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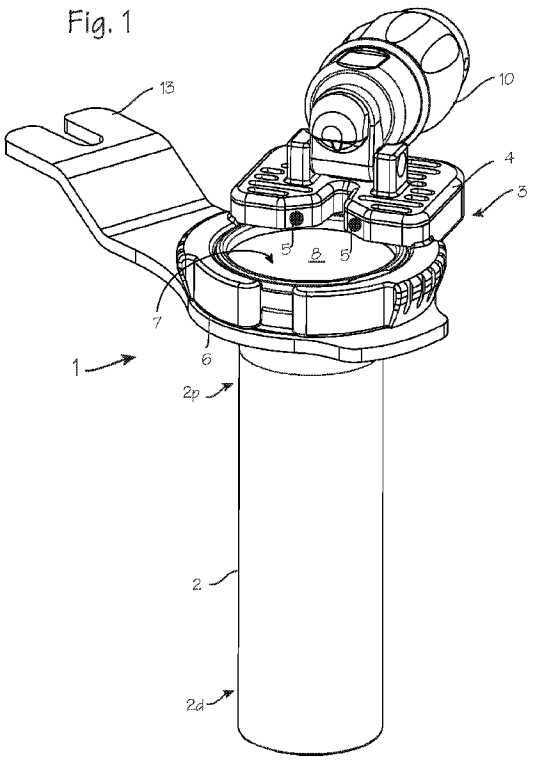
(54) Titre : SYSTEME DE CANULE ECLAIREE
(54) Title: LIGHTED CANNULA SYSTEM

Fig. 1



(57) Abrégé/Abstract:
A cannula suitable for use in minimally invasive surgery is improved with a highly polished and very smooth luminal wall and/or LED's or other light sources focused at particular angles relative to the axis of the cannula. The devices provide for improved lighting and/or reduced lighting requirements for cannulas used for minimally invasive surgery.

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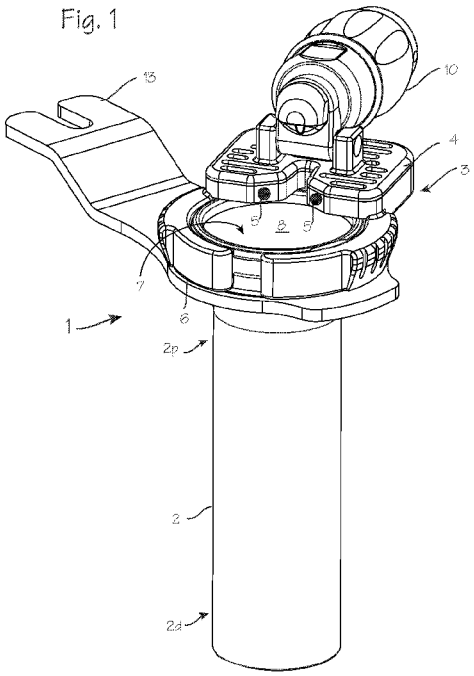
(54) Title: LIGHTED CANNULA SYSTEM



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Lighted Cannula System

Field of the Inventions

[0001] The inventions described below relate to the field of minimally invasive brain or spine surgery.

Background

[0002] U.S. Patent 10,172,525 discloses a cannula and proximally mounted camera system for improved visualization of the brain during minimally invasive surgery. The system includes a cannula with a camera mounted on the proximal end of the cannula with a view into the cannula lumen and the tissue within and below the lumen, along with a prism, reflector or other suitable optical element oriented between the camera and the lumen of the cannula to afford the camera a view into the cannula while minimizing obstruction of the lumen. Lighting disclosed in this patent included lights in the cannula to illuminate the distal end of the cannula or tissue near the distal end of the cannula, or light sources provided outside the assembly, or from lights mounted on the proximal end of the cannula.

Summary

[0003] The devices and methods describe below provide for improved lighting and/or reduced lighting requirements for cannulas used for minimally invasive surgery. A cannula suitable for use in minimally invasive surgery is improved with a highly polished and very smooth luminal wall and/or LED's or other light sources focused at particular angles relative to the axis of the cannula.

Brief Description of the Drawings

[0004] Figures 1 through 4 illustrate a lighted cannula system.

[0005] Figures 5 through 7 illustrate a lighted cannula system with an cannula tube of non-uniform diameter.

[0006] Figure 8 illustrates a lighted cannula system with a cannula tube of non-uniform diameter, with a proximal light source consisting of two LED's.

