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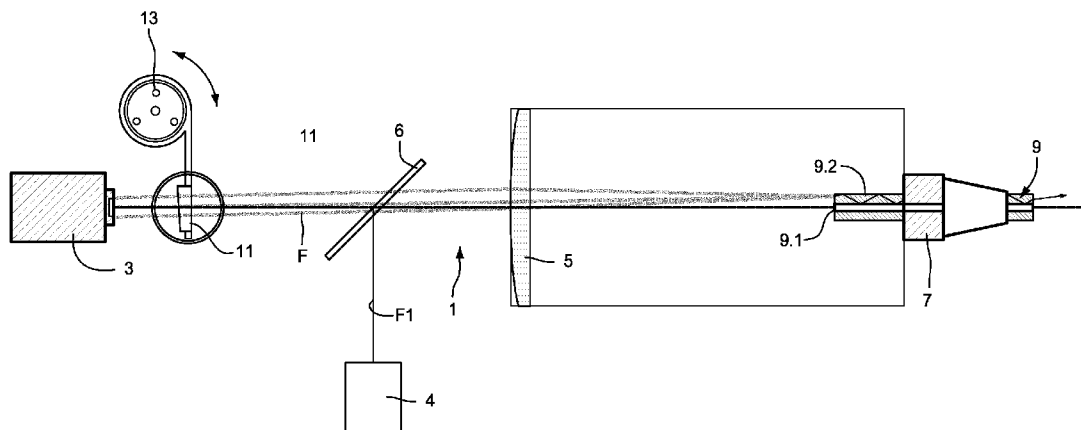


Fig.2

(57) Abstract: The equipment comprises a first laser source (3) adapted to emit a laser beam (F3) and a first output (1.3) which can be interfaced with an optical fiber (9), for conveying the first laser beam (F3) into the optical fiber (9). A deflector (11) moveable between a first inactive position and a second active position allows to direct the laser beam (F3) at least partially into a cladding (9.2) surrounding the core (9.1) of the optical fiber (9) interfaced with the first output (1.3).



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A laser equipment with a laser source and a beam deflector

DESCRIPTION

TECHNICAL FIELD

5 [0001] The present invention relates to improvements to laser equipment, in particular (but not exclusively) laser equipment for medical use, which use a waveguide in the form of an optical fiber to convey the laser radiation coming from the source toward an application point.

BACKGROUND ART

10 [0002] In many applications, both industrial and medical, laser sources which emit a coherent light beam at a determined wavelength are used. The laser beam is conveyed toward the application point by means of a waveguide. The nature of the waveguide generally depends on the emission wavelength and it may depend on other factors, for example the type of use, the power of the conveyed radiation, etc.

15 [0003] In some applications the waveguide consists of a hollow tubular arm, comprising a plurality of tubular pieces connected to each other by joints containing deflection mirrors.

[0004] In other applications the waveguide consists of an optical fiber.

20 [0005] In yet other applications, the possibility of alternatively using an optical fiber or a hollow tubular arm is provided, depending upon the type of use to be applied for the laser beam each time.

[0006] Optical fibers generally have a core and a cladding. Typically, the cladding and the core have two different refractive indexes, to allow the propagation of the laser beam in the core from an input end to the output end of the optical fiber.

25 [0007] Hollow optical fibers, i.e., whose core is empty, also exist, which are typically used to convey a laser beam which cannot propagate into other materials (typically based on silica, SiO₂) of which optical fibers are normally made. For example, hollow optical fibers are used to convey laser beams generated by CO₂ laser sources.

[0008] In some applications it is useful to have, in the same equipment, a main laser source, which generates the laser beam that is used for the various applications for which the equipment is intended, and an aiming laser source. The latter generates a so-called aiming laser beam with characteristics different from those of the main laser beam, for example a different in wavelength. These combinations of main laser source and aiming laser source are used, for example, in cases where the operator needs to precisely position the handpiece, from which the laser beam exits, with respect to an object on which the main laser beam is to be applied. If the main laser beam has an invasive effect on the object to which it is directed, aiming operations require the use of a laser beam with different characteristics, which do not create invasive effects on the object but which allow the correct display of the interaction point of the main laser even when the operator wears the appropriate protective equipment (eyeglasses) for the main beam radiation.

[0009] In particular, this requirement is important in the medical field, where the physician must be able to correctly position the handpiece where the waveguide output is positioned, without activating the main laser emission, which could harm the patient.

[0010] The aiming laser beam can easily propagate in a hollow arm, but in some cases it cannot propagate in a hollow optical fiber because the inner coating is not always optimized for propagation of the aiming beam. As a matter of fact, the aiming laser beam is not confined in the core, but rather dissipated due to the losses suffered at each reflection on the inner surface of the axial cavity of the optical fiber. This is the case of optical fiber waveguides, which have a silica cladding with a silver metal coating therein, protected by a silver iodide layer. These waveguides, made with a typical length of 2.5 m, transmit infrared radiation at 10.6 micrometers with a transmittance of 70%. However, the radiation of the aiming laser in the visible undergoes at each reflection an estimated loss in the order of 5%, which with a number of reflections of several tens before reaching the output, entails an attenuation level of the order of at least 20dB (1/100). Basically, these fibers are not capable of transmitting an aiming laser beam.

[0011] To solve this problem hollow optical fibers were provided, i.e. having a hollow core and a cladding surrounding the core, in the cladding whereof optical fibers for conveying the aiming laser beam are inserted. A composite optical fiber of this

type is disclosed in US2010/0100085.

[0012] Also provided are devices in which a main laser source and an aiming laser source are used to direct the two laser beams into a waveguide in the form of a tubular arm; and wherein an additional aiming laser source is used, together with an additional beam combiner, when the main laser beam is conveyed into the hollow optical fiber. In this case, the aiming laser source combined with the main laser source is deactivated and the additional aiming laser source (which is positioned so that the laser beam thereof is injected into the cladding of the hollow fiber and propagated therealong) is activated to replace it.

10 [0013] An equipment of this type is disclosed for example in EP3605173, EP2987012 and in US2016/0025933. The additional aiming laser source is mounted in an adapter, which has two outputs and one input. The input is interfaced with a base, in which the following are housed: the main laser source and the aiming laser source associated with the main laser source. This equipment provides for the selective use of one or the other of the two aiming laser sources, depending on which of the two waveguides (articulated tubular arm or hollow optical fiber) is used to convey the main laser beam.

[0014] This known equipment is particularly complex and expensive, both because it requires the use of two aiming laser sources as well as due to the need to consequently use two beam combiners.

[0015] It would therefore be advantageous to provide an equipment adapted to solve or alleviate the problems of known equipment.

SUMMARY

[0016] According to one aspect, herein disclosed is a laser equipment, comprising a first laser source adapted to emit a first laser beam, namely an aiming beam and a second laser source, adapted to emit a second laser beam, namely a treatment beam. The equipment further comprises a beam combiner, adapted to combine the first laser beam and the second laser beam directing them into a common path downstream of the beam combiner. As will be clarified hereinafter, the common path is not necessarily a precisely coaxial path for the two laser beams. The equipment further comprises at

least one first output, which can be interfaced with an optical fiber, for conveying the first laser beam and the second laser beam into the optical fiber.

[0017] Advantageously, the equipment comprises a deflector arranged along a path of the first laser beam, between the first laser source and the beam combiner. The deflector is moveable between a first position and a second position and is adapted to be inserted into the path of the first laser beam coming from the first laser source and removed from said path. In the second position, the first laser beam is at least partially directed into a cladding surrounding a core of the optical fiber interfaced with the first output. The first laser source, the second laser source and the beam combiner are arranged in a manner such that, when the deflector is in the first position, the first laser beam and the second laser beam downstream of the beam combiner are substantially coincident, i.e., coaxial.

[0018] According to a further aspect, disclosed herein is a laser equipment, comprising, in combination, an aiming laser source, adapted to emit an aiming laser beam, and a treatment laser source adapted to emit a treatment laser beam. The laser equipment comprises a first output, which can be interfaced with a flexible waveguide, typically an optical fiber, for example but not necessarily hollow, for directing the treatment laser beam into a core of the flexible waveguide. Furthermore, a second output is provided, which can be interfaced with a second waveguide, preferably an articulated tubular hollow arm, for directing the treatment laser beam into the second waveguide.

[0019] The laser equipment comprises a switch moveable between a first position for directing the treatment laser beam and the aiming laser beam toward the first output, and a second position for directing at least the treatment laser beam, and preferably also the aiming laser beam, toward the second output.

[0020] A deflector associated with the aiming laser source is moveable between a first position and a second position. In the second position, the deflector is arranged so as to direct an aiming laser beam into a cladding of the flexible waveguide, when the switch is in the first position. In the first position, the aiming laser beam can propagate toward the output of the laser equipment according to a path substantially coincident with the path of the treatment laser beam, i.e., more precisely coaxial with the path of the treatment laser beam.

[0021] This allows to selectively direct both laser beams (treatment and aiming laser beams) into a flexible waveguide associated with the first output and into a waveguide defined by the tubular arm. When the two beams are directed into the flexible waveguide, they can be deflected with respect to each other, so as to propagate the aiming laser beam into the cladding of the flexible waveguide, while the treatment laser beam is propagated into the core. Vice versa, when the tubular arm is used as a waveguide, the two aiming and treatment laser beams can propagate along a common path coaxial with the waveguide.

