination of small particles of the chosen fluid. The nozzle 71 may comprise several different designs including liquid only, air blast, air assist, swirl, solid cone, etc. When fluid exits the nozzle 71 at a given pressure and rate, it is transformed into particles of user-controllable sizes, velocities, and spatial distributions.

Figure 6 illustrates a control panel 77 for allowing user-programmability of the atomized fluid particles. By changing the pressure and flow rates of the fluid, for example, the user can control the atomized fluid particle characteristics. These characteristics determine absorption efficiency of the laser energy, and the subsequent cutting effectiveness of the electromagnetically induced mechanical cutter. This control panel may comprise, for example, a fluid particle size control 78, a fluid particle velocity control 79, a cone angle control 80, an average power control 81, a repetition rate 82, and a fiber selector 83.

The cone angle may be controlled, for example, by changing the physical structure of the nozzle 71. For example, various nozzles 71 may be interchangeably placed on the electromagnetically induced mechanical cutter. Alternatively, the physical structure of a single nozzle 71 may be changed.

Figure 7 illustrates a plot 85 of mean fluid particle size versus pressure. According to this figure, when the pressure through the nozzle 71 is increased, the mean fluid particle size of the atomized fluid particles decreases. The plot 87 of Figure 8 shows that the mean fluid particle velocity of these atomized fluid particles increases with increasing pressure.

According to the present invention, materials are removed from a target surface by mechanical cutting forces, instead of by conventional thermal cutting forces. Laser energy is used only to induce mechanical forces onto the targeted material. Thus, the atomized fluid particles act as the medium for transforming the electromagnetic energy of the laser into the mechanical energy required to achieve the mechanical cutting effect of the present invention. The laser energy itself is not directly absorbed by the targeted material. The mechanical interaction of the present invention is safer, faster, and eliminates the negative thermal side-effects typically associated with conventional laser cutting systems.

The fiberoptic guide 23 (Figure 5) can be placed into close proximity of the target surface. This fiberoptic guide 23, however, does not actually contact the target surface. Since the atomized fluid particles from the nozzle 71 are placed into the interaction zone 59, the purpose of the fiberoptic guide 23 is for placing laser energy into this interaction zone, as well. A novel feature of the present invention is the formation of the fiberoptic guide 23 of sapphire. Regardless of the composition of the fiberoptic guide 23, however, another novel feature of the present invention is the cleaning effect of the air and water, from the nozzle 71, on the fiberoptic guide 23.

Applicants have found that this cleaning effect is optimal when the nozzle 71 is pointed somewhat directly at the target surface. For example, debris from the mechanical cutting are removed by the spray from the nozzle 71.

Additionally, applicants have found that this orientation of the nozzle 71, pointed toward the target

surface, enhances the cutting efficiency of the present invention. Each atomized fluid particle contains a small amount of initial kinetic energy in the direction of the target surface. When electromagnetic energy from the fiberoptic guide 23 contacts an atomized fluid particle, the spherical exterior surface of the fluid particle acts as a focusing lens to focus the energy into the water particle's interior.

As shown in Figure 9, the water particle 201 has an illuminated side 103, a shaded side 105, and a particle velocity 107. The focused electromagnetic energy is absorbed by the water particle 201, causing the interior of the water particle to heat and explode rapidly. This exothermic explosion cools the remaining portions of the exploded water particle 201. The surrounding atomized fluid particles further enhance cooling of the portions of the exploded water particle 201. A pressure-wave is generated from this explosion. This pressure-wave, and the portions of the exploded water particle 201 of increased kinetic energy, are directed toward the target surface 107. The incident portions from the original exploded water particle 201, which are now traveling at high velocities with high kinetic energies, and the pressure-wave, impart strong, concentrated, mechanical forces onto the target surface 107.

These mechanical forces cause the target surface 107 to break apart from the material surface through a "chipping away" action. The target surface 107 does not undergo vaporization, disintegration, or charring. The chipping away process can be repeated by the present invention until the desired amount of material has been removed from the target surface 107. Unlike prior art systems, the present invention does not require a thin layer of fluid. In fact, it is preferred that a thin

layer of fluid does not cover the target surface, since this insulation layer would interfere with the above-described interaction process.

5 Figures 10, 11 and 12 illustrate various types of absorptions of the electromagnetic energy by atomized fluid particles. The nozzle 71 is preferably configured to produce atomized sprays with a range of fluid particle sizes narrowly distributed about a mean value. The user input device for controlling cutting efficiency 10 may comprise a simple pressure and flow rate gauge 75 (Figure 5) or may comprise a control panel as shown in Figure 6, for example. Upon a user input for a high resolution cut, relatively small fluid particles are generated by the nozzle 71. Relatively large fluid 15 particles are generated for a user input specifying a low resolution cut. A user input specifying a deep penetration cut causes the nozzle 71 to generate a relatively low density distribution of fluid particles, and a user input specifying a shallow penetration cut 20 causes the nozzle 71 to generate a relatively high density distribution of fluid particles. If the user input device comprises the simple pressure and flow rate gauge 75 of Figure 5, then a relatively low density distribution of relatively small fluid particles can be 25 generated in response to a user input specifying a high cutting efficiency. Similarly, a relatively high density distribution of relatively large fluid particles can be generated in response to a user input specifying a low cutting efficiency. Other variations are also 30 possible.

These various parameters can be adjusted according to the type of cut and the type of tissue. Hard tissues include tooth enamel, tooth dentin, tooth cementum, bone, and cartilage. Soft tissues, which the

electromagnetically induced mechanical cutter of the present invention is also adapted to cut, include skin, mucosa, gingiva, muscle, heart, liver, kidney, brain, eye, and vessels. Other materials may include glass or crystalline materials and semiconductor chip surfaces, for example. In the case of bone tissues, for example, a portion of cancer affected bone may be removed by the electromagnetically induced mechanical cutter of the present invention. The
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electromagnetically induced mechanical cutter of the present invention provides a clean, high-precision cut with minimized cross-contamination, and thus allows for a precise removal of the cancer affected bone. After the bone is cut, it tends to grow back with an increased success rate and with a reduction in the likelihood of cross-contamination.

In the case of glass or crystalline materials, for example, the surface of the glass or crystalline material may be conventionally prepared using acid before silver or other dielectric materials are adhered to the glass or crystalline material surface to make a mirror. The conventional use of acid can undesirably slightly degrade the surface of the glass or crystalline material by unevenly reacting with the surface and by changing the structure on the surface. The
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electromagnetically induced mechanical cutter of the present invention, however, can be used to remove a thin layer from the surface in a uniform manner, to thereby clean and degrease the surface in preparation for adhesion of the silver or other dielectric material. Use of the electromagnetically induced mechanical cutter of the present invention on the surface further does not change the microscopical structure of the glass or crystalline material.

In the case of semi-conductor chips, these chips are formed from silicon wafers. A silicon crystal is first grown, before the silicon crystal is sliced into silicon wafers. Many different fabrication procedures are available. According to a series of substeps used in one exemplary procedure, each silicon wafer is coated with a layer of silicon dioxide using conventional means. The goal is to selectively deposit dopants into the silicon wafer, to thereby form conductive paths or circuits in the silicon wafer. In order to accomplish this goal, portions of the silicon dioxide layer are selectively removed in places where the dopant is to be deposited. The dopant is then deposited over the entire wafer, but only the portions of the wafer not covered by the silicon dioxide layer receive the dopant. The areas covered by the silicon dioxide layer are not penetrated by the dopant, since the dopant over these areas is absorbed by the layer of silicon dioxide.

A fairly involved procedure is used to accomplish the selective removal of the portions of the layer of silicon dioxide, before the introduction of dopants into the silicon wafer. The first step required for the conventional selective removal of portions of the silicon dioxide layer involves application of a coat of light-sensitive polymer material commonly referred to as a resist. A few drops of the resist are conventionally applied to the wafer as the wafer is spun rapidly, in order to apply an even coat of the resist and in order to effectuate drying thereof. Next, a partially transparent photographic negative or photomask is placed over the wafer and aligned using a microscope, for example. The photomask is transparent only in areas where silicon dioxide is to be removed, for positive resist, and the opposite stands true for negative

resist. The photomask is then exposed to ultraviolet or near ultraviolet light. The transparent portions of the photomask pass the light onto corresponding portions of the resist. The regions of the resist that receive the light are structurally changed, and the regions of the resist that do not receive the light (those regions beneath the photomask) are not affected. For a negative resist, the molecules of the resist which are illuminated become cross linked (polymerized). For a positive resist, the molecular bonds of the resist that are illuminated are broken. The unpolymerized areas of the resist can then be dissolved, using a solvent such as trichloroethylene. The polymerized areas of the resist are acid-resistant and thus are not affected by the solvent, so that the photomask is replicated by the remaining protective coating of oxide.

The remaining resist, however, must then be removed with a chemical and water compound. Preferably, the chemical and water compound will completely remove the resist, and will be completely washed away without any remnants remaining on the silicon wafer. After the resist and the chemical and water compound are removed, the dopants are implanted into the silicon wafer using ion implantation, for example. Subsequently, a portion of the silicon wafer, which was originally covered with the resist and the chemical and water compound, will have a conductor adhered thereto. A light acid etch may be applied to these areas before the adhesion of a conductor thereto, to thereby slightly roughen the silicon wafer surface and improve adhesion.

In one application of the present invention, the electromagnetically induced mechanical cutter may be used to directly selectively etch the layer of silicon dioxide. In such an application, the

electromagnetically induced mechanical cutter is focussed directly onto the silicon dioxide layer to thereby remove portions thereof. Resist, photomasks, ultraviolet light, solvents, chemical and water
5 compounds, and acids are not needed in this application, since the portions of the silicon dioxide layer are removed directly with the electromagnetically induced mechanical cutter. The control panel 77 of Figure 6 may be used to control the cutting resolution and the
10 cutting depth of the electromagnetically induced mechanical cutter. Precision equipment for implementing cutting patterns corresponding to images of the photomask, for example, are preferably used to control the removal of portion of the silicon dioxide layer by
15 the electromagnetically induced mechanical cutter.

In another application of the present invention, the electromagnetically induced mechanical cutter may be used in place of the chemical and water compound, to remove the layer of resist. In this application, the
20 chemical and water compound is not needed, resulting in a savings in water, for example. Also, a very good contaminant-free surface for adhesion ion implantation is formed, since the chemical and water compound is not used. This contaminant-free surface is suitable for any
25 subsequent adhesion of a conductor to a dopant-implanted portion of the silicon wafer. The electromagnetically induced mechanical cutter may be used with atomized fluid particles comprising distilled water, which is relatively free of contaminants, for example. A very
30 shallow cut or ablation is preferably generated to remove only the layer of remaining resist. The use of precision equipment, in combination with the control panel 77 of Figure 6, is preferred for implementing shallow surface layer removal patterns on the silicon

wafer corresponding to regions of resist that need to be removed. The ablating may be done using a focussed cutting beam of the electromagnetically induced mechanical cutter, or the cutting beam of the
5 electromagnetically induced mechanical cutter may be dispersed in order to cover a larger portion of the chip. For example, a focussed cutting beam may be rapidly scanned across portions of resist; or a larger defocussed cutting beam, or a number of beams, may be
10 scanned or applied without scanning onto the portions of resist.

A wide variety of other semiconductor chip fabrication procedures are available, including CMOS, bipolar, C4 and other multi-chip module or flip-chip
15 technologies, which may be used to fabricate various active and passive components, including resistors, transistors, and capacitors. Additionally, fabrication of other non-component elements, such as vias, may be used with the electromagnetically induced mechanical
20 cutter of the present invention. The electromagnetically induced mechanical cutter may be used to cut or remove any of a variety of materials in any of these or other similar procedures.

A user may adjust the combination of atomized fluid particles exiting the nozzle 71 to efficiently implement
25 cooling and cleaning of the fiberoptics 23 (Figure 5). According to the presently preferred embodiment, the combination of atomized fluid particles may comprise a distribution, velocity, and mean diameter to effectively
30 cool the fiberoptic guide 23, while simultaneously keeping the fiberoptic guide 23 clean of particular debris which may be introduced thereon by the surgical site.

Looking again at Figure 9, electromagnetic energy contacts each atomized fluid particle 101 on its illuminated side 103 and penetrates the atomized fluid particle to a certain depth. The focused
5 electromagnetic energy is absorbed by the fluid, inducing explosive vaporization of the atomized fluid particle 101.

The diameters of the atomized fluid particles can be less than, almost equal to, or greater than the
10 wavelength of the incident electromagnetic energy. In each of these three cases, a different interaction occurs between the electromagnetic energy and the atomized fluid particle. Figure 10 illustrates a case where the atomized fluid particle diameter is less than
15 the wavelength of the electromagnetic energy ($d < \lambda$). This case causes the complete volume of fluid inside of the fluid particle 101 to absorb the laser energy, inducing explosive vaporization. The fluid particle 101 explodes, ejecting its contents radially. Applicants
20 refer to this phenomena as the "explosive grenade" effect. As a result of this interaction, radial pressure-waves from the explosion are created and projected in the direction of propagation. The direction of propagation is toward the target surface
25 107, and in the presently preferred embodiment, both the laser energy and the atomized fluid particles are traveling substantially in the direction of propagation.

The resulting portions from the explosion of the water particle 101, and the pressure-wave, produce the
30 "chipping away" effect of cutting and removing of materials from the target surface 107. Thus, according to the "explosive grenade" effect shown in Figure 10, the small diameter of the fluid particle 101 allows the laser energy to penetrate and to be absorbed violently

within the entire volume of the liquid. Explosion of the fluid particle 101 can be analogized to an exploding grenade, which radially ejects energy and shrapnel. The water content of the fluid particle 101 is evaporated due to the strong absorption within a small volume of liquid, and the pressure-waves created during this process produce the material cutting process.

Figure 11 shows a case where the fluid particle 101 has a diameter, which is approximately equal to the wavelength of the electromagnetic energy ($d \approx \lambda$). According to this "explosive ejection" effect, the laser energy travels through the fluid particle 101 before becoming absorbed by the fluid therein. Once absorbed, the fluid particle's shaded side heats up, and explosive vaporization occurs. In this case, internal particle fluid is violently ejected through the fluid particle's shaded side, and moves rapidly with the explosive pressure-wave toward the target surface. As shown in Figure 11, the laser energy is able to penetrate the fluid particle 101 and to be absorbed within a depth close to the size of the particle's diameter. The center of explosive vaporization in the case shown in Figure 11 is closer to the shaded side 105 of the moving fluid particle 101. According to this "explosive ejection" effect shown in Figure 11, the vaporized fluid is violently ejected through the particle's shaded side toward the target surface 107.

A third case shown in Figure 12 is the "explosive propulsion" effect. In this case, the diameter of the fluid particle is larger than the wavelength of the electromagnetic energy ($d > \lambda$). In this case, the laser energy penetrates the fluid particle 101 only a small distance through the illuminated surface 103 and causes this illuminated surface 103 to vaporize. The

vaporization of the illuminated surface 103 tends to propel the remaining portion of the fluid particle 101 toward the targeted material surface 107. Thus, a portion of the mass of the initial fluid particle 101 is converted into kinetic energy, to thereby propel the remaining portion of the fluid particle 101 toward the target surface with a high kinetic energy. This high kinetic energy is additive to the initial kinetic energy of the fluid particle 101. The effects shown in Figure 12 can be visualized as a micro-hydro rocket with a jet tail, which helps propel the particle with high velocity toward the target surface 107. The exploding vapor on the illuminated side 103 thus supplements the particle's initial forward velocity.

The combination of Figures 10-12 is shown in Figure 13. The nozzle 71 produces the combination of atomized fluid particles which are transported into the interaction zone 59. The laser 51 is focused on this interaction zone 59. Relatively small fluid particles 131 explode via the "grenade" effect, and relatively large fluid particles 133 explode via the "explosive propulsion" effect. Medium sized fluid particles, having diameters approximately equal to the wavelength of the laser 51 and shown by the reference number 135, explode via the "explosive ejection" effect. The resulting pressure-waves 137 and exploded fluid particles 139 impinge upon the target surface 107.

Figure 14 illustrates the clean, high resolution cut produced by the electromagnetically induced mechanical cutter of the present invention. Unlike the cut of the prior art shown in Figure 15, the cut of the present invention is clean and precise. Among other advantages, this cut provides an ideal bonding surface,

is accurate, and does not stress remaining materials surrounding the cut.

Turning to Figure 16, the presently preferred embodiment of light delivery for medical applications comprises a fiberoptic conductor or trunk fiber 201, housed within a medical handpiece 203. The medical handpiece 203 comprises a sleeve housing 205 having an elongate aperture 207 for accommodating a shaft assembly 209. The shaft assembly 209 accommodates the trunk fiber 201, which is wrapped with one or more jackets 211 in the presently preferred embodiment. The jackets 211 are snugly formed around the trunk fiber 201. In addition to the jackets 211, an inner protective tube 213 and an outer protective tube 215 are disposed around the trunk fiber 201. In contrast to the jacket 201, both the inner protective tube 213 and the outer protective tube 215 are slidably disposed over the trunk fiber 201. According to the present invention, the inner protective tube 213 and the outer protective tube 215 add strength to the trunk fiber 201 and prevent the trunk fiber 201 from being damaged or breaking as a result of bending or other stresses placed on the trunk fiber 201. For example, the permanent ferrule 217, as presently embodied, houses only the trunk fiber 201 and the jackets 211, and comprises a rigid material. Any bending or other stresses placed on the trunk fiber 201 would, conventionally, put the trunk fiber 201 at a high risk of breaking either within the permanent ferrule 217 or at the proximal end 219 of the ferrule 217. The inner protective tube 213 and the outer protective tube 215 distribute bending and other stressful forces on the trunk fiber 201 across a larger surface area of the trunk fiber 201, to thereby attenuate risks of breaking of the trunk fiber 201. As presently embodied, the

inner protection tube 213 is secured (preferably glued) to both the permanent ferrule 217 and the SMA connector 341, but the outer protective tube 215 is secured to only the SMA connector 341 and abuts against the permanent ferrule 217. The inner protection tube 213 is preferably secured to both the permanent ferrule 217 and the SMA connector 341 to prevent rotation of the trunk fiber 201, when the permanent ferrule 217 and the SMA connector 341 are rotated relative to one another. These two protective tubes 213 and 215 are therefore able to slide over both one another and the jacket 211. Although two protective tubes 213 and 215 are presently embodied, a single protective tube may be used, or three or more protective tubes may be used, according to desired operational parameters. The protective tubes preferably comprise a plastic material, but may also comprise metals or Teflon.

The permanent ferrule 217 is secured to the shaft assembly 209 via an outer housing, which defines an air conditioning input chamber 221. The air conditioning input chamber 221 is similar to the air knife line 11 of Figure 1b in that the air conditioning input chamber 221 provides air to the interface 223 for cooling the distal end of the trunk fiber 201, the permanent ferrule 217, the intermediate ferrule 225, and the proximal end of the bent fiber tip 227. The permanent ferrule 217 and the intermediate ferrule 225 are separated by a spacer 226. Air travels through the air conditioning input chamber 221 in the direction of the arrows A1 and A2 and passes through a plurality of drilled apertures, shown generally at 231 and 233, within the permanent ferrule 217. The air from the air conditioning input chamber 221 exits from the drilled apertures 231 and 233 into the interface 223, and passes from the interface 223

into the air cooling exhaust chamber 241. The air travels through the air cooling exhaust chamber 241 in the directions of the arrows A3 and A4 back out of the medical handpiece 203. As presently embodied, the air conditioning input chamber 221 and the air cooling exhaust chamber 241 are both angularly shaped and concentric.

According to the present invention, the permanent ferrule 217, the intermediate ferrule 225, and the spacer 226 comprise a heat resistant material, such as ceramic. This heat resistant material facilitates greater operating temperatures of the permanent ferrule 217, the intermediate ferrule 225, and the spacer 226 and, consequently, requires less air flow through the air conditioning input chamber 221 and the air cooling exhaust chamber 241. The permanent ferrule 217, the intermediate ferrule 225, and the spacer 226 may also comprise a crystalline material, such as sapphire. A fiber-to-fiber coupler 246 surrounds the intermediate ferrule 225, and may comprise any heat resistant material similar to that of the intermediate ferrule 225 or, alternatively, may comprise a metal such as aluminum or stainless steel.

Optical energy is coupled from the distal end of the trunk fiber 201 into the proximal end of the bent fiber tip 227. The bent fiber tip 227 provides a desirable curvature, and, consequently, does not require the fiberoptic to be stressed or strained from bending, for example. According to the present invention, the bent fiber tip 227 is manufactured of a crystalline material, and is pre-formed before installation into a bent configuration having a predetermined angle.

As illustrated in Figure 18, the presently preferred embodiment of the bent fiber tip 227 has a

first length 256 of approximately 30 millimeters, a second length 259 of approximately 20 millimeters, and an angle 261 of approximately 90 degrees. A radial length 263 is preferably 10 millimeters. According to the present invention, the crystalline fiber 227 is bent by hand under a flame of approximately 2000 degrees Fahrenheit. The bent fiber tip 227 fits within a cavity 270 (Figure 16), which has an enlarged cavity area at the bending portion 272 to accommodate bent fiber tips 227 having slight manufacturing deviations. The bent crystalline material must subsequently be tested to insure that the bent crystalline material has ideal optical qualities. Although the presently preferred embodiment of the bent fiber tip 227 comprises an angle of approximately 90 degrees, other bent tips may be manufactured having one or more angles from zero to 180 degrees, and different shapes, according to design preference. Also, although the bent fiber tip 227 of the presently preferred embodiment extends from the intermediate ferrule 225 to a tip ferrule 275, a variety of other configurations are possible. As just one example, a small-diameter, flexible bent crystalline fiber may extend from the laser source (not shown) and standard miniature type-A (SMA) connector 341 (Figure 19) to the tip ferrule 275. As presently embodied, the bent fiber tip 227 comprises sapphire which, according to the present invention, is ideal for carrying wavelengths on the order of approximately 3 microns. In the presently preferred embodiment, the bent fiber tip 227 formed of sapphire conducts wavelengths of 2.78 and 2.94 microns. In addition to sapphire, any other crystalline materials suitable for conducting optical energy may be used, according to design parameters.

The tip ferrule 275 holds the bent fiber tip 227 securely in place near the radiation delivery end of the medical handpiece 203. The tip ferrule 275 may comprise a heat resistant material, such as described above with reference to the permanent ferrule 217 and the intermediate ferrule 225. An air line 277 and a water line 279 disposed within the sleeve housing 205 output air and water into the mixing chamber 281, which is defined by the radiation delivery end of the sleeve housing 205 and the cap 284. The air and water from the air line 277 and the water line 279 form an air assist spray within the mixing chamber 281. The air assist spray exits the mixing chamber 281 in the directions of the arrows A5 and A6 along the output end of the bent fiber tip 227.