Detailed Description of the Inventions

[0007] Figure 1 illustrates a cannula system **1** for accessing a target site in the body of a patient. The cannula system comprises a cannula tube **2** and a lighting assembly **3** disposed proximate the proximal end 2p of the cannula tube. The lighting assembly 3 comprises a housing **4** with a number of lights **5** (LED's, incandescent bulbs, etc.). The lighting assembly may be mounted on a ring, or partial ring **6** as illustrated, and may be permanently fixed or releasably attachable to the proximal end 2p of the cannula tube, through releasable attachment means such as a C-ring expandable to engage a groove in the proximal end outer surface, or with an annular snap ring, or with screw threads or other easily attachable and detachable mechanisms. The lighting assembly may instead be directly fixed to the proximal end of the cannula tube or fixed on the ring 18 which in turn is fixed to the cannula tube (as shown in Figure 5 through 8). The cannula tube is characterized by a distal end 2d and a proximal end 2p, and a lumen **7** extending from the proximal end to the distal end, a central longitudinal axis 2L defined by the lumen, and a luminal surface **8** on the inner wall of the cannula tube. The cannula tube most conveniently has a circular radial cross section, but the radial cross section may be varied to provide for access to particular surgical

sites. The cannula tube may consist of an opaque material, non-transmissive to visible light, such as metal, or it may comprise an opaque construction including a luminal surface comprising an opaque material which is non-transmissive to visible light in a cannula tube of transmissive or non-transmissive material (for example, an acrylic tube with a metallic coating).

[0008] The lighting assembly 3 is disposed proximate the proximal end of the cannula tube, and is configured to hold light 5 proximal to the proximal opening of the cannula tube (this is preferable, but the lights may extend slightly distally into the lumen) to project light into the lumen of the cannula tube. The cannula tube may consist of an opaque material, non-transmissive to visible light, and is preferably made of metal such as stainless steel or aluminum.

[0009] The effectiveness of the lighting is preferably enhanced by providing a very smooth surface on the inner wall of the cannula tube. Preferably, the luminal surface is highly polished/smooth with an Average Roughness of 8 micro-inches or smoother (8^{-6} inches, equivalent to Ra (um) 0.2 (0.2 microns), USA #8 finish, Japan Buff #300, or ISO N4 or smoother), to enhance the transmission of light from the proximal end of the cannula to the distal end of the cannula and a target site beyond the distal end of the cannula. The lights of Figure 1 may have a total output of 200 to 700 lumens, which, in combination with the smooth luminal surface, will provide in ample light at a surgical workspace at the distal end of the cannula tube. Combinations of slightly rougher surfaces with higher power lights may be used. The luminal surface may be provided in a Average Roughness in the range of 9 to 32 micro-inches (between 0.22 to 0.81 micrometers, ISO N5 or N6 finish, #6 or #7 finish (roughly), Japan Buff #100 or smoother) and the lights may be chosen to provide additional lumens, in the higher end of the range.

Alternatively, the luminal surface may be provided in a Average Roughness in the range of 33 to 63 micro-inches (0.82 to 1.6 micrometers, ISO N7 finish, USA #3 or #4 finish) and the lights may be chosen to provide additional lumens, in the higher end of the range.

[0010] As illustrated in Figure 2, the light 5 are characterized by a main beam axis **9**, which may be directed at an angle α_1 of 70° to 85°, though preferably about 80° downward (distally) from the radial axis 2R, or, comparably, directed at an angle $ß_1$ or 5° to 15°, and preferably about 10°, inward relative to the long axis 2L of the cannula tube, directed distally, in this embodiment where the cannula has a distal portion with a straight inner bore (of consistent diameter throughout the length of the distal portion) and a proximal conical section with a conical bore which is larger than the diameter of the straight inner bore at the proximal end of the proximal conical section and necks down to match the diameter of the straight inner bore of the straight distal portion.

[0011] As illustrated in Figure 2, the lights are characterized by a main beam axis 9, which may be directed at an angle α_1 of 80° from the radial axis 2R, directed distally, or at an angle $ß_1$ of 10° relative to the luminal surface of the cannula tube (toward the center of the lumen).

[0012] Though Figures 1 and 2 illustrate the system with a cannula tube having a conical lumen in a proximal portion of the cannula tube, the cannula tube may be isodiametric throughout its length, having a consistent or uniform inner diameter and straight luminal walls from the proximal end to the distal end, without a conical portion or a neckdown portion.

[0013] Figure 3 is a view of the cannula system from the bottom, or distal end of the cannula tube. As shown in this Figure, the beam axis 9 may be aimed to intersect the central axis 2C of the cannula tube, or the beam axis may be aimed at angle γ from the radian 2R (the line between the LED and the central axis 2C, or, along a chord of the circle defined by the cannula tube). This angle is preferably in the range of about 10 to 30°. As shown in Figures 3 and 4, the light source may consist of only two LED's disposed over (proximal to) the proximal end of the cannula tube, either directly or on the ring 6 and separated by a first arc α_2 of 50° to 70°, and preferably about 60° as shown in Figure 3 (or, conversely, the second arc $ß_2$ of 290° to 310°, and preferably about 300° as shown in Figure 3). The light source may consist of two pairs of closely spaced lights, with the pairs similarly separated. Preferably, the lights and any associated lenses are disposed proximal to the proximal opening of the cannula tube without extending distally into the lumen. The proximal end of the cannula tube has an inner bore/lumen that is conical, with a proximal opening slightly larger than the diameter of the distal portion of the cannular tube.