[0022] In this manner, for example optical fibers with cores can be used, along which the aiming laser beam cannot be propagated efficiently. Contrary to the solutions of the prior art, the result of an efficient propagation of the aiming laser beam into the cladding of the optical fiber is obtained with a single aiming laser source and a single beam combiner, therefore with a simpler, more compact and more cost-effective equipment.

[0023] Alternatively, the equipment may allow the aiming laser beam to be propagated along the flexible waveguide alternately into the core or into the cladding of the flexible waveguide. This can be useful, for example, for obtaining at the output from the flexible waveguide an aiming spot having a variable shape, depending on which portion of the waveguide (cladding or core) is used for the propagation of the laser beam. Particularly significant is the case of obtaining an annular-shaped (i.e., circular crown-shaped) aiming beam obtained by propagating the guide beam into the cladding of the fiber and using a handpiece capable of creating an image of the intensity distribution at the output of the fiber, with appropriate magnification (M). The treatment beam, propagating into the core, will result in a circular-shaped spot with a diameter equal to $M \times$ diameter of the core, while the aiming beam will result in a circular crown with an inner/outer radius equal to $M \times$ diameter of the core/cladding.

[0024] According to a further aspect, herein disclosed is a laser equipment comprising a first laser source adapted to emit a first aiming laser beam and a second laser source, adapted to emit a second treatment laser beam. The equipment further comprises an optical arrangement, which may comprise a beam combiner, and which is adapted to direct the first laser beam and the second laser beam in a common path toward a first output which can be interfaced with an optical fiber, to convey the first

laser beam and the second laser beam into the optical fiber. The combiner for example may be provided if the two beams come from different directions.

[0025] In some embodiments, the equipment may comprise a deflector arranged along a path of the first laser beam, between the first laser source and the optical arrangement, comprising the possible the beam combiner. The deflector, if present, is moveable between a first position and a second position and it is adapted to be inserted into the path of the first laser beam in output from the first laser source and disengaged from said path. In the second position, the first laser beam is at least partially directed into a cladding surrounding a core of the optical fiber interfaced with the output of the equipment and in the first position the first laser beam is directed at least predominantly into the core of the optical fiber.

[0026] This allows to obtain an equipment in which the aiming beam can generate a lit area focused in the same area struck by the treatment laser beam, or alternatively in an annular area, which surrounds the area struck by the treatment beam, depending on whether the aiming laser beam is directed into the core or into the cladding of the optical fiber.

[0027] The first laser source, the second laser source and the possible beam combiner are arranged in a manner such that, when the deflector is in the first position, the first laser beam and the second laser beam downstream of the beam combiner are substantially coincident, that is coaxial.

[0028] In simplified versions of the equipment, the deflector may be omitted and the aiming laser beam and the treatment laser beam are arranged and combined together so that the aiming laser beam is directed into the cladding of the fiber while the treatment laser beam is directed into the core of the fiber. In this manner, the aiming laser beam generates, on the surface struck by the laser beams, an annular-shaped lit area, which surrounds the area struck by the treatment beam.

[0029] Further advantageous characteristics and embodiments of the laser equipment described hereinafter are defined in the dependent claims, which are an integral part of the present description. Such characteristics can be combined with laser equipment as defined above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] The invention will be clearer from the description and the attached drawings, which illustrate an embodiment provided by way of non-limiting example of the invention. More particularly, in the drawings:

5 Fig.1 is a schematic view of a laser equipment according to an embodiment in a possible operative condition;

 Fig.2 is a schematic view similar to Fig.1, in a different operative condition of the laser equipment;

 Fig.3 is an axonometric view of a laser equipment in a further embodiment;

10 Fig. 4 is a first axonometric view, with parts removed, of the laser equipment of Fig.3 in a use mode;

 Fig.4A is an enlarged view of a portion of Fig.4;

 Fig. 5 is a second axonometric view, with parts removed, of the laser equipment of Fig.3 in the use mode of Fig.4, according to a different angle;

15 Fig. 6 is an axonometric view similar to that of Fig. 4 in a different use mode;

 Fig.6A is an enlarged view of a portion of Fig.6;

 Fig. 7 is an axonometric view similar to that of Fig.5 in the use mode of Fig.6;

20 Fig. 7A is an enlarged view of a portion of Fig.7; and

 Figs.8A, 8B are illustrative diagrams of a function which can be obtained with a switch rotating about the optical axis thereof.

DETAILED DESCRIPTION

[0031] Figs. 1 and 2 schematically represent views of an embodiment of the laser equipment according to the present disclosure. Referring first to such figures, in principle the laser equipment, indicated in its entirety with 1, comprises a laser source 3 which emits a laser beam F toward a focusing optics, schematically represented by a single lens 5. The laser source 3 may comprise a diode laser. The apparatus 1 comprises an output from which the laser beam F is conveyed toward a point of use. At the
30 output of the laser equipment 1 there is arranged a ferrule 7 for connecting a flexible waveguide, in particular in the form of an optical fiber 9. Typically, the optical fiber 9 comprises a core 9.1 and a cladding 9.2. In some embodiments, the optical fiber 9 may

be a hollow optical fiber, in which case the core 9.1 consists of an empty volume.

[0032] In general, the core 9.1 and the cladding 9.2 are made of materials having refractive indexes different from each other.

[0033] In order to direct the laser beam F selectively into the core 9.1 or into the cladding 9.2 of the optical fiber 9, a deflector 11 is provided that is moveable between a first distanced position (Fig.1), in which it does not interfere with the path of the laser beam F, and a second operative position (Fig.2), in which the deflector 11 is inserted into the path of the laser beam F. The displacement movement from one to the other of the two positions may be imparted by an actuator 13. The movement can be a rotary movement, as shown schematically in Figs.1 and 2. In other embodiments, not shown, the movement may be a translation movement, for example, or a combined roto-translation movement.

[0034] As shown in Fig.1, the components described above of the equipment 1 are arranged in a manner such that, when the deflector 11 is distanced with respect to the path of the laser beam F, the latter is directed into the core 9.1 of the optical fiber 9. Basically, in the diagram of Figs. 1 and 2, the laser source 3, the optics 5 and the ring nut 7 are coaxial. Therefore, in the operative condition of Fig.1 the laser beam F is propagated along the core 9.1 of the optical fiber 9.

[0035] When the deflector 11 is arranged in the position of Fig.2, it deflects the laser beam F so that the beam enters into the cladding 9.2 of the optical fiber 9 instead of into the core 9.2 thereof. Therefore, in the operative condition of Fig.2 the laser beam F is propagated along cladding 9.2 of the optical fiber 9.

[0036] The deflector 11 can be obtained in any suitable manner and with any optical system capable of imparting the requested slight deflection of the laser beam F described above. In some embodiments, the deflector 11 may comprise an optical wedge. In other embodiments, the deflector 11 may comprise, for example, a diffraction grating, and more generally a diffractive optical element.

[0037] The simplified embodiment of Figs. 1 and 2 shows an equipment which allows, using the same optical components, to direct the laser beam selectively into the core or cladding of an optical fiber.

[0038] In some applications, the deflector 11 may deflect only a part of the energy of the laser beam into the cladding 9.2 of the optical fiber 9. This can be obtained, for example, by using a diffraction grating, instead of an optical wedge as a deflector element 11.

5 [0039] The laser beam F is typically an aiming laser beam. It can be combined with a treatment laser beam F1, coming from a further laser source 4. The sources 3 and 4 and the paths of the respective laser beams are arranged so as to converge toward a beam combiner 6, which is arranged so that downstream thereof the beams F and F1 are directed along a common path toward the output of the equipment where the optical
10 fiber 9 is interfaced. In this manner, the treatment laser beam F1 is directed into the core 9.1 of the fiber and the aiming beam F is selectively directed into the core 9.1 or into the cladding 9.2, depending on the position of the deflector 11.

[0040] This allows to obtain an equipment which allows the operator to identify the area to be treated by the laser beam F1 with two different types of aiming spots: annular
15 (when the beam F enters into the cladding 9.2) or circular (when the beam F enters into the core 9.1). The annular area surrounds the circular area, which is struck by the treatment laser beam F1 during the treatment.

[0041] In the illustrated embodiment, the laser beam F is directed into the cladding 9.2 of the optical fiber 9 when the deflector is arranged in the path of the laser beam
20 F, between the laser source 3 and the beam combiner 6. However, an inverse arrangement, in which the laser beam F is directed into the cladding 9.2 when the deflector 11 is outside the path of the beam F, and it is directed into the core 9.1 of the optical fiber 9 when the deflector 11 is in the path of the beam F, cannot be ruled out.

[0042] A dual aiming mode can be useful in certain cases. When the possibility of
25 choosing between two different aiming modes is required, or when the core 9.1 of the optical fiber 9 is not capable of propagating the aiming beam F, the deflector 11 can be omitted and the paths of the beams F, F1, as well as the optics along such paths, can be configured so that the aiming beam F always enters into the cladding 9.2, while the treatment beam F1 always enters into the core 9.1 of the optical fiber 9. In this manner,
30 the aiming beam always generates - on the surface to be treated - an annular lit area, which surrounds the area struck by the treatment laser.

[0043] Figs. 3 to 7 show a second embodiment of a laser equipment according to the present disclosure. As will be clarified in greater detail below, in this second embodiment the laser equipment 1 comprises a first laser source which typically acts as an aiming laser, and a second laser source which may be a generic treatment laser. The treatment laser may be a laser for industrial uses or medical uses, or for any other use. In some embodiments, the first laser source may comprise a diode laser and the second laser source may comprise, for example, a higher power gas laser.