According to another feature of the present invention, another crystalline material suitable for conducting optical energy may be disposed around the bent fiber tip 227 near the interface 223. This additional crystalline material may comprise the intermediate ferrule 225 or, alternatively, may be a cylindrical crystalline material disposed around the bent fiber tip 227 near the interface 223 and also surrounded by the intermediate ferrule 225. In some instances, it may be desirable to form the bent fiber tip 227 with a smaller diameter than the diameter of the trunk fiber 201. The trunk fiber 201 may be formed of a relatively large diameter, for example, for added strength. If the bent fiber tip 227 is very small in diameter, such as, for example, 50 microns, then the proximal end of this bent fiber tip 227 near the interface 223 may be damaged from a relatively large amount of energy output from the distal end of the trunk fiber 201. The additional annular crystalline fiber

disposed around the bent fiber tip 227 near the interface 223 helps to protect the bent fiber tip 227 from damage. One or more annular crystalline fibers may be disposed around the proximal end of the bent fiber tip 227, and each of these annular crystalline fibers may extend along the length of the intermediate ferrule 225 or longer. When one or more of these annular crystalline fibers are used, as presently preferred, any of the sealed passages 301, 303, 304, 306, 309, and 311 may be opened to facilitate additional air flow and cooling therethrough. Opening of any of these passage 301-311 further facilitates an air flow path leading along the bent fiber tip 227 and into the mixing chamber 281, according to the present invention.

Figures 17a and 17b illustrate the medical handpiece 203 with the shaft assembly 209 removed from the elongate aperture 207 of the sleeve housing 205, according to the present invention. As presently embodied, a collar 316 (Figure 16) is provided with threads 318. The threads 318 of the collar 316 engage threads 320 of the proximal end of the sleeve housing 205 and allow the collar 316 to exert radially inwardly directed forces onto the sleeve housing 205. These radially inwardly directed forces from the collar 316 onto the sleeve housing 205 frictionally engage the shaft assembly 209 within the elongate aperture 207 and prevent the shaft assembly 209 from movement within the elongate aperture 207 of the sleeve housing 205.

Figure 19 illustrates many of the components which supply resources to the medical handpiece 203 of Figure 16. The water line 326 is adapted for supplying water to the water line 279 of the medical handpiece 203. Similarly, the air line 328 is adapted for supplying air to the air line 277, and the air conditioning line 330

is adapted for supplying air to the air conditioning input chamber 221. An illumination and/or medication cable 332 provides illumination and/or medication to the illumination and/or medication line 334 of the medical handpiece 203. Although the medical handpiece 203 is illustrated for operation with a laser-cutting assembly, such as that shown in Figure 1b, the presently preferred embodiment of the medical handpiece 203 operates in combination with an electromagnetically-induced mechanical cutter having a head similar to that shown in Figure 5. According to the presently preferred embodiment, the air line 277 and the water line 279 preferably correspond to the air tube 63 and the water tube 65 of the head assembly shown in Figure 5. In this presently preferred embodiment, the cap 284 of Figure 16 is not necessarily required. In one embodiment, the air line 277 corresponding to the air tube 63 is not used.

Since the distal end of the bent fiber tip 227 of the presently preferred embodiment is placed into close proximity of the target surface, a source of coherent or non-coherent illumination through the illumination line 334 (Figure 16) can be quite advantageous. On the other hand, when a traditional laser cutting mechanism is used, the illumination from the illumination line 334 may not be as advantageous and a conventional aiming beam may be routed through the illumination line 334.

The illumination and/or medication line 334 may comprise only a medication, or may comprise both an illumination line and a medication line. The medication line facilitates introduction of medications, such as anesthetics, to the target area of the patient.

Looking at Figure 19, the trunk fiber 201 and the jackets 211 are secured within a sum miniature type A (SMA) connector 341. The SMA connector facilitates

introduction and securing of the trunk fiber 201 and the jacket 211 into a laser source (not shown).

The inner protective tube 213 and the outer protective tube 215 extend from the medical handpiece 203 all of the way to the SMA connector 341 and provide similar protection functions to the trunk fiber 201 at the interface of the SMA connector 341. As mentioned previously, only one protective tube may be used or, alternatively, three or more protective tubes may be used. In the presently preferred embodiment, a metal tube 352 surrounds the inner protective tube 213 and the outer protective tube 215, and an additional outer plastic tube covering 355 surrounds the metal tube 352.

A plastic protective covering 357 encases these elements surrounding the trunk fiber 201. In the presently preferred embodiment, the plastic protective covering 357 is secured to the water line 326, the air line 328, the air conditioning line 330, and the illumination and/or medication cable 332 and routed into close proximity to the medical handpiece 203. The metal tube 352 and the outer tube covering 355 do not extend to the medical handpiece and preferably terminate at a short distance from the SMA connector 341. Of course, other distances may be set according to design parameters. A power cap 372 and a grippable knob 374 further facilitate the attachment of the trunk fiber 201 to the laser source.

The dental/medical work station 1111 of the present invention is shown in Figure 20. The dental/medical work station 1111 comprises a conventional air line 1113 and a conventional water line 1114 for supplying air and water, respectively. A vacuum line 1112 and an electrical outlet 1115 supply negative air pressure and electricity to the dental/medical unit 1116, similarly

to the vacuum 8 and electrical 14 lines shown in Figure 1a. The fluid conditioning unit 1121 may, alternatively, be placed between the dental/medical unit 1116 and the instruments 1117, for example. According to the present invention, the air line 1113 and the water line 1114 are both connected to a fluid conditioning unit 1121.

A controller 1125 allows for user inputs, to control whether air from the air line 1113, water from the water line 1114, or both, are conditioned by the fluid conditioning unit 1121. A variety of agents may be applied to the air or water by the fluid conditioning unit 1121, according to a configuration of the controller 1125, for example, to thereby condition the air or water, before the air or water is output to the dental/medical unit 1116. Flavoring agents and related substances, for example, may be used, such as disclosed in 21 C.F.R. Sections 172.510 and 172.515, the details of which are incorporated herein by reference. Colors, for example, may also be used for conditioning, such as disclosed in 21 C.F.R. Section 73.1 to Section 73.3126.

Similarly to the instruments 18 shown in Figure 1a, the instruments 1117 may comprise an electrocauterizer, an electromagnetic energy source, a laser, a mechanical drill, a mechanical saw, a canal finder, a syringe, and/or an evacuator. All of these instruments 1117 use air from the air line 1113 and/or water from the water line 1114, which may or may not be conditioned depending on the configuration of the controller 1125. Any of the instruments 1117 may alternatively be connected directly to the fluid conditioning unit 1121 or directly to any of the air 1113, water 1114, vacuum 1112, and/or electric 1115 lines. For example, a laser 1118 and delivery system 1119 is shown in phantom connected to

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the fluid conditioning unit 1121. The laser 1118a and delivery system 1119a may be connected to the dental/medical unit 1116, instead of being grouped with the instruments 1117.

5 The block diagram shown in Figure 21 illustrates one embodiment of a laser 1151 directly coupled with, for example, the air 1113, water 1114, and power 1115 lines of Figure 20. A separate fluid conditioning system is used in this embodiment. As an alternative to the laser, or any
10 other tool being connected directly to any or all of the four supply lines 1113-1115 and having an independent fluid conditioning unit, any of these tools may instead, or additionally, be connected to the dental/medical unit 1116 or the fluid conditioning unit 1121, or both.

15 According to the exemplary embodiment shown in Figure 21, an electromagnetically induced mechanical cutter is used for cutting. Details of this cutter are disclosed in U.S. Patent No. 5,741,247, assigned to the assignee of this application. The electromagnetic cutter energy
20 source 1151 is connected directly to the outlet 1115 (Figure 20), and is coupled to both a controller 1153 and a delivery system 1155. The delivery system 1155 routes and focuses the laser 1151. In the case of a conventional laser system, thermal cutting forces are imparted onto the
25 target 1157. The delivery system 1155 preferably comprises a fiberoptic guide for routing the laser 1151 into an interaction zone 1159, located above the target 1157. The fluid router 1160 preferably comprises an atomizer for delivering user-specified combinations of atomized fluid
30 particles into the interaction zone 1159. The atomized fluid particles are conditioned, according to the present invention, and

may comprise flavors, scents, saline, and other agents, as discussed below.

In the case of a conventional laser, a stream or mist of conditioned fluid is supplied by the fluid router 1160. The controller 1153 may control various operating parameters of the laser 1151, the conditioning of the fluid from the fluid router 1160, and the specific characteristics of the fluid from the fluid router 1160.

Although the present invention may be used with conventional drills and lasers, for example, one preferred embodiment is the electromagnetically induced mechanical cutter. Other preferred embodiments include an electrocauterizer, a syringe, an evacuator, or any air or electrical driver, drilling, filling, or cleaning mechanical instrument. Figure 4 shows a simple embodiment of the electromagnetically induced mechanical cutter, in which a fiberoptic guide 61, an air tube 63, and a fluid tube 65 are placed within a hand-held housing 67. Although a variety of connections are possible, the air tube 63 and water tube 65 are preferably connected to either the fluid conditioning unit 1121 or the dental/medical unit 1116 of Figure 20. The fluid tube 65 is preferably operated under a relatively low pressure, and the air tube 63 is preferably operated under a relatively high pressure.

According to the present invention, either the air from the air tube 63 or the fluid from the fluid tube 65, or both, are selectively conditioned by the fluid conditioning unit 1121, as controlled by the controller 1125.

A mechanical drill 1161 is shown in Figure 22a, comprising a handle 1162, a drill bit 1164, and a water output 1166. The mechanical drill 1161 comprises a

motor 1168, which may be electrically driven, or driven by pressurized air.

When the motor 1168 is driven by air, for example, the fluid enters the mechanical drill 1161 through the first supply line 1170. Fluid entering through the first supply line 1170 passes through the motor 1168, which may comprise a turbine, for example, to thereby provide rotational forces to the drill bit 1164. A portion of the fluid, which may not appeal to a patient's taste and/or smell, may exit around the drill bit 1164, coming into contact with the patient's mouth and/or nose. The majority of the fluid exits back through the first supply line 1170.

In the case of an electric motor, for example, the first supply line 1170 provides electric power. The second supply line 1174 supplies fluid to the fluid output 1166. The water and/or air supplied to the mechanical drill 1161 may be selectively conditioned by the fluid conditioning unit 1121, according to the configuration of the controller 1125.

The syringe 1176 shown in Figure 22 comprises an air input line 1178 and a water input line 1180. A user control 1182 is movable between a first position and a second position. The first position supplies air from the air line 1178 to the output tip 1184, and the second position supplies water from the water line 1180 to the output tip 1184. Either the air from the air line 1178, the water from the water line 1180, or both, may be selectively conditioned by the fluid conditioning unit 1121, according to the configuration of the controller 1125, for example.

Turning to Figure 23, a portion of the fluid conditioning unit 1121 (Figure 20) is shown. This fluid conditioning unit 1121 is preferably adaptable to

existing water lines 1114, for providing conditioned fluid to the dental/medical unit 1116 as a substitute for regular tap water in drilling and cutting operations, for example. The interface 1189 connects to an existing water line 1114 and feeds water through the fluid-in line 1181 and the bypass line 1191. The reservoir 1183 accepts water from the fluid-in line 1181 and outputs conditioned fluid to the fluid-out line 1185. The fluid-in line 1181, the reservoir 1183, and the fluid-out line 1185 together comprise a fluid conditioning subunit 1187.

Conditioned fluid is output from the fluid conditioning subunit 1187 into the combination unit 1193. The fluid may be conditioned by conventional means, such as the addition of a tablet, liquid syrup, or a flavor cartridge. Also input into the combination unit 1193 is regular water from the bypass line 1191. A user input 1195 into the controller 1125, for example, determines whether fluid output from the combination unit 1193 into the fluid tube 1165 comprises only conditioned fluid from the fluid-out line 1185, only regular water from the bypass line 1191, or a combination thereof. The user input 1195 comprises a rotatable knob, a pedal, or a foot switch, operable by a user, for determining the proportions of conditioned fluid and regular water. These proportions may be determined according to the pedal or knob position. In the pedal embodiment, for example, a full-down pedal position corresponds to only conditioned fluid from the fluid out-line 1185 being output into the fluid tube 1165, and a full pedal up position corresponds to only water from the bypass line 1191 being output into the fluid tube 1165. The bypass line 1191, the combination unit 1193, and the user input 1195 provide versatility,

but may be omitted, according to preference. A simple embodiment for conditioning fluid would comprises only the fluid conditioning subunit 1187.

5 An alternative embodiment of the fluid conditioning subunit 1187 is shown in Figure 24. The fluid conditioning subunit 1287 inputs air from air line 1113 via an air input line 1281, and outputs conditioned fluid via a fluid output line 1285. The fluid output line 1285 preferably extends vertically down into the reservoir 1283 into the fluid 1291 located therein. The lid 1284 may be removed and conditioned fluid inserted into the reservoir 1283. Alternatively, a solid or liquid form of fluid conditioner may be added to water already in the reservoir 1283. The fluid is preferably conditioned, using either a scent fluid drop or a scent tablet (not shown), and may be supplied with fungible cartridges, for example.

10 The fluid 1291 within the reservoir 1283 may be conditioned to achieve a desired flavor, such as a fruit flavor or a mint flavor, or may be conditioned to achieve a desired scent, such as an air freshening smell. A conditioned fluid having a scent, a scented mist, or a scented source of air, may be particularly advantageous for implementation in connection with an air conditioning unit, as shown in Figure 25 and discussed below. In addition to flavor and scents, other conditioning agents may be selectively added to a conventional water line, mist line, or air line. For example, an ionized solution, such as saline water, or a pigmented solution may be added, as discussed below. Additionally, agents may be added to change the density, specific gravity, pH, temperature, or viscosity of water and/or air supplied to a drilling or cutting operation. Medications, such as antibiotics, steroids, anesthetics,

anti-inflammatories, disinfectants, adrenaline, epinephrine, or astringents may be added to the water and/or air used in a drilling or cutting operation. For example, an astringent may be applied to a surgical
5 area, via the water line to reduce bleeding. Vitamins, herbs, or minerals may also be used for conditioning the air or water used in a cutting or drilling procedure. An anesthetic or anti-inflammatory applied to a surgical wound may reduce discomfort to the patient or trauma to
10 the wound, and an antibiotic or disinfectant may prevent infection to the wound.

The air conditioning subunit shown in Figure 25 is connectible into an existing air line 1113, via interfaces 1386 and 1389. Conventional air enters the
15 conditioning subunit via the air input line 1381, and exits an air output line 1385. The air input line 1381 preferably extends vertically into the reservoir 1383 into a fluid 1391 within the reservoir 1383. The fluid 1391 is preferably conditioned, using either a scent
20 fluid drop or a scent tablet (not shown). The fluid 1391 may be conditioned with other agents, as discussed above in the context of conditioning water. According to the present invention, water in the water line 1131 or air in the air line 1132 of a conventional laser
25 cutting system (Figure 1b) is conditioned. As presently preferred, either the fluid tube 65 or the air tube 63 (Figure 4) of the electromagnetically induced mechanical cutter is conditioned. In addition to laser operations, the air and/or water of a dental drilling, irrigating,
30 suction, or electrocautery system may also be conditioned.

Many of the above-discussed conditioning agents may change the absorption of the electromagnetic energy into the atomized fluid particles in the electromagnetically

induced mechanical cutting environment of the presently preferred embodiment. Accordingly, the type of conditioning may effect the cutting power of an electromagnetic or an electromagnetically induced mechanical cutter. Thus, in addition to the direct benefits achievable through these various conditioning agents discussed above, such as flavor or medication, these various conditioning agents further provide versatility and programmability to the type of cut resulting from the electromagnetic or electromagnetically induced mechanical cutter. For example, introduction of a saline solution will reduce the speed of cutting. Such a biocompatible saline solution may be used for delicate cutting operations or, alternatively, may be used with a higher laser-power setting to approximate the cutting power achievable with regular water.

Pigmented fluids may also be used with the electromagnetic or the electromagnetically induced mechanical cutter, according to the present invention. The electromagnetic energy source may be set for maximum absorption of atomized fluid particles having a certain pigmentation, for example. These pigmented atomized fluid particles may then be used to achieve the mechanical cutting. A second water or mist source may be used in the cutting operation, but since this second water or mist is not pigmented, the interaction with the electromagnetic energy source is minimized. As just one example of many, this secondary mist or water source could be flavored.

According to another configuration, the atomized fluid particles may be unpigmented, and the electromagnetic or the electromagnetically induced energy source may be set to provide maximum energy

absorption for these unpigmented atomized fluid particles. A secondary pigmented fluid or mist may then be introduced into the surgical area, and this secondary mist or water would not interact significantly with the electromagnetic energy source. As another example, a single source of atomized fluid particles may be switchable between pigmentation and non-pigmentation, and the electromagnetic energy source may be set to be absorbed by one of the two pigment states to thereby provide a dimension of controllability as to exactly when cutting is achieved.

Disinfectant may be added to an air or water source in order to combat bacteria growth within the air and water lines, and on surfaces within a dental operating room. The air and water lines of the dental unit 1116, for example, may be periodically flushed with a disinfectant selected by the controller 1125 and supplied by the fluid conditioning unit 1121. An accessory tube disinfecting unit 1123 may accommodate disinfecting cartridges and perform standardized or preprogrammed periodic flushing operations.

Even in a dental or medical procedure, an appropriate disinfectant may be used. The disinfectant may be applied at the end of a dental procedure as a mouthwash, for example, or may be applied during a medical or dental procedure. The air and water used to cool the tissue being cut or drilled within the patient's mouth, for example, is often vaporized into the air to some degree. According to the present invention, a conditioned disinfectant solution will also be vaporized with air or water, and condensate onto surfaces of the dental equipment within the dental operating room. Any bacteria growth on these moist

surfaces is significantly attenuated, as a result of the disinfectant on the surfaces.

Although an exemplary embodiment of the invention has been shown and described, many changes, modifications and substitutions may be made by one
5 having ordinary skill in the art without necessarily departing from the spirit and scope of this invention.

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CLAIMS:

1. An apparatus comprising:

a plurality of fluid outputs carrying a fluid during use and being constructed to direct the fluid to a first vicinity relative to the plurality of fluid outputs;
5 and

an electromagnetic energy source for supplying electromagnetic energy to a second vicinity;

the first vicinity and the second vicinity being
10 disposed at respective locations relative to the plurality of fluid outputs and intersecting in a volume relative to the plurality of fluid outputs, said plurality of fluid outputs operable to place a combination of fluid particles into said volume; said electromagnetic energy source
15 comprising a specifically configured electromagnetic energy source that is arranged, when said apparatus is in use, to supply electromagnetic energy of a wavelength which is substantially absorbed by said combination of fluid particles and to direct a concentration of said
20 electromagnetic energy into said volume to be substantially absorbed by at least a portion of said combination of fluid particles wherein disruptive forces are imparted to a target.

2. The apparatus of claim 1 wherein:

25 said concentration of said electromagnetic energy directed into said volume comprises a peak concentration of said electromagnetic energy; and

said disruptive forces comprise disruptive mechanical forces.

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3. The apparatus of any one of claims 1 and 2 wherein said combination of fluid particles comprises a combination of fluid particles which are sized and distributed in such a way that when placed into said volume and irradiated with said electromagnetic energy source, said fluid particles expand.

4. The apparatus of any one of claims 1 to 3 wherein said plurality of fluid outputs comprises an atomizer, and said combination of fluid particles comprises a combination of atomized fluid particles having diameters narrowly distributed about a mean value.

5. The apparatus of any one of claims 1 to 3, wherein:

said combination of fluid particles comprise a combination of atomized fluid particles;

the plurality of fluid outputs further comprises an atomizer for generating the combination of atomized fluid particles; and

said combination of atomized fluid particles is sized and distributed in such a way that, when placed into said volume and irradiated with said concentration of said electromagnetic energy, said concentration of said electromagnetic energy is substantially absorbed by at least a portion of said combination of atomized fluid particles.

6. The apparatus according to any one of claims 1 to 5 wherein when said apparatus is positioned in use such that the volume is positioned above the target, the portion of fluid particles expand and impart disruptive mechanical forces to said target.

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7. The apparatus of any one of claims 1 to 6 wherein the electromagnetic energy is highly absorbed by the portion of fluid particles.

8. The apparatus of any one of claims 1 to 7 wherein
5 when said apparatus is positioned in use such that said volume is positioned above a target and said apparatus imparts disruptive cutting and ablating mechanical forces on to the target.

9. The apparatus according to any one of claims 1
10 to 8 wherein the plurality of fluid outputs is fed with an air input line and a water input line.

10. The apparatus according to any one of claims 1 to 9 wherein the energy is delivered through a fiberoptic; and

15 wherein the fluid particles contact the fiberoptic to thereby cool and clean the fiberoptic.

11. The apparatus of claim 10, wherein the fluid particles contact the fiberoptic to thereby remove particulate debris from the fiberoptic.

20 12. The apparatus of any one of claims 10 and 11 wherein the fiberoptic comprises sapphire.

13. An apparatus according to any one of claims 4 and 5 further comprising:

a user control for inputting a user-specified
25 combination of atomized fluid particles, the combination of atomized fluid particles corresponding to a user-specified average size, spatial distribution, and velocity of atomized fluid particles; wherein the atomizer is responsive to the user control.

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14. The apparatus according to claim 13, wherein the absorption of the electromagnetic energy by the portion of fluid particles in said volume causes said portion of fluid particles to impart the disruptive forces to said target.

5 15. The apparatus according to any one of claims 1 to 12, wherein the absorption of the electromagnetic energy by the portion of fluid particles in said volume causes said portion of fluid particles to impart the disruptive forces to said target.

10 16. The apparatus of any one of claims 14 and 15, wherein:

the disruptive forces comprise cutting and ablating mechanical forces; and

15 when said apparatus is positioned in use such that said volume is positioned above the target, said portion of the fluid particles is caused to impart the cutting and ablating mechanical forces onto the target.

17. An apparatus according to any one of claims 13 and 14, wherein said user control comprises a user input device for specifying one of a high resolution cut and a low resolution cut, and for specifying one of a deep-penetration cut and a shallow penetration cut; and

said atomizer is responsive to the user input device to generate:

25 (1) a combination of atomized fluid particles comprising relatively small fluid particles, in response to a user input specifying a high resolution cut;

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(2) a combination of atomized fluid particles comprising relatively large fluid particles, in response to a user input specifying a low resolution cut;

(3) a combination of atomized fluid particles
5 comprising a relatively low-density distribution of fluid particles, in response to a user input specifying a deep-penetration cut; and

(4) a combination of atomized fluid particles which comprises a relatively high-density distribution of
10 fluid particles, in response to a user input specifying a shallow-penetration cut.

18. The apparatus according to claim 17, wherein the user input device comprises a single input for controlling the cutting efficiency.

