US006813289B2

(12) **United States Patent**
Gruzdev et al.

(10) **Patent No.: US 6,813,289 B2**
(45) **Date of Patent: Nov. 2, 2004**

(54) **PORTABLE LASER DEVICE**

(75) Inventors: **Valentin A. Gruzdev**, Moscow (RU); **Pavel V. Efremkin**, Ardsley, NY (US)

(73) Assignee: **Innotech, USA, Inc.**, Tarrytown, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/202,325**

(22) Filed: **Jul. 24, 2002**

(65) **Prior Publication Data**

US 2003/0021312 A1 Jan. 30, 2003

Related U.S. Application Data

(60) Provisional application No. 60/307,628, filed on Jul. 25, 2001.

(51) **Int. Cl.**[7] **H01S 3/04**
(52) **U.S. Cl.** **372/34**
(58) **Field of Search** 372/34–36

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,096,450	A	*	6/1978	Hill et al.	331/94.5
4,232,276	A	*	11/1980	Iwata	331/94.5
4,612,646	A	*	9/1986	Zerr	372/58
4,887,270	A	*	12/1989	Austin	372/22
4,901,324	A	*	2/1990	Martin	372/36
4,953,176	A		8/1990	Ekstrand	
5,165,418	A		11/1992	Tankovich	
5,172,388	A	*	12/1992	Long et al.	372/70
5,251,223	A		10/1993	Hiroshima	
5,253,261	A		10/1993	Chaffee	
5,432,811	A		7/1995	Polushkin et al.	
5,481,556	A		1/1996	Daikuzono	
5,548,604	A	*	8/1996	Toepel	372/35
5,572,538	A	*	11/1996	Saitoh et al.	372/34
5,868,731	A		2/1999	Budnik et al.	
5,940,420	A		8/1999	Blair et al.	
6,251,102	B1		6/2001	Gruzdev et al.	
6,550,934	B2	*	4/2003	Tao et al.	362/260

OTHER PUBLICATIONS

WO 85/00688, Feb. 1985, O'Connor, G12B 15/02.*

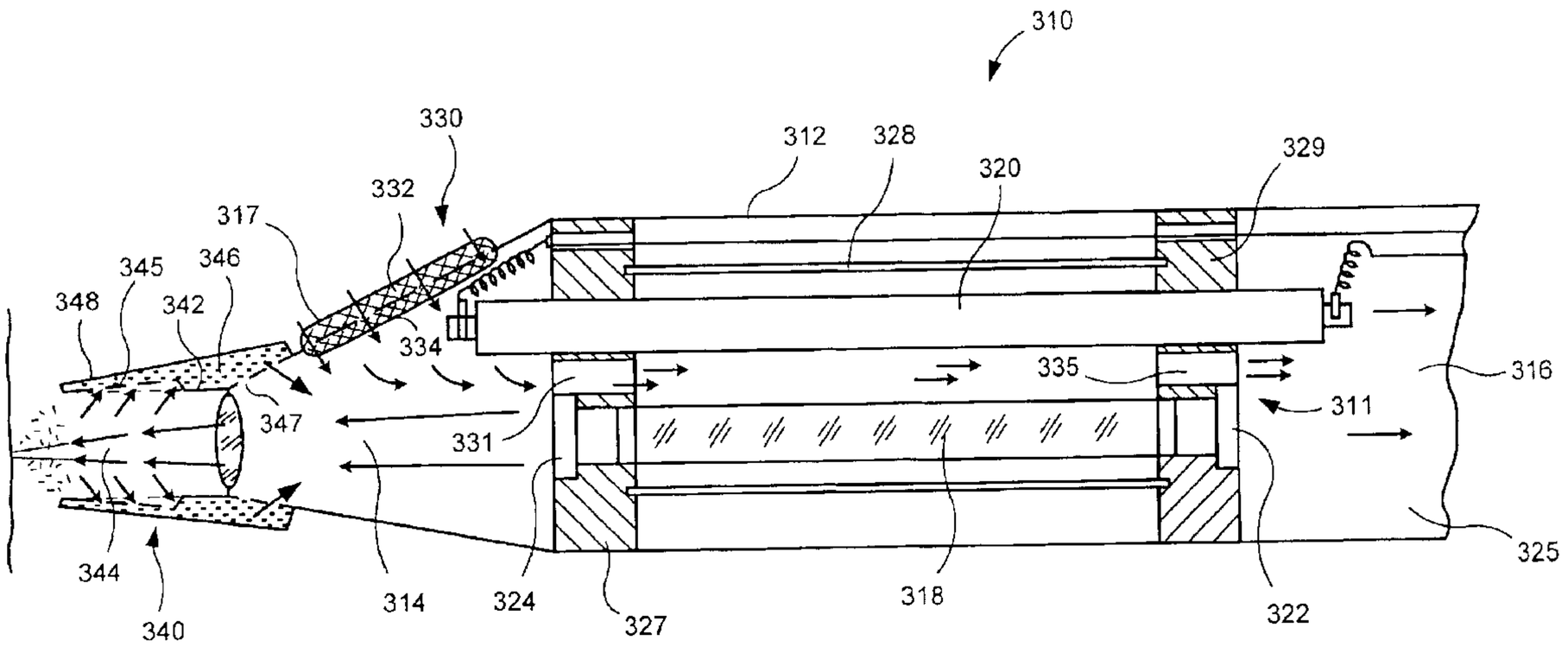
* cited by examiner

Primary Examiner—David Porta
Assistant Examiner—Davienne Monbleau
(74) *Attorney, Agent, or Firm*—Lawrence G. Fridman

(57) **ABSTRACT**

A hand-held laser device includes a casing formed with a substantially hollow interior space and having a laser emitter thereinside. The laser emitter is formed with an exciting lamp and a laser rod. A source generating a stream of gaseous coolant is provided within the interior space. A fluid cooling arrangement at least partially surrounding the laser rod is disposed within the stream of gaseous coolant for heat removal therefrom.