[0044] Furthermore, as will be described in detail below, in the embodiment of Figs. 3 to 7, the laser equipment may comprise two outputs, for directing the laser beam/s alternately toward a first waveguide, which may be or may comprise a solid or hollow optical fiber, and toward a second waveguide, which may be or may comprise an articulated tubular arm.

[0045] With initial reference to Fig. 3, in this embodiment, the laser equipment is still indicated in its entirety with 1. It may comprise a base 1.1 and an overlying part 1.2, hereinafter referred to as “adapter”. The adapter 1.2 may configure a first output 1.3, to which an optical fiber 9, typically a hollow optical fiber, can be coupled. Furthermore, the adapter 1.2 may feature a second output 1.4, connected to which is an articulated arm 21, which is a second waveguide that can be used alternatively to the optical fiber 9. The articulated arm 21 can be connected to the adapter 1.2 by means of a rotary joint 1.5, which allows the arm 21 to rotate about a vertical axis A-A.

[0046] The arm 21 may comprise tubular pieces 21.1, 21.2, connected to each other and to the output 1.4 of the adapter 1.2 by means of joints 21.3, 21.4, 21.5, in which reflection mirrors or prisms are arranged, so that the laser beam injected into the waveguide 21 is reflected repeatedly until it reaches, by means of a last joint 21.6, an output 21.7. Arms of this type are per se known and do not require further description.

[0047] In the embodiment illustrated in Figs. 3 to 7 the laser sources are housed in the base 1.1. The arrangement of the laser sources and the relative optical components defining the path of the respective beams is shown in particular in Figs. 4 to 7, where parts of the external housing have been removed to make the internal optical components visible.

[0048] More particularly (see Figs. 4 to 7) housed in the base 1.1 is a first laser source

again labeled 3, which may be an aiming laser. The laser source 3 may comprise a diode laser. The equipment 1 further comprises a second laser source 31, which may be a treatment laser. For example, the laser source 31 may be a CO₂ laser.

5 [0049] The laser beam coming from the second laser source 31 may follow two distinct optical paths, depending on whether the beam is to be conveyed to the first output 1.3, interfaced with the optical fiber 9, or to the second output 1.4, interfaced with the articulated arm 21. A first part of the two optical paths is common in the two cases of use.

10 [0050] More specifically, an optical path is defined by a first reflection mirror 33, for example inclined by 45° with respect to the optical axis of the laser source 31, opposite to the output of the second laser source 31. The first reflection mirror 33 reflects the laser beam toward a second reflection mirror 35, also inclined by 45° with respect to the optical axis of the second laser source 31. The path of the laser beam generated by the second laser source 31 is indicated with F31. The beam F31 reflected by the mirror
15 35 passes through a beam combiner 37, which is transparent to the laser beam of the second laser source 31, and is coaxial to a fitting 39 connecting the base 1.1 to the adapter 1.2 and forming an input of the laser beams into the adapter 1.2. The fitting 39 is hollow and coaxial to the rotary joint 1.5 and to the output 1.4. In the operative condition illustrated in Figs. 4, 4A and 5, the laser beam F31 follows this path to be
20 conveyed toward the second output 1.4 and therefrom into the articulated tubular arm 21.

[0051] To convey the laser beam F31 toward the first output 1.3, there are provided three further optical components which, in the illustrated embodiment, are housed in the adapter 1.2. More specifically, these components comprise a switch 41, which can
25 selectively take two positions, namely: a first position, hereinafter conventionally also referred to as an inactive position, illustrated in Figs. 4 and 5, in which the switch 41 does not interfere with the laser beam F31; and a second active position, illustrated in Figs. 6 and 7, in which the switch 41 intersects the path of the laser beam F31 and deflects it toward the first output 1.3 as described below.

30 [0052] In the illustrated embodiment, the switch 41 has, by way of example, a rotary movement to move from one to the other of the two positions described above. The

rotary movement may be imparted by an actuator 42.

5 [0053] When the switch 41 is in the operative position of Figs. 6 and 7, the beam F31 coming from the mirror 35 strikes the switch 41 at an angle such to cause the reflection thereof by the switch 41 toward a third inclined reflection mirror 43, which in turn reflects the laser beam toward a fourth inclined reflection mirror 45, so that the re-
flected laser beam is substantially coaxial to the first output 1.3 and with the optical fiber 9 interfaced with said first output 1.3. The path of the laser beam coming from the second laser source 31 downstream of the switch 41 is indicated with F31x in Figs. 6 and 7.

10 [0054] In summary, displacing the switch 41, which comprises a moveable reflection mirror, allows to direct the laser beam F31, F31x of the second laser source 31 alternately toward the articulated arm 21 or toward the optical fiber 9.

[0055] The first laser source 3 emits a laser beam indicated with F3 in Figs. 4 to 7. The previously mentioned beam combiner 37 is located along the path of the laser beam F3 coming from the first laser source 3. In the illustrated embodiment, the optical characteristics of the beam combiner 37 are such that it is transparent to the laser beam F31 coming from the second laser source 31 and reflective to the laser beam F3 coming from the first laser source 3. It should be noted that, in a different arrangement, the beam combiner may be transparent to the laser beam of the first laser source 3 and
15 reflective to the beam of the second laser source 31, with an inverted arrangement of the two laser sources.

[0056] In the illustrated embodiment, the beam F3 coming from the first laser source 3 is reflected by the beam combiner 37 and downstream thereof it follows a path approximately coincident with, i.e. coaxial to, the path of the laser beam F31 or F31x coming from the second laser source 31.
20

[0057] The laser beam F3 coming from the first laser source 3 may therefore be directed toward the second output 1.4 when the switch 41 is in the inactive position (Figs. 4, 5), or toward the first output 1.3, when the switch 41 is in the active position (Figs. 6, 7).

30 [0058] In principle, the optical axes of the two laser sources 3, 31 and the optical

components along the paths of the respective laser beams are arranged in a manner such that downstream of the beam combiner 37 the paths of the two beams are coincident, i.e. coaxial. In this manner, if the apparatus 1 is in the operative condition of Figs. 4 and 5, the two laser beams F3 and F31 enter coaxially into the articulated arm 21 and they are propagated therein. In actual operation, the two beams can be emitted alternately, in the sense that the laser beam F3 is propagated along the articulated arm 21 in a first aiming step, during which the second laser beam F31 is not propagated. Vice versa, the laser beam F31 is propagated along the articulated arm 21 after the emission of the aiming laser beam F3 has ended. The possibility of leaving the aiming laser beam F3 always active, even during treatment with the laser beam F31, cannot be ruled out.

[0059] Generally speaking, when the equipment 1 is in the operative condition of Figs. 6 and 7, the aiming laser beam F3 of the first laser source 3 and the laser beam F31 of the second laser source may follow two coincident paths and be injected into the core of the optical fiber 9 through the defined path, downstream of the beam combiner 37, by the switch 41 and the reflection mirrors 43, 45.

[0060] However, in some cases, for example in particular if the optical fiber 9 is a hollow optical fiber, the aiming laser beam F3 coming from the laser source 3 cannot be propagated with a transmission efficiency adequate to ensure visibility of the transmitted radiation to the naked eye. In this case, in order to allow the use of the aiming laser beam F3, the latter is slightly deflected from the path of the laser beam F31 introducing a deflector, again indicated with 11 similarly to Figs. 1 and 2, into the path of the laser beam F3. The deflector 11 may take a first position, conventionally herein indicated as an inactive position, shown in Figs. 4, 4A, 5, or a second position, conventionally herein indicated as active position, shown in Figs. 6, 6A, 7, 7A. The deflector 11 may be mounted on a pivoting arm 11.1, whose rotation may be controlled by an actuator 11.2. The deflector 11 is arranged along the path of the laser beam F3 between the first laser source 3 and the beam combiner 37.

[0061] As in the embodiment of Figs. 1 and 2, the deflector 11 may be an optical wedge, or a diffraction grating or a generic diffractive optical element, or any other optical component which performs a similar function of at least partial deflection of the laser beam F3 coming from the first laser source 3, so that - downstream of the

deflector 11 - the paths of the laser beams F3 and F31 are no longer precisely coaxial. As described in greater detail below, the deflector 11 can be rotatable about an axis thereof approximately parallel to the direction of propagation of the laser beam F3, in order to obtain particular functions described hereinafter.

5 **[0062]** As schematically illustrated in Figs. 1 and 2, also in the embodiment of Figs. 3 to 7, the deflection imparted onto the laser beam F3 of the first laser source 3 is such that, when the laser beams are directed toward the first output 1.3, the laser beam F3 of the laser source 3 is propagated into the cladding of the optical fiber 9, instead of into the core thereof.

10 **[0063]** The laser equipment 1 described heretofore for example allows to operate as follows. When the tubular arm 21 is used as a waveguide, the switch 41 is in the inactive position of Figs. 4 and 5. The deflector 11 is also in the inoperative position and it is therefore outside the path of the laser beam F3. Either or both of the laser beams F3 and F31 are propagated along the same path downstream of the beam combiner 37
15 and coaxially to the tubular arm 21.

[0064] When the optical fiber 9 is used as a waveguide, the switch 41 is in the active position of Figs. 6 and 7 and therefore the two beams F31 and F3 are directed toward the optical fiber 9. Usually (but this depends on the nature of the optical fiber 9 used) in this operative condition the deflector 11 is inserted into the path of the laser beam
20 F3 (see in particular Fig. 7a). In this manner, the laser beam F31 of the second laser source 31 is propagated along the path F31x and it enters into the core of the optical fiber 9, while the laser beam F3 of the first laser source 31 follows a slightly deflected path and enters into the cladding of the optical fiber 9.