15 19. The apparatus according to claim 18, wherein the user input device generates a relatively low-density distribution of relatively small fluid particles when the single input specifies a high cutting efficiency and a relatively high-density distribution of relatively large
20 fluid particles when the single input specifies a low cutting efficiency.

20. The apparatus according to claim 19, wherein each of the relatively small fluid particles has a fluid-particle diameter, and

25 wherein a mean fluid-particle diameter of the fluid-particle diameters of the relatively small fluid particles is less than the wavelength of the electromagnetic energy focused into the volume of air adjacent to the target.

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21. The apparatus according to claim 19, wherein each of the relatively large fluid particles has a fluid-particle diameter, and

wherein a mean fluid-particle diameter of the
5 fluid-particle diameters of the relatively large fluid particles is greater than the wavelength of the electromagnetic energy focused into the volume of air adjacent to the target.

22. The apparatus according to any one of claims 1
10 to 21, wherein the electromagnetic energy source is an erbium, chromium, yttrium scandium gallium garnet (Er, Cr:YSGG) solid state laser, which generates electromagnetic energy having a wavelength of approximately 2.78 microns.

23. The apparatus according to any one of claims 1
15 to 22, wherein the fluid comprises water, and

wherein the electromagnetic energy source is an erbium, chromium, yttrium, scandium, gallium garnet (Er, Cr:YSGG) solid state laser, which generates light having a wavelength in a range of about 2.70 to about 2.80 microns.

20 24. The apparatus according to any one of claims 1 to 22, wherein the fluid comprises water, and

wherein the electromagnetic energy source comprises one of the following:

(a) erbium, yttrium, scandium, gallium garnet
25 (Er:YSGG) solid state laser, which generates electromagnetic energy having a wavelength in a range of about 2.70 to about 2.80 microns;

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(b) erbium, yttrium, aluminium garnet (Er:YAG) solid state laser, which generates electromagnetic energy having a wavelength of about 2.94 microns;

(c) chromium, thulium, erbium, yttrium, aluminium garnet (CTE:YAG) solid state laser, which generates electromagnetic energy having a wavelength of about 2.69 microns;

(d) erbium, yttrium orthoaluminate (Er:YAL03) solid state laser, which generates electromagnetic energy having a wavelength in a range of about 2.71 to about 2.86 microns;

(e) holmium, yttrium, aluminium garnet (Ho:YAG) solid state laser, which generates electromagnetic energy having a wavelength of about 2.10 microns;

(f) quadrupled neodymium, yttrium, aluminum garnet (quadrupled Nd:YAG) solid state laser, which generates electromagnetic energy having a wavelength of about 266 nanometers;

(g) argon fluoride (ArF) excimer laser, which generates electromagnetic energy having a wavelength of about 193 nanometers;

(h) xenon chloride (XeCl) excimer laser, which generates electromagnetic energy having a wavelength of about 308 nanometers;

(i) krypton fluoride (KrF) excimer laser, which generates electromagnetic energy having a wavelength of about 248 nanometers; and

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(j) carbon dioxide (CO₂), which generates electromagnetic energy having a wavelength in a range of about 9.0 to about 10.6 microns.

25. The apparatus according to claim 24, wherein the
5 Er, Cr:YSGG solid state laser has a repetition rate greater than about 1 Hz, a pulse duration range between about 1 picosecond and about 1000 microseconds, and an energy greater than about 1 millijoule per pulse.

26. The apparatus according to claim 24, wherein the
10 Er, Cr:YSGG solid state laser has a repetition rate of about 20 Hz, a pulse duration of about 140 microseconds, and an energy between about 1 and about 300 millijoules per pulse.

27. The apparatus according to any one of claims 1
15 to 26, suitable for use with a target which comprises a hard tissue.

28. The apparatus according to claim 27, said hard tissue comprising one of a tooth, tooth enamel, tooth dentin, tooth cementum, bone, and cartilage.

20 29. The apparatus according to any one of claims 1 to 28, suitable for use with a target which comprises a soft tissue.

30. The apparatus according to claim 29, said soft tissue comprising one of skin, mucosa, gingiva, muscle,
25 heart, liver, kidney, brain, eye, and vessels.

31. The apparatus according to any one of claims 1 to 30, suitable for use with a target which comprises one of a glass material, a crystalline material, and a semiconductor chip surface.

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32. The apparatus according to claim 31, wherein the electromagnetically induced mechanical cutter is arranged such that, in use, it slightly ablates the glass or crystalline material surface making it suitable for silver or another dielectric material to be adhered to the glass or crystalline material surface to form a mirror.

33. The apparatus according to claim 29, wherein the electromagnetically induced mechanical cutter is arranged such that, in use, it cleans and degreases the glass or crystalline material surface making it suitable for silver or other dielectric material to be adhered to the glass or crystalline material surface to form the mirror.

34. The apparatus according to claim 31, said semiconductor chip surface comprising an oxide layer, which is selectively removed by the electromagnetically induced mechanical cutter to thereby form windows in the oxide layer for dopant implantations into the semiconductor chip surface.

35. The apparatus according to claim 34, said oxide layer comprising silicon dioxide.

36. The apparatus according to claim 35, wherein the electromagnetically induced mechanical cutter is adaptable, in use, for removing portions of the silicon dioxide layer without a need of resist, photomasks, ultraviolet light, solvents, chemical and water compounds, and acids.

37. The apparatus according to claim 31, said target being a semiconductor chip surface having a layer of resist and the electromagnetically induced mechanical cutter being adapted for, in use, removing the layer of resist from the semiconductor chip surface.

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38. The apparatus according to claim 37, wherein the electromagnetically induced mechanical cutter is adapted for slightly ablating the semiconductor chip surface to thereby remove the layer of resist and condition the semiconductor
5 chip surface for adhesion of a conductor to the semiconductor chip surface.

39. The apparatus according to any one of claims 13 and 14, wherein said user control comprises a specification input for specifying at least one of a cutting resolution
10 and a penetration level for the cutting efficiency; and

said atomizer comprises means for selecting one of a plurality of fluid spray nozzles, in response to a user specification of the cutting resolution, and means for selecting an upstream fluid pressure for the selected fluid
15 spray nozzle in response to a user specification of the penetration level;

said atomizer being arranged to apply the upstream fluid pressure to the fluid spray nozzle, to thereby generate the user-specified combination of atomized fluid
20 particles.

40. The apparatus according to claim 39, wherein the specification input comprises:

a first user input for specifying a level of resolution for the cutting efficiency, the level of
25 resolution including one of a high resolution cut and a low resolution cut; and

a second user input for specifying a level of penetration for the cutting efficiency, the level of penetration including one of a deep-penetration cut and a
30 shallow-penetration cut.

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41. The apparatus according to claim 40, wherein the atomizer generates a combination of atomized fluid particles comprising relatively small fluid particles, in response to the first user input specifying a high resolution cut,

5 wherein the atomizer generates a combination of atomized fluid particles comprising relatively large fluid particles, in response to the first user input specifying a low resolution cut,

10 wherein the atomizer generates a combination of atomized fluid particles which comprises a relatively low-density distribution of fluid particles, in response to the second user input specifying a deep-penetration cut, and

15 wherein the atomizer generates a combination of atomized fluid particles which comprises a relatively high-density distribution of fluid particles, in response to the second user input specifying a shallow penetration cut.

42. A non therapeutic method comprising the following steps:

20 supplying fluid to a first vicinity in relation to a target; and

supplying electromagnetic energy to a second vicinity in relation to the target;

the first vicinity and the second vicinity intersecting in a volume relative to the target;

25 said step of supplying fluid comprising using a plurality of fluid outputs to generate a combination of fluid particles and placing said combination of fluid particles into said volume relative to the target;

said step of supplying electromagnetic energy comprising directing a concentration of electromagnetic energy, which has a wavelength that is substantially absorbed by said fluid, into said volume so as to be absorbed by at least a portion of said fluid particles wherein particles of the portion of fluid particles expand, and wherein disruptive forces are imparted to said target.

43. The method according to claim 42 wherein the volume is adjacent to the target.

10 44. The method according to any one of claims 42 and 43 wherein the concentration of electromagnetic energy comprises a peak concentration of electromagnetic energy, and the disruptive forces comprise disruptive mechanical forces.

15 45. The method of any one of claims 42 to 44 wherein the combination of fluid particles comprises a combination of atomized fluid particles.

46. The method according to claim 45, wherein the step of placing atomized fluid particles into the first vicinity includes a substep of placing atomized water particles into the first vicinity.

47. The method of claim 46, wherein the step of focusing electromagnetic energy onto the atomized fluid particles in the volume comprises a substep of focussing electromagnetic energy from an erbium, chromium, yttrium scandium gallium garnet (Er, Cr:YSGG) solid state laser, which generates electromagnetic energy having a wavelength of approximately 2.78 microns, onto the atomized water particles in the interaction zone.

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48. The method of claim 46 comprising the step of providing electromagnetically induced mechanical cutting forces onto a target to thereby remove portions of the target, and

5 further comprising the step of inputting via a user control a user-specified combination of atomized fluid particles, the user-specified combination of atomized fluid particles corresponding to a user-specified average size, spatial distribution, and velocity of atomized fluid
10 particles; and wherein

in said step of generating a combination of particles, said user-specified combination of atomized fluid particles is generated in response to the input from the user control; and

15 said portion of said atomized fluid particles is a portion of the user-specified combination of atomized fluid particles.

49. The method according to any one of claims 42 to 48, wherein the target comprises at least one of
20 cartilage, a bone, or a tooth.

50. The method according to any one of claims 42 to 48, wherein the target comprises one of a glass material, a crystalline material, and a semiconductor chip surface.

51. The method of claim 50 comprising mechanically
25 removing portions of a target, wherein the glass or crystalline material surface is slightly ablated before silver or another dielectric material is adhered to the glass or crystalline material surface to form a mirror.

52. The method of claim 50 comprising mechanically
30 removing portions of a target, wherein the semiconductor

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chip surface comprises an oxide layer, which is selectively removed to thereby form windows in the oxide layer for dopant implantations into the semiconductor chip surface.

53. The method of claim 50 comprising mechanically removing portions of a target, wherein a layer of resist is removed from the semiconductor chip surface.

54. A method according to claim 47, wherein said step of inputting comprises specifying at least one of a cutting resolution and a penetration level for the cutting efficiency; and

said step of generating comprises selecting one of a plurality of fluid spray nozzles, in response to a specification of the cutting resolution;

selecting an upstream fluid pressure for the selected fluid spray nozzle, in response to a specification of the penetration level; and

applying the upstream fluid pressure to the fluid spray nozzle, to thereby generate the user-specified combination of atomized fluid particles.

55. The method according to claim 54, the step of specifying at least one of a cutting resolution and a penetration level for the cutting efficiency further comprising the following steps:

specifying, via a user input, one of a high resolution cut and a low resolution cut; and

specifying, via a user input, one of a deep penetration cut and a shallow-penetration cut.

56. The method of claim 55 comprising the step of controlling a cutting efficiency of an electromagnetically

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induced mechanical cutter, wherein the step of applying the upstream fluid pressure to the fluid spray nozzle comprises the following substeps:

generating a combination of atomized fluid particles comprising relatively small fluid particles, in response to a user input specifying a high resolution cut;

generating a combination of atomized fluid particles comprising relatively large fluid particles, in response to a user input specifying a low resolution cut;

generating a combination of atomized fluid particles which comprises a relatively low-density distribution of fluid particles, in response to a user input specifying a deep-penetration cut; and

generating a combination of atomized fluid particles which comprises a relatively high-density distribution of fluid particles, in response to a user input specifying a shallow-penetration cut.

57. The method of claim 56 comprising the step of controlling a cutting efficiency of an electromagnetically induced mechanical cutter, wherein the step of applying the upstream fluid pressure to the fluid spray nozzle further comprises the following substeps:

generating atomized fluid particles with relatively high kinetic energies, in response to at least one of a user specification for a deep-penetration cut and a user specification for high resolution cut; and

generating atomized fluid particles with relatively low kinetic energies, in response to at least one of a user specification for a shallow-penetration cut and a user specification for low resolution cut.

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58. An optical cutter for dental use, comprising apparatus according to any one of claims 1 to 17, and

a housing having a lower portion, an upper portion, and an interfacing portion;

5 the electromagnetic energy source comprising:

a first fiber optic tube for carrying laser energy through the housing to the upper portion of the housing:

a first abutting member fitting around the first fiber optic tube at the upper portion of the housing;

10 a second fiber optic tube having a proximal end and a distal end;

a second abutting member surrounding the second fiber optic tube at the proximal end and contacting the interfacing portion of the housing; and

15 a focusing optic positioned between the first abutting member and the second abutting member, the focusing optic focusing laser energy as the laser energy passes from the first fiber optic to the second fiber optic to thereby reduce dissipation of laser energy between the first fiber
20 optic and the second fiber optic.

59. The optical cutter for dental use according to claim 58, further comprising a cap having an input portion and an output portion, the cap fitting over the interfacing portion of the housing.

25 60. The optical cutter for dental use according to claim 58, wherein the second fiberoptic tube comprises sapphire.

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61. A medical handpiece, comprising apparatus according to any one of claims 1 to 17, and

a housing including a proximal housing end and a radiation delivery end;

5 said electromagnetic energy source including a first fiber guide having an output end and being disposed within the housing for conducting laser radiation from an external laser source toward the radiation delivery end of the housing;

10 a first ferrule comprising a ceramic or crystalline material and being adapted for securing the first fiber guide to the housing so that the output end of the first fiber guide faces the radiation delivery end of the housing;

15 a second fiber guide having a receiving end adapted for receiving laser radiation from the output end of the first fiber guide; and

a second ferrule comprising a ceramic or crystalline material and being adapted for securing the
20 second fiber guide to the housing so that the receiving end of the second fiber guide faces the output end of the first fiber guide.

62. The medical handpiece as recited in claim 61, the first ferrule detachably securing the first fiber guide to
25 the housing so that the output end of the first fiber guide faces the radiation delivery end of the housing.

63. The medical handpiece as recited in claim 62, the first ferrule and the second ferrule forming a gas flow path in a direction from the first fiber guide toward the
30 receiving end of the second fiber guide.

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64. The medical handpiece as recited in claim 63, the gas flow path extending across the receiving end of the second fiber guide and across the second ferrule.

65. Apparatus according to any one of claims 1 to 17,
5 further comprising an electromagnetic energy conducting apparatus, comprising:

a housing;

an inner electromagnetic energy guide disposed within the housing, the inner electromagnetic energy guide
10 having a proximal end, a distal end, and an axis extending between the proximal end and the distal end; and

an outer electromagnetic energy guide surrounding and contacting the inner electromagnetic energy guide, the outer electromagnetic energy guide having an axis that is
15 substantially co-linear with the axis of the inner electromagnetic energy guide.

66. The apparatus as defined in claim 65, the outer electromagnetic energy guide comprising a ferrule.

67. The apparatus as defined in claim 66, both the
20 inner electromagnetic energy guide and the outer electromagnetic energy guide comprising a crystalline material.

68. The apparatus as defined in claim 65, further comprising at least one other electromagnetic energy guide
25 surrounding and contacting the outer electromagnetic energy guide, the other electromagnetic energy guide having an axis that is substantially co-linear with the axis of the outer electromagnetic energy guide.

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69. The apparatus as defined in claim 65, further comprising a source electromagnetic energy guide for inputting electromagnetic energy into both the inner electromagnetic energy guide and the outer electromagnetic energy guide.

70. The apparatus as defined in claim 66, a diameter of the source electromagnetic energy guide being greater than a diameter of the inner electromagnetic energy guide.

71. The apparatus as recited in claim 65, the inner electromagnetic energy guide and the outer electromagnetic energy guide being concentric.

72. The apparatus as recited in claim 65, the inner electromagnetic energy guide and the outer electromagnetic energy guide sharing the same axis.

73. The apparatus as recited in claim 72, at least one of the inner electromagnetic energy guide and the outer electromagnetic energy guide comprising sapphire.

74. Apparatus according to any one of claims 1 to 17, further comprising an optical energy conducting apparatus, comprising a bent crystalline fiber adapted for conducting optical energy therethrough, the bent crystalline fiber having a proximal end, a distal end, and an axis extending between the proximal end and the distal end, a first portion of the axis near the proximal end of the bent crystalline fiber not being parallel with a second portion of the axis near the distal end of the bent crystalline fiber.

75. The apparatus as recited in claim 74, the bent crystalline fiber extending between a laser source and a distal end of a laser delivery device.

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76. The apparatus as recited in claim 74, an angle formed between the first portion of the axis and the second portion of the axis being approximately 90 degrees.

77. The apparatus as recited in claim 74, further comprising a housing, the bent crystalline fiber being disposed within the housing.

78. The apparatus as recited in claim 77, the housing being connected to a medical handpiece, and the bent crystalline fiber being cooled by a gas flow path within the medical handpiece.

79. The apparatus as recited in claim 74, the optical energy comprising a source of coherent light.

80. The apparatus as recited in claim 79, the coherent light having a wavelength on an order of approximately 2.5 to 3.0 microns.

81. The apparatus as recited in claim 80, the coherent light having a wavelength within a range of about 2.78 to about 2.94 microns.

82. The apparatus as recited in claim 81, the bent crystalline fiber comprising sapphire.

83. Apparatus according to any one of claims 1 to 17, comprising an optical energy conducting apparatus, comprising:

a housing;

a crystalline fiber disposed within the housing, the crystalline fiber being adapted for conducting optical energy therethrough, the crystalline fiber having a proximal end, a distal end, and an axis extending between the proximal end and the distal end; and

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a gas flow path within the housing, the gas flow path enveloping the crystalline fiber and extending from the proximal end of the crystalline fiber to the distal end of the crystalline fiber.

5 84. The apparatus as recited in claim 83, the crystalline fiber being bent.

85. A medical handpiece, comprising:

a housing including a proximal housing end and a distal housing end;

10 apparatus according to any one of claims 1 to 30, disposed at the distal housing end and adapted for cutting tissue; and

15 a medication line having a proximal line end and a distal line end, the medication line adapted for receiving medication into the proximal line end and outputting the medication through the distal line end, which is disposed near the distal housing end.

86. The medical handpiece as recited in claim 85, the tissue cutter comprising one of a laser and a drill.

20 87. The medical handpiece as recited in claim 86, the tissue cutter further being adapted for ablating tissue.

88. A medical handpiece delivery system, comprising apparatus according to any one of claims 1 to 17, and

25 a housing including a proximal housing end and a radiation delivery end;

a fiber guide having an output end and being disposed within the housing for conducting laser radiation

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from an external laser source toward the radiation delivery end of the housing;

a ferrule adapted for securing the fiber guide to the housing so that the output end of the fiber guide faces
5 the radiation delivery end of the housing;

an inner protective tube disposed over the fiber guide; and

an outer protective tube disposed over the inner protective tube.

10 89. The medical handpiece delivery system as recited in claim 88, the fiber guide comprising a plurality of tubular jackets surrounding and affixed to the fiber guide.

90. The medical handpiece delivery system as recited in claim 88, the ferrule comprising a proximal end and a
15 distal end, the inner protective tube comprising a proximal end and a distal end, the outer protective tube comprising a proximal end and a distal end, and at least one of the distal end of the inner protective tube and the distal end of the outer protective tube contacting the proximal end of
20 the ferrule.

91. The medical handpiece delivery system as recited in claim 90, the ferrule comprising an aperture for accommodating the fiber guide, a diameter of the aperture being approximately equal to an outer diameter of the fiber
25 guide.

92. The medical handpiece delivery system as recited in claim 90, the proximal end of the inner protective tube and the proximal end of the outer protective tube being disposed near an SMA connector, which surrounds a proximal
30 end of the fiber guide.

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93. The medical handpiece delivery system as recited in claim 92, the SMA connector having a proximal end and a distal end, and the fiber guide spanning a distance between the proximal end of the ferrule and the distal end of the SMA connector;

a length of at least one of the inner protective tube and the outer protective tube being less than the distance spanned by the fiber guide between the proximal end of the ferrule and the distal end of the SMA connector.

94. The medical handpiece delivery system as recited in claim 93, a length of at least one of the inner protective tube and the outer protective tube being at least one quarter of an inch less than the distance spanned by the fiber guide between the proximal end of the ferrule and the distal end of the SMA connector.

95. The medical handpiece delivery system as recited in claim 94, the shorter length of the at least one of the inner protective tube and the outer protective tube facilitating sliding of the at least one of the inner protective tube and the outer protective tube over the fiber guide.

96. The medical handpiece delivery system as recited in claim 92, the SMA connector being adapted for attaching the fiber guide to an electromagnetic energy source;

the inner protective tube and the outer protective tube comprising one of a flexible plastic material and a flexible metallic material; and

the medical handpiece delivery system further comprising a metal tube disposed around the outer protective tube near the proximal end of the outer protective tube.

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97. The medical handpiece delivery system as recited in claim 96, the electromagnetic energy source comprising a laser.

98. The medical handpiece delivery system as recited in claim 96, the medical handpiece delivery system further comprising a plastic tube surrounding and contacting the metal tube.

99. The medical handpiece delivery system as recited in claim 98, both the inner protective tube and the outer protective tube reducing a risk of damage to the fiber guide.

100. The medical handpiece delivery system as recited in claim 99, both the inner protective tube and the outer protective tube reducing a probability that bending of the fiber guide will result in breaking of the fiber guide.

101. The medical handpiece delivery system as recited in claim 98, both the inner protective tube and the outer protective tube reducing a probability of the fiber guide breaking near the ferrule.

102. The medical handpiece delivery system as recited in claim 101, the inner protective tube and the outer protective tube comprising a flexible plastic material.

103. The medical handpiece delivery system as recited in claim 88, the inner protective tube being slidably disposed over the fiber guide.

104. The medical handpiece delivery system as recited in claim 88, the outer protective tube being slidably disposed over the inner protective tube.

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105. The medical handpiece delivery system as recited in claim 104, further comprising at least one other protective tube slidably disposed over the outer protective tube.

5 106. The medical handpiece delivery system as recited in claim 105, the inner protective tube being slidably disposed over the fiber guide.

107. The medical handpiece delivery system as recited in claim 88, further comprising:

10 a second fiber guide having a receiving end adapted for receiving laser radiation from the output end of the fiber guide;

a second ferrule adapted for securing the second fiber guide to the housing so that the receiving end of the
15 second fiber guide faces the output end of fiber guide; and

a spacer disposed between the ferrule and the second ferrule.

108. The medical handpiece delivery system as recited in claim 107, at least one of the ferrule, the second
20 ferrule, and the spacer comprising at least one of a ceramic and a crystalline material.