18 Claims, 6 Drawing Sheets



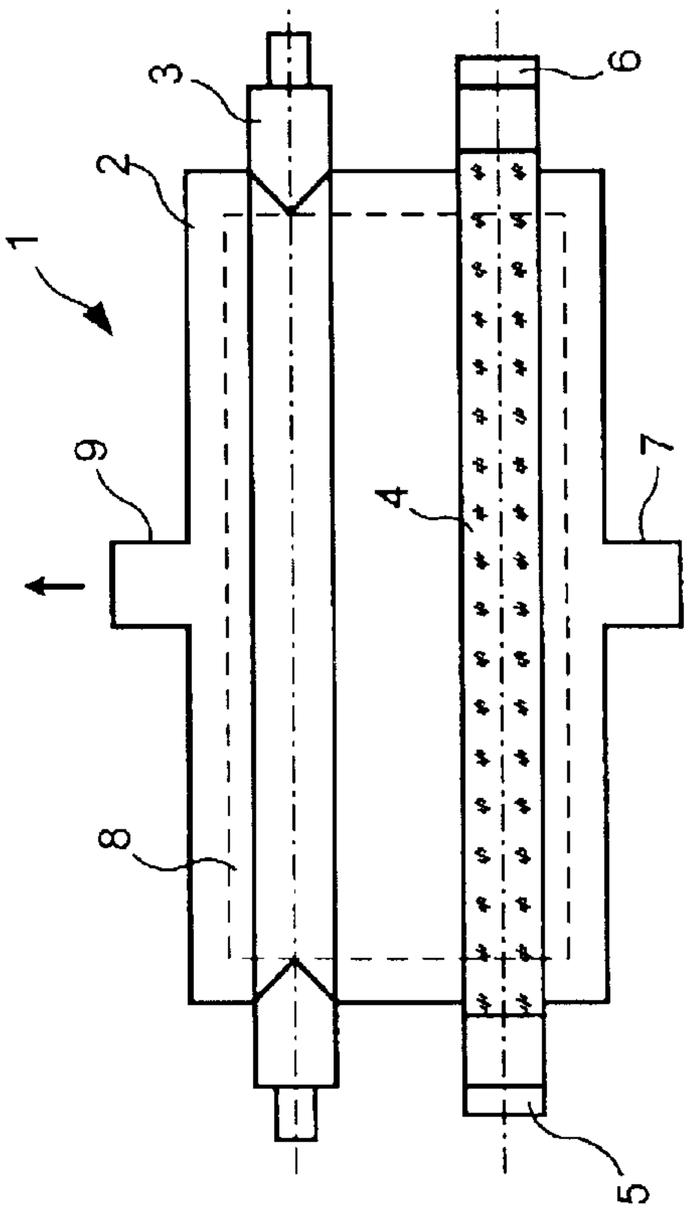


FIG. 1
PRIOR ART

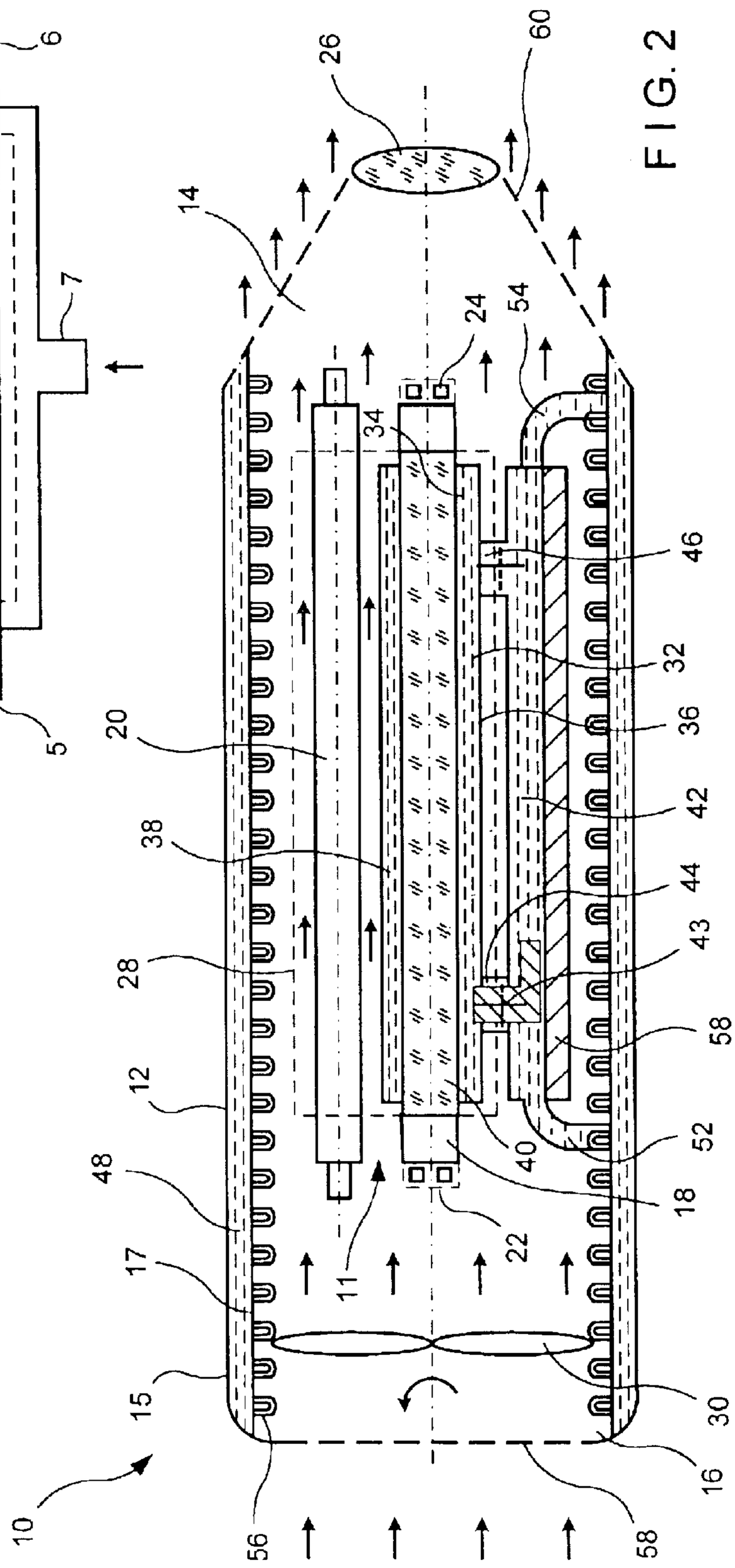


FIG. 2

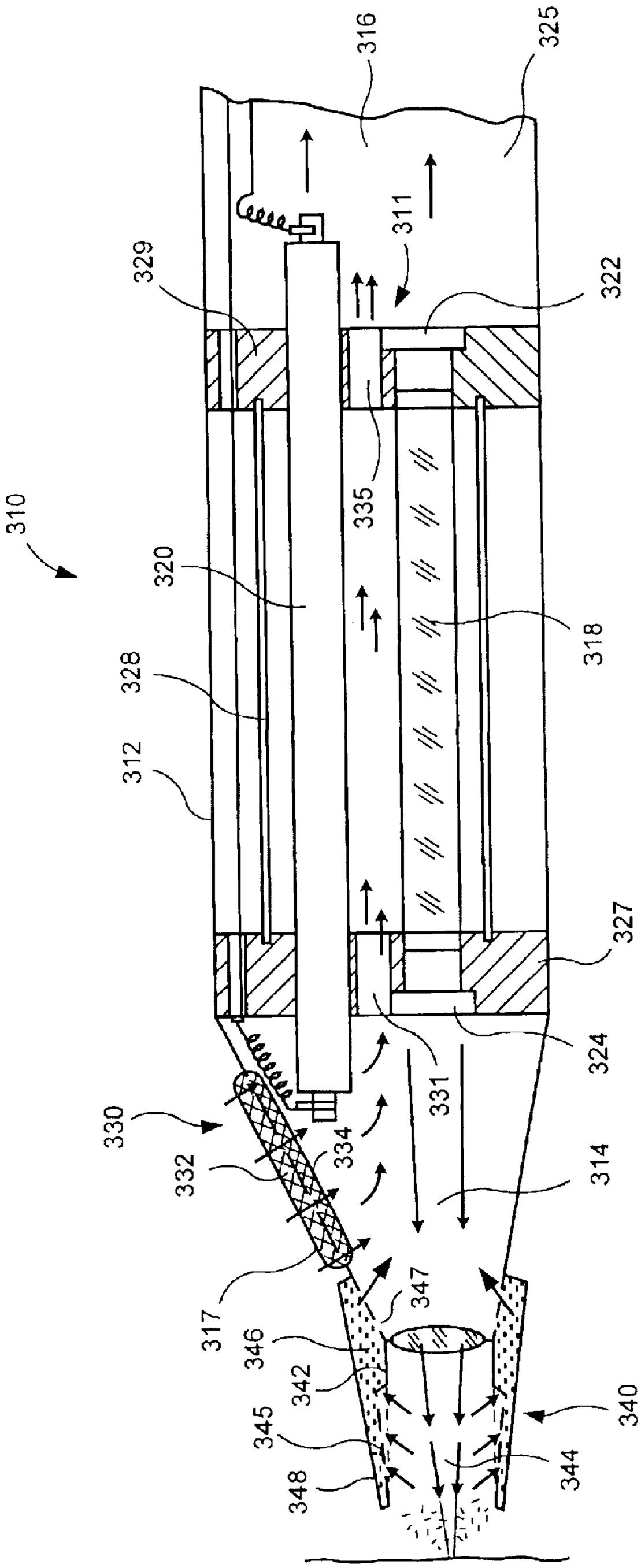

316
325
311
329
322
310
320
335
328
318
312
327
324
331
330
334
314
332
347
317
346
342
345
340
348
344