[0014] As shown in Figure 1, the cannula system may include a camera assembly **10** secured to the proximal end of the cannula, with a portion of the camera assembly overhanging the lumen and extending into a cylindrical space defined by the lumen of the cannula tube. The camera assembly has a distal-most optical surface, which may be a distal surface of an objective lens or a prism (the prism **11** is shown in Figure 2, and the distal-most optical surface **12** is visible in the distal view of Figure 3), and the distal-most optical surface is disposed proximate the proximal end of the cannula tube. The objective lens or prism may be the portion of the camera assembly overhanging the lumen. The distal-most optical surface of the camera system is spaced proximally from the

proximal end of the cannula tube in the illustration, but may be placed a short distance distal to the very proximal edge of the cannula tube (without extending to the distal end of the cannula tube). Also as shown in Figure 1, the cannula system can include a tab **13** for securing the cannula to a table-fixed flex arm. As illustrated in Figures 3 and 4, the distal most optical surface of the camera assembly is disposed between the lights, in the smaller arc α_2 separating the two lights. A gap in the housing, between the two lights (or two pairs of lights), provides an unobstructed sight-line between the distal-most optical surface and the workspace at the distal end of the cannula tube, and the distal most optical surface of the camera assembly is disposed within this gap or proximal to the gap.

[0015] Figure 5 illustrates a second version of the cannula system for accessing a target site in the body of a patient. The cannula system **14** of Figure 5 comprises a cannula tube **15** and a lighting assembly **16** disposed proximate the proximal end of the cannula tube. The lighting assembly 16 comprises a number of lights **17** (LED's, incandescent bulbs, etc.) mounted on a ring **18** as illustrated (though a partial ring may be used, or the ring may be omitted), and may be permanently fixed or releasably attachable to the proximal end of the cannula tube, through releasable attachment means such as an annular snap ring, a threaded fitting (or a C-ring expandable to engage a groove in the proximal end outer surface). The cannula tube is characterized by a distal end 15d and a proximal end 15p, and a lumen **19** extending from the proximal end to the distal end, a central longitudinal axis 15L defined by the lumen, and a luminal surface **20** on an inner wall of the cannula tube. The inner diameter of the cannula tube proximal end 15p is longitudinally isodiametric (straight-walled, and not conical as in Figure 2), and the inner diameter of the cannula tube distal end 15d is longitudinally isodiametric,

and the inner diameter of the cannula tube distal end is smaller than the inner diameter of that cannula tube proximal end, and the cannula tube proximal end 15p and cannula tube distal end 15d are joined by a neck-down portion 15N of the cannula tube.

[0016] Similar to the construction described in relation to Figures 1 through 3, the lighting assembly 16 of Figure 5 is disposed proximate the proximal end of the cannula tube, and is configured to project light into the lumen of the cannula tube. The cannula tube may consist of an opaque material, non-transmissive to visible light, again preferably metal such as stainless steel or aluminum. The luminal surface is highly polished/smooth with a Average Roughness less that 8 micro-inches, to enhance the transmission of light from the proximal end of the cannula to the distal end of the cannula and a target site beyond the distal end of the cannula. The lights of Figure 5 may have a total output of 1500 to 2500 lumens, which, in combination with the smooth luminal surface, will provide in ample light at a surgical workspace at the distal end of the cannula tube. As with the cannula tube of Figure 1, the lights may be chosen to provide additional lumens, in the higher end of the range, with luminal walls of Average Roughness within the range of 9 to 32 micro-inches or in the range of 33 to 63 micro-inches.

[0017] As shown in Figure 6, the lighting assembly 16 may comprise a plurality of LED's 17 disposed on the proximal end of the cannula tube, either directly fixed to the proximal end of the cannula tube or fixed on the ring 18 which in turn is fixed to the cannula tube. The ring 18 may be permanently fixed or releasably attachable to the proximal end 15p of the cannula tube, through releasable attachment means such as a C-ring expandable to engage a groove in the proximal end outer surface, or with an annular snap ring, or with screw threads or other easily attachable and detachable mechanisms.