109. The medical handpiece delivery system as recited in claim 108, the crystalline material comprising sapphire.

110. A medical handpiece, comprising apparatus
25 according to any one of claims 1, 13, 14 and 15,

wherein a sleeve housing adapted to be held by a hand of a user and including a proximal sleeve housing end, an intermediate sleeve housing portion, a radiation delivery end, and an elongate aperture extending within the sleeve

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housing from the proximal sleeve housing end to the intermediate sleeve housing portion, the sleeve housing comprising a delivery fiber guide extending between the intermediate sleeve housing portion and the radiation
5 delivery end, the delivery fiber guide having a proximal end and a distal end; and

a shaft assembly adapted for being removably disposed within the elongate aperture, the shaft assembly comprising a source fiber guide adapted for supplying
10 electromagnetic energy to the intermediate sleeve housing portion, the source fiber guide having a proximal end and a distal end.

111. The medical handpiece as recited in claim 110, further comprising a collar for fitting around the proximal
15 sleeve housing end when the shaft assembly is disposed within the sleeve housing, the collar holding the shaft assembly within the sleeve housing.

112. The medical handpiece as recited in claim 111, the proximal sleeve housing end comprising threads for
20 accommodating threads of the collar.

113. The medical handpiece as recited in claim 110, the distal end of the source fiber guide being surrounded by a first ferrule, and

the proximal end of the delivery fiber guide being
25 surrounded by a second ferrule.

114. The medical handpiece as recited in claim 113, further comprising a third ferrule surrounding a portion of the delivery fiber guide near the radiation delivery end of the sleeve housing.

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115. The medical handpiece as recited in claim 113, the shaft assembly comprising an air supply line disposed around the source fiber guide.

116. The medical handpiece as recited in claim 113, the
5 fiber comprising a plurality of protective tubes disposed around the source fiber guide and an air supply line disposed around the plurality of protective tubes.

117. The medical handpiece as recited in claim 115 the sleeve housing comprising an air line extending from the
10 proximal sleeve housing end to the radiation delivery end; and

a water line extending from the proximal sleeve housing end to the radiation delivery end.

118. The medical handpiece as recited in claim 116 the
15 sleeve housing further comprising a medication line extending generally from the proximal sleeve housing end to the radiation delivery end.

119. An apparatus for implementing a medical procedure comprising:

20 apparatus according to any one of claims 1 to 30 for performing a medical treatment function on an operating site located inside of or connected to a human body; and

a fluid router for routing flavoured fluid in the direction of the operating site.

25 120. The apparatus for implementing a medical procedure according to claim 119, wherein a flavoured fluid is selected in use to be flavoured to appeal to taste buds of the patient undergoing the surgical procedure.

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121. The apparatus for implementing a medical procedure according to claim 120, wherein the flavoured fluid is selected in use to be one which comprises one of a fruit flavour and a mint flavour.

5 122. The apparatus for implementing a medical procedure according to claim 119, wherein the medical instrument comprises one of an electrocauterizer, an electromagnetic energy source, a laser, a mechanical drill, a mechanical saw, a canal finder, a syringe, and an evacuator.

10 123. The apparatus for implementing a medical procedure according to claim 122, wherein the electromagnetic energy source focuses the electromagnetic energy on the operating site; and

wherein the fluid router routes flavoured fluid
15 onto the operating site, to thereby cool the operating site as the operating site is being cut.

124. The apparatus for implementing a medical procedure according to claim 122, wherein the fluid router is operable between a first mode where the routed fluid is flavoured,
20 and a second mode where the routed fluid is not flavoured.

125. The apparatus for implementing a medical procedure according to claim 121, wherein the fluid router comprises an atomizer for atomizing the flavoured fluid into atomized flavoured fluid particles before routing the flavoured fluid
25 in the direction of the operating site.

126. The apparatus for implementing a medical procedure according to claim 125, wherein the atomizer is arranged to route the atomized flavoured fluid particles into a volume of air above the operating site; and

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wherein the electromagnetic energy source is arranged to focus electromagnetic energy into the volume of air, the electromagnetic energy having a wavelength which is substantially absorbed by the atomized flavoured fluid particles in the volume of air, the absorption of the electromagnetic energy by the atomized flavoured fluid particles causing the atomized flavoured fluid particles to explode and impart mechanical forces onto the operating site.

10 127. The apparatus for implementing a medical procedure according to claim 126, wherein the fluid router is operable between a first mode where the routed fluid is flavoured, and a second mode where the routed fluid is not flavoured.

128. An apparatus for implementing a medical procedure,
15 comprising:

apparatus according to any one of claims 1 to 30, for performing a medical treatment function on an operating site located inside of or connected to a human body; and

20 a router for routing a scented medium in the direction of the operating site.

129. The apparatus for implementing a medical procedure according to claim 128, wherein the scented medium is selected in use to be one which is scented to appeal to a sense of smell of the patient undergoing the surgical
25 procedure.

130. The apparatus for implementing a medical procedure according to claim 129, wherein the scented medium is selected in use to comprise one of a fruit scent, a mint scent, and an air freshener.

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131. The apparatus for implementing a medical procedure according to claim 128, wherein the medical instrument comprises one of an electrocauterizer, an electromagnetic energy source, a laser, a mechanical drill, a mechanical
5 saw, a canal finder, a syringe, and an evacuator.

132. The apparatus for implementing a medical procedure according to claim 129, said scented medium comprising scented air.

133. The apparatus for implementing a medical procedure
10 according to claim 128, wherein the electromagnetic energy source is arranged, in use, to focus the electromagnetic energy on the operating site,

said scented medium comprising scented water, and

said router being arranged to route, in use, the
15 scented water onto the operating site, to thereby cool the operating site as the operating site is being cut by the electromagnetic energy source.

134. The apparatus for implementing a medical procedure according to claim 129, wherein the electromagnetic energy
20 source is arranged, in use, to focus the electromagnetic energy on the operating site, and

said scented medium comprising a scented mist, and

said router being arranged to route, in use, the
25 scented mist onto the operating site, to thereby cool the operating site as the operating site is being cut by the electromagnetic energy source.

135. The apparatus for implementing a medical procedure according to claim 128, wherein the router is operable

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between a first mode where the routed medium is scented, and a second mode where the routed medium is not scented.

136. The apparatus for implementing a medical procedure according to claim 129, wherein the router comprises an
5 atomizer for atomizing the scented medium before routing the scented medium in the direction of the operating site.

137. The apparatus for implementing a medical procedure according to claim 133, wherein the atomizer is arranged to route, in use, the atomized scented medium into a volume of
10 air above the operating site; and

wherein the electromagnetic energy source is arranged to focus, in use, electromagnetic energy into the volume of air, the electromagnetic energy having a wavelength which is substantially absorbed by portions of
15 the atomized scented medium in the volume of air, the absorption of the electromagnetic energy by the portions of the atomized scented medium causing the portions of the atomized scented medium to explode and impart mechanical forces onto the operating site.

20 138. The apparatus for implementing a medical procedure according to claim 136, wherein the router is operable between a first mode where the routed medium is scented, and a second mode where the routed medium is not scented.

139. An apparatus for implementing a medical procedure,
25 comprising:

a cutter according to any one of claims 1 to 30, for performing a medical treatment function on an operating site located inside of or connected to a human body; and

a fluid router for routing, in use, an ionized
30 solution in the direction of the operating site.

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140. The apparatus for implementing a medical procedure according to claim 139, said ionized solution comprising a biocompatible saline solution.

141. The apparatus for implementing a medical procedure according to claim 139, wherein the medical instrument comprises one of an electrocauterizer, an electromagnetic energy source, a laser, a mechanical drill, a mechanical saw, a canal finder, a syringe, and an evacuator.

142. The apparatus for implementing a medical procedure according to claim 141, wherein the electromagnetic energy source focuses the electromagnetic energy onto the operating site; and

wherein the fluid router routes the ionized solution onto the operating site, to thereby cool the operating site as the operating site is being cut.

143. The apparatus for implementing a medical procedure according to claim 141, wherein the fluid router comprises an atomizer for atomizing the ionized solution into atomized particles before routing the atomized particles in the direction of the operating site.

144. The apparatus for implementing a medical procedure according to claim 143, wherein the atomizer routes the atomized particles into a volume of air above the operating site; and

wherein the electromagnetic energy source focuses electromagnetic energy into the volume of air, the electromagnetic energy having a wavelength which is substantially absorbed by the atomized particles in the volume of air, the absorption of the electromagnetic energy by the atomized particles causing the atomized particles to

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explode and impart mechanical forces onto the operating site.

145. The apparatus for implementing a medical procedure according to claim 143, wherein the fluid router is operable
5 between a first mode where solution routed therefrom is ionized, and a second mode where the solution routed therefrom is not ionized.

146. The apparatus for implementing a medical procedure according to claim 145 wherein the fluid router is operable
10 in a plurality of modes between the first mode and the second mode to thereby continuously control a cutting power of the electromagnetic energy source.

147. The apparatus for implementing a medical procedure according to claim 146, wherein the cutting power of the
15 electromagnetic energy source decreases as the fluid from the fluid router becomes more ionized.

148. The apparatus for implementing a medical procedure according to claim 147, wherein a strength of the
20 electromagnetic energy source is adjustable to control the cutting power of the electromagnetic energy source.

149. The apparatus for implementing a medical procedure according to claim 148, wherein the strength of the
25 electromagnetic energy source can be increased when the fluid from the fluid router becomes more ionized, to thereby maintain a constant cutting power of the electromagnetic energy source; and

wherein the strength of the electromagnetic energy source can be decreased when the fluid from the fluid router becomes less ionized, to thereby maintain a constant cutting
30 power of the electromagnetic energy source.

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150. Apparatus according to any one of claims 1 to 30,
wherein

said atomizer is arranged to place, in use,
pigmented atomized fluid particles into said predefined
5 volume.

151. Apparatus according to any one of claims 1 to 30,
further comprising:

a fluid source for delivering, in use, pigmented
fluid to an approximate vicinity of the target, the
10 pigmented fluid having a color which is substantially
unabsorbed by the electromagnetic energy.

152. Apparatus according to any one of claims 1 to 30,
further comprising a fluid source for delivering fluid to an
approximate vicinity of the target, the fluid having a color
15 which is substantially unabsorbed by the electromagnetic
energy.

153. Apparatus according to any one of claims 1 to 30,
further comprising supplying means connected to the
atomizer, for selectively supplying a pigmentation to the
20 atomized fluid particles.

154. The apparatus according to claim 153, wherein the
pigmentation is selectively supplied to the atomized fluid
particles according to a user input.

155. The apparatus according to claim 153, wherein the
25 electromagnetic energy has a wavelength that is
substantially absorbed by the atomized fluid particles when
the pigmentation is supplied to the atomized fluid
particles.

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156. The apparatus according to claim 153, wherein the electromagnetic energy has a wavelength that is substantially absorbed by the atomized fluid particles when the pigmentation is not supplied to the atomized fluid particles.

157. The apparatus according to claim 153, wherein the atomizer comprises a water source line and an air source line; and

wherein the pigmentation is selectively supplied to the atomized fluid particles via one of the air source line and the water source line.

158. An apparatus for implementing a medical procedure, comprising:

apparatus according to any one of claims 1 to 30 for performing a medical treatment function on an operating site located inside of or connected to a human body; and

a fluid router for routing a fluid, which has a measurable fluid parameter different than a corresponding measurable fluid parameter of water, in the direction of the operating site.

159. The apparatus according to claim 158 wherein the measurable fluid parameter comprises one of a density, a specific gravity, a pH level, a viscosity, and a temperature.

160. An apparatus for implementing a medical procedure, comprising:

a cutter according to any one of claims 1 to 30 for performing a medical treatment function on an operating site located inside of or connected to a human body; and a

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router for routing a medication medium in the direction of the operating site.

161. The apparatus for implementing a medical procedure according to claim 160 wherein, in use, the medication
5 medium may comprise one of an antibiotic, iodine, a steroid, an anaesthetic, an anti-inflammatory, a disinfectant, adrenaline, epinephrine, an antiseptic, and a stringent.

162. The apparatus for implementing a medical procedure according to claim 160 wherein, in use, the medication
10 medium may comprise one of vitamins, herbs, and minerals.

163. The apparatus for implementing a medical procedure according to claim 160, wherein the medical instrument comprises one of an electrocauterizer, an electromagnetic energy source, a laser, a mechanical drill, a mechanical
15 saw, a canal finder, a syringe, and an evacuator.

164. The apparatus for implementing a medical procedure according to claim 163 wherein the electromagnetic energy source is arranged to focus, in use, the electromagnetic energy on the operating site; and

20 wherein the router, in use, routes the medication medium onto the operating site to thereby cool and medicate the operating site as the operating site is being cut.

165. The apparatus for implementing a medical procedure according to claim 164, wherein the router is operable
25 between a first mode where the routed medium is medicated, and a second mode where the routed medium is not medicated.

166. The apparatus for implementing a medical procedure according to claim 165, wherein the router comprises an atomizer for atomizing the medication medium into atomized

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particles before routing the medication medium in the direction of the operating site.

167. The apparatus for implementing a medical procedure according to claim 166, wherein the atomizer is arranged, in use, to route, in use, the atomized particles into a volume of air above the operating site; and

wherein the electromagnetic energy source is arranged, in use, to focus electromagnetic energy into the volume of air, the electromagnetic energy having a wavelength which is substantially absorbed by the atomized particles in the volume of air, the absorption of the electromagnetic energy by the atomized particles causing the atomized particles to explode and impart mechanical forces onto the operating site.

168. The apparatus for implementing a medical procedure according to claim 166, wherein the fluid router is operable between a first mode where the fluid routed therefrom is medicated, and a second mode where the fluid routed therefrom is not medicated.

169. An apparatus for killing bacteria in or on both a patient's mouth and a dental instrument within a vicinity of the patient's mouth, comprising:

a surgical tool comprising an apparatus according to claim 1 for cutting or drilling material within a patient's mouth; and

a fluid router for routing disinfectant into the patient's mouth, a portion of the routed disinfectant becoming airborne and settling onto the dental instrument to thereby disinfect the dental instrument.

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170. A drilling and conditioning apparatus, comprising:
an apparatus according to any one of claims 1
to 30 for performing a drilling operation on a tooth within
a patient's mouth; and

5 a fluid router for routing conditioned fluid in
the direction of the tooth being operated upon, the
conditioned fluid having a measurable property that is
different than a corresponding measurable property of water.

171. The drilling and conditioning apparatus according
10 to claim 170, said measurable property comprising at least
one of a flavour detectable by taste buds of the patient, a
scent detectable by olfactory senses of the patient, a
salinity, a pigment, a medication, and a disinfectant.

172. The drilling and conditioning apparatus according
15 to claim 171, said medication comprising at least one of an
antibiotic, a steroid, an anaesthetic, an anti-inflammatory,
a disinfectant, adrenaline, epinephrine, an antiseptic, and
a stringent.

173. The drilling and conditioning apparatus according
20 to claim 171, wherein the medication comprises one of
vitamins, herbs, and minerals.

174. An apparatus for implementing a medical procedure,
comprising:

apparatus according to any one of claims 1 to 30
25 for performing a medical treatment function on an operating
site located inside of or connected to a human body; and

a fluid router for selectively routing pigmented
fluid in the direction of the tissue.

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175. The apparatus for implementing a medical procedure according to claim 174, wherein the medical instrument comprises one of an electrocauterizer, an electromagnetic energy source, a mechanical drill, a mechanical saw, a canal
5 finder, a syringe, and an evacuator.

176. The apparatus for implementing a medical procedure according to claim 175, wherein the fluid router is operable between a first mode where the routed fluid is pigmented, and a second mode where the routed fluid is not pigmented.

10 177. The apparatus for implementing a medical procedure according to claim 176, wherein a wavelength of the electromagnetic energy source is substantially absorbed by the pigmented fluid.

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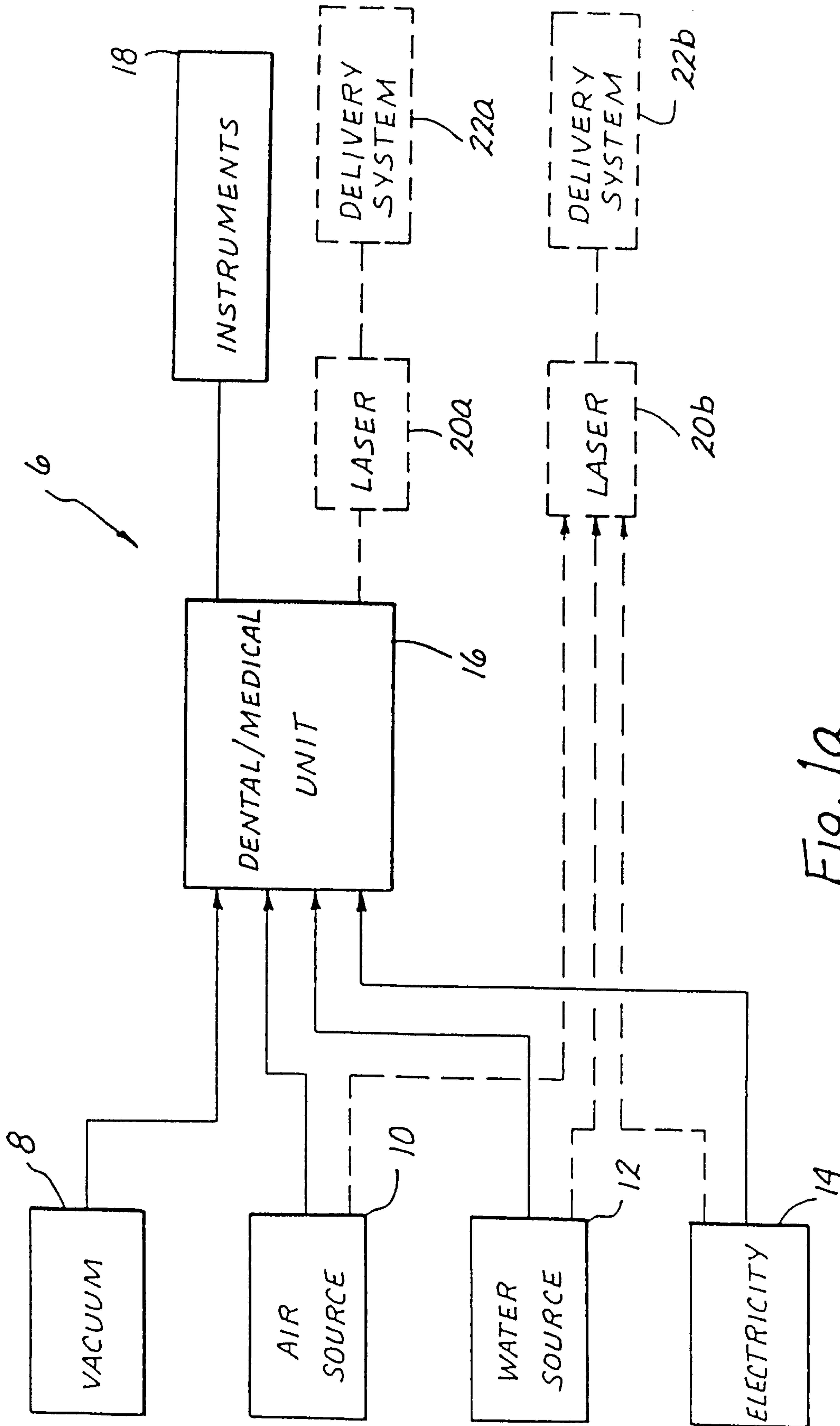