FIG. 3

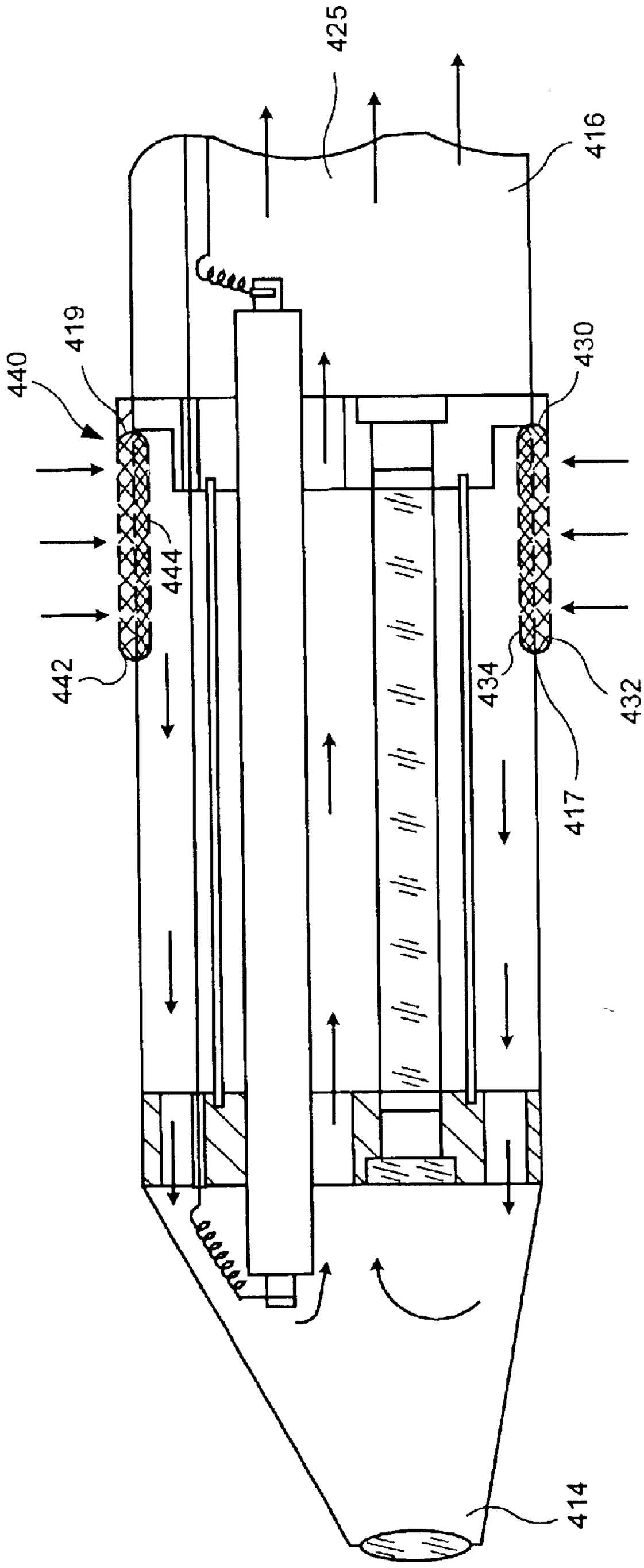


FIG. 4

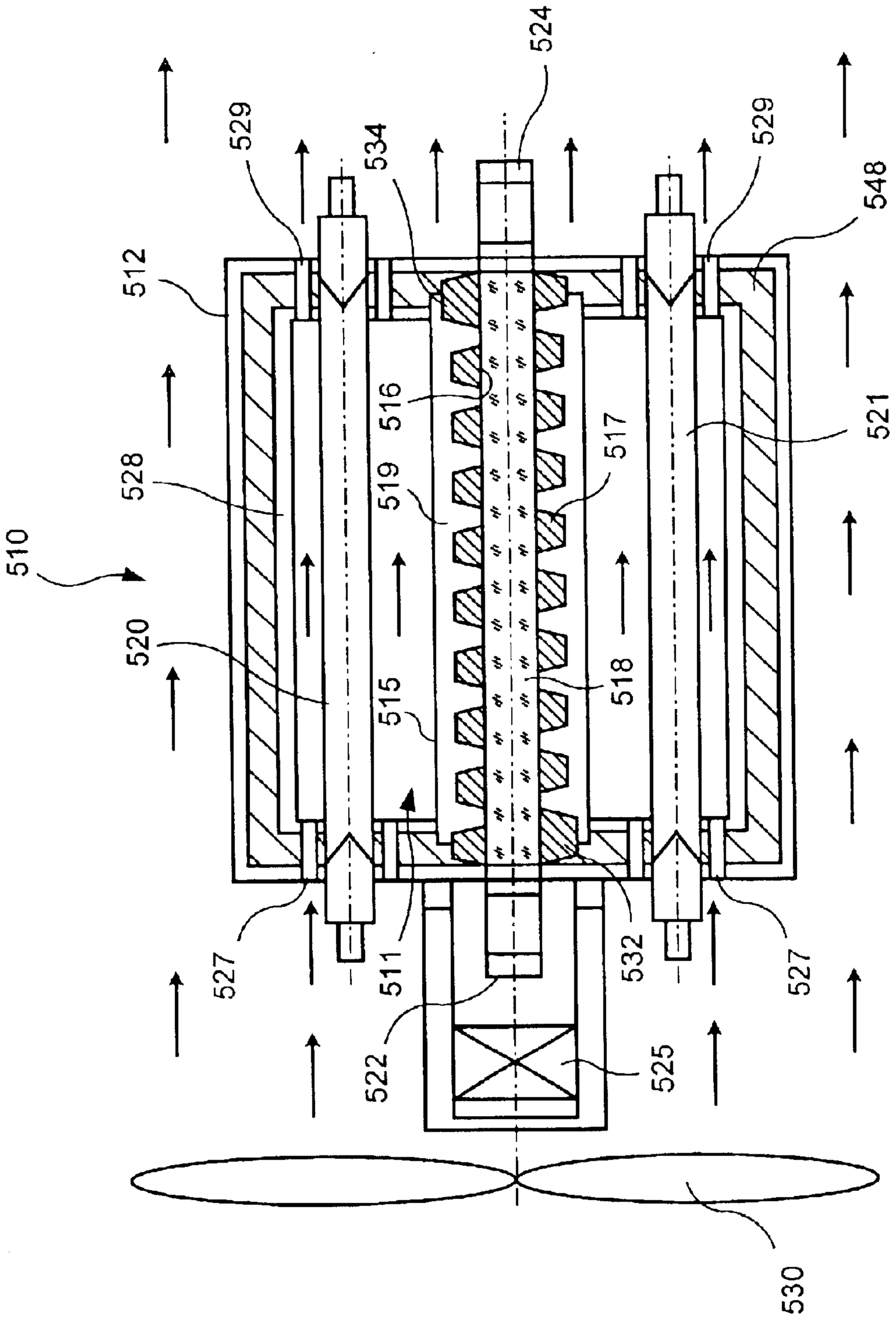

524
529
534
529
548
512
516
521
528
517
519
510
520
518
515
527
511
532
527
522
525
530