[0065] Thus, the use of the deflector 11 allows to use the same two laser sources (in
25 particular a single main source 31 which generates the operative beam, and the respective aiming laser source 3), whether the guide in the tubular arm 21 is used, or the optical fiber 9 is used as a waveguide, even should the core of the optical fiber not be suitable to transport the aiming laser beam F3.

[0066] In some embodiments, the optical fiber 9 may have an inner diameter of 500
30 micrometers with a cladding having a thickness of 75 micrometers. In this case, the deflector may have a deflection of 3.5 mrad.

[0067] In the simplest embodiment thereof, the deflector 11 may be an optical wedge with a very low angle (optical wedge plate). It can be made variably shaped, for example circular or rectangular-shaped. The substrate may be glass, for example BK7, but it could also be plastic.

- 5 [0068] In a particular embodiment, the deflector is circular-shaped, with a diameter of 10 mm, and a thickness of about 1.5 mm.

[0069] The angle of the optical wedge may be, for example, about 7 mrad, so as to produce a deflection of about 3.5 mrad when the laser beam is, for example, an aiming beam having a wavelength comprised between about 400 nm and about 700 nm.

- 10 [0070] In some improved embodiments, the deflector 11 may be rotatable about the optical axis thereof, in order to obtain a further advantageous characteristic which allows to correct alignment errors between the laser beam and the optical fiber 9. This aspect is clearer with reference to Figs. 8A and 8B, which schematically represent the input face of a hollow optical fiber 9, the hollow core whereof is labeled 9.1 and the
15 cladding whereof is labeled 9.2. The abscissa and ordinate indicate exemplary dimensions of these two parts of the optical fiber 9.

- [0071] If the optics are perfectly aligned, so that the aiming beam F3 is coaxial to the hollow fiber 9 when the deflector 11 is inserted into the path of the beam F3, the spot of the aiming beam F3 is deflected onto the cladding 9.2 of the optical fiber 9. Rotating
20 the deflector 11 about the optical axis thereof, for example by 90° steps, the spot of the aiming beam moves from one to the other of the positions indicated by S1, S2, S3 and S4 in Fig.8A. Typically, the spot may not be circular, but for example elliptical, as shown in Figs. 8A and 8B and the centroid thereof moves on a circumference C which is concentric with the axis of the optical fiber 9.

- 25 [0072] In reality, however, situations of flawed alignment of the optical components may occur, so that the circumference C on which the centroids of the spots S1-S4 of the aiming beam F3 lie in the various possible angular positions of the deflector 11 is eccentric with respect to the axis of the optical fiber 9. A condition of this type is shown by way of example in Fig 8B. As clear from such figure, the energy of the
30 aiming beam F3 which enters into the cladding 9.2 of the optical fiber 9 varies depending on the angular position of the deflector 11.

[0073] The angular position of the deflector 11 may then be chosen so as to maximize the superimposition between the spot S of the aiming laser beam F3 and the section of the cladding 9.2 of the optical fiber 9. In the example of Fig. 8B the position of the spot S2 is the one which maximizes the coupling between the cladding of the fiber and the aiming beam F3 and therefore the amount of energy that is injected into the cladding.

[0074] Although in the example described with reference to the attached drawings there is provided for a deflector 11 so as to modify the path of an aiming beam deflecting it into the cladding of a hollow fiber 9, the deflector can also be advantageously used in combination with solid fibers, for example with silica/silica fibers. In this case, the deflector can be used to direct a laser beam, typically for example an aiming laser beam, alternately in the core or in the cladding of the fiber, in order to obtain two different shapes and dimensions of the spot of the laser beam, associated respectively with propagation in the core (diameter of the core and numerical aperture (NA) of the core), or in the cladding (diameter of the cladding and numerical aperture (NA) of the cladding).

Claims

1. A laser equipment (1), comprising:
 - a first laser source (3) adapted to emit a first laser beam (F3), wherein the first laser beam is an aiming laser beam (F3);
 - 5 – a second laser source (31) adapted to emit a second laser beam (F31), wherein the second laser beam (F31) is a treatment laser beam;
 - a beam combiner (37), adapted to combine the first laser beam (F3) and the second laser beam (F31) directing them into a common path downstream of the beam combiner (37);
 - 10 – a first output (1.3) which can be interfaced with an optical fiber (9), for conveying the first laser beam (F3) and the second laser beam (F31) into the optical fiber (9);
 - a deflector (11) arranged along a path of the first laser beam (F3), between the first laser source (3) and the beam combiner (37);
 - 15 wherein: the deflector (11) is moveable between a first position and a second position and is adapted to be inserted into the path of the first laser beam (F3) coming from the first laser source (3) and removed from said path; wherein the deflector (11), the first laser source (3), the second laser source (31) and the beam combiner (37) are arranged in a manner such that: when the deflector (11) is in the second position the
 - 20 first laser beam (F3) is at least partially directed into a cladding (9.2) surrounding a core (9.1) of the optical fiber (9) interfaced with the first output (1.3); and when the deflector (11) is in the first position, the first laser beam (F3) and the second laser beam (F31) downstream of the beam combiner (37) are substantially coaxial.
2. The laser equipment (1) of claim 1, wherein in the first position the
- 25 deflector (11) is distanced with respect to the path of the first laser beam (F3) and in the second position the deflector is inserted into the path of the first laser beam (F3).
3. The laser equipment (1) of claim 1 or 2, wherein when the deflector (11) is in the first position the first laser beam (F3) and the second laser beam (F31) are directed into the core (9.1) of the optical fiber (9).
- 30 4. The laser equipment (1) of claim 1, 2 or 3, wherein the optical fiber (9) is a hollow optical fiber with the cladding (9.2) surrounding the hollow core (9.1).

5. The laser equipment (1) of one or more of the preceding claims, wherein the deflector (11) comprises an optical wedge or a diffractive optical element.

6. The laser equipment (1) of one or more of the preceding claims, comprising: a second output (1.4), which can be interfaced with a second waveguide (21),
5 in particular to an articulated tube for guiding a laser beam; and a switch (41) adapted to take two positions, for directing at least the second laser beam (F31), and preferably the first laser beam (F1) and the second laser beam (F31) selectively toward the first output (1.3) or toward the second output (1.4).

7. The laser equipment (1) of claim 6, wherein the movement of the
10 deflector (11) and the movement of the switch (41) are coordinated with respect to each other so that the deflector (11) is in the second position when the switch (41) is in the position for directing the second laser beam (F31) toward the first output (1.3).

8. The laser equipment (1) of claim 6 or 7, wherein the switch (41) comprises a movable mirror.

9. The laser equipment (1) of claim 8, wherein the switch (41) is arranged to cooperate with a pair of reflection mirrors (43, 45) arranged in sequence
15 along the path of the first laser beam (F3) and of the second laser beam (F31) downstream of the moveable mirror of the switch (41) when the moveable mirror of the switch (41) is in the path of the first laser beam (F3) and of the second laser beam
20 (F31); wherein the reflection mirrors (43, 45) are inclined to receive the first laser beam (F3) and the second laser beam (F31) from the mirror of the switch (41) and reflect the first laser beam (F3) and the second laser beam (F31) toward the first output (1.3).

10. The laser equipment (1) of one or more of claims 6 to 9, wherein the
25 first laser source (3) and the second laser source (31) are housed in a base unit (1.1); wherein the base unit is associated with an adapter (1.2) having an input (39) which can be interfaced with the base unit (1.1) and adapted to receive the first laser beam (F3) and the second laser beam (F31); and wherein the first output (1.3), the second output (1.4) and the switch (41) are arranged in the adapter (1.2).

11. The laser equipment (1) of claim 10, wherein the input (39) of the
30

adapter (1.2) and the second output (1.4) are coaxial with respect to each other, and wherein in the second position the switch (41) is distanced with respect to the optical path of the first laser beam and of the second laser beam.

12. The laser equipment of claim 9 or 10 or 11, wherein the deflector (11) and the beam combiner (37) are housed in the base unit (1.1).

13. The laser equipment (1) of one or more of the preceding claims, wherein the deflector (11) is rotatable about the optical axis thereof.

14. A laser equipment (1), comprising:

- an aiming laser source (3) adapted to emit an aiming laser beam (F3);
- a laser treatment source (31), adapted to emit a treatment laser beam (F31);
- a first output (1.3) which can be interfaced with a flexible waveguide (9), for directing the treatment laser beam (F31) into a core of the flexible waveguide (9);
- a second output (1.4), which can be interfaced with a second waveguide, preferably comprising an articulated tubular arm (21), for directing the treatment laser beam (F31) into the second waveguide (21);
- a switch (41) moveable between: a first position for directing the treatment laser beam (F31) and the aiming laser beam (F3) toward the first output (1.3); and a second position for directing at least the treatment laser beam (F31), and preferably also the aiming laser beam (F3), toward the second output (1.4);

characterized by a deflector (11) associated with the aiming laser source (3), moveable between a first position and a second position, in the second position the aiming laser beam (F3) being directed into a cladding (9.2) of the flexible waveguide (9), when the switch (41) is in the first position.

15. The laser equipment (1) of claim 14, wherein the flexible waveguide (9) is an optical fiber and in particular a hollow optical fiber.