[0018] As shown in the cross section of Figure 7, the lights 17 are characterized by a main beam axis **21**, which may be directed parallel to the straight side wall or the portion of the luminal surface on the inner wall of the proximal end of the cannula tube (that is, the beam axes of each LED may be parallel to a portion of the luminal surface on an inner wall of the cannula). Alternatively, as in the systems of Figures 1 and 2, the main beam axis 21 may also be directed at an angle α_1 of 70° to 85°, though preferably about 80° downward (distally) from the radial axis 2R, or, comparably, directed at an angle $ß_1$ of 5° to 15°, and preferably about 10° relative to the luminal surface of the cannula tube (toward the center of the lumen).

[0019] The cannula system of Figure 5 may include a camera assembly 10 secured to the proximal end of the cannula, with a portion of the camera assembly overhanging the lumen and extending into a cylindrical space defined by the lumen of the cannula tube. The camera assembly has a distal-most optical surface, which may be a distal surface of an objective lens or a prism, and the distal-most optical surface is disposed proximate the proximal end of the cannula tube, the objective lens or prism may be the portion of the camera assembly overhanging the lumen. The distal-most optical surface of the camera system is spaced proximally from the proximal end of the cannula tube in the illustration, but may be placed a short distance distal to the very proximal edge of the cannula tube.

[0020] Figures 8 illustrates a lighted cannula system with a cannula tube of non-uniform diameter, with a proximal light source consisting of two LED's 5. Figure 8 illustrates that the cannula tube of Figure 5 can be combined with the two-LED light source of Figures 1 through 4, to obtain the benefits of the larger proximal lumen in a system using a light source consisting of two LED's. In this embodiment, the two LED's

(or two pairs) can be aimed directly distally, with the beam axes parallel to the side wall of the cannula tube, as with Figure 7, or the beam axes may be angled toward the center of the lumen, as with Figure 2.

[0021] The extreme smoothness of the luminal surface provides for abundant reflection of light from the proximal light sources into the cannula distal end and minimization of shadows cast by tools disposed within the cannula lumen, without the need to resort to more complex tube constructions such as optical fibers embedded in the cannula wall, or optical transmission of light from a light ring into a transparent wall, or construction of the cannula wall to serve as a light guide with rough surface features needed to extract and deliver light at that proximal end of the cannula tube. Though the cannula tube can comprise a transparent material, it is more conveniently made of metal, such as stainless steel or aluminum, which can be made with thinner walls vis-à-vis plastics, and can be sterilized and re-used, and is not subject to abrasion or skiving from abrading tools (more of a concern for spinal surgery). Thus, the cannula tube can consist of an opaque material, preferably metal, without embedded optical fibers or wave guide features. The cannula tube can also consist of a transparent polymer, without embedded optical fibers or wave guide features, though the transparency of the tube is not necessary to obtain the advantages of the inventive features of the cannula system.

[0022] Alternatively, the cannula tube can be made of other materials, with a highly reflective material adhered to the luminal walls, which will also provide for good light transmission from the proximal lighting assembly, without embedded optical fibers or wave guide features.

[0023] The luminal surface of the cannula tube may be coated to enhance performance in various aspects. The luminal

surface may be coated with parylene or other dielectric compound for use in surgeries that require delivery of ablation energy through tools to be inserted into a surgical workspace through the cannula tube. The luminal surface may be coated with a hydrophobic coating, or a lipophobic or oleophobic coating, to minimize build-up of body fluids or irrigation fluids during use.

[0024] While the preferred embodiments of the devices and methods have been described in reference to the environment in which they were developed, they are merely illustrative of the principles of the inventions. The elements of the various embodiments may be incorporated into each of the other species to obtain the benefits of those elements in combination with such other species, and the various beneficial features may be employed in embodiments alone or in combination with each other. Other embodiments and configurations may be devised without departing from the spirit of the inventions and the scope of the appended claims.

We claim:

1. A cannula system for accessing a target site in the body of a patient, said cannula system comprising:

a cannula tube having a distal end and a proximal end, and a lumen extending from said proximal end to said distal end, a central longitudinal axis defined by the lumen, and a luminal surface on an inner wall of said cannula tube; and

a light source disposed proximate the proximal end of the cannula tube, said light source configured to project light into the lumen of the cannula tube; wherein

the cannula tube comprises an opaque material, non-transmissive to visible light; and

the luminal surface has an Average Roughness of about 0.2 microns (8 micro-inches) or smoother.

2. The cannula system of claim 1, wherein:

the cannula tube consists entirely of a material which is non-transmissive to visible light.

3. The cannula system of claim 1, wherein:

the cannula tube comprises a material which is transmissive to visible light with a luminal surface comprising a material which is non-transmissive to visible light.

4. The cannula system of claim 1, wherein:

the light source comprises a plurality of lights disposed on the proximal end of the cannula tube, where the lights are characterized by a main beam axis, and said

main beam axis is directed at an angle of about 80° from a radial axis of the cannula tube.

5. The cannula system of claim 1, wherein:

the light source comprises of a plurality of lights disposed on the proximal end of the cannula tube, where the lights are characterized by a main beam axis, and said main beam axis is directed at an angle of about 10° relative to the luminal surface of the cannula tube.