Fig. 10a
PRIOR ART

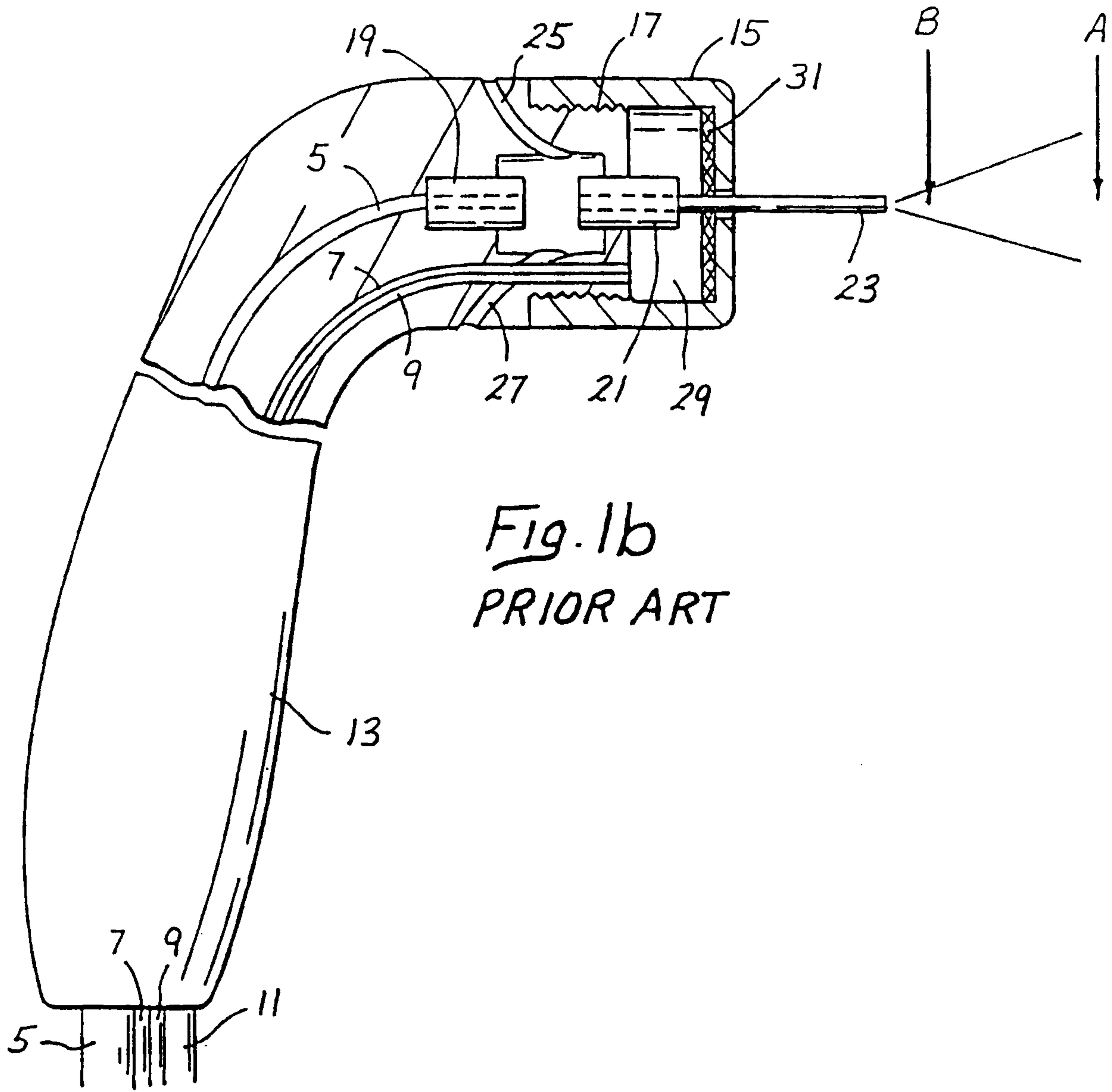


Fig. 1b
PRIOR ART

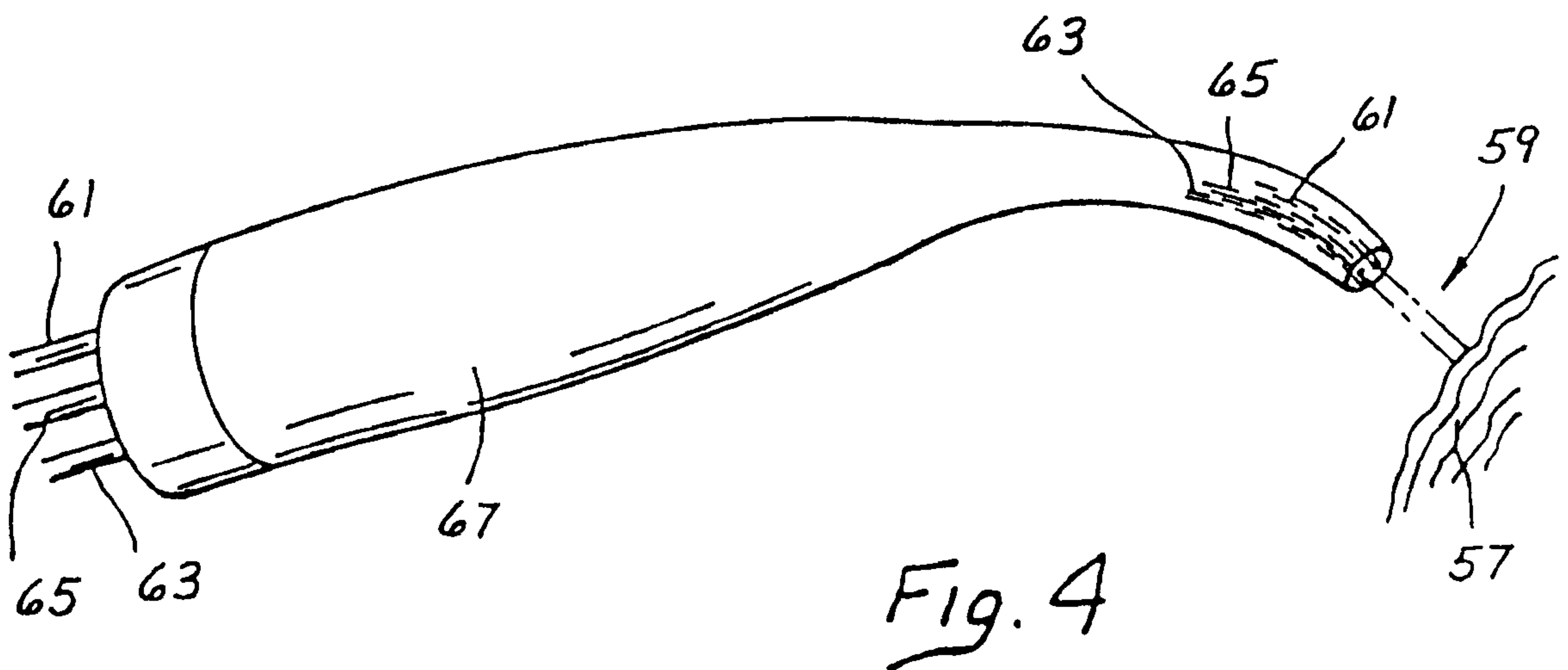


Fig. 4

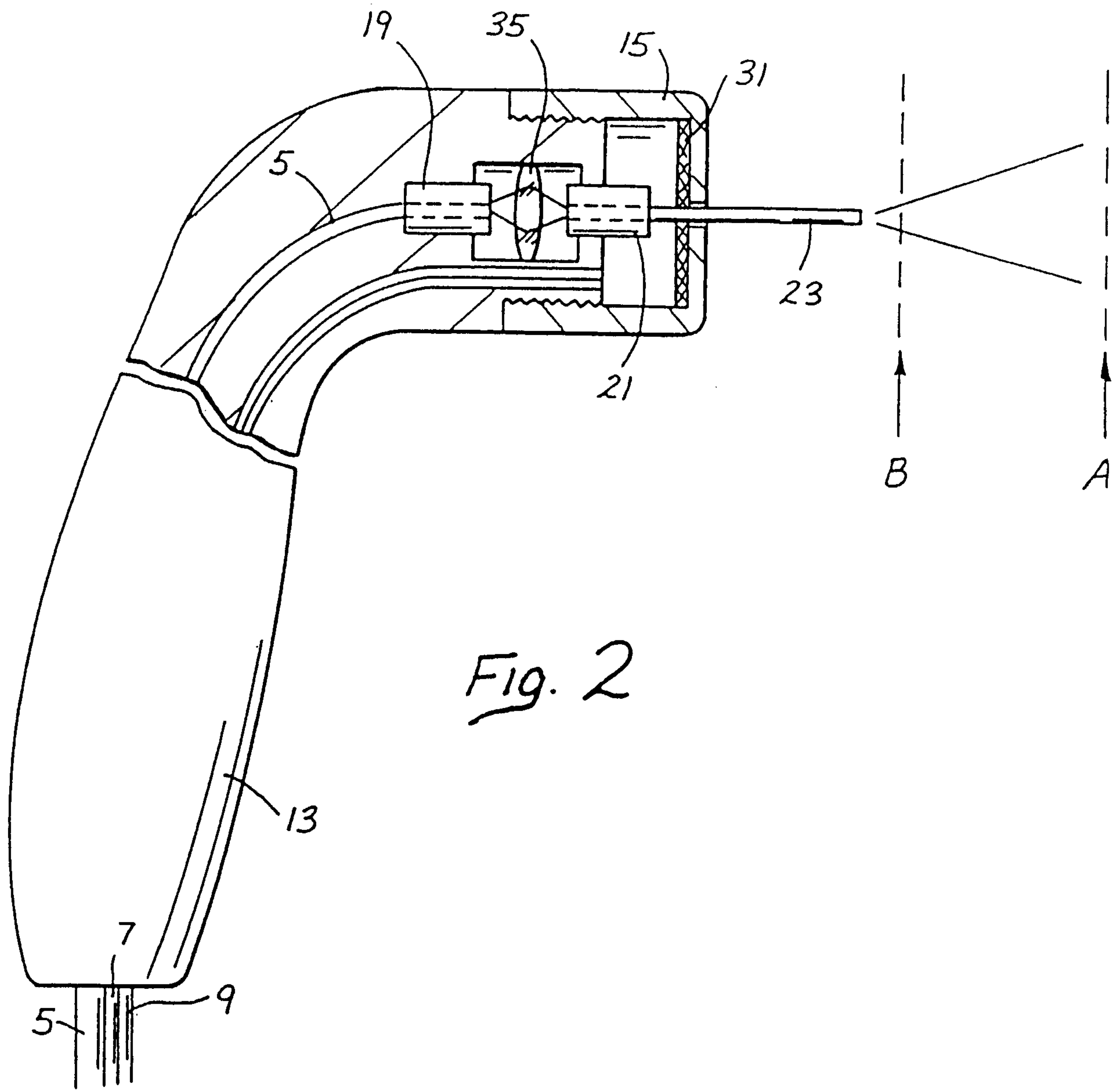


Fig. 2

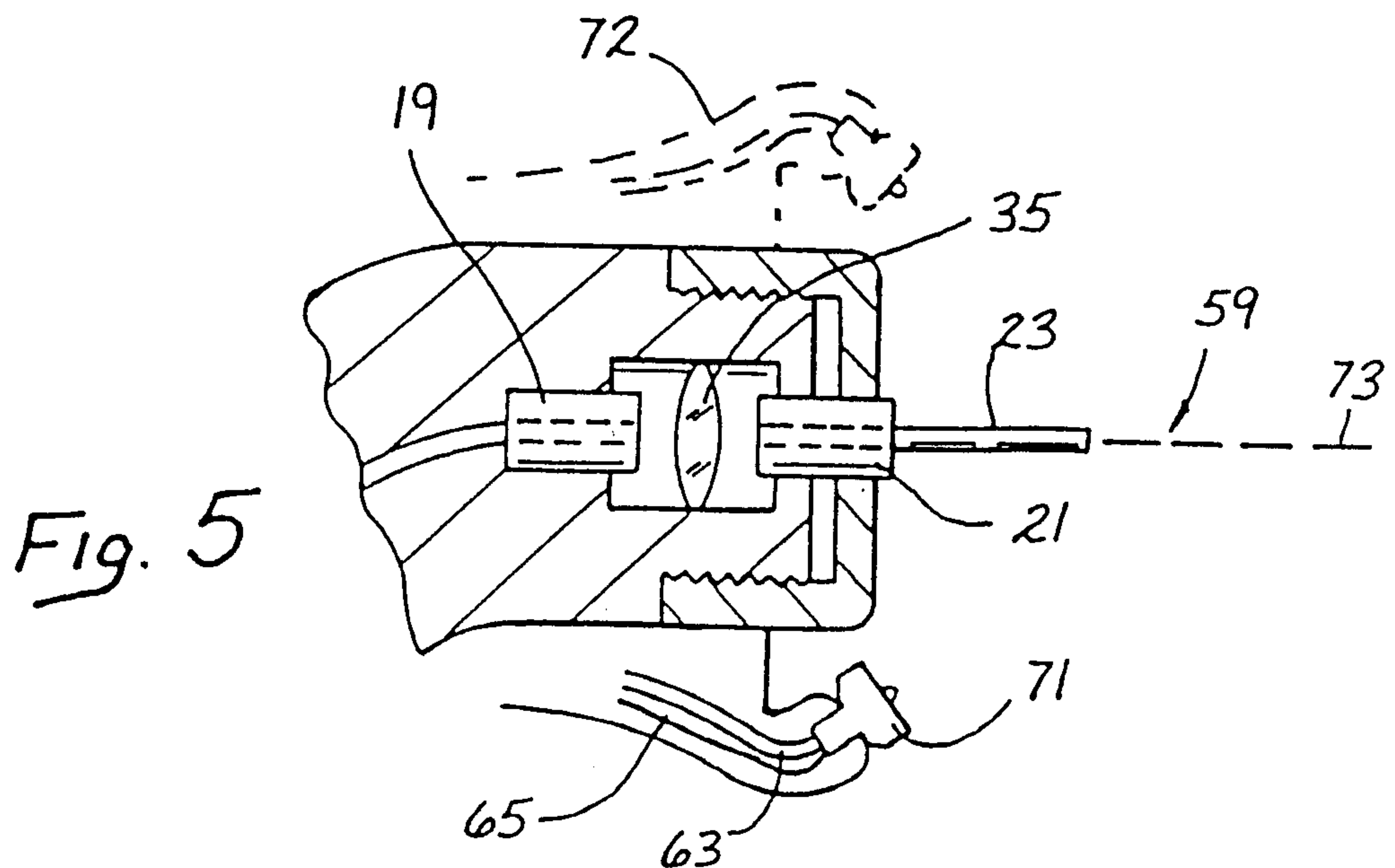


Fig. 5

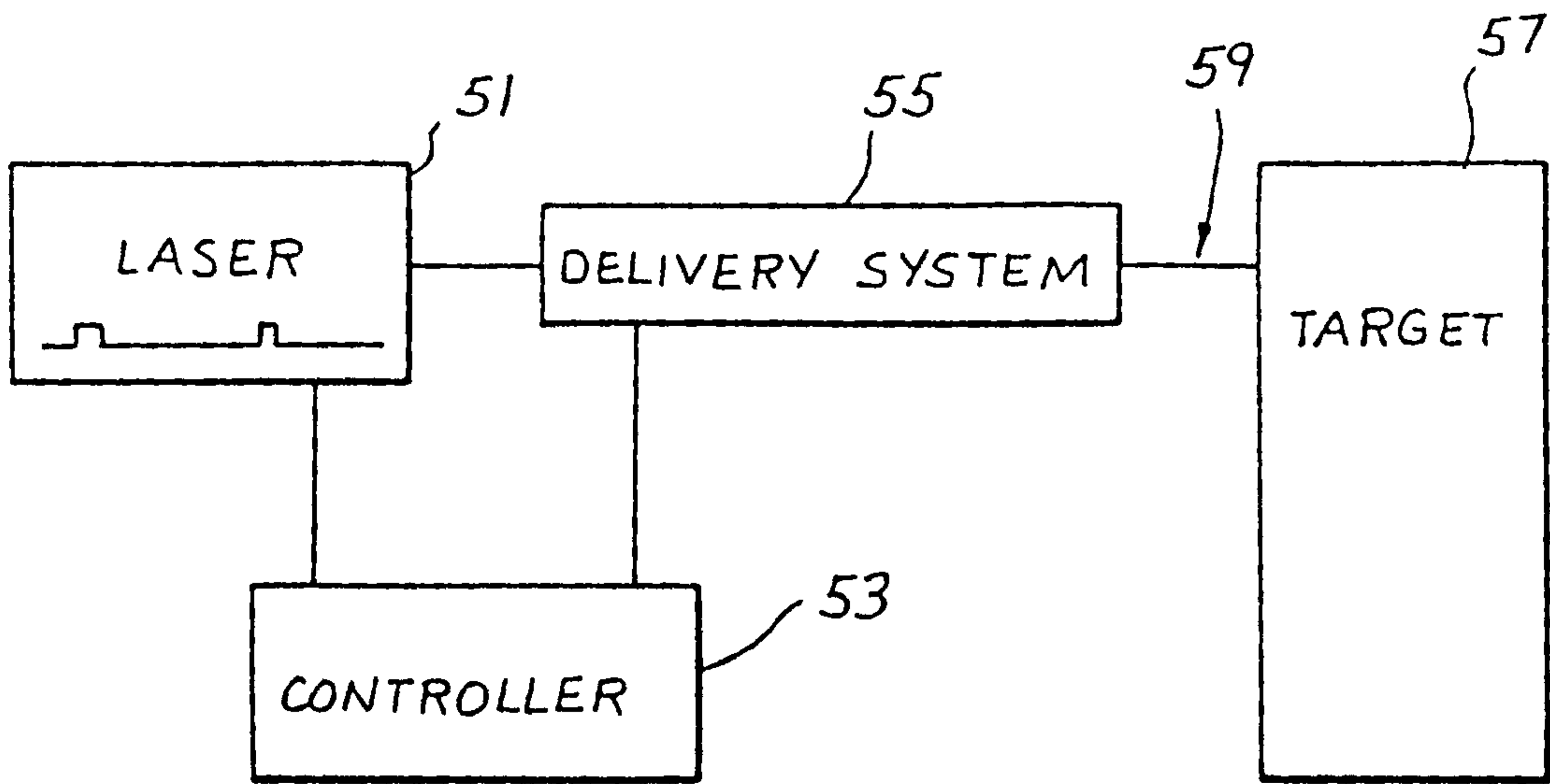


Fig. 3

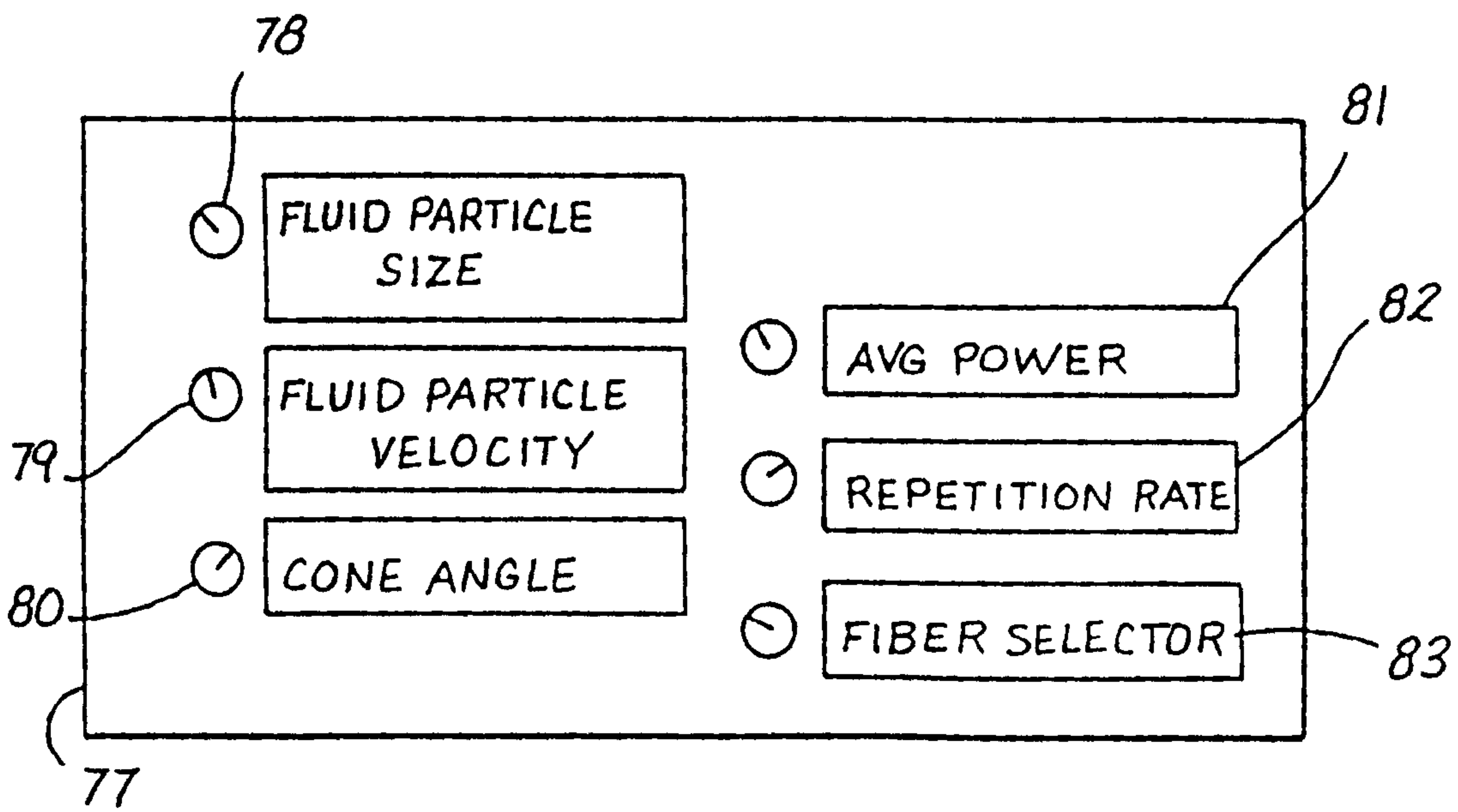