FIG. 5

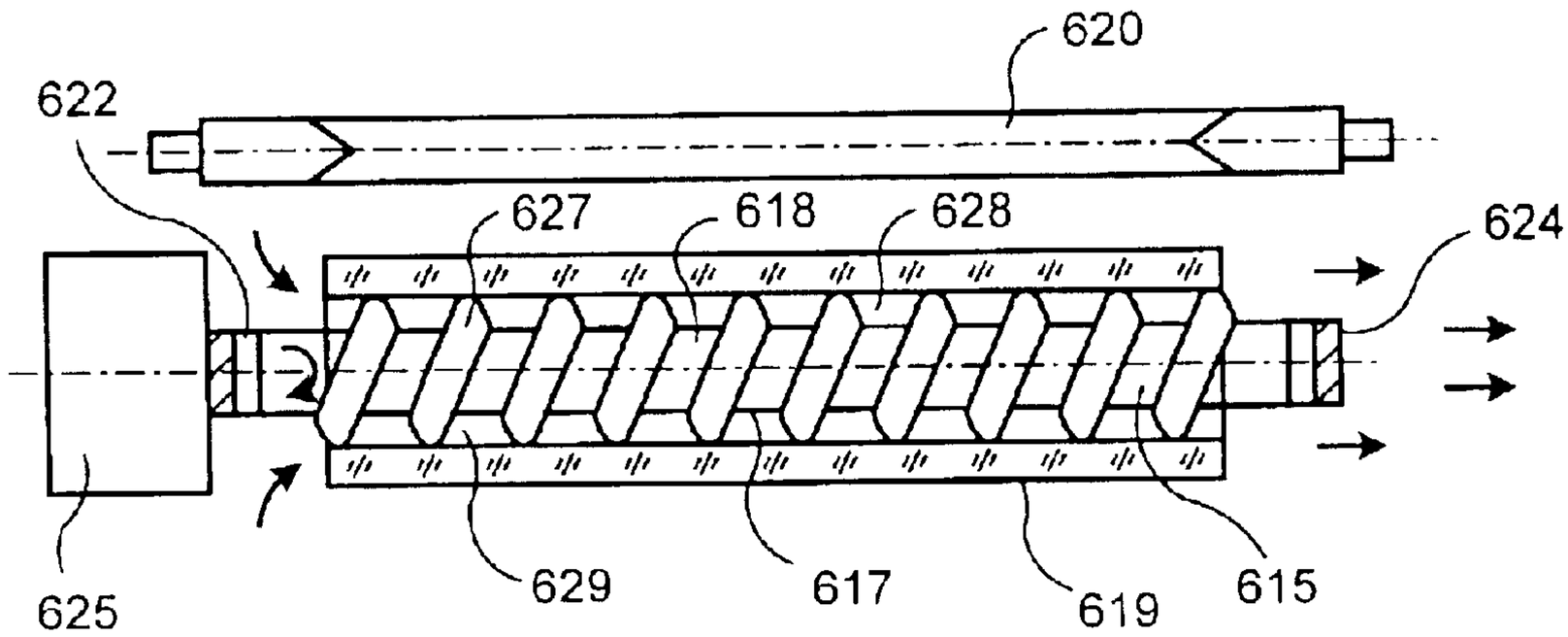

620
622
627
618
628
624
625
629
617
619
615

FIG. 6

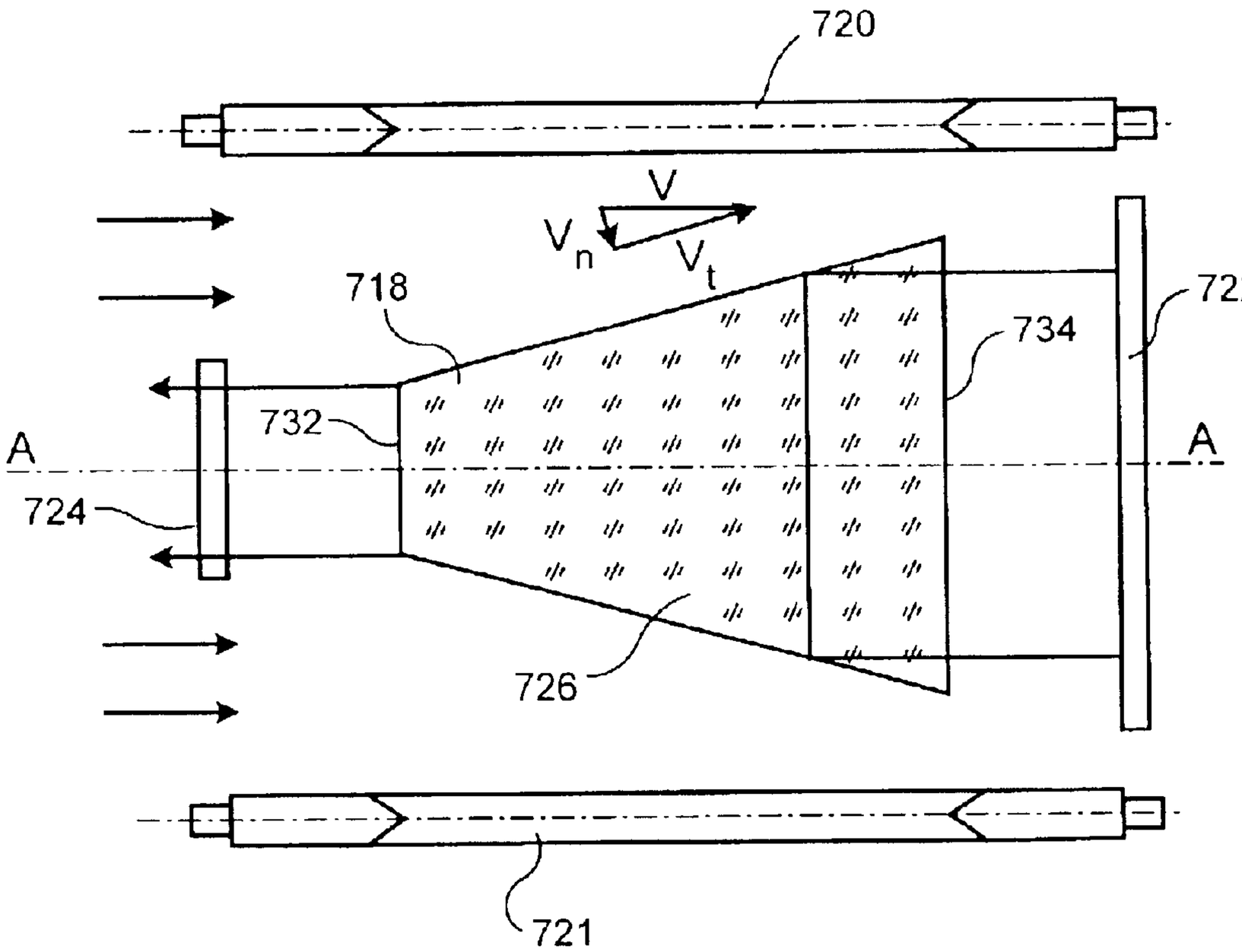

720
V
V_n
V_t
718
722
734
732
A
A
724
726
721

FIG. 7

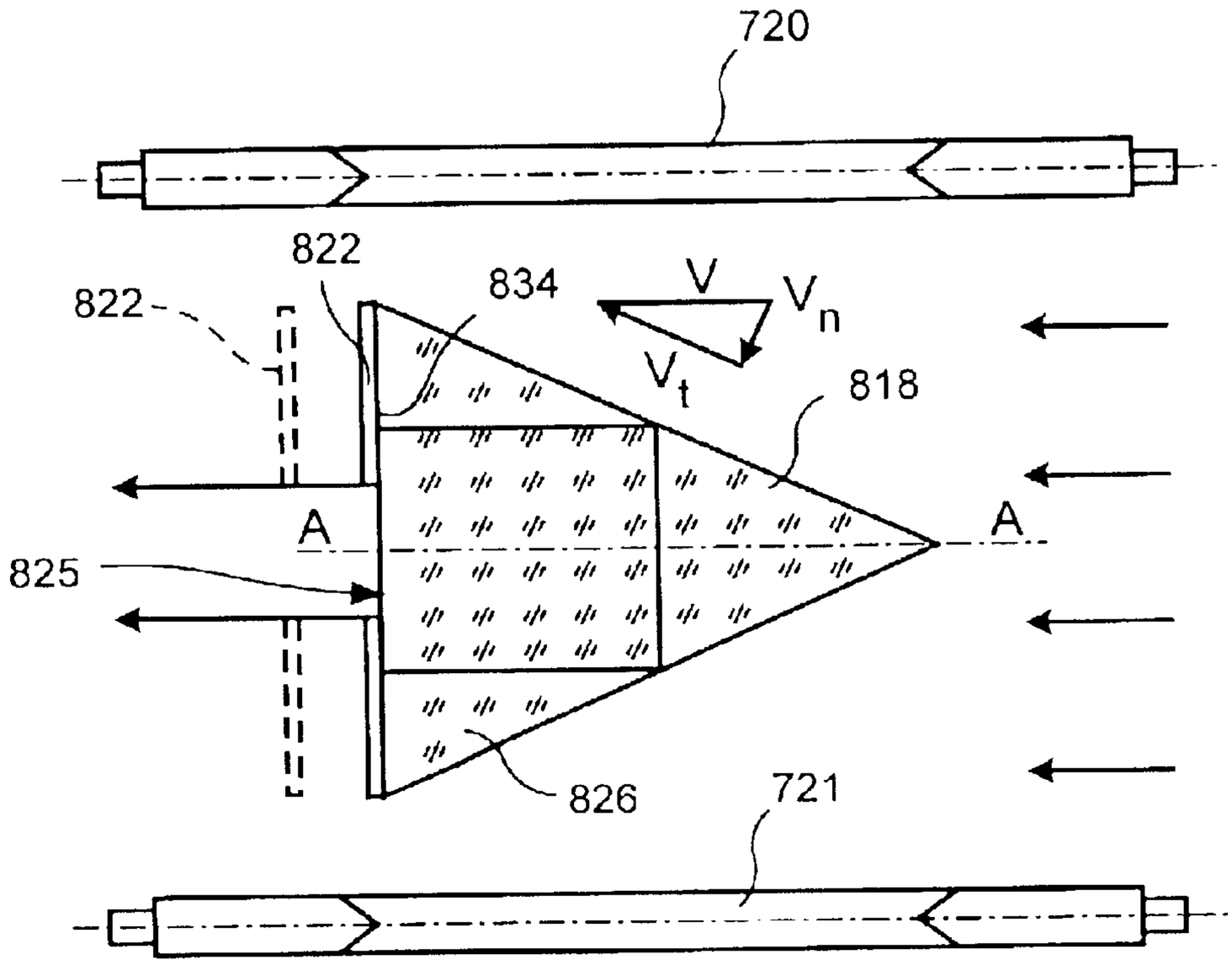

720
822
822
834
V
V_n
V_t
818
A
A
825
826
721

FIG. 8

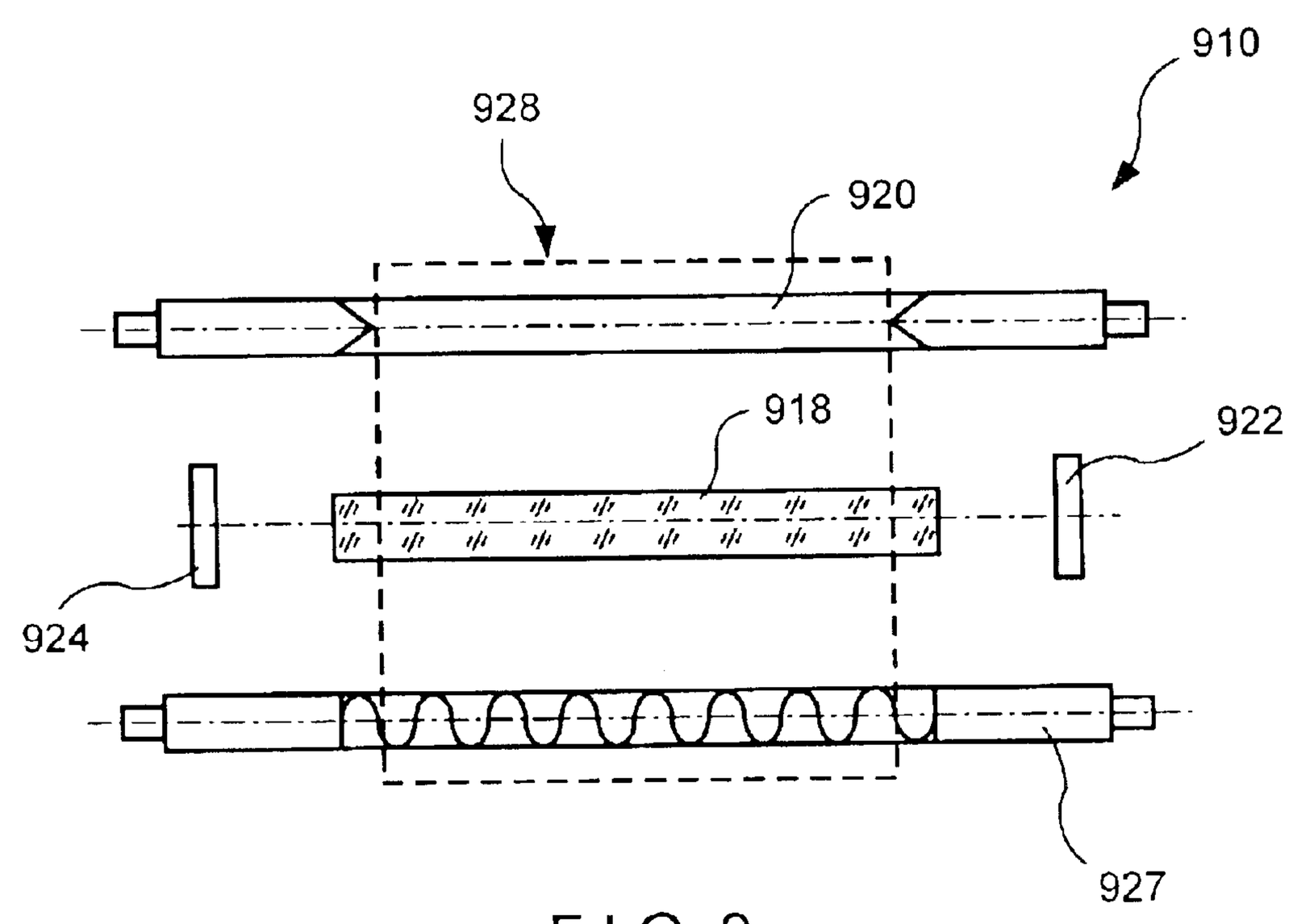

910
928
920
918
922
924
927

FIG. 9

PORTABLE LASER DEVICE

This non-provisional application claims benefit under 35 USC 119(e) of U.S. Provisional application Ser. No. 60/307,628 filed by Valentin A. Gruzdev and Pavel V. Efremkin on Jul. 25, 2001.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates in general to portable laser devices based on a solid-state laser technology, and in particular it relates to hand-held laser devices with direct cooling of a laser rod assembly.

2. Discussion of Background and Prior Art

The laser radiation generated by solid-state lasers is widely used in the industry and medicine. As illustrated in FIG. **1** a typical laser emitted assembly consists of a laser rod **6**, an exciting lamp **3**, a reflector **8**, a pair of resonant mirrors **5**, **6** and a cooling arrangement **7**, **9**. The wavelength of a laser radiation is determined by the type of a laser rod. The duration of the laser impulse and its energy are primarily set by the power source associated with the laser device. Among lasers most commonly used in the medical field are solid-state lasers utilizing crystals of yttrium aluminum garnet doped by ions of neodymium, erbium, holmium, and also ruby laser on the basis of emery doped by atoms of chromium.

The portability is an important aspect for the effective usage of the medical laser devices. In this respect, miniature laser devices capable of being fitted in a hand of an operator are of great interest to the medical professionals. Among major elements of such handheld laser devices are: a cooling arrangement and a system of aiming and focusing of a laser beam. A power source of such laser device can be positioned either inside or outside of the casing. In the hand-held laser devices a special attention has to be paid to minimizing their dimensions and weight. Exciting lamps, which are mainly used in pulsed solid-state lasers, emit optical radiation which is within the range between 0.2 and 0.7 microns. This range is substantially greater than an absorption band of the laser rod. Therefore, a considerable portion of the exciting lamp optical radiation which passes through the laser rod is wasted by converting into a useless thermal energy. As a result, when the exciting lamp constantly pulses its radiation in the direction of the laser rod to generate a required laser output beam, the temperature of the laser rod rises, diminishing its efficiency. For example, when the temperature of the erbium laser rod rises to 70° C., the laser radiation is almost absent. This makes an efficient cooling arrangement to be a very important component of stable and efficient operation of solid-state laser rod assemblies. In resolving these problems an important factor is that an extensive pulsed thermal energy must be dissipated from a very small surface of the laser rod. Thus, development of effective, miniature cooling arrangements adapted for the removal of thermal energy from the laser rod assemblies is considered to be a key problem in the development of hand-held laser devices.

Currently, there are two basic methods utilized to facilitate heat dissipation from the laser rod assemblies. The first method is based on utilization of a gaseous cooling medium, whereas according to the second method, the liquid cooling medium is used. Minimal absorption of the exciting lamp optical radiation by the coolant, stability of the optical medium and relatively small weight and size of the cooling system are among important advantages of the first method.

The liquid cooling of the second method provides considerably higher (compared to the gaseous cooling) heat transfer efficiency from the laser rod to the coolant. On the other hand, use of the liquid coolants does not provide the long-term stability of the optical medium, and often leads to contamination of the optical surfaces of the laser rod, exciting lamp and reflector. Furthermore, the currently available liquid cooling arrangements substantially increase weight and dimensions of the respective laser devices.