6. The cannula system of claim 1, wherein:

the light source comprises of a plurality of lights disposed on the proximal end of the cannula tube, where the lights are characterized by a main beam axis, and said main beam axis is directed parallel to a portion of the luminal surface on an inner wall of the cannula.

7. The cannula system of claim 1, wherein:

the light source is characterized by a main beam axis, and said beam axis 9 is aimed at angle of 10 to 30° from a radian of the cannula tube.

8. The cannula system of any of claims 2 through 7, wherein:

the light source consists of two lights, disposed on the proximal end of the cannula tube and separated by a first arc of about 60°, or two pairs of closely spaced lights, with the pairs separated by a first arc of about 60°.

9. The cannula system of any of claims 2 through 7, wherein:

the inner diameter of that cannula tube proximal end is conical, and the inner diameter of the cannula tube distal end is isodiametric.

10. The cannula system of any of claims 2 through 7, wherein:

the inner diameter of that cannula tube proximal end is isodiametric, and the inner diameter of the cannula tube distal end is isodiametric, and the inner diameter of the cannula tube distal end is smaller than the inner diameter of that cannula tube proximal end, and the cannula tube proximal end and cannula tube distal end are joined by a neck-down portion of the cannula tube.

11. The cannula system of any of claims 2 through 7, wherein:

the inner diameter of that cannula tube, from the proximal end to the distal end, is isodiametric.

12. The cannula system of any of claims 2 through 7, wherein:

the cannula tube consists of metal.

13. The cannula system of any of claims 2 through 7, wherein:

the opaque material of the cannula tube is free of any optical fibers.

14. The cannula system of any of claims 2 through 7, further comprising:

a camera assembly secured to the proximal end of the cannula, with a portion of the camera assembly overhanging the lumen and extending into a cylindrical space defined by the lumen of the cannula tube; wherein

the camera assembly has a distal-most optical surface, and said distal-most optical surface is disposed proximate the proximal end of the cannula tube.

15. The cannula system of claim 8, further comprising:

a camera assembly secured to the proximal end of the cannula, with a portion of the camera assembly overhanging the lumen and extending into a cylindrical space defined by the lumen of the cannula tube; wherein

the camera assembly has a distal-most optical surface, and said distal-most optical surface is disposed proximate the proximal end of the cannula tube; wherein

the camera assembly is radially disposed between the two lights, within the first arc of about 60°.

16. The cannula system of any of claims 2 through 7, further comprising:

an electrically isolating coating on the luminal surface of the cannula tube.

17. The cannula system of any of claims 2 through 7, further comprising:

a hydrophobic coating on the luminal surface of the cannula tube.

18. The cannula system of any of claims 2 through 7, further comprising:

a lipophobic or oleophobic coating on the luminal surface of the cannula tube.