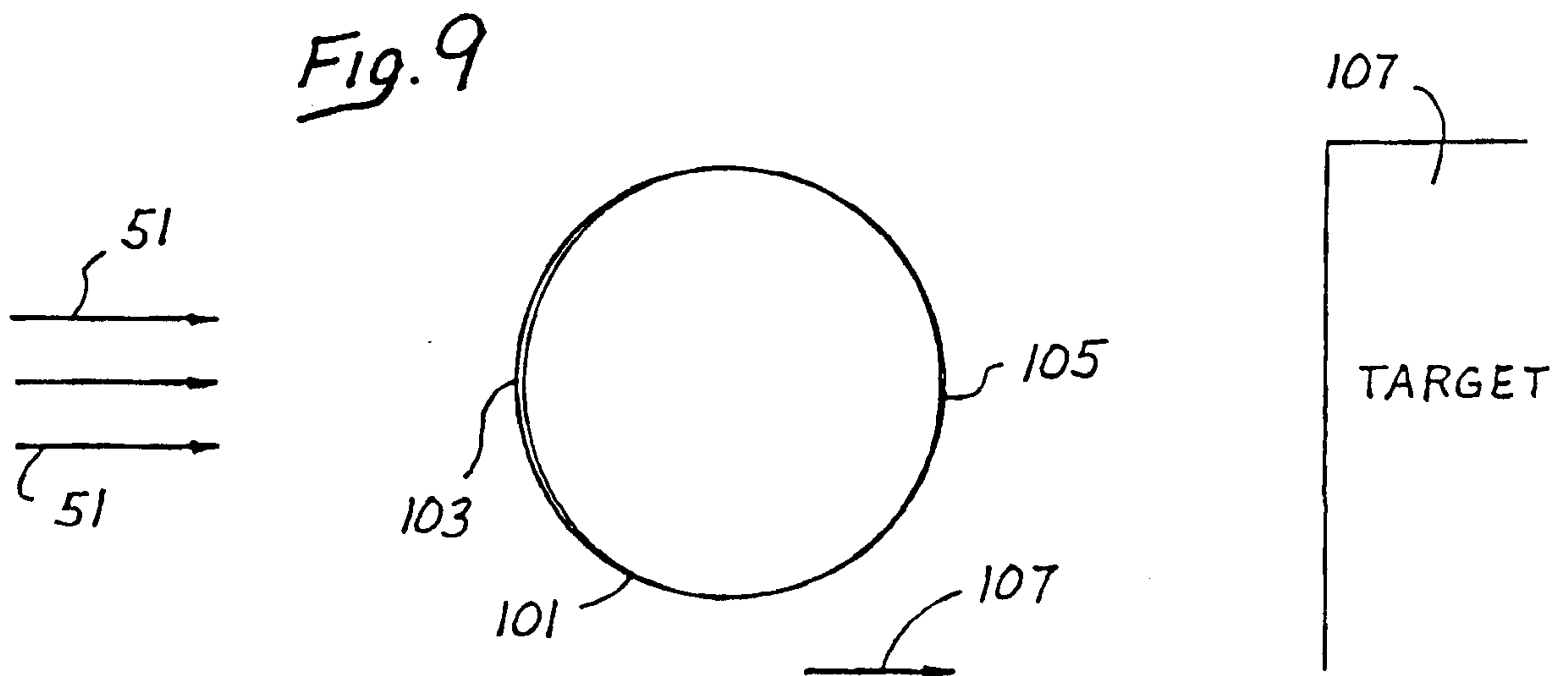
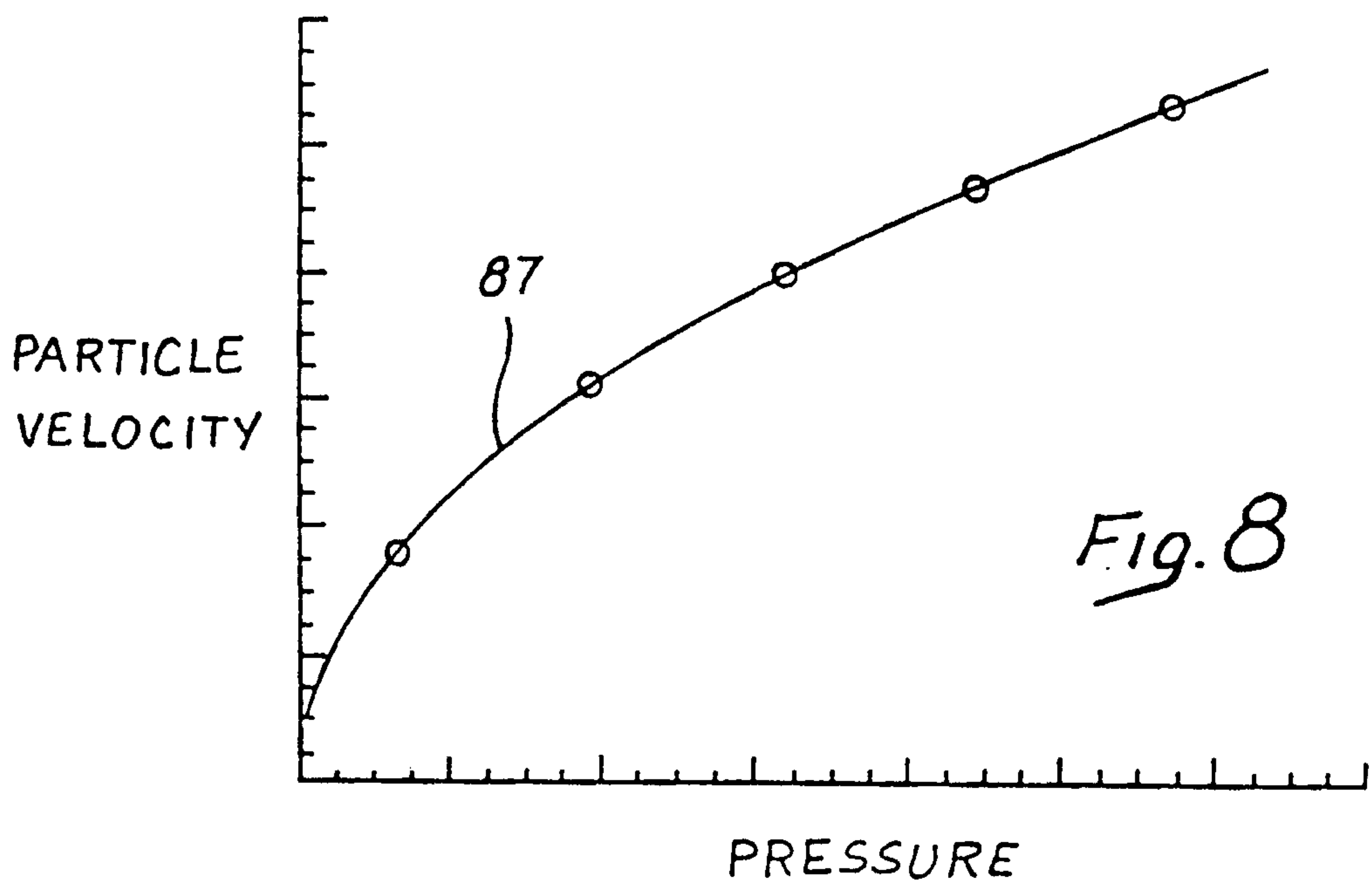
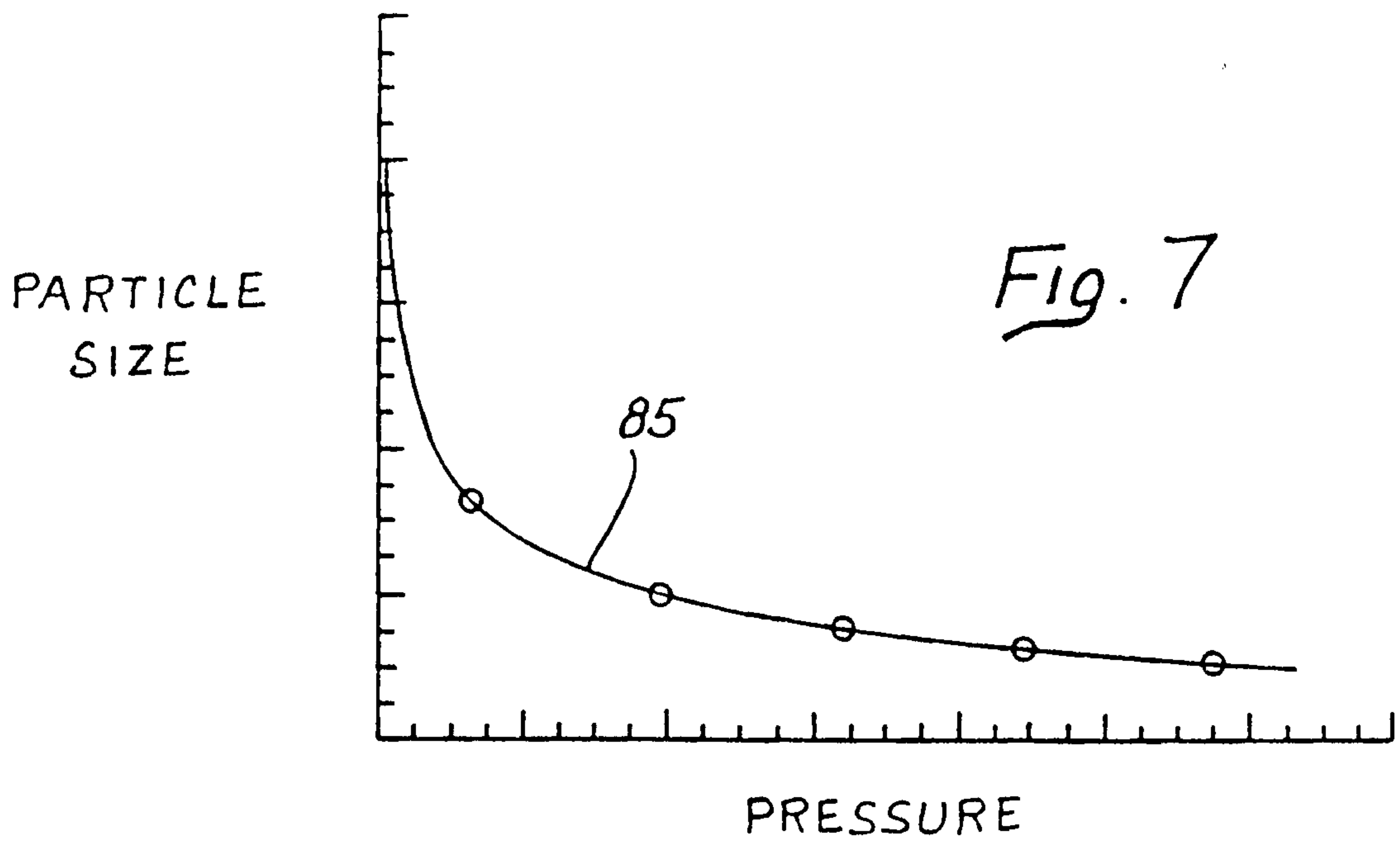
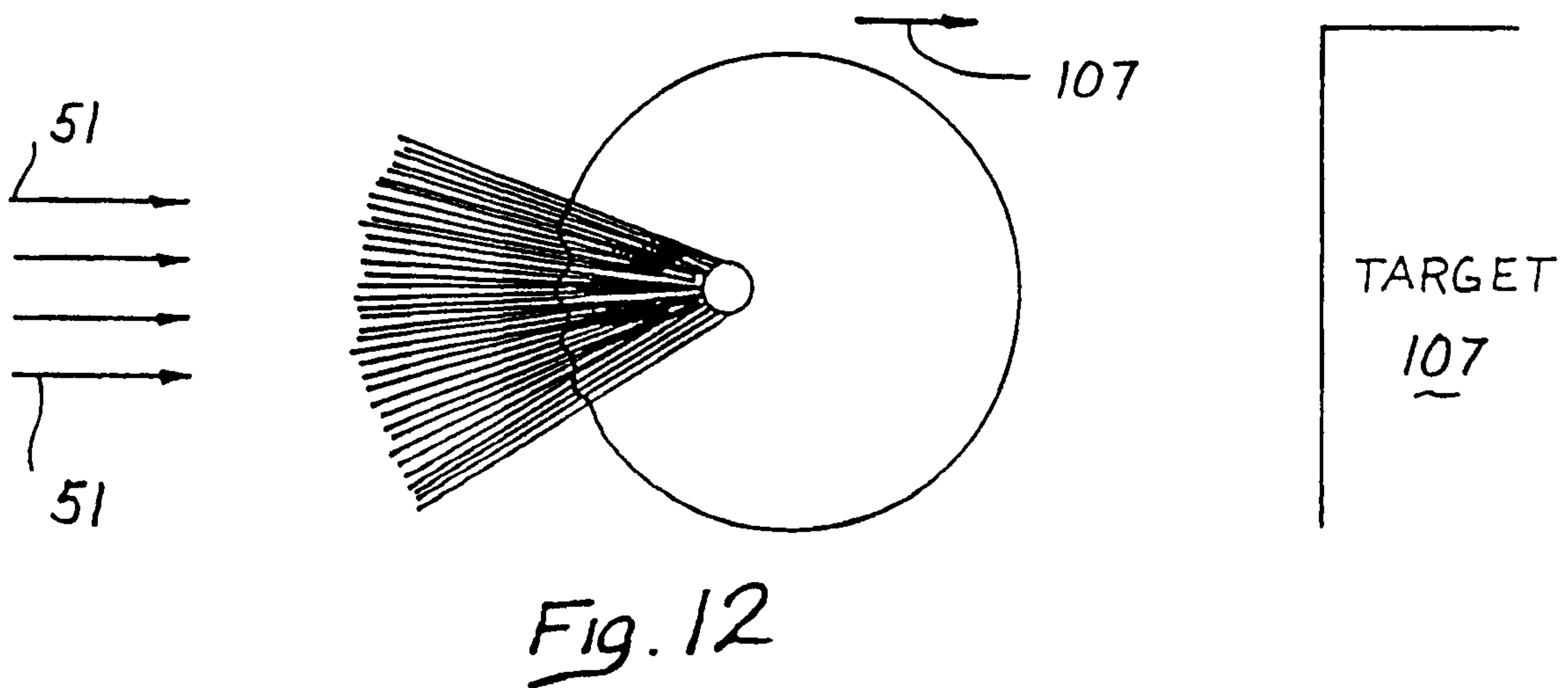
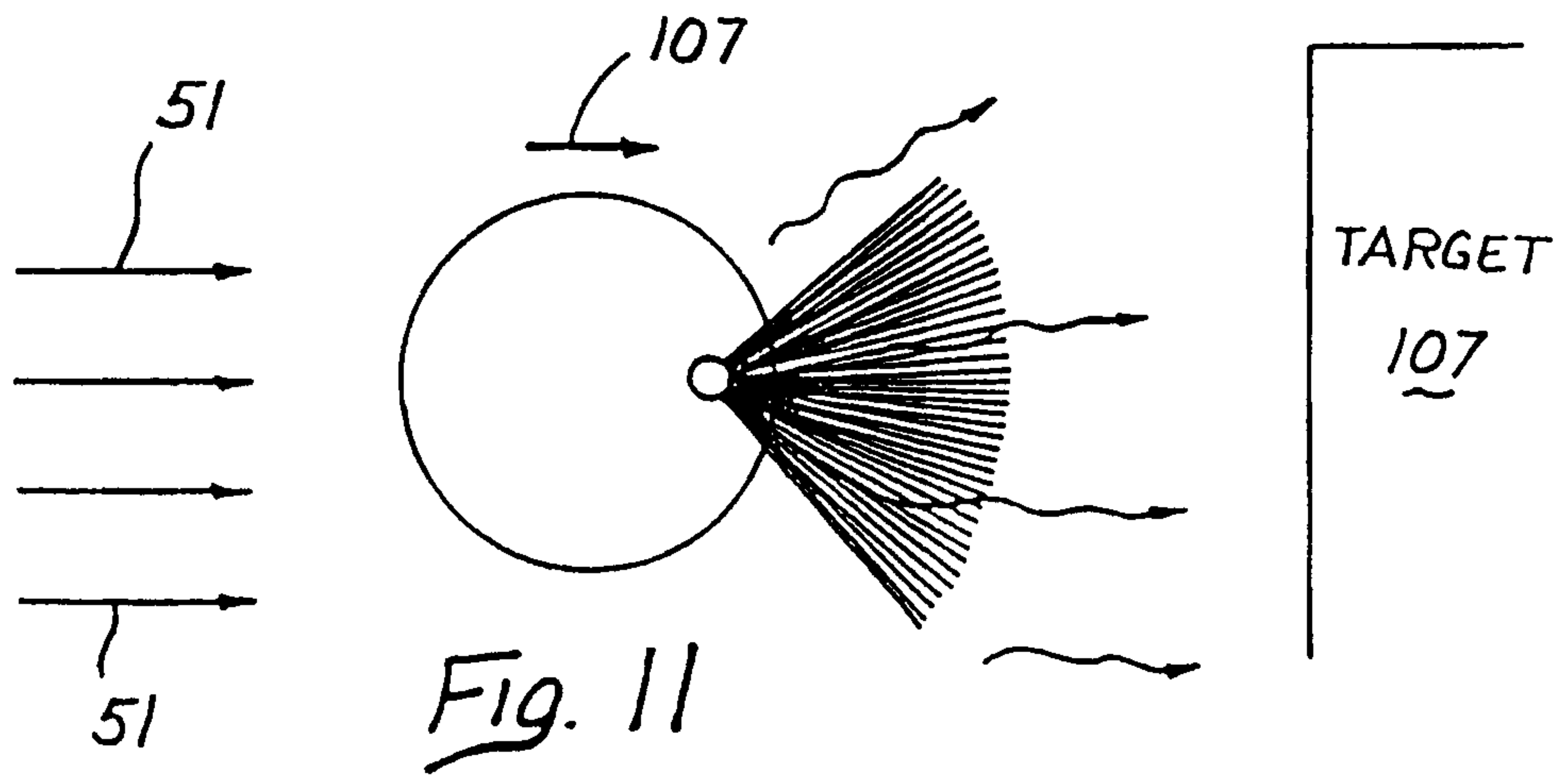
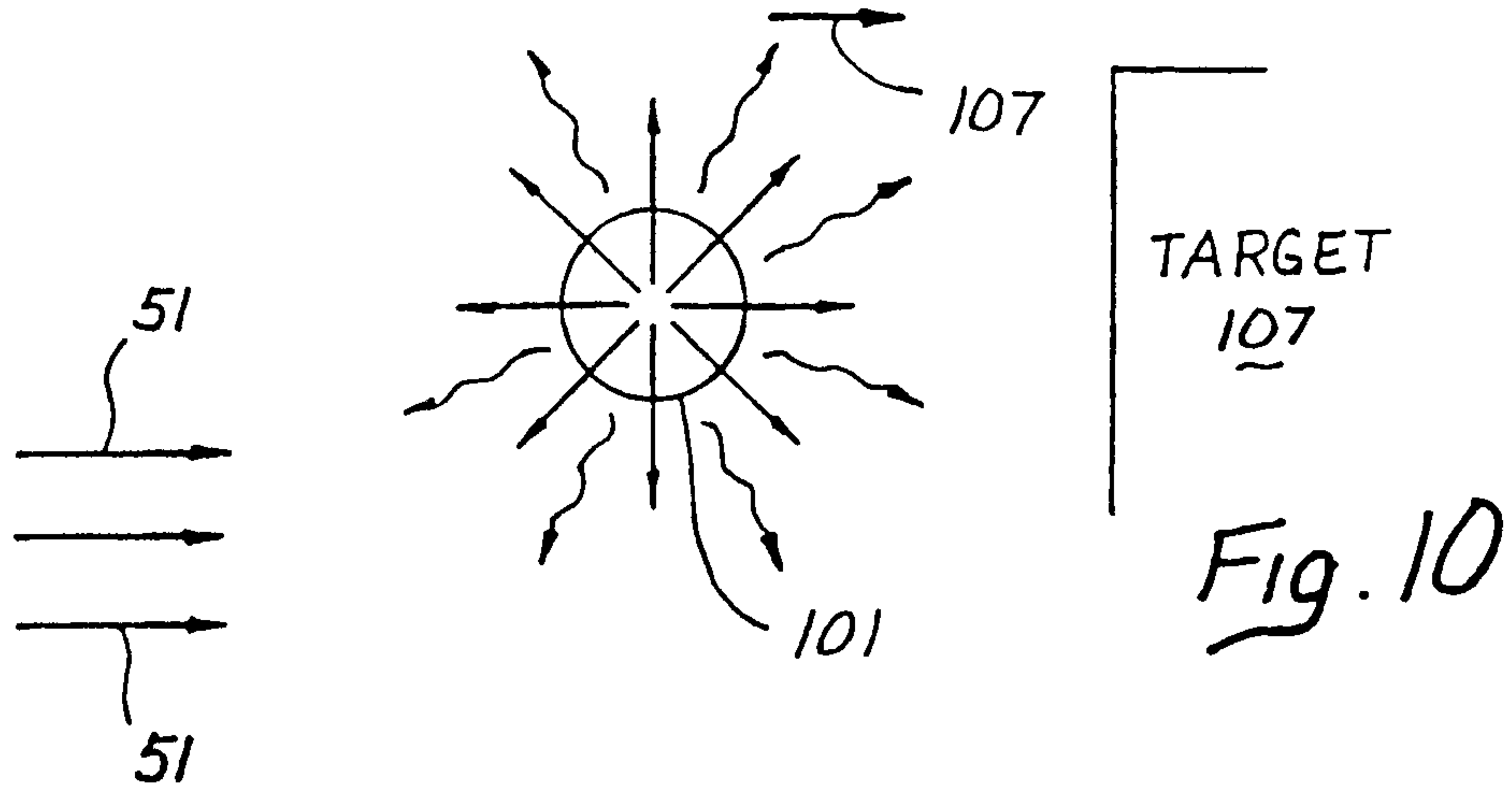


Fig. 6

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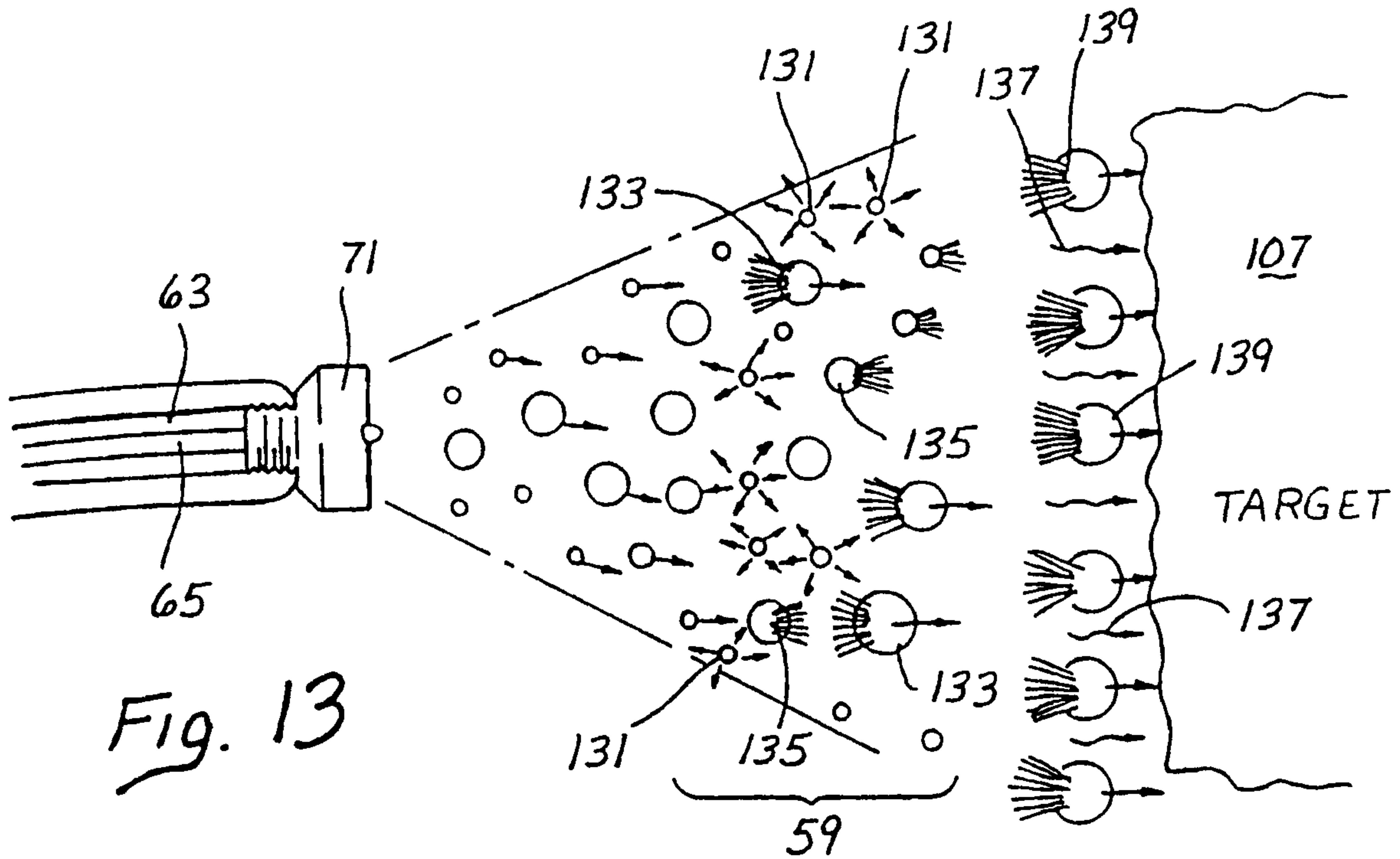