16. The laser equipment (1) of claim 14 or 15, comprising a beam combiner (37), adapted to combine the aiming laser beam (F3) and the treatment laser beam (F31) directing them into a common path downstream of the beam combiner (37), and wherein the deflector (11) is arranged along the path of aiming laser beam (F3), between the aiming laser source (3) and the beam combiner (37).

17. The laser equipment (1) of claim 16, wherein the aiming laser source (3), the second treatment laser source (31) and the beam combiner (35) are arranged in a manner such that, when the deflector (11) is in the first position, the aiming laser beam (F3) and the treatment laser beam (F31) downstream of the beam combiner (35) are substantially coincident, i.e. coaxial.

18. The laser equipment (1) of one or more of claims 14 to 17, wherein the deflector (11) comprises an optical wedge or a diffractive optical element.

19. The laser equipment (1) of one or more of claims 14 to 18, wherein the deflector (11) is rotatable about the optical axis thereof.

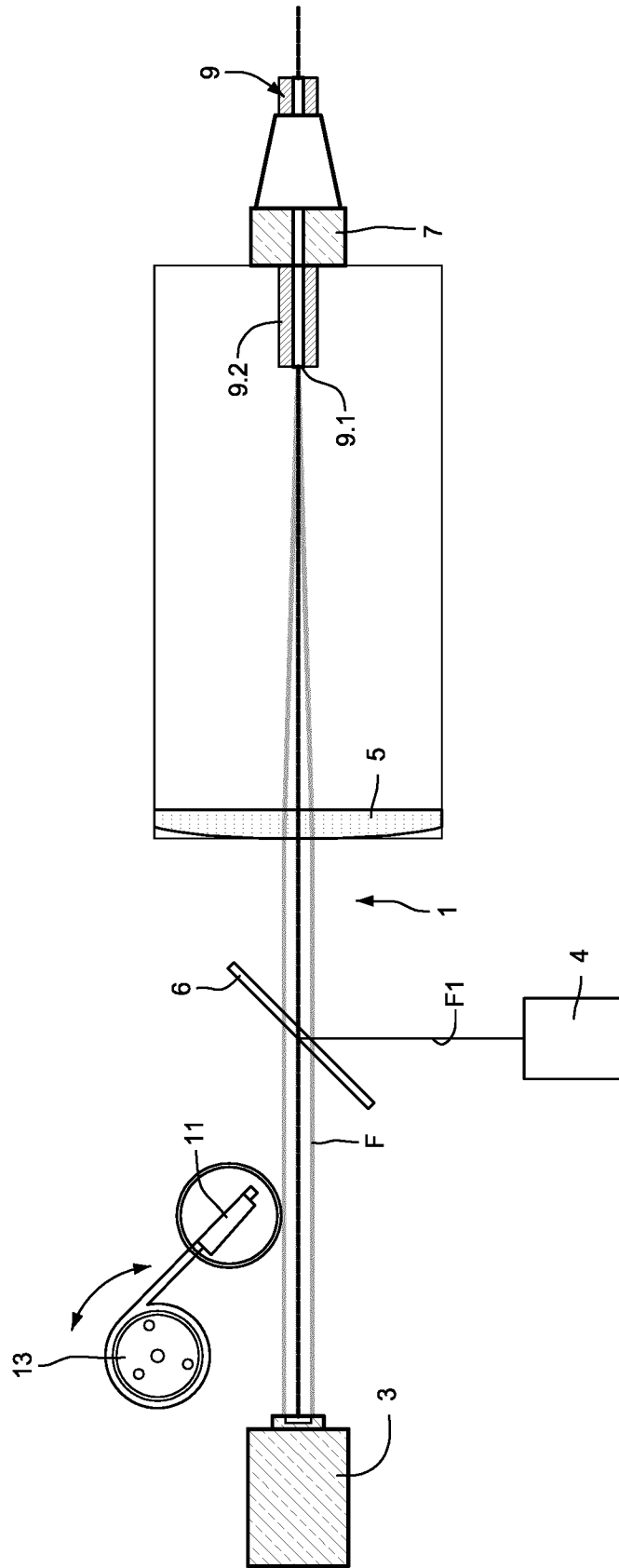


Fig.1

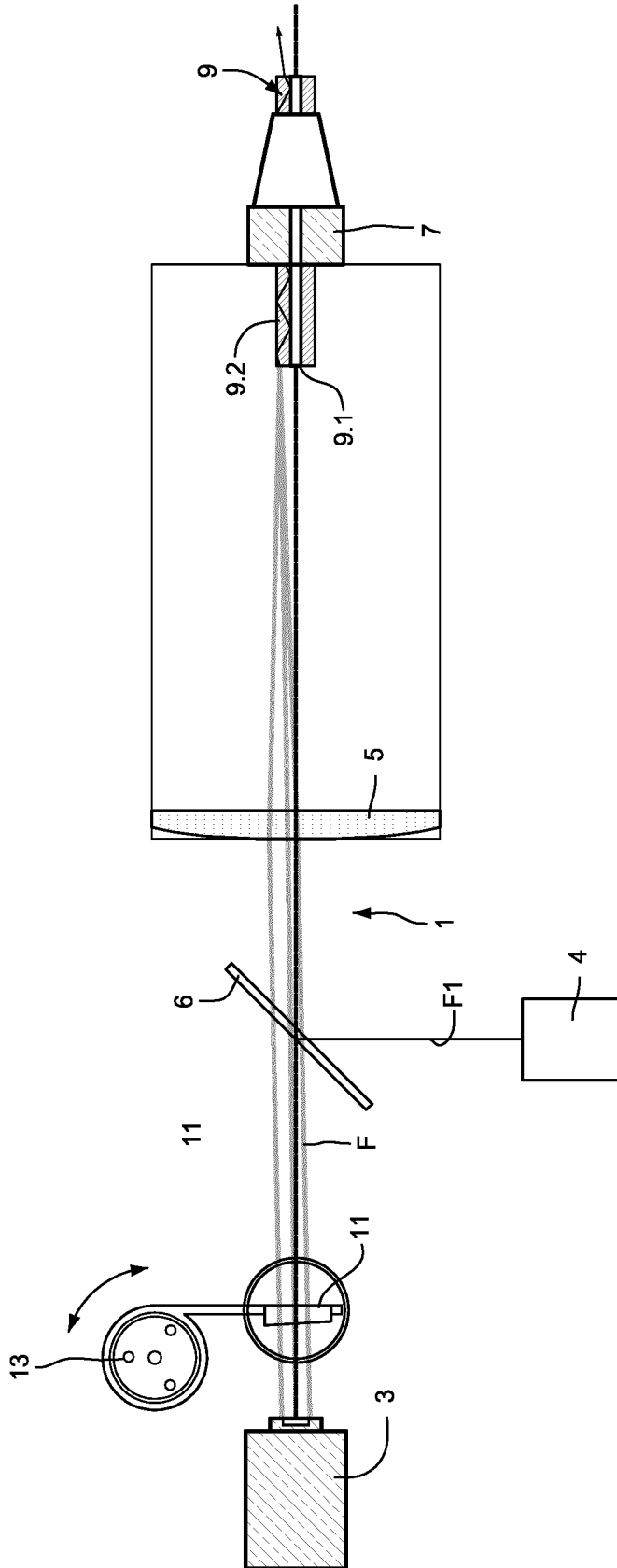


Fig.2

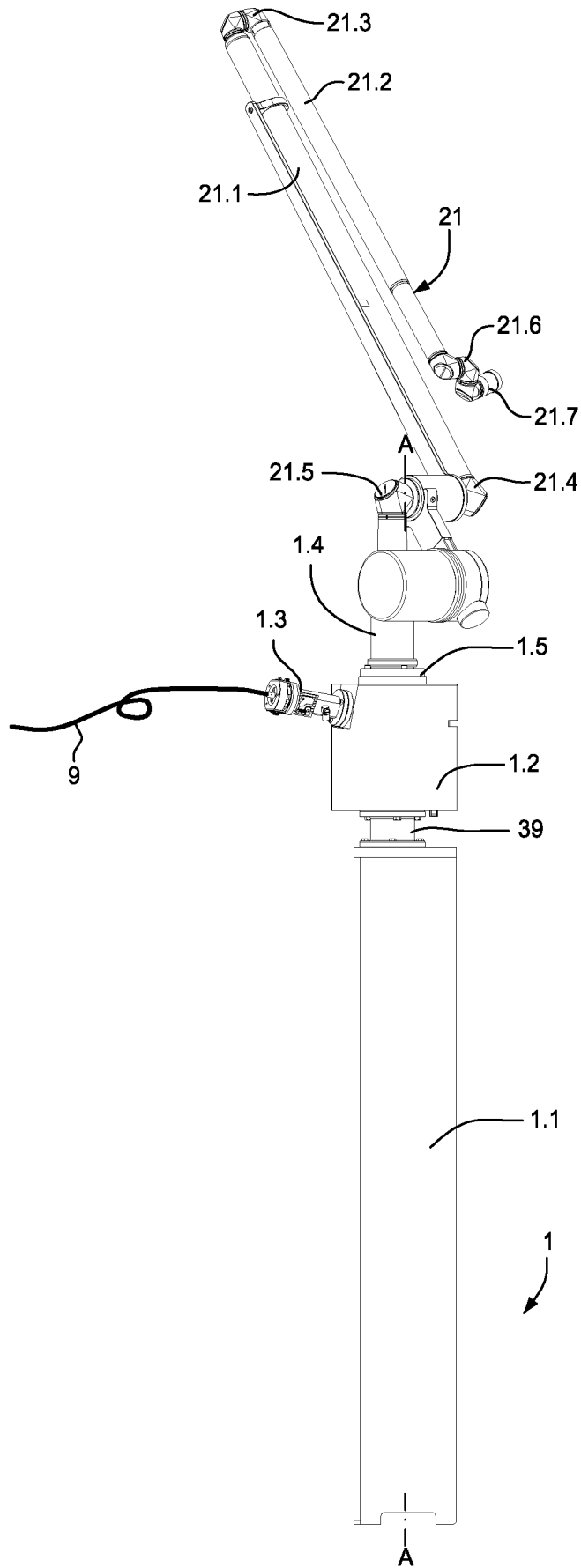