It is known that the amount of heat which has to be removed from a laser rod or crystal is dependent upon the following factors: the size of the cooling surface; the difference between the temperature of the laser rod and the temperature of the cooling agent, as well as the speed of the cooling agent in the vicinity of the laser rod surface. When the liquid cooling is utilized, the coefficient of heat transfer is much greater than that of the gas cooling. This is the reason why in the pulsed laser devices, the gas cooling is used very infrequently. However, utilization of the liquid cooling for the cooling of the laser rods and the exciting lamps increases the dimensions of the laser emitter, as well as brings up many other problems associated with the liquid cooling discussed hereinabove.

There are also known cooling arrangements for laser devices which combine the usage of the gaseous and liquid cooling principles. One such arrangement is disclosed by U.S. Pat. No. 5,481,556. According to this disclosure the outer casing of laser cavity containing an exciting lamp, a laser rod and a reflector is cooled by a liquid circulating within a closed circuit surrounding the laser cavity. The liquid coolant and the laser cavity are cooled by an air flow generated by a fan situated within the housing. One of the major drawbacks of this arrangement is that the heat removal from the laser rod is carried out indirectly through cooling of the exterior of the entire laser cavity. This approach substantially diminishes the efficiency of the laser assembly cooling process.

SUMMARY OF THE INVENTION

One aspect of the invention provides a hand-held laser device containing a casing formed with a substantially hollow interior space. A laser emitter is provided within the interior space and includes at least an exciting lamp and a laser rod. A source generating a stream of gaseous coolant is provided within the interior space. A fluid cooling arrangement at least partially surrounding the laser rod is disposed within the stream of gaseous coolant for heat removal therefrom.

The fluid cooling arrangement can be in the form of a liquid cooling arrangement which comprises a housing having an elongated opening passing therethrough. The elongated opening is adapted to at least partially receive the laser rod. An intermediate accumulation chamber is disposed within the casing, so as to communicate with the housing.

As to another embodiment of the invention, at least one connecting element for communication between the housing and the intermediate accumulation chamber is provided. A pumping arrangement is associated with the connecting element, so as to provide circulation of a liquid coolant between the housing and the intermediate accumulation chamber. A buffer space is formed between the exterior and interior walls of the casing. The buffer space communicates with the intermediate accumulation chamber. The exterior of the housing and intermediate accumulation chamber are situated within the stream of gaseous coolant, so as to

facilitate heat removal from the liquid coolant contained thereinside. A plurality of cooling fins are formed of a heat conducting material and extend from the inner wall of the casing. The plurality of cooling fins are positioned within the stream of gaseous coolant for heat removal from the liquid coolant situated within the buffer space.

As to a further embodiment of the invention, a hand-held laser device is provided consisting of an elongated casing formed with a substantially hollow interior space. A laser emitter is formed by at least an exciting lamp and a laser rod. A low pressure zone is generated within the interior space to facilitate formation of a stream of gaseous coolant therein-side. An inlet opening is situated at a front end of the housing. A low pressure zone is formed at the rear end of the housing. A stream of gaseous coolant enters the interior space through the opening and axially extends in the front to rear direction for heat removal from the laser emitter. A filter is provided at an inlet opening for filtering a stream of gaseous coolant entering the interior space. Alternately, an inlet opening can be formed at a rear area of the housing, so that upon entering the interior space, the stream of gaseous coolant initially moves axially in the rear to front direction and then moves in the front to rear direction.

A still another embodiment of the invention provides a cooling arrangement for a hand-held laser device which consists of a laser emitter formed by at least a laser rod and exciting lamp. A jacket is defined by spaced from each other exterior and interior walls. A longitudinal opening is developed within the jacket and adapted to rotatably receive the laser rod. A continuous internal spiral groove is provided within a body of the jacket adjacently to the interior wall thereof, so as to provide positive displacement of a cooling fluid within the internal groove about an outer periphery of the laser rod during rotation of the jacket about the laser rod.