Fig. 13

Fig. 14

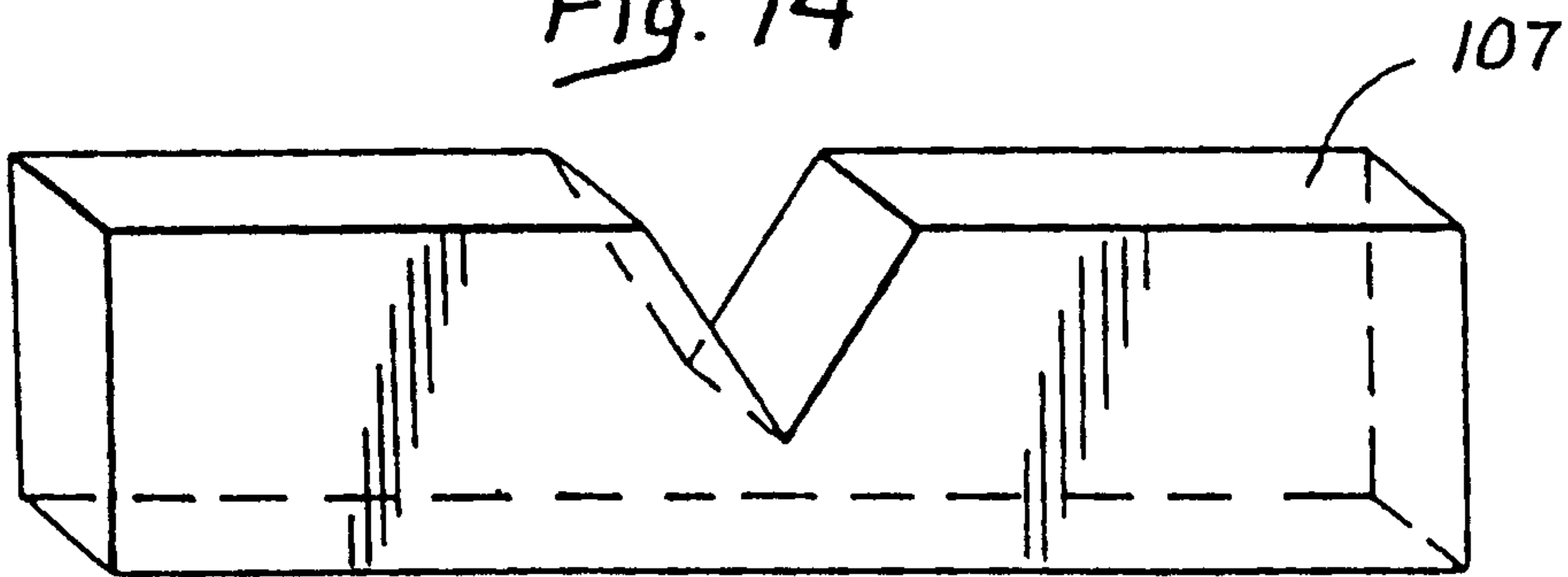
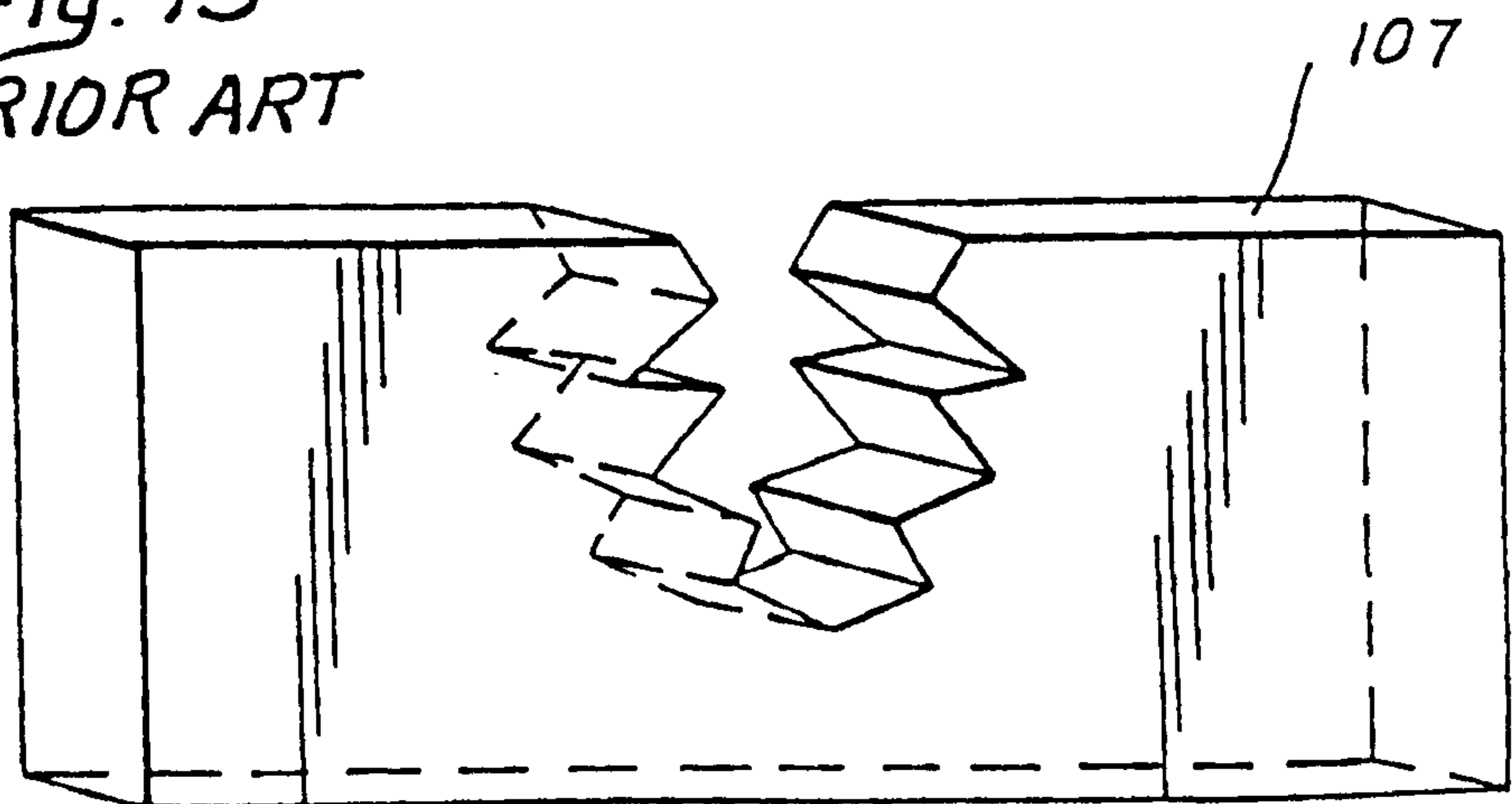
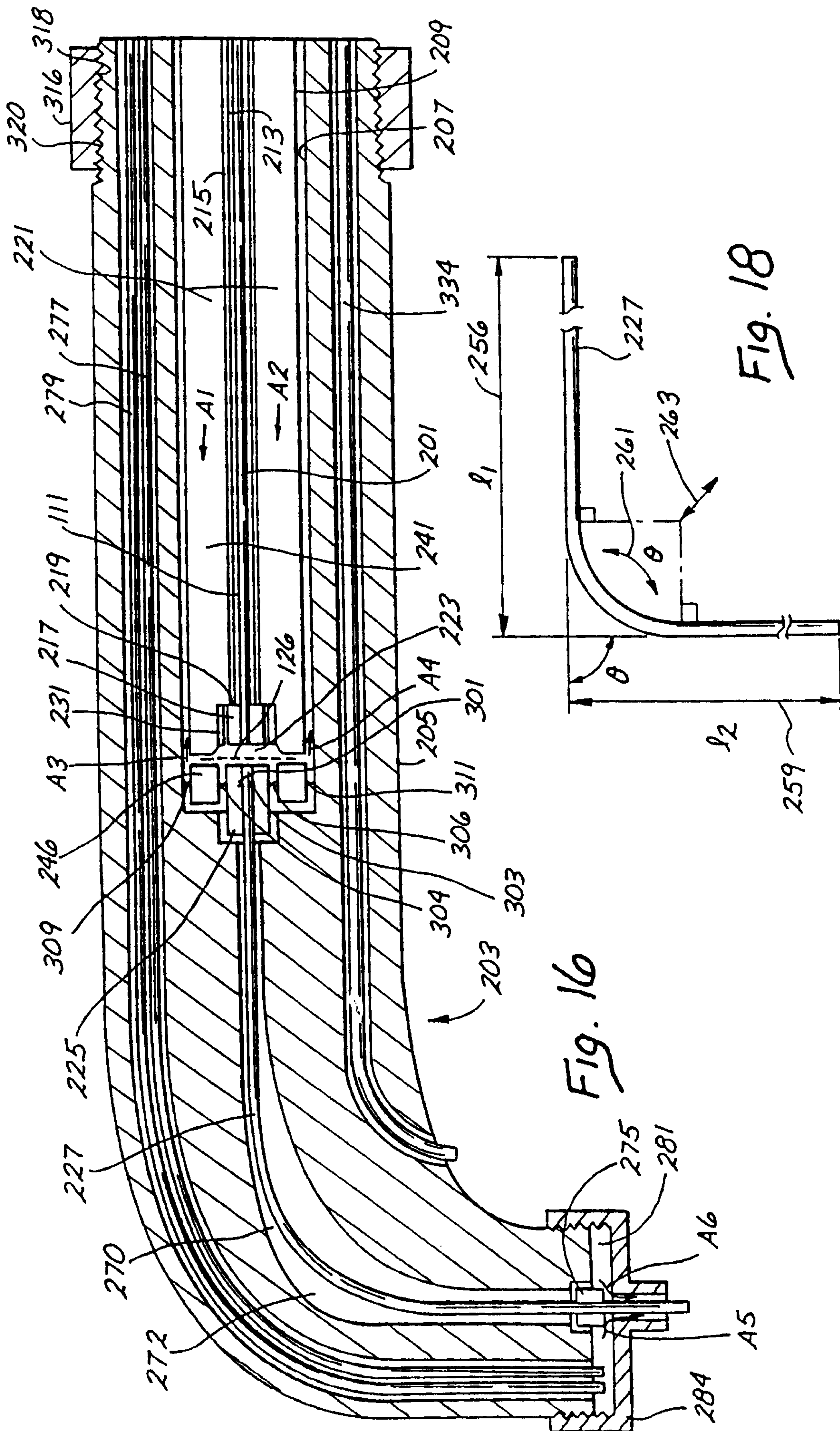


Fig. 15
PRIOR ART





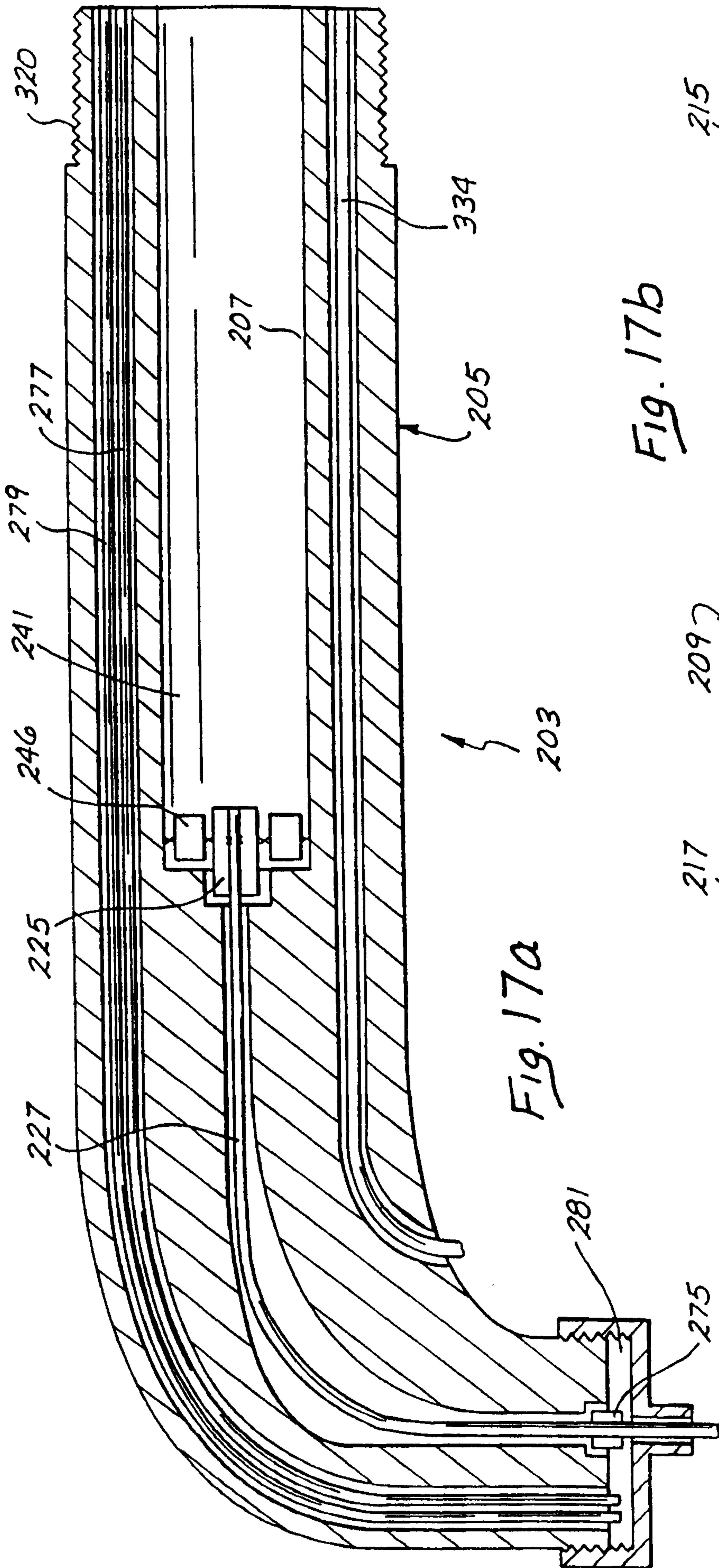


Fig. 17a

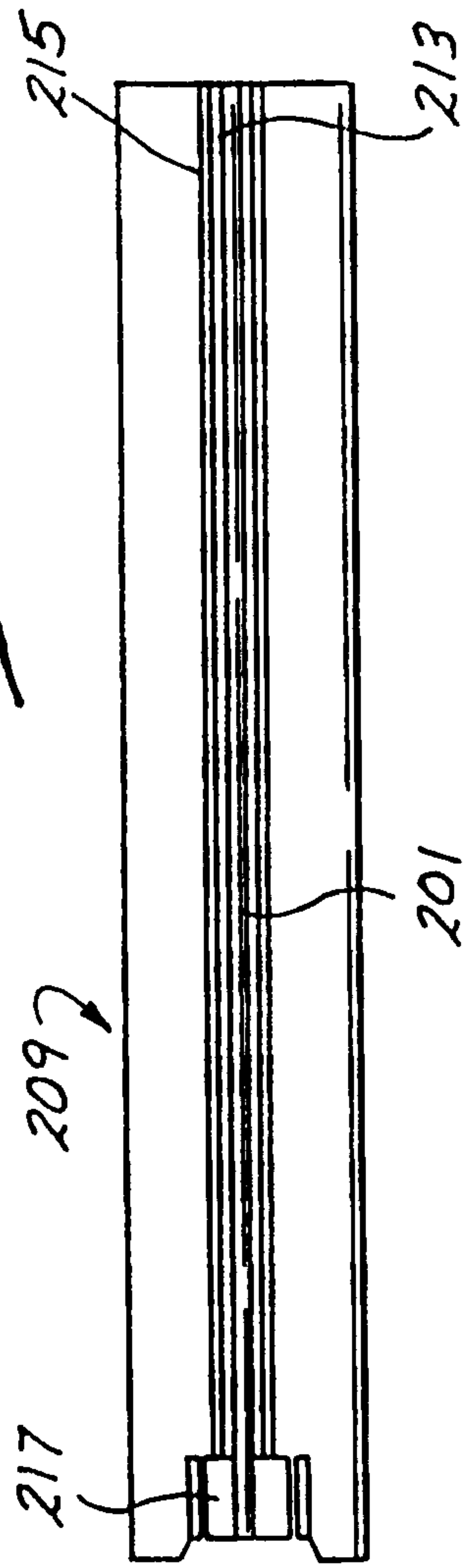
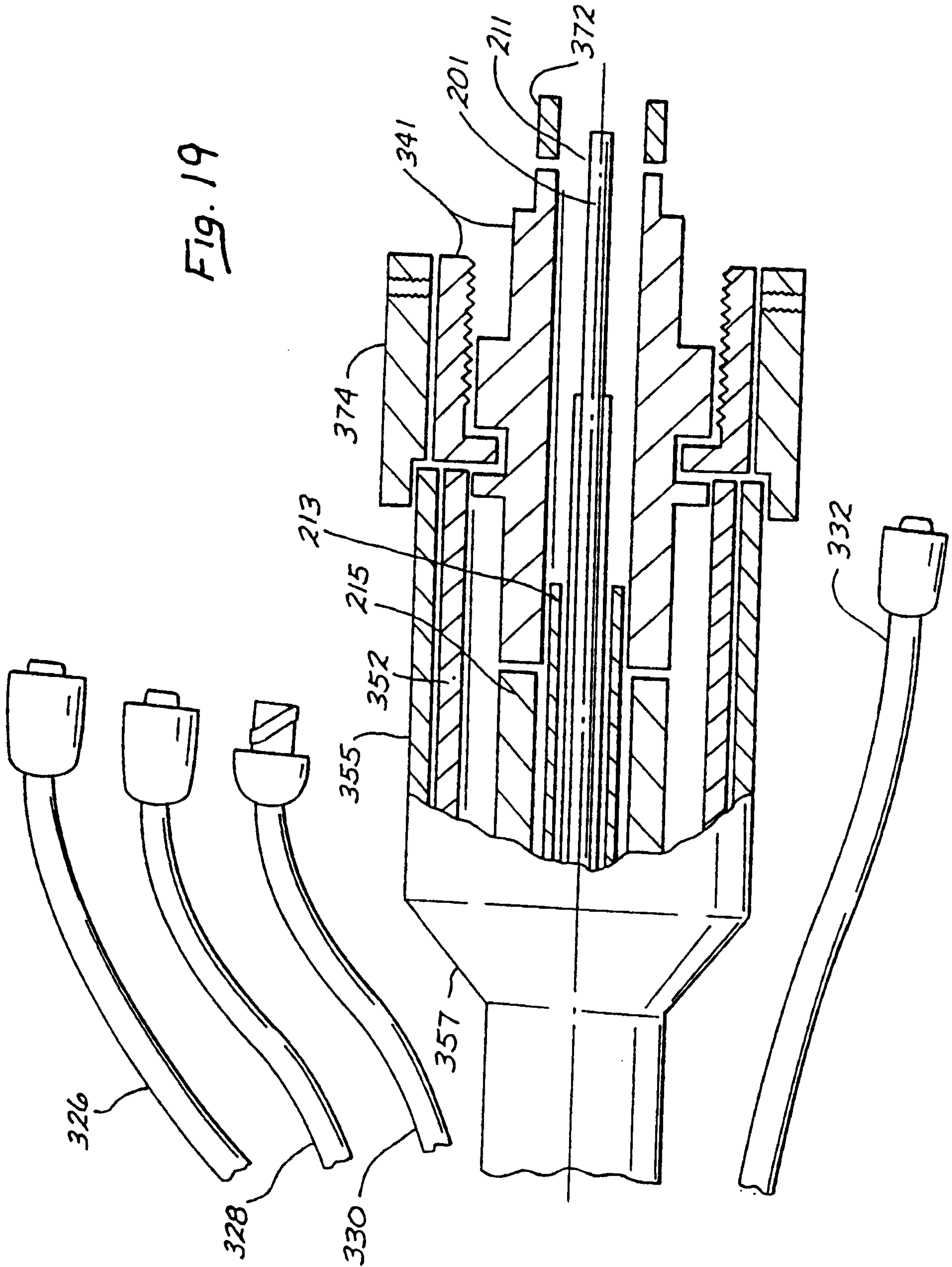
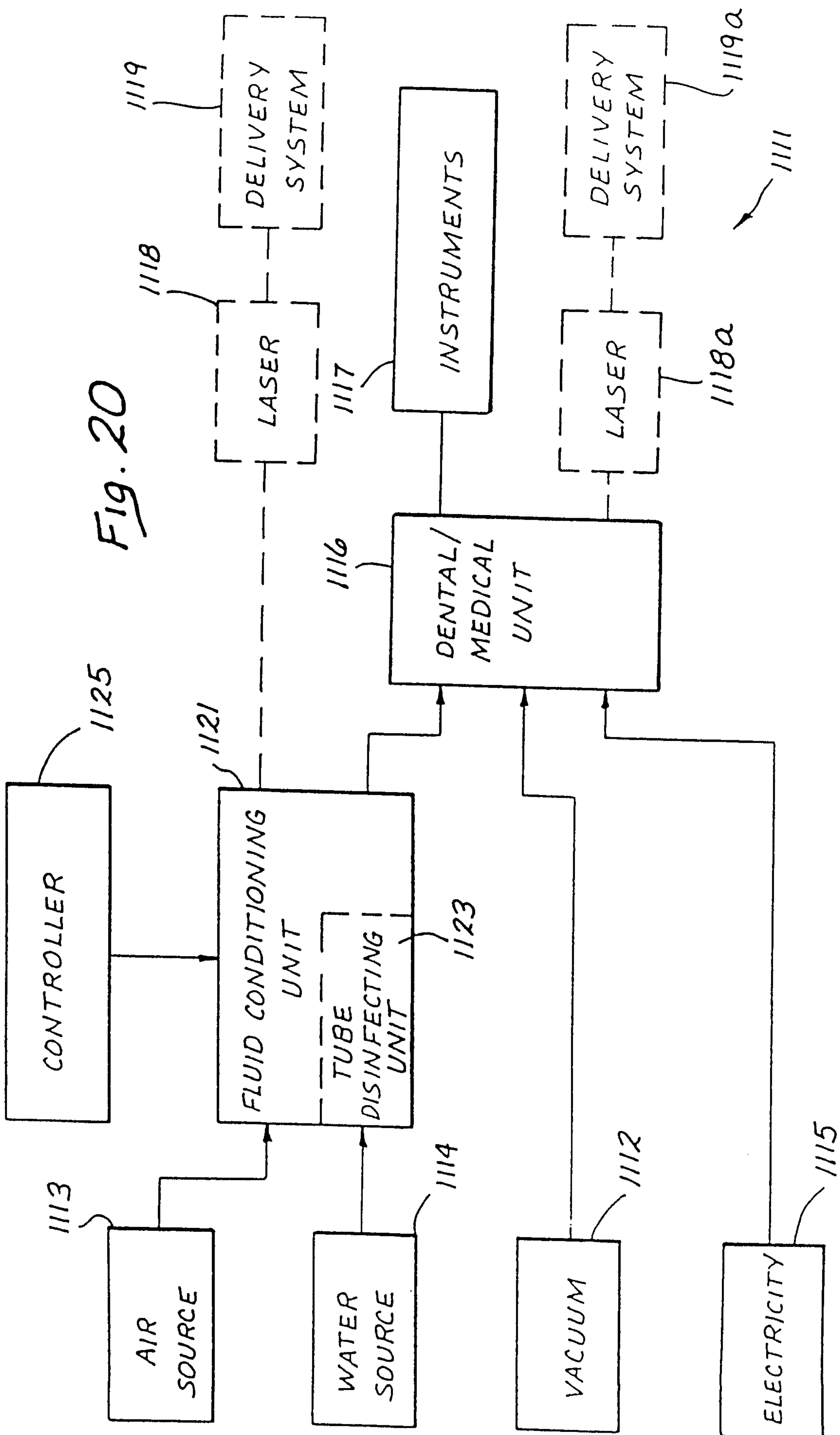