Fig.3

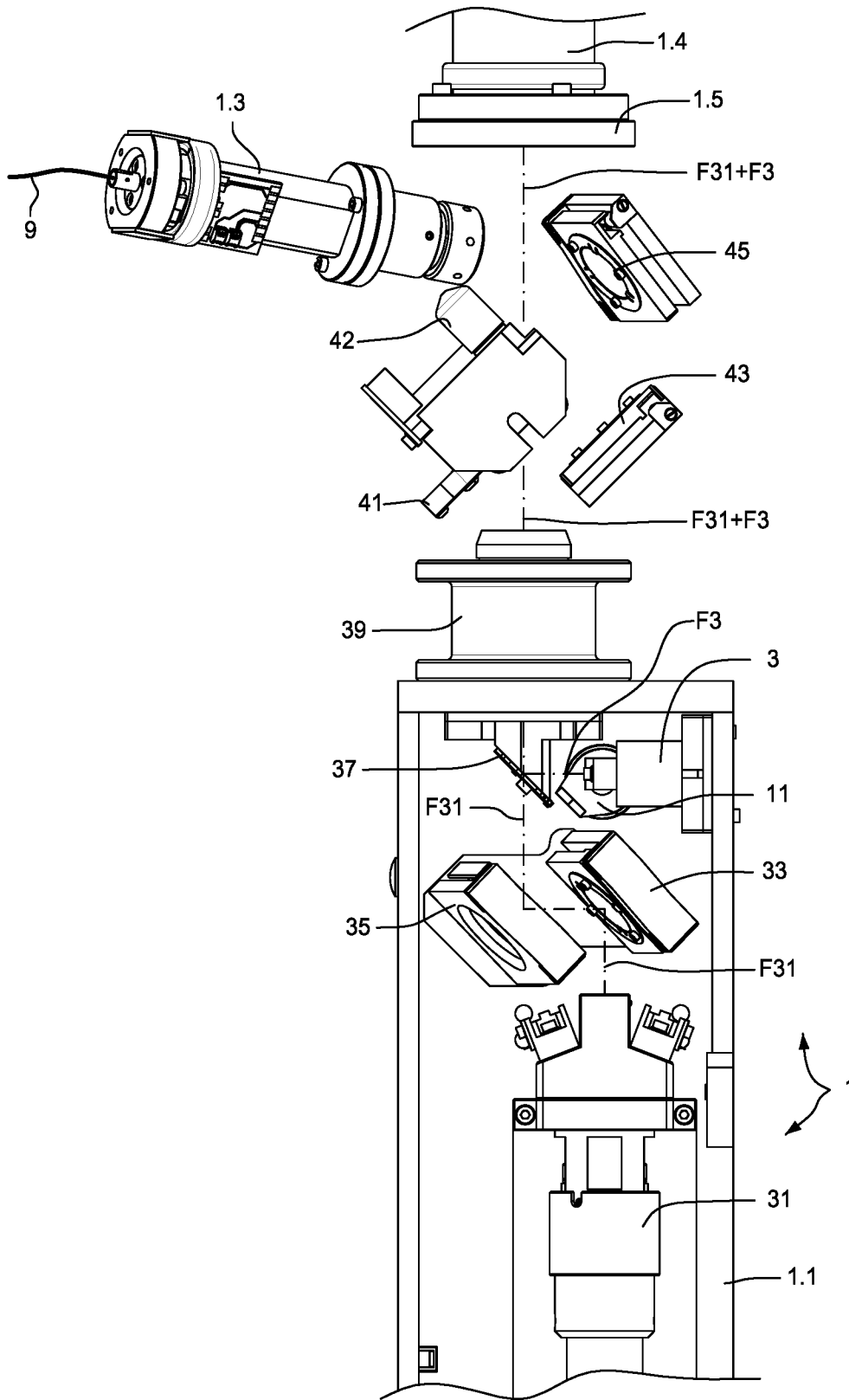


Fig.4

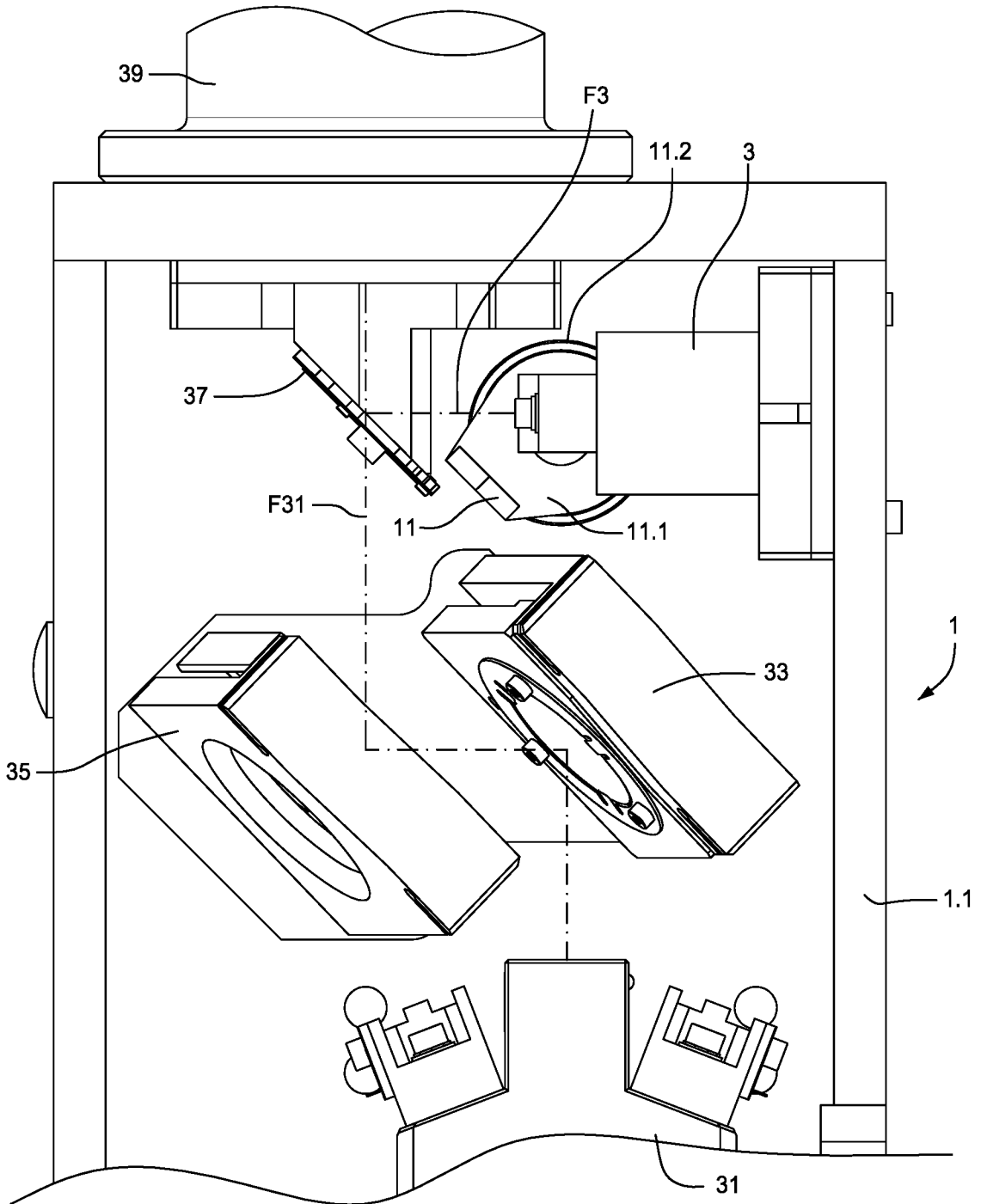


Fig.4A

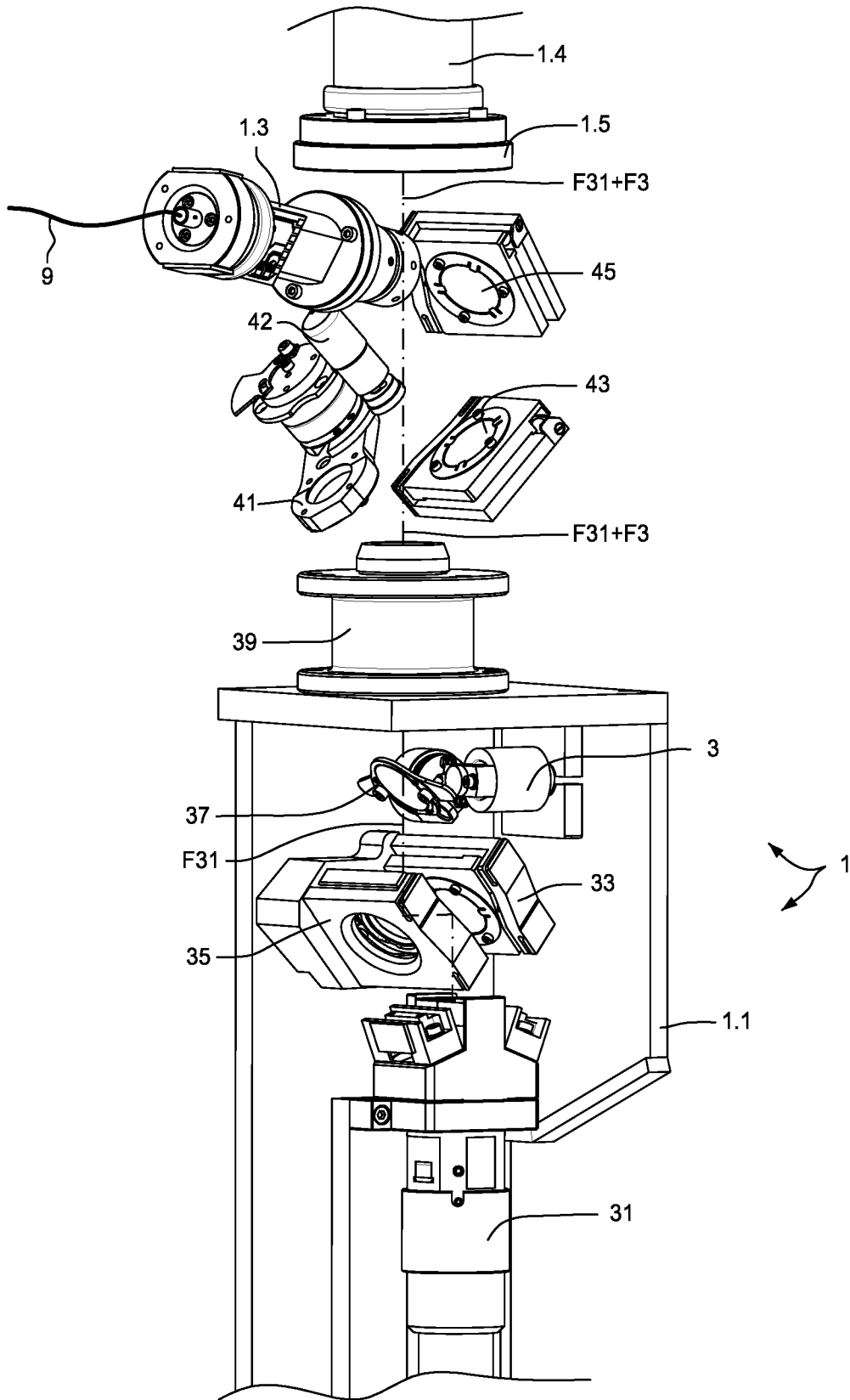


Fig.5

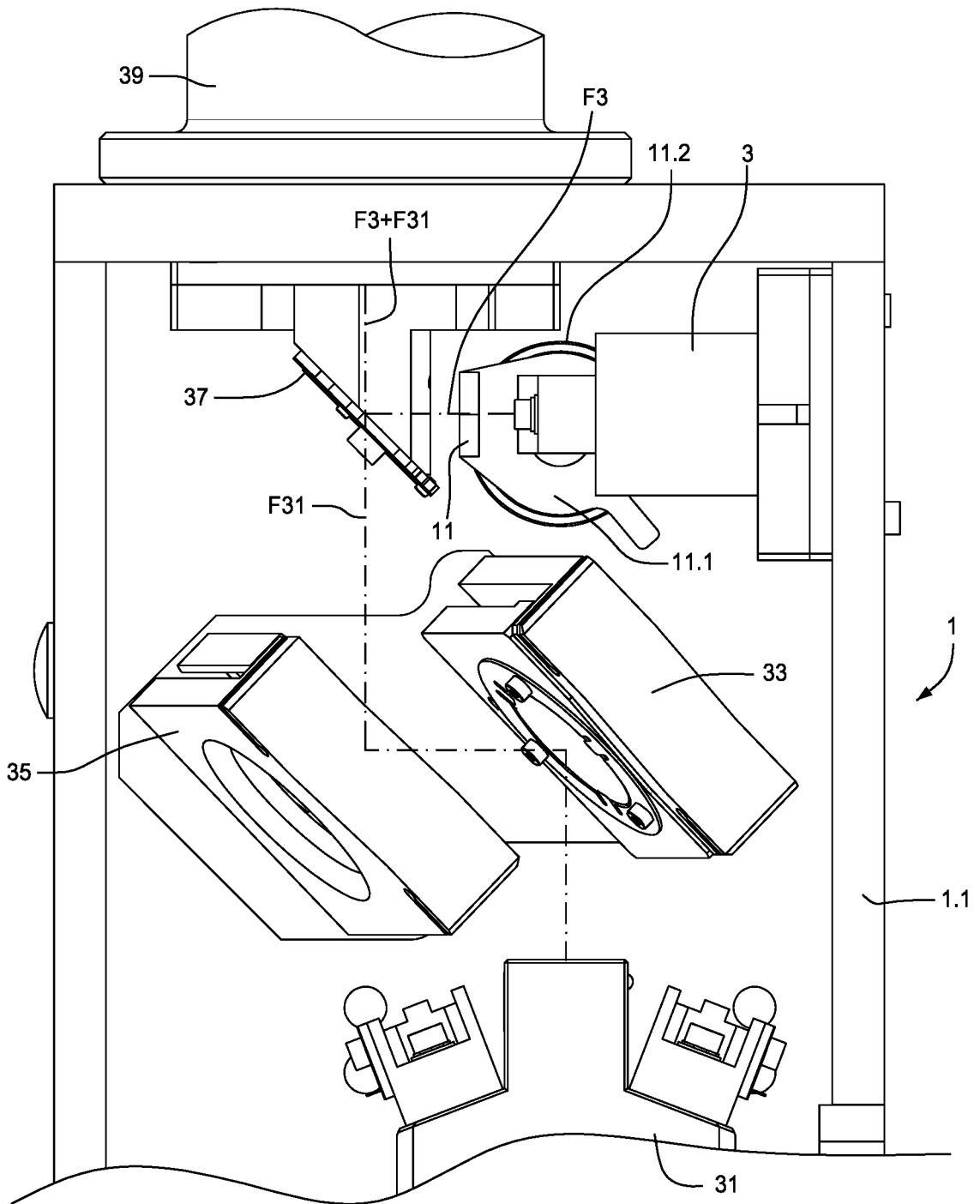


Fig.6A

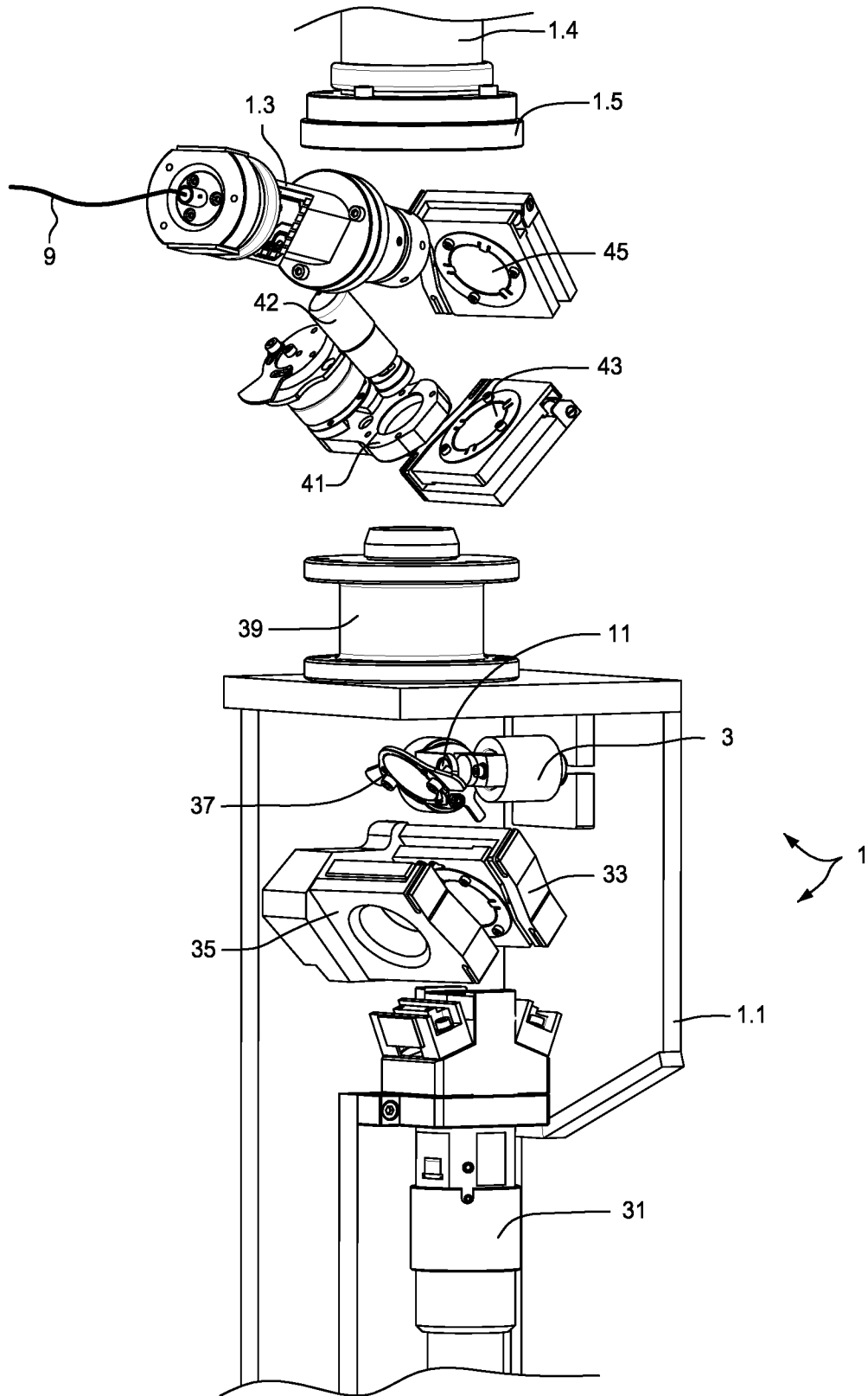


Fig.7

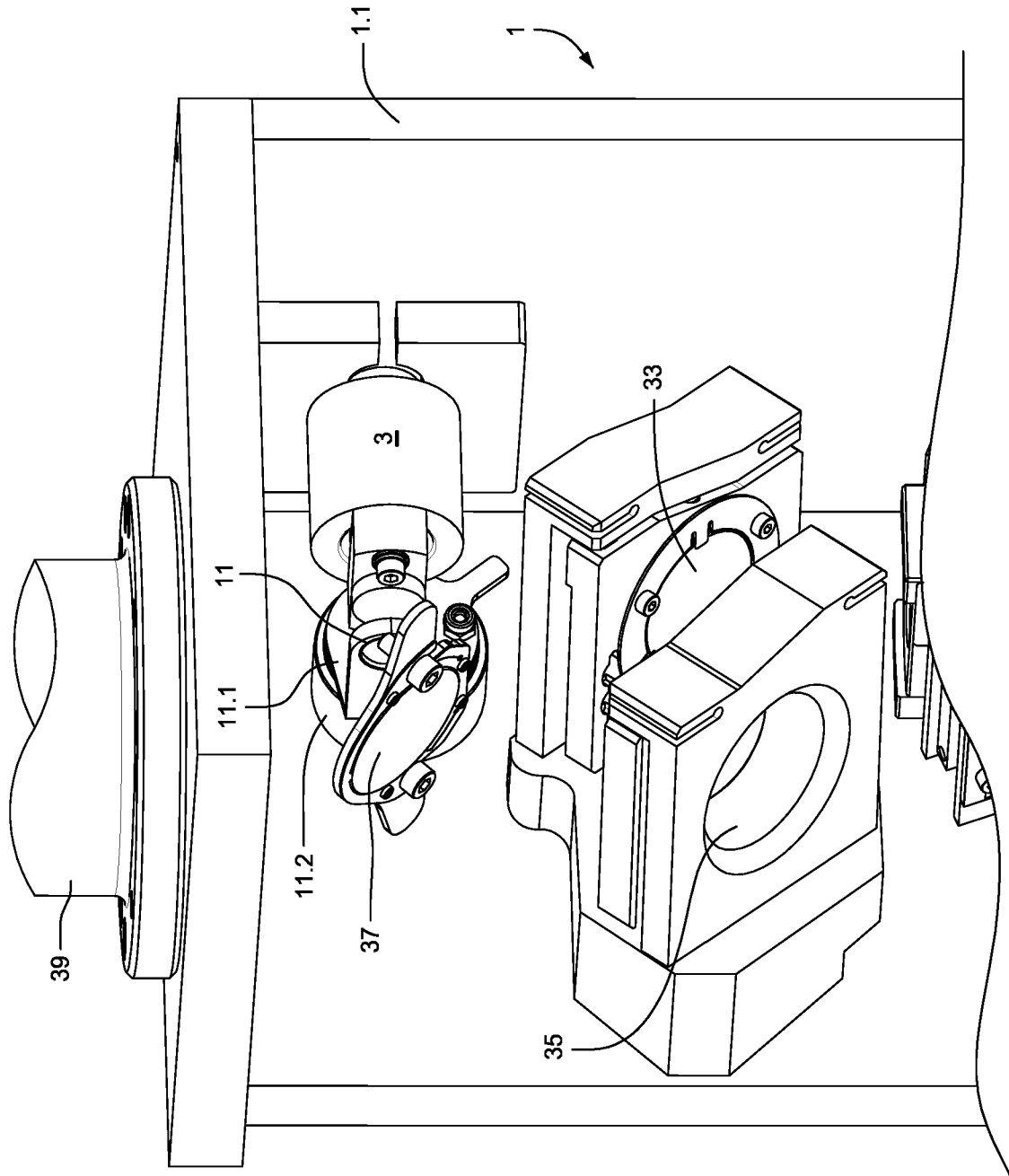


Fig. 7A

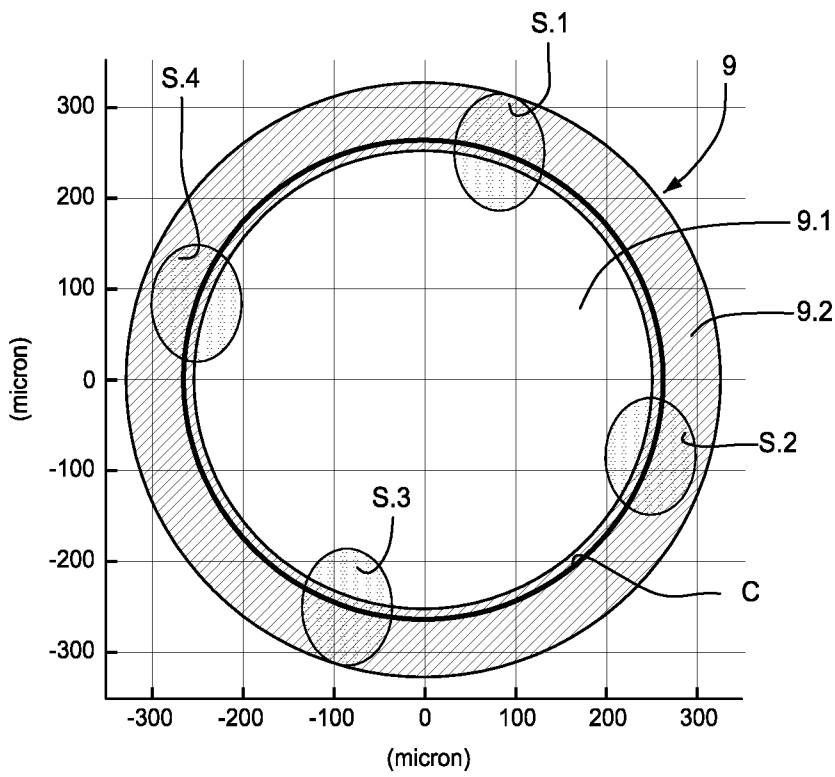


Fig.8A

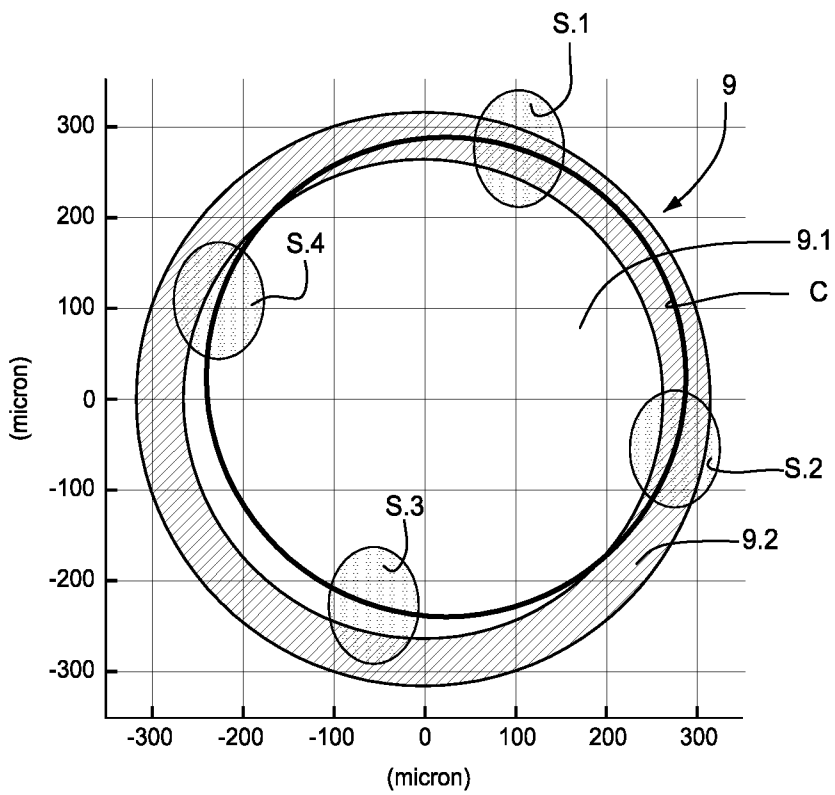


Fig.8B

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2021/069312

A. CLASSIFICATION OF SUBJECT MATTER
 INV. A61B18/22 B23K26/064 G02B6/34
 ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
 Minimum documentation searched (classification system followed by classification symbols)
 A61B B23K G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
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Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search 8 October 2021	Date of mailing of the international search report 19/10/2021
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Beck, Ewa
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INTERNATIONAL SEARCH REPORT

International application No
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