A still further embodiment of the invention provides a cooling arrangement for a laser device which includes a laser emitter formed by an exciting lamp and a laser rod. A jacket having a longitudinal interior opening which is stationary positioned with respect to the laser rod. An external continuous spiral arrangement is provided at an outer periphery of the laser rod. Rotational motion of the continuous external spiral arrangement results in the rotary positive displacement of a cooling fluid along the laser rod.

As to still another embodiment of the invention, a hand-held laser device includes a laser emitter wiyh a laser rod having a frustoconical configuration or being shaped as a frustum of polygonal pyramid. The laser rod can also be formed having a substantially conical configuration.

BRIEF DESCRIPTION OF THE DRAWINGS

Other advantages and features of the invention are described with reference to exemplary embodiments, which are intended to explain and not to limit the invention, and are illustrated in the drawings in which:

FIG. **1** is a schematic diagram of a laser emitter according to the prior art;

FIG. **2** is a partial cross-sectional view of an embodiment of the invention utilizing gaseous and liquid cooling agents;

FIG. **3** is a partial cross-sectional view showing an interior of a hand-held laser device according to another embodiment of the invention;

FIG. **4** is a partial cross-sectional view showing an interior of a hand-held laser device according to a further embodiment of the invention;

FIG. **5** is a partial cross-sectional view showing an interior of a hand-held laser device according to still another embodiment of the invention;

FIG. **6** is a partial cross-sectional view showing an interior of a hand-held laser device according to a still further embodiment of the invention;

FIG. **7** illustrates an alternative design of the laser rod assembly;

FIG. **8** shows the assembly having a conically-shaped laser rod; and

FIG. **9** illustrates an embodiment of the invention with a pulsed laser emitter utilizing an additional lamp providing a continuous visible optical irradiation.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. **2**, illustrating one embodiment of a portable, handheld laser device **10** having a laser emitter **11** disposed in a substantially hollow, elongated casing **12** which extends longitudinally between front **14** and rear **16** ends thereof. The casing is formed by exterior **15** and interior **17** walls defining a buffer space **48** therebetween. We shall revert to this structure later on in the application. Within an interior of the casing a laser rod **18** is disposed substantially centrally with an exciting lamp **20** being spaced therefrom. A fully-reflective or rear resonant mirror **22** is positioned at a rear end of the laser rod and at an optical axis thereof. An output or front resonant mirror **24** is situated in front of the laser rod at an optical axis thereof. A laser beam forming arrangement or focusing lens **26** is housed at the front end **14**, so that the output mirror **24** is interposed between the laser rod **18** and the lens **26**. To facilitate passage of the laser beam the output resonant mirror **24** is formed with reduced reflective characteristics relative to the fully reflective rear resonant mirror **22**. Alternatively, the mirror **24** can be formed with an opening in the central area thereof. The laser rod **18** and the exciting lamp **20** are at least partially surrounded by a reflector **28**.

During operation of the portable laser device, the flash lights are emitted from the exciting lamp **20** which is powered by a drive power source (not shown). The flash lights are reflected on the inner surface of the reflector to cause the laser rod to absorb the generated energy. A light is injected from the exciting lamp **20** into the laser material of the laser rod **18** initiating the discharge of photons in the crystal. These photons travel between the front **24** and rear **22** resonant mirrors producing a harmonic amplification. A laser light emitted from the laser rod is resonated and amplified by resonating mirrors. The amplified laser beam escapes the system through the output mirror **24**. The emitted laser light beam is focused by the lens **26** and is incident upon either an optical fiber to be transmitted to a laser probe positioned at the front end of the apparatus or directly targeted on a body of a patient.

A cooling system of the laser device **10** illustrated in FIG. **2** is of a combined liquid-gaseous type. A convective cooling arrangement or cooling fan **30** generating a stream of gaseous coolant, such as an ambient air, for example, is provided within the interior of the casing **12** at the rear end **16**. The liquid cooling arrangement includes a housing **32** formed by spaced from each other interior and exterior walls thereof **34** and **36**, respectively. A cooling chamber **38** adapted to receive a liquid cooling medium is formed within the hollow space between the walls of the housing **32**. The interior wall **34** defines an elongated opening **40** extending through the entire length of the housing and adapted to at least partially receive the laser rod **18**. The walls **34** and **36** of the housing are made of an optically transparent material. An intermediate accumulation chamber **42** is provided

within the casing **12** and is connected to the cooling chamber **38** by means of inlet and outlet connecting elements **44** and **46**, respectively. In order to increase the volume of the available liquid cooling medium and to further intensify the cooling process, the buffer space **48** is provided within the interior space of the casing **12** along the exterior wall thereof **15**. Communication between the buffer space **48** and the intermediate accumulation chamber **42** is accomplished by means of input **52** and discharge **54** elements. A multiplicity of fins **56** extends outwardly from the inner wall **17** of the casing toward a central region of the apparatus **10**.

In the cooling system of the hand-held laser device **10** each of the gaseous and liquid cooling agents are applied to different elements of the laser unit **11**. In this respect, the stream of a gaseous cooling agent, such as air, for example, generated by the fan **30** and directed longitudinally within the casing is typically directed toward the elements of the laser unit exposed to the maximal temperature. Most specifically, it is directed toward the exciting lamp **20** and the reflector **28**. On the other hand, the laser rod **18** is cooled by the liquid cooling medium, such as water, for example, circulating primarily between the cooling chamber **38**, the intermediate accumulation chamber **42** and the buffer space **48**. In the embodiment of FIG. **2** the liquid coolant is supplied to the cooling chamber **38** from the intermediate accumulation chamber **42** by means of a pump **43** associated with the inlet connecting element **44**. Upon circulation within the cooling chamber **38**, the liquid coolant having an elevated temperature is recycled to the intermediate accumulation chamber **42** through the outlet element **46** and ultimately can re-enter the buffer space **48** through the discharge element **54**. An auxiliary cooling element **58** having a thermal contact with the wall of the intermediate accumulation chamber **42** can be provided for intensifying the cooling process.

As illustrated in FIG. **2**, the flow of gaseous coolant generated by the fan **30** is directed to the exterior surfaces of the elements forming the liquid cooling system such as: the cooling chamber **38** and the intermediate accumulation chamber **42**. The multiplicity of fins **56** increases the heat exchanging surface of the interior wall **17** forming the buffer space **48** which is also subject to the flow of gaseous coolant. To further intensify the flow of gaseous coolant within the casing **12**, the rear **16** and front **14** regions thereof are provided with openings **58**, **60**, respectively.

The elements of the hand-held laser device **10** subjected to the maximum temperature, such as the exciting lamp **20** and the reflector **28** are effectively cooled by the steam of gaseous coolant generated by the fan **30**. On the other hand, the temperature of the laser rod **18** is reduced directly by the flow of liquid coolant. Furthermore, the elements of the liquid cooling system are also cooled by the stream of gaseous coolant generated by the fan **30**. Such combined cooling capability provides the required stability of the temperature of the laser rod **10** which generate under the conditions of hand-held laser device.

The effectiveness of heat removal from the laser rod unit **11** can be enhanced by increasing the velocity, speed and rate of flow of the gaseous coolant along its elements. In the embodiment of FIG. **2**, this can be accomplished through the increase in the rotational speed of the fan **30** or through a provision of an outside air pump supplying a relatively high pressure gaseous coolant inside the casing of laser device. In the laser device illustrated in FIG. **2** the gaseous cooling arrangement is adapted to utilize the ambient air as the gaseous cooling medium and water as a liquid cooling medium. However, utilization of other gaseous and liquid cooling agents which can be pre-cooled prior to entering the interior of the casing is also contemplated. One of the examples of such pre-cooled gaseous agent can be carbon dioxide.

Referring now to FIG. **3**, illustrating another embodiment of the invention. The hand-held laser apparatus **310** is formed with an elongated casing **312** having a substantially hollow internal area extending between front **314** and rear **316** ends thereof. The emitter assembly **311** including the laser rod **318**, the front **324** and rear **322** resonant mirrors, the exciting lamp **320** and the reflector **328** are supported by spaced from each other support elements **327** and **329**. A low pressure or vacuum zone **325** is provided at the rear end **316**. In the embodiment of FIG. **3** a stream of gaseous coolant enters the interior of the casing through an inlet opening **317** disposed at the front end **314** and is discharged through an exit opening provided at the rear end of the device (not shown). The low pressure zone **325** results in the pressure differential between the rear and front ends, so that a longitudinal flow of gaseous coolant is generated passing along the laser rod **318**, the exciting lamp **320** and other elements of the emitter assembly. To facilitate passage of the coolant the support elements **327** and **329** are formed with apertures **331** and **335**, respectively. The low pressure zone can be generated at the front **314** or rear **316** of the casing by any conventional means such as an air pump, etc. which can be positioned inside or outside of the casing **312**. Such arrangement results in the high speed of the gaseous coolant flow and assures smaller dimensions of the cooling system. Furthermore, in comparison with a fan which has been typically utilized to provide a flow of gaseous coolant, the low pressure zone requires less power to be energized. Another important advantage of the low pressure zone **325** is that it substantially improves homogenuity of the gaseous coolant flow within the interior of the casing and substantially eliminates gaseous vortexes and stagnation areas thereinside.