Fig. 1

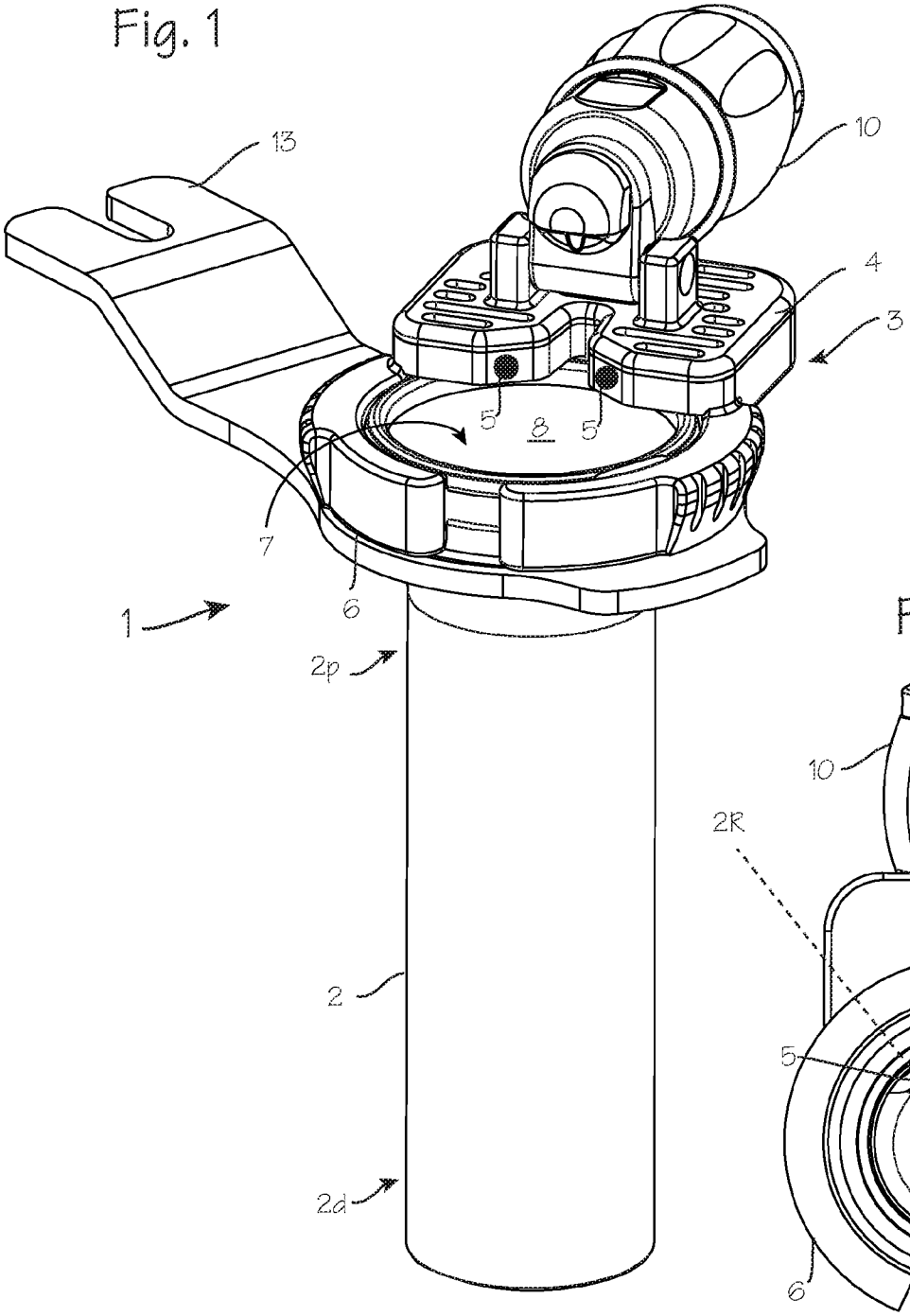

Fig. 3

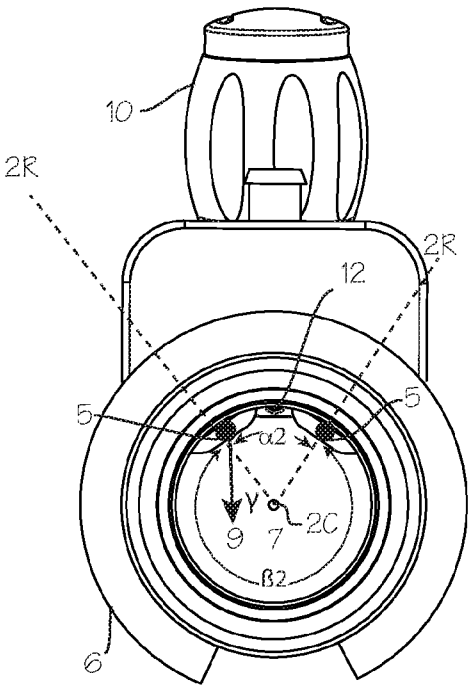

Fig. 2

