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(54) CATHETER WITH OPTICAL SENSING

KATHETER MIT OPTISCHER ABTASTUNG

CATHÉTER AVEC DÉTECTION OPTIQUE

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Description

FIELD OF THE INVENTION

[0001] The invention relates to a catheter with optical sensing, for example for measuring a passageway.

BACKGROUND OF THE INVENTION

[0002] A catheter camera for example comprises a radial imaging system in which a reflecting cone redirects light received (mainly) radially inwardly towards an essentially axial direction, for collection by an axially aligned camera. The received light is originally generated by a lighting system that projects a structured light pattern (e.g. a ring pattern) to the inside walls of the cavity in which the catheter is situated. A processor calculates the cross section of a passageway in which the catheter is located, for example by triangulation based on the image from the camera. An example of the use of such a catheter camera is for analysis of the upper airway, for determining the causes of obstructive sleep apnea.

[0003] Obstructive sleep apnea (OSA) is the most common kind of sleep apnea, affecting up to one in ten adults, and is characterized by the occurrence of pauses in breathing, or instances of shallow or infrequent breathing, during sleep. It is caused by blockage or obstruction of the oral cavity or upper airway, often due to loss of muscular tone during sleep. The incidence of OSA is often correlated with the onset of old age, obesity, or abuse of drugs or alcohol.

[0004] A range of therapies exist for treatment of OSA, the most common of which is positive airway pressure (PAP), in which a ventilator is used to deliver a stream of air through the airway at an elevated pressure, in order to hold open the airway. PAP is needed in more severe cases, where patients exhibit an apnea hypopnea index (AHI) > 30. OSA patients may also suffer from daytime sleepiness and require therapy to prevent the development of comorbidities over the longer term. Mild-moderate OSA patients often have more difficulty adhering to PAP therapy because the disease burden is not as strong as in severe patients, and are therefore reluctant to submit to so invasive a therapy. In these cases, various alternative treatments exist, such as positional therapy, mandibular advancement (oral appliances), upper airway surgery and implantable devices.

[0005] In each of these therapies, however, it is important to understand which part(s) of the upper airway in particular is (are) causing obstruction, such that the therapy can be directed most effectively. This explains the interest in dynamic examinations of the upper airway preferably during natural sleep. One approach is to perform an examination of the airway non-invasively using acoustic reflectometry techniques. In such techniques, acoustic waves are propagated along the airway of the patient, by an emitter, via the mouth or nose, and reflections are listened for using a microphone adjacent to the emitter. It is possible, through algorithmic analysis of the detected reflections (see for example: Hoffstein, V., and J. J. Fredberg. "The acoustic reflection technique for non-invasive assessment of upper airway area." European Respiratory Journal 4.5 (1991): 602-611.), to determine an estimate of the cross-sectional area of the examined airway as a function of distance from the emitter. From this, narrowing of the airway at particular locations can be identified, and the specific positions therefore of airway obstructions ascertained.

[0006] Reflectometry techniques however suffer the disadvantage that the accuracy of cross-sectional area estimations declines with distance from the emitter. This is compounded by acoustic leakage and also patient movements during the measurement process, which both act to further compromise the accuracy of the obtained results. Furthermore, since the first obstruction encountered by a wave propagating along the airway causes reflection of much of the wave's initial intensity, reflections from subsequent portions of the airway are typically too weak in intensity to derive any accurate measurements. Hence it is typically only possible to accurately determine the location of the upper-most airway obstruction using these techniques. Finally the noise, size and the acoustic seal needed make the technique unfeasible for the examination of patients during natural sleep.

[0007] It is known instead to use endoscopic procedures, in particular procedures for inspecting or investigating the patency of the human upper airway. Using a standard flexible endoscope for airway examination, specific sites in the upper airway can be inspected for some time to see whether temporary obstructions occur. This however requires the endoscope to be moved from one spot to the other during an examination while the patient is asleep which is time-consuming and inconvenient for both the patient and the physician. For this reason endoscopic examination during natural sleep did not become part of common practice. An alternative version called Drug-Induced Sleep Endoscopy (DISE), which has become the standard care approach in some countries, involves bringing the patient to artificial sleep by means of sedative drugs. This is believed to cause collapses at sites that also participate in real sleep apneas and hypopneas. Also the sedation relieves the discomfort of endoscope travel. Acceptance of DISE remains limited, however, because the link between collapses in a sedated state and collapses during natural sleep remain unclear and may depend strongly on the depth of sedation and because of the costs and risks involved with sedation in general.

[0008] To inspect the upper airway at some discrete critical sites, it is also possible to use a catheter with multiple sensors; once the catheter has been inserted it can remain in the same position during a longer period without additional discomfort for the patient.

[0009] Image sensors can be used to obtain a measure of radial distance, for example if the image sensor is combined with an illumination element that projects a structured illumination pattern (e.g. a ring) on the inside of the airway, the captured image sensor information in respect of the ring image