The gaseous coolant entering the interior of the casing typically contains particles of an environmental dust as well as particles of substances treated by a laser device. Such particles, when passing through the interior of the casing contaminate optical elements disposed thereinside. This ultimately results in diminishing the essential characteristics of the laser device. To minimize this undesirable effect, a filtration unit **330** containing an exterior, disposable filter **332** and an interior, long lasting filter **334** is provided at the inlet **317**.

In medical applications of the hand-held laser apparatus **310** the gaseous coolant may also contain particles of human flesh (debris) formed during interaction of the laser beam with a treated tissue. Such debris are considered to be a possible pathogen and need to be evacuated from the air for further proper disposal. To serve this purpose a disposablde filter **340** can be provided at the front end of the apparatus **310**. As illustrated in FIG. **3**, the filter **340** includes an inner wall **342** defining a central aperture **344** passing through the entire length thereof. A substantially hollow space **346** formed between the interior wall **342** and exterior wall **348** is adapted to receive a filtering material therein. A multiplicity of inlet openings **345** are disposed at the front region of the inner wall **342**, whereas the outlet apertures **347** are provided at the rear region of the filter. In view of the lower pressure zone **325** and the suction process associated therewith, the air stream containing particles of human flesh initially enter the interior of the filter **340** through the multiplicity of openings **345**. Upon passage through the filtering material, the air stream separated from the particles

and debris enters the front region **314** of the apparatus through the outlet openings **347**.

The embodiment of FIG. **4** is in many respects similar to the embodiment of FIG. **3**. However, the inlet openings **417** and **419** containing the respective filtering units **430** and **440** are positioned at the rear region **416** of the laser emitter. As illustrated in FIG. **4**, the flow of gaseous coolant upon entering the interior of the casing through the respective exterior and interior filters **432**, **434** and **442**, **444** is initially directed toward the front region **414** of the device enhancing heat dissipation from the exterior of the laser emitter. At the front region **414** the flow of gaseous coolant is diverted back toward the low pressure zone **425**, so as to circulate along the interior area of the laser emitter. In the embodiment of FIG. **4** the stream of gaseous coolant enters the interior of the casing at the rear end thereof where concentration of particles resulted from the usage of the device is lower than at the front of the device.

It should be noted that the low pressure or vacuum zone can be also used in the embodiment of FIG. **2** instead of the fan to generate a flow of gaseous coolant within the housing. In the embodiment of FIG. **2** the low pressure zone can be provided, for example, at the front region of the housing.

Turning now to FIG. **5**, which illustrates another embodiment of a cooling arrangement **510** for a hand-held laser device. A laser emitter **511** consists of two exciting lamps **520** and **521** which are disposed on opposite sides of the laser rod **518**. In the longitudinal direction the laser rod **518** is interposed between the fully reflective rear resonant mirror **522** and a semi-reflective output or front resonant mirror **524**. The lamps and the laser rod are surrounded by a reflector **528** which is positioned within and spaced from the outer casing **512**. A substantially hollow buffer space **548** is formed between the outer casing **512** and the reflector **528**.

A jacket **519** made of an optically transparent material is disposed along an exterior surface of the laser rod **518**. The jacket is defined by at least an exterior surface **515** and a longitudinal interior opening **516** passing therethrough. A continuous internal spiral groove **517** is formed within a body of the jacket at the opening **516** and extends through the entire length thereof. The longitudinal opening including the internal groove is adapted to rotationally receive the exterior surface of the laser rod **518**. The rotational motion of the jacket **519** relative to the laser rod is facilitated by a small gap provided between the internal opening **516** of the jacket and the outside surface of the laser rod. The internal spiral groove **517** is adapted to receive the cooling liquid and pass it along the exterior surface **515** of the laser rod. To increase the volume of the available liquid cooling and to further intensify the cooling process, the internal spiral groove **517** is in fluid communication with the buffer space **548** also filled with the liquid coolant. A conventional rotational arrangement, such as an electric motor **525** provided with a magnetic clutch, for example, generate rotational motion of the jacket **519** including the internal spiral groove **517** relative to the laser rod **518**.

In the embodiment of FIG. **5** the cooling fan **530** is positioned rearwardly from the casing **512**. To facilitate entering and exiting the flow of gaseous coolant generated by the fan **530** into and from the laser cavity, apertures **527** and **529** are formed within rear and front walls of the casing, respectively. In operation the inner space of the continuous spiral groove **517** and the buffer space **548** are filled with the liquid cooling medium. The rotational motion of the jacket **519** including the continuous internal spiral groove **517** relative to the stationary laser rod **518** provides longitudinal motion of the liquid coolant medium along the exterior surface **515** of the heated laser rod. The continuous spiral groove communicates with the buffer space **548** filled with the liquid coolant. To further enhance the efficiency of the laser rod cooling, the cooling fluid circulates between the buffer space and the internal spiral groove. After being discharged from the groove **517**, the spent cooling liquid having an elevated temperature upon entering the buffer space **548** transfers its heat to the casing **512** which is absorbed by the air stream generated by the fan **530**.

In the embodiment of FIG. **5**, the close rotational fit between the continuous spiral groove **517** of the jacket and the exterior surface **515** of the laser rod form a plurality of enclosed cavities which move continuously from the inlet **532** to outlet **534** of the laser rod assembly. This arrangement results in the positive pressure capability for the liquid coolant. In use these cavities trap the liquid coolant agent at the inlet **532** carry it along the outer surface **515** of the laser rod and discharge at the outlet **534**, providing uninterrupted flow of the coolant along the laser rod. Thus, the rotational motion of the internal spiral groove **517** along the laser rod form a positive-displacement arrangement, which is capable of moving a definite quantity of the liquid coolant with every revolution of the spiral groove.

Turning now to FIG. **6**, illustrating another embodiment of the invention. A laser rod assembly consisting of a laser rod **618**, the fully reflective rear resonant mirror **622** and the output, semi-reflective front resonant mirror **624** are movably associated with a shaft of the electrical motor **625** or any other conventional rotational arrangement. An outwardly extending continuous spiral arrangement **627** is wound around or distributed over the outer surface **615** of the laser rod **618**. The spiral arrangement **627** can be carved out from a body of the laser rod. Alternatively, an independent spiral arrangement can be positioned over the exterior surface of the laser rod. In this manner a continuous external spiral groove formation **629** is developed over the outer surface **615** of the laser rod. A jacket **619** defined by at least the internal longitudinal opening **628** and external surface **619** is formed of an optically transparent material. The exterior surface **619** of the jacket is fixedly positioned within the interior of the casing (not shown), whereas the internal longitudinal opening **628** is adapted to rotationally receive the laser rod **618** with the continuous external spiral arrangement **627**. This rotational motion is facilitated by a minor gap provided between the outer extremities of the spiral arrangement and the interior surface of the jacket **619**. As in the previously described embodiments the exciting lamp **620** is provided in spaced relationship from the laser rod.

In the embodiment of FIG. **6**, the rotation motion of the laser rod **618** within the longitudinal opening **628** provides rotary positive displacement in which the flow of liquid coolant is axially directed through the opening, for heat removal from the outer surface **615** of the laser rod. The coolant is carried by the outwardly extending threads on the rotational laser rod and is displaced axially as the spiral rotates.

In operation, upon activation of the rotational arrangement by the electrical motor **625**, the laser rod along with the continuous spiral arrangement and resonant mirrors **622** and **624** are rotated within the inner hollow space of the optically transparent jacket. The rotational motion of the external spiral develops suction at the inlet of the jacket **619**, so that the coolant is introduced into the gap between the laser rod and the interior of the jacket. Upon passing through hollow space of the jacket, the heat exchanging process is taking place between the coolant and the external surface of the

laser rod lowering its temperature. When the frequency of rotation of the laser rod exceeds the pulse frequency of the exciting lamp, one flash pulse of the exciting lamp corresponds to the several revolutions of the laser rod. This condition results in the increased uniformity of the laser beam generated by the device of the invention.

In the embodiment of FIG. **6** the temperature of the laser rod is reduced by the flow of the coolant developed during the rotation of the laser rod and the external spiral arrangement about the longitudinal axis of the device. In this case the speed of the flow of the coolant at the surface of the laser rod in addition to the axial component also has a radial component which directly dependent upon a rotational speed of the laser rod. Thus, the quantity of heat removed from the rod is dependent upon the rotational speed thereof. If the rotational speed of the rod exceeds the repetition rate of the laser pulses, then the uniformity of the laser beam over its cross section will increase respectively. It has been determined that upon the increase of the ratio of the rotational speed of the laser rod to the repetition rate of the laser pulses, the higher uniformity of the laser beam will take place.

In an alternative embodiment the spiral arrangement **27** can be rotated within the internal longitudinal opening **628** of the jacket about a stationary positioned laser rod.