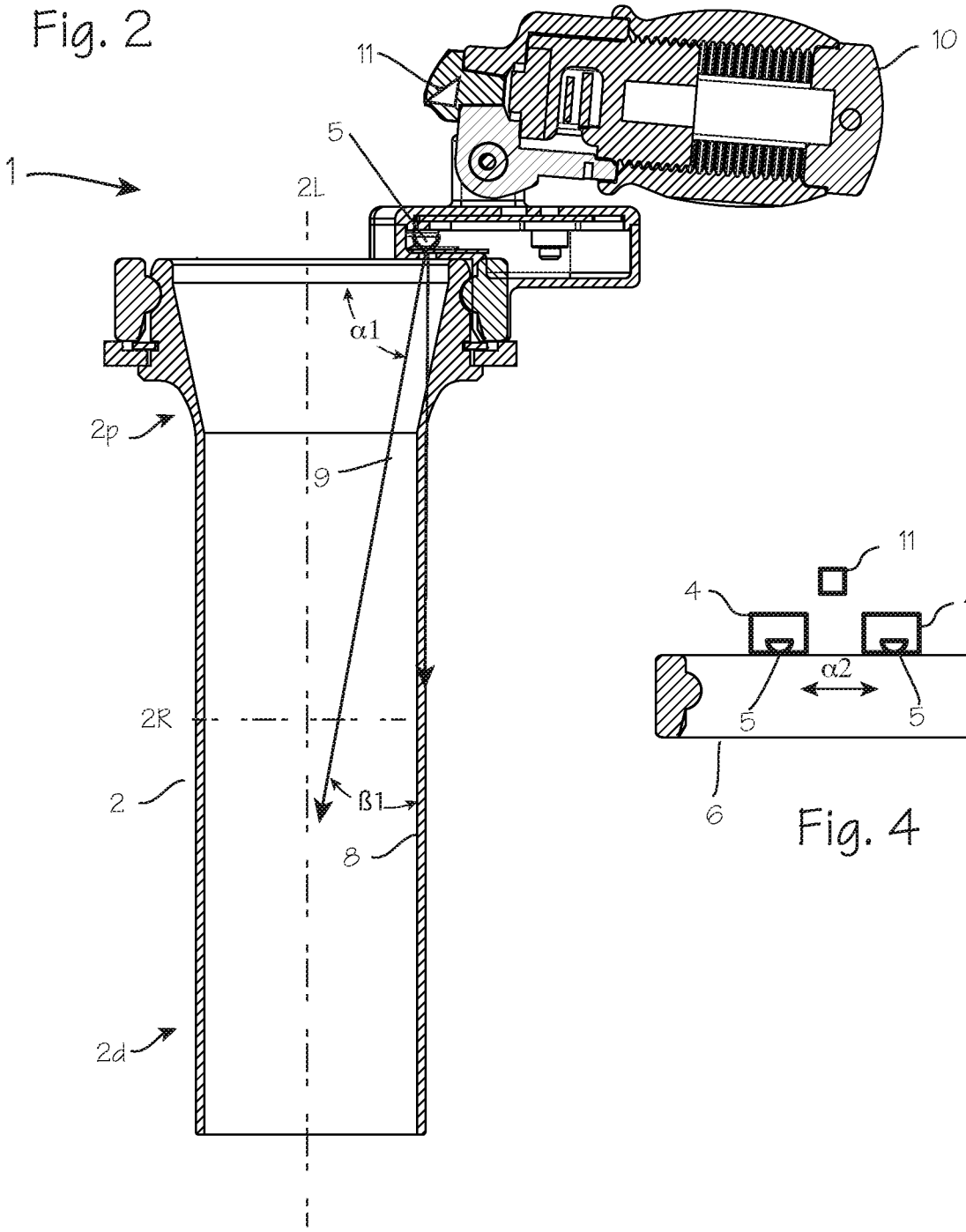

Fig. 4

Fig. 5

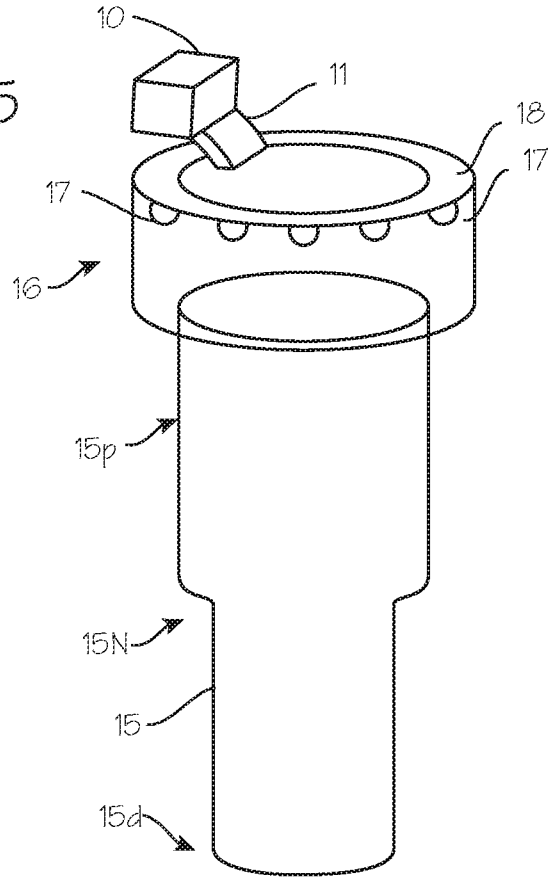

Fig. 6

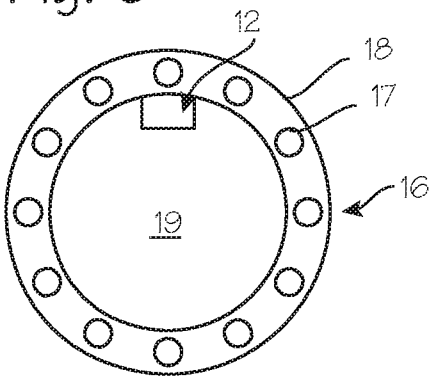