Fig. 17b

Fig. 19





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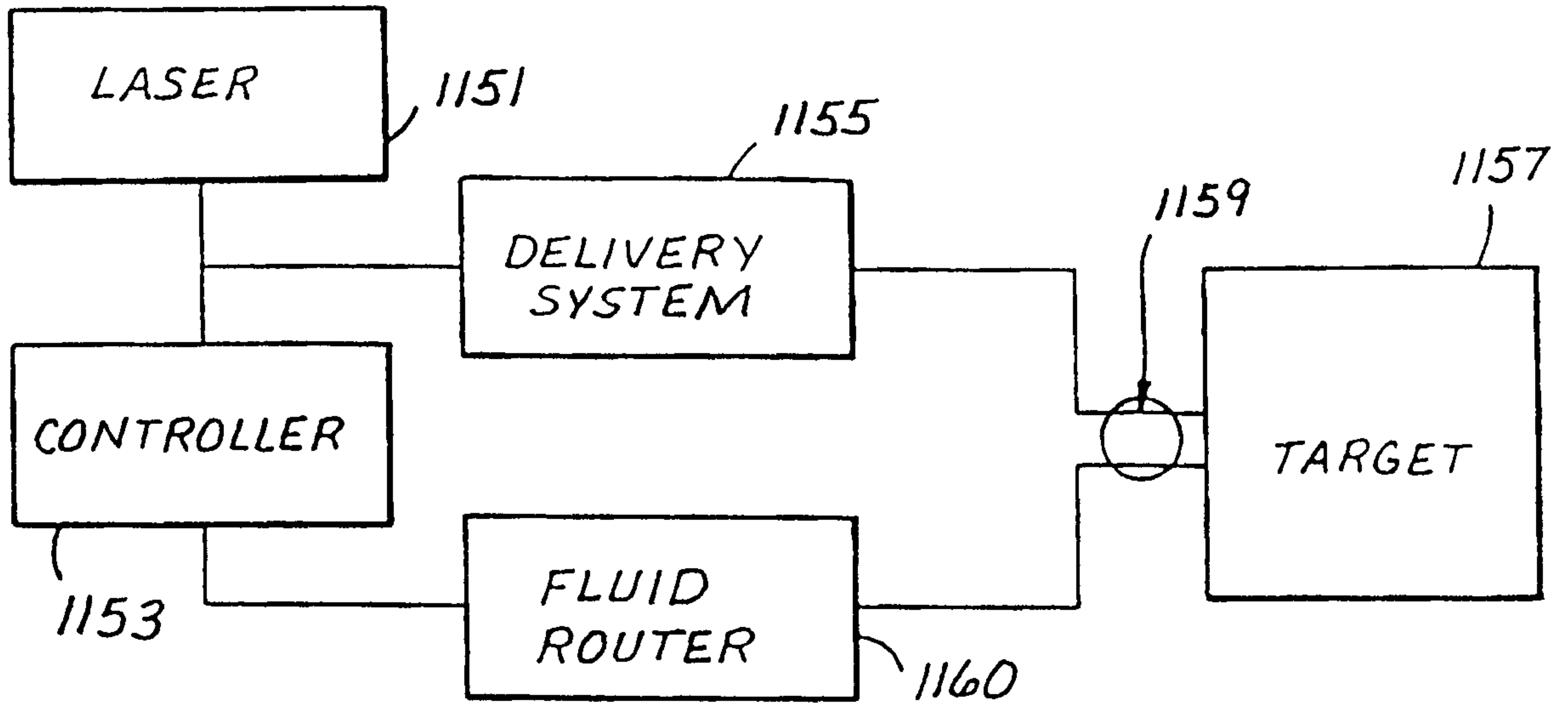


Fig. 21

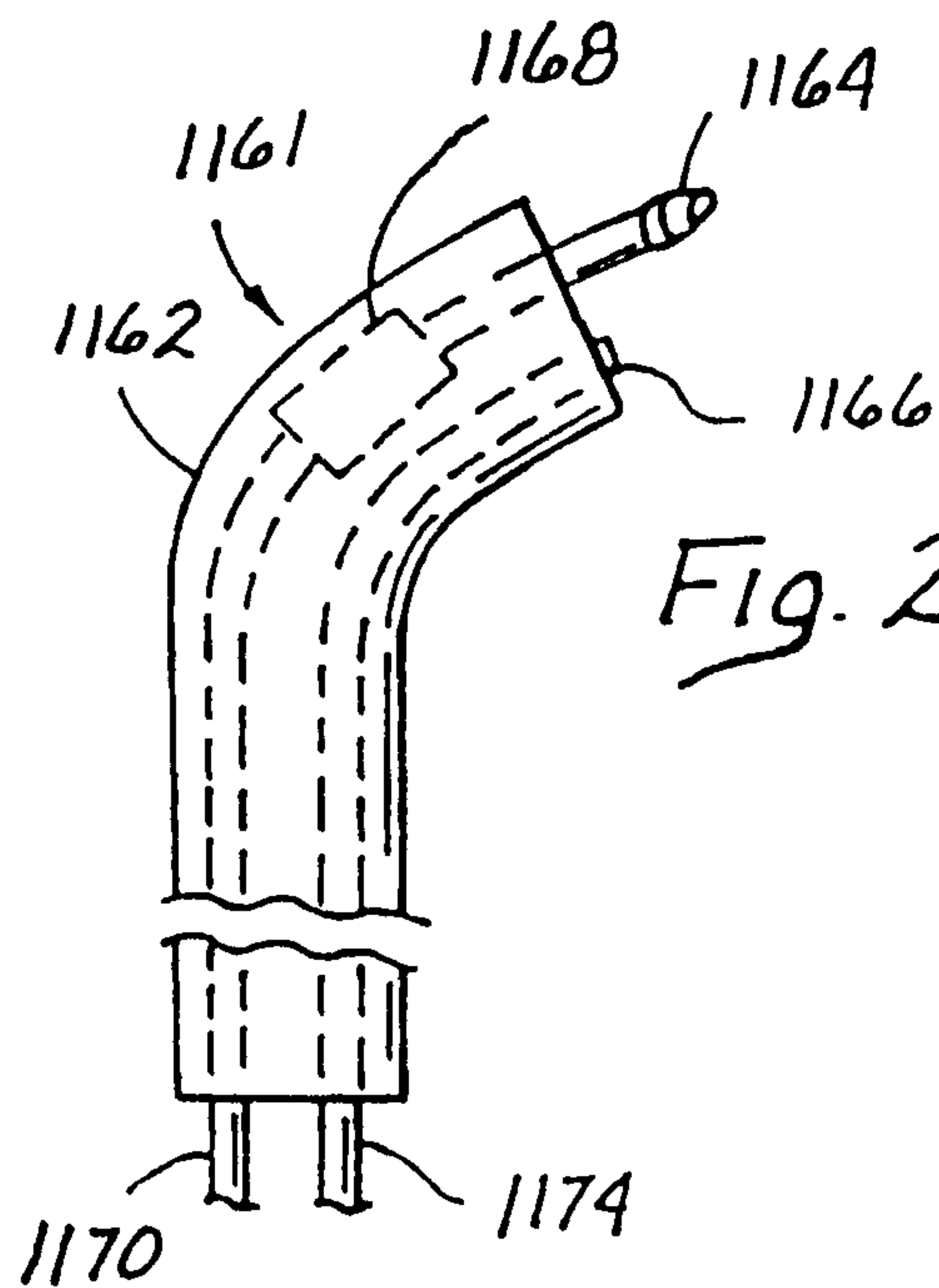
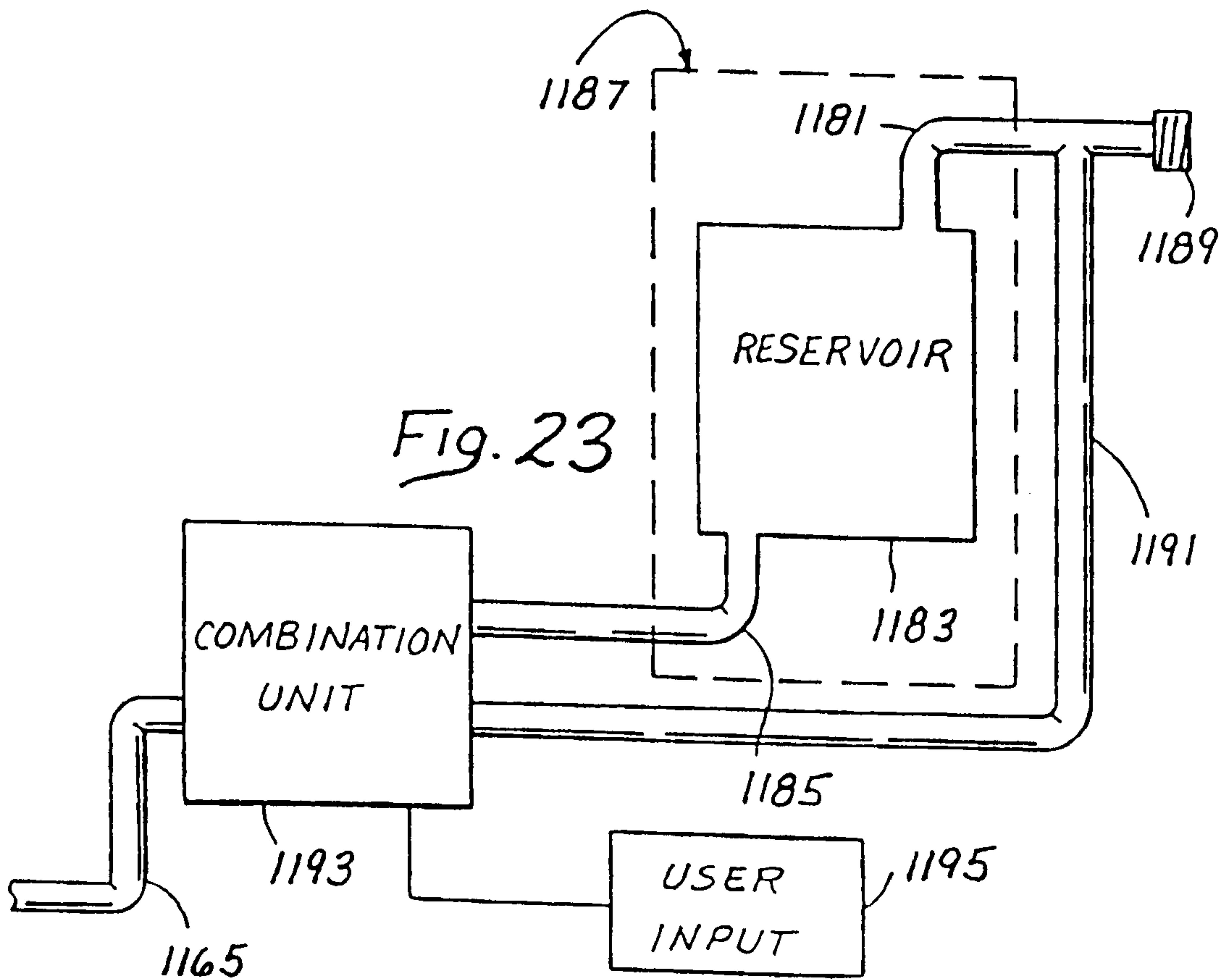
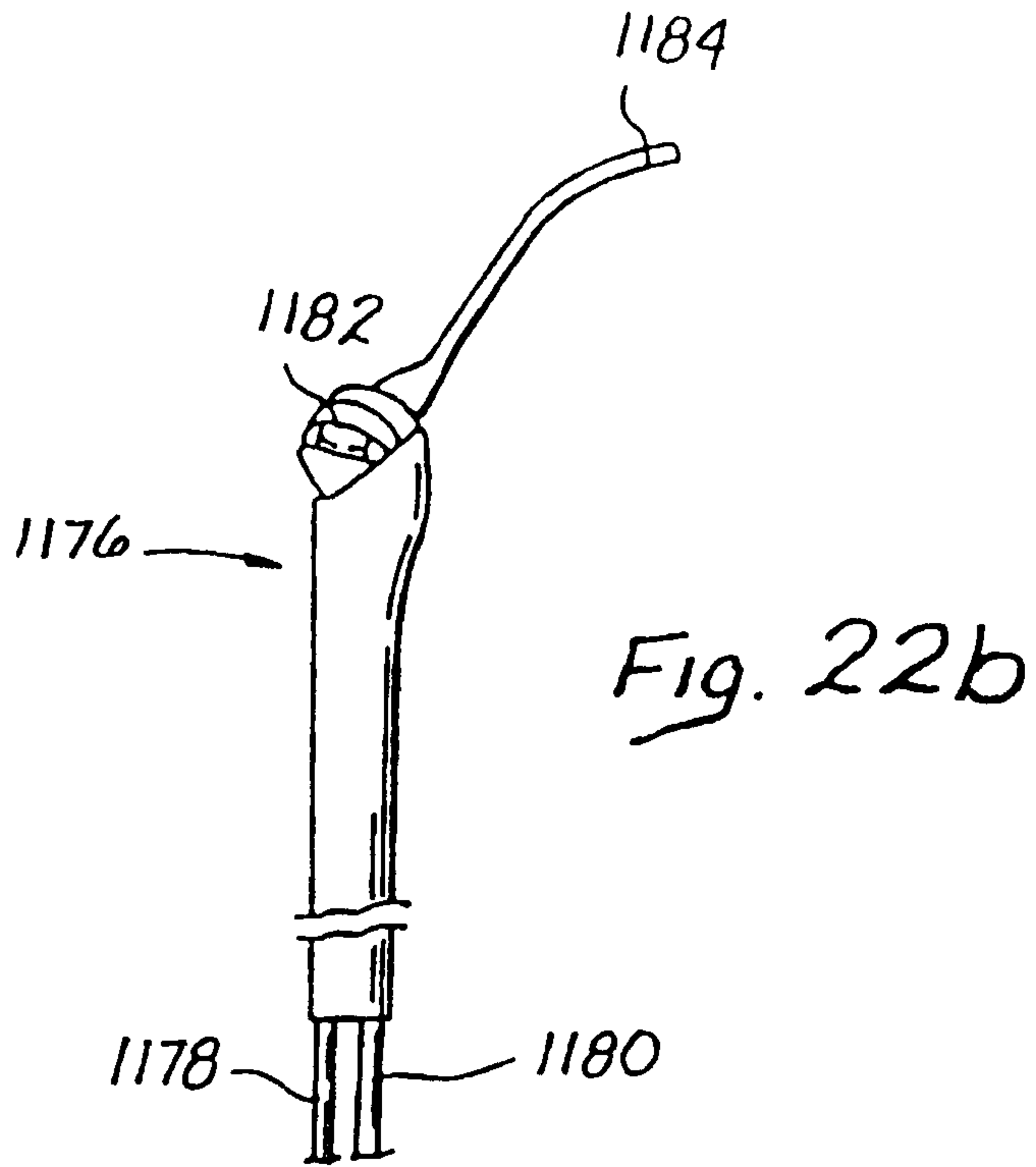


Fig. 22a

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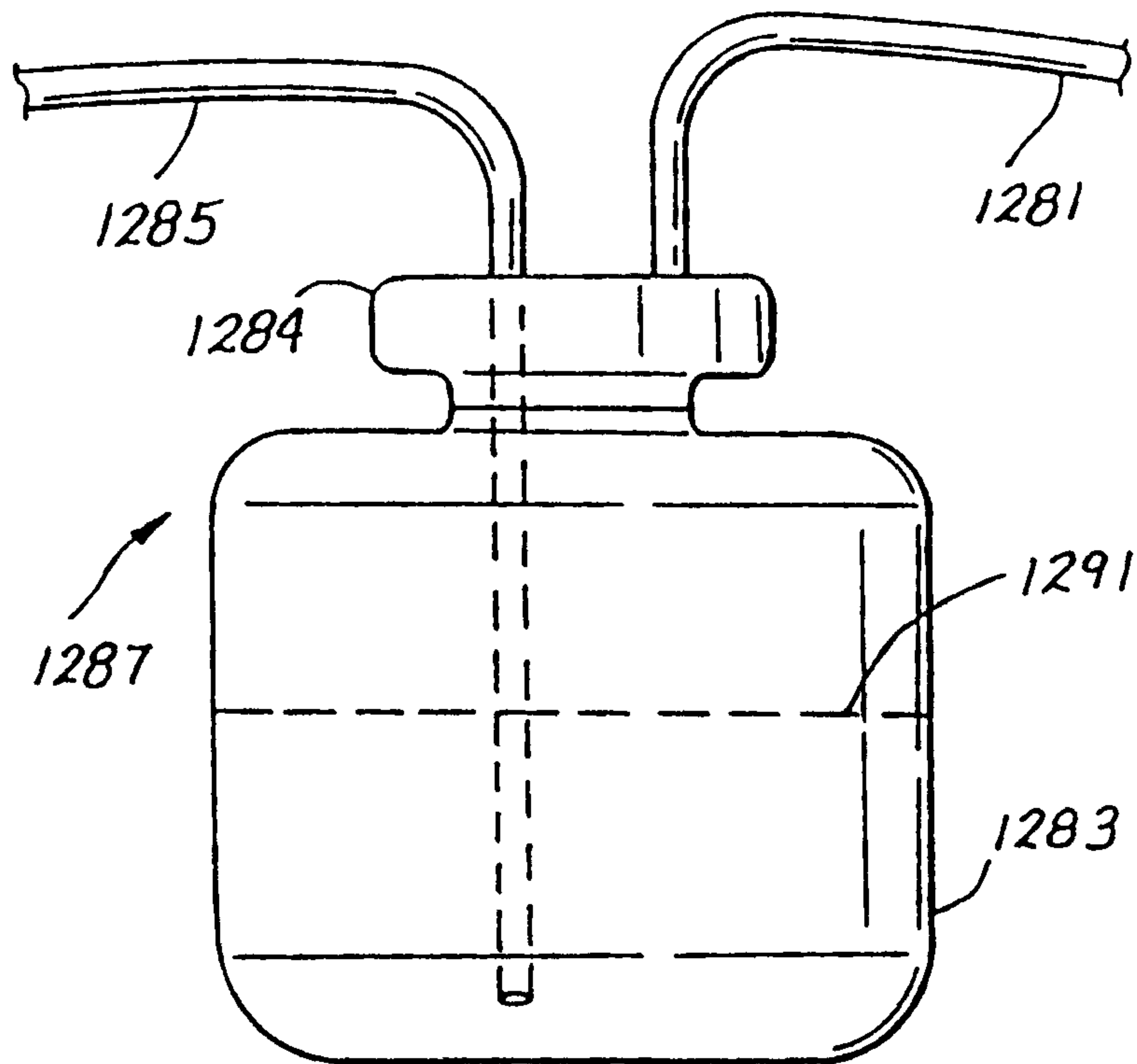


Fig. 24

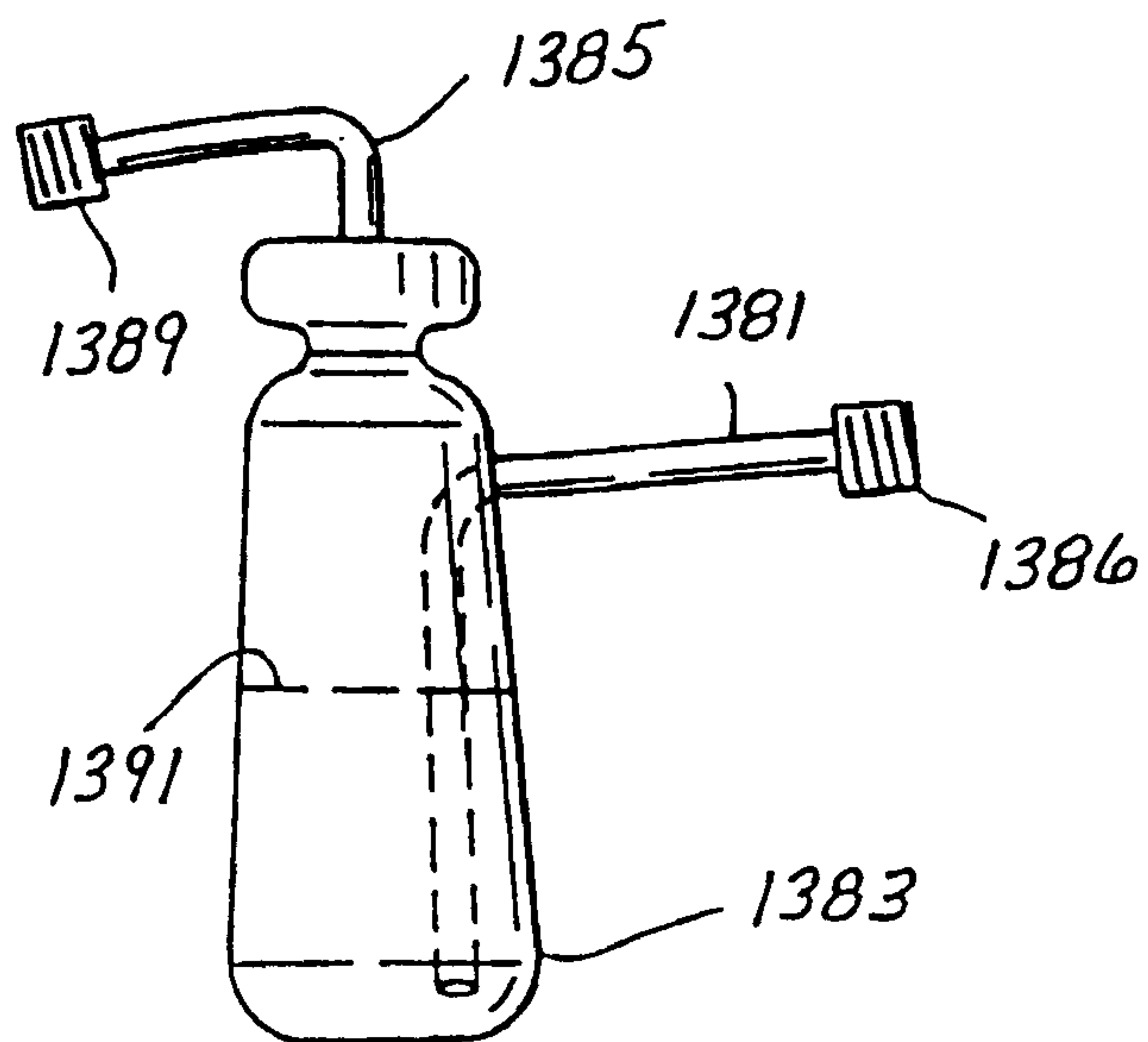


Fig. 25