It should be noted that the coolant displacement arrangement as discussed hereinabove with reference to FIG. **6** can be utilized in the hand-held laser apparatus of FIG. **2**. In this respect, the laser rod formed with the continuous external spiral arrangement is rotationally positioned within the internal space of the cooling chamber which communicates with the intermediate accumulation chamber by means of the inlet and outlet connecting elements. Upon rotation of the laser rod including the external spiral arrangement suction is developed at the inlet connecting element, so as to bring the liquid coolant from the intermediate accumulation chamber into the interior space of the cooling jacket. The spent liquid coolant having elevated temperature is discharged back to the intermediate accumulation chamber through the outlet connecting element. The rotational motion of the laser rod and the external spiral arrangement generates suction within the cooling chamber ultimately resulted in an uninterrupted flow of the coolant along the rod. In view of that, the special pumping arrangement utilized in the embodiment of FIG. **2** for bringing the liquid coolant from the intermediate accumulation chamber into the cooling chamber is no longer required.

In the embodiment of FIG. **7** the laser rod **718** is formed having a frustoconical configuration or a shape of a frustum of polygonal pyramid. A lateral or side surface **726** of the rod extends between first **732** and second **734** bases which are substantially normal to the optical axis A—A of the device. The exciting lamps **720** and **721** are disposed on both sides of the laser rod **718**. The bases **732** and **734** as well as the lateral surface **726** of the laser rod are transparent to the radiation of the exciting lamps. Similar to the previously described embodiments, the laser rod **718** is interposed between the fully reflective rear resonant mirror **722** and a semi-reflective front resonant mirror **724**. The front resonant mirror **724** faces the first base **732** of the laser rod having a cross section substantially smaller than the second base **734** which faces the fully reflective rear resonant mirror **722**. As illustrated in FIG. **7**, the flow of the cooling medium extends along the longitudinal axis A—A of the laser rod **718** in the front to rear direction. The lateral surface **726** of the laser rod is subject to a stream of coolant extending along the longitudinal axis A—A of the laser rod.

As illustrated in the diagram forming a part of FIG. **7** at the area of engagement with the lateral surface **726** the directional vector of the velocity V of the stream of coolant can be broken into a component V_n which extends substantially normally to the lateral surface and a tangential component V_t directed along the lateral surface. It is known that the normally directed stream of coolant provides the cooling process of greater efficiency compared to the arrangement in which the entire stream of coolant is directed only tangentially or along the surface of the laser rod.

In the embodiment of FIG. **7** the existence of the normal component V_n in the velocity of the flow of coolant reduces stagnation areas of the coolant flow caused by the frictional forces between the surface of the laser rod and the flow of coolant. This arrangement further increases the efficiency of the heat transfer between the laser rod to the coolant.

In the laser apparatus of FIG. **7** an outside periphery or diameter of the fully reflective rear resonant mirror **722** exceeds the largest cross section of the laser rod **718**. In this respect, it is illustrated in FIG. **7** that the outside periphery of the rear mirror **722** is greater than the outside periphery of the rear base **734**. Thus, upon multiple reflections of the optical radiation between the fully reflective rear resonant mirror **722** and lateral surface **726** of the laser rod, an additional amplification of the laser radiation has taken place. This is most common when the angle at the tip of the laser rod **718** is about 90°.

Turning now to FIG. **8** which illustrates a further embodiment of the invention with a laser rod **818** having a substantially conical configuration or formed in the shape of polygonal pyramid having one base **834**. The lateral surface **826** and the base **834** of the laser rod are transparent to the optical radiation. The fully reflective resonant mirror **822** is provided with a central opening **825** for discharging the laser beam radiation generated by the device. The resonant mirror **822** can be attached to the base **834** or can be spaced from the base **834** (as shown in phantom). The resonant mirror **822** can be formed by applying a special reflective coating to the base **834**. The laser rod **818** is interposed between two exciting lamps **720** and **721**.

As illustrated in FIG. **8**, the flow of cooling medium is directed along the longitudinal axis A—A of the laser rod **818**. Similar to the embodiment of FIG. **7**, at the area of engagement of the flow of coolant with the lateral surface **826** the directional vector V of the velocity of the coolant stream is formed with a normal component V_n extending substantially normally to the lateral surface **826** and a tangential component V_t directed along the lateral surface **826**. In a manner similar to the above-discussed, the normally directed stream provides the cooling process of greater efficiency compared to the arrangement in which the entire stream of coolant is directed only tangentially or along the surface of the laser rod. This arrangement also increases the efficiency of the heat transfer between the laser rod **818** to the coolant medium.

Turning now to FIG. **9** illustrating the pulsed laser device **910** having the laser rod **928**, front and rear resonant mirrors **924** and **922** and the exciting lamp **920** situated within the reflector **928**. A source of continuous optical radiation **927** is provided within the reflector on a side of the laser rod **918** opposite to the exciting lamp **920**. The source **927** should be positioned in such a way as to minimally interfere with interaction between the laser rod and the exciting lamp. A part of a continuous visible optical radiation generated by the source **927** and amplified in the rod **928** serves as a pilot visual light to enhance targeting of an infrared laser beam at a treated area. Furthermore, the continuous optical radiation after being absorbed by the laser rod reduces a lazing-action

threshold. This enables the invention to reduce the electrical power consumed by the exciting lamp **920** so as to ultimately reduce the temperature of the laser rod **918**.

What is claimed is:

1. A portable laser medical device comprising:

a hand-held elongated casing having a substantially hollow interior space;

a laser emitter formed by at least an exciting lamp and a laser rod spaced from each other; and

a gaseous, cooling arrangement including at least a low pressure zone provided at one end of said interior space and an inlet formed in said casing at an opposite end of said interior space causing a pressure differential between said ends of the interior space, said pressure differential facilitating formation of a stream of gaseous coolant passing through said interior space along said laser emitter.

2. The portable laser medical device according to claim **1**, wherein said stream of gaseous coolant longitudinally passes within said interior space along said laser rod and exciting lamp.

3. The portable laser medical device according to claim **1**, wherein said low pressure zone is generated by a low pressure generating arrangement.

4. The portable laser medical device according to claim **3**, wherein said low pressure generating arrangement is one of an air pump and air vacuum pump.

5. The portable laser medical device according to claim **3**, wherein at least a portion of said low pressure generating arrangement is located outside the hand-held casing.

6. The portable laser medical device according to claim **3**, wherein at least a portion of said low pressure zone generating arrangement is located within said interior space of the hand-held casing.

7. The portable laser medical device according to claim **1**, further comprising a filtration unit provided at said inlet for filtering said stream of gaseous coolant entering said interior space of the casing.

8. The portable laser medical device according to claim **7**, wherein said filtration unit comprises at least an exterior filter and an interior filter.

9. The portable laser medical device according to claim **8**, wherein said exterior filter is a disposable filter and said interior filter is a long lasting filter which is exposed to said interior space of the casing.

10. The portable laser medical device according to claim **7**, wherein said exterior filter is adapted to receive particles formed during interaction of a laser beam generated by the device with a treated object.

11. The portable laser medical device according to claim **1**, further comprises a filtration arrangement including: spaced from each other outer and inner portions, said inner portion defining a central aperture passing through the entire length of the filtration arrangement and adapted for the passage of a laser beam; a substantially hollow space formed between said inner and outer portions and adapted to receive a filtering material therein; a multiplicity of inlet openings formed within said inner portion; and an outlet opening provided at a region of said filtration arrangement facing said casing and adapted to direct said stream of gaseous coolant into said interior space.

12. The portable laser medical device according to claim **11**, wherein said filtration arrangement is positioned at a front end of said laser medical device and said outlet opening is formed between said inner and outer portions.

13. The portable laser medical device according to claim **1**, wherein said hand-held casing extends between front and rear ends thereof; and

said inlet is provided at said front end, said low pressure zone is formed at said rear end, said stream of gaseous coolant enters said interior space through said inlet and axially extends in the front to rear direction for heat removal from said laser emitter.

14. The portable laser medical device according to claim **1**, wherein said low pressure zone is adjusted according to a pattern of a laser beam generated by said laser emitter.

15. A portable laser medical device comprising:

a hand-held elongated casing having a substantially hollow interior space;

a laser emitter formed by at least an exciting lamp and a laser rod spaced from each other; and

a gaseous cooling arrangement including at least a low pressure zone provided at one area of said interior space and an inlet formed in said casing at another area of said interior space causing a pressure differential between said areas of the interior space, said pressure differential facilitating formation of a stream of gaseous coolant passing through said interior space along said laser emitter.

16. The portable medical device according to claim **15**, wherein said casing is provided with interior and exterior walls spaced from each other and forming passages therebetween, said passages being adapted to accommodate said stream of gaseous coolant so as to direct said stream of gaseous coolant within said interior space from said area containing said inlet to said area accommodating said low pressure zone.

17. The portable laser medical device according to claim **15**, wherein said low pressure zone is adjusted according to a pattern of a laser beam generated by said laser emitter.

18. The portable laser medical device according to claim **15**, wherein said inlet opening is formed at a rear area thereof, so that upon entering the interior space the stream of gaseous coolant initially moves axially in the rear to front direction and then moves in the front to rear direction.

* * * * *