Fig. 7

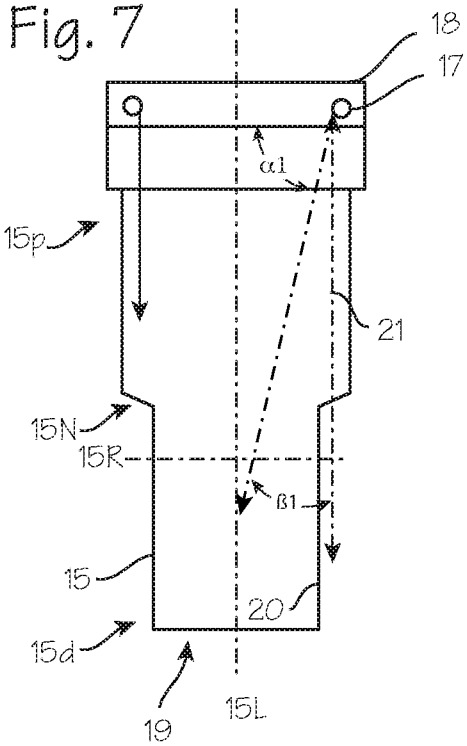

Fig. 8

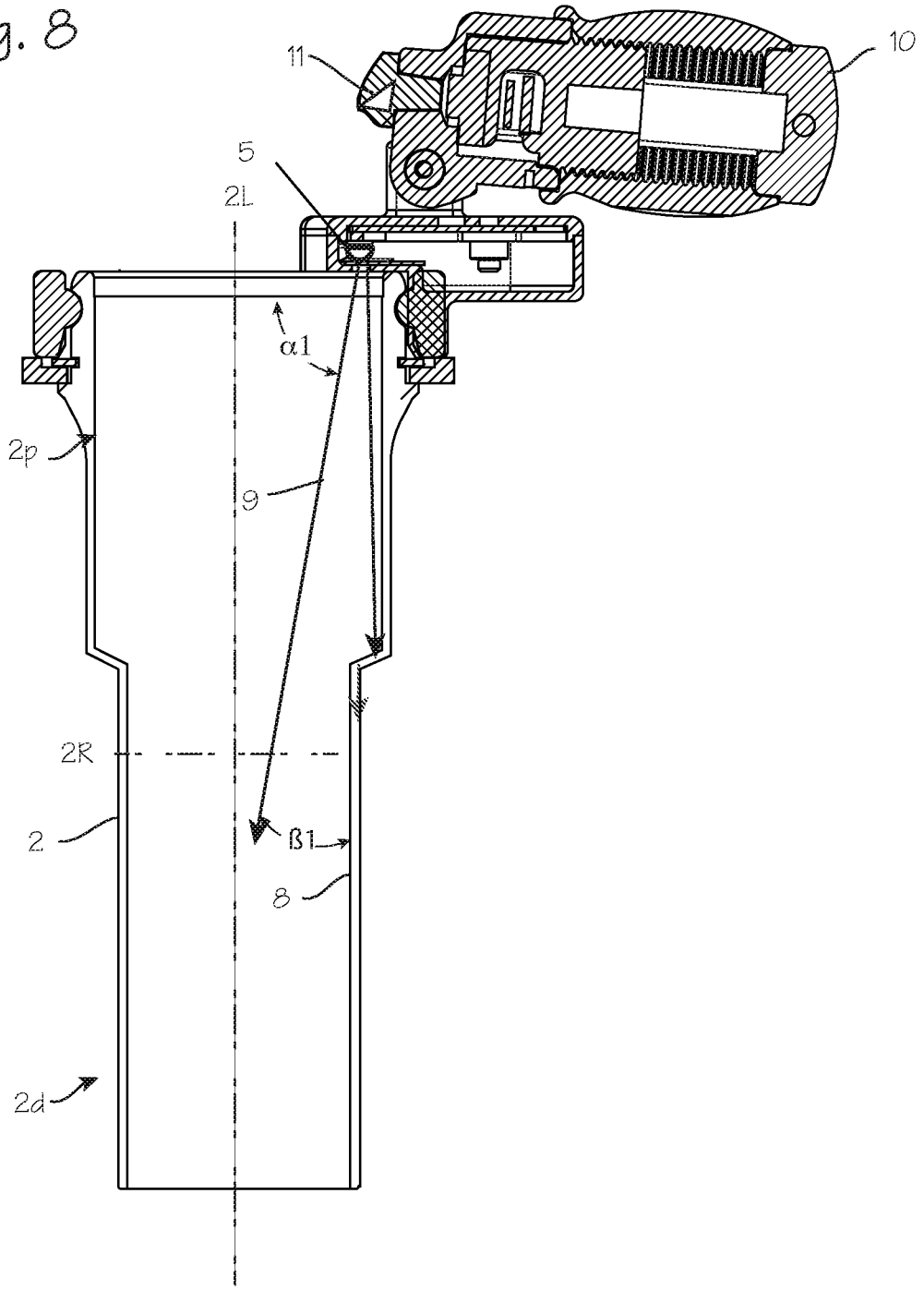

Fig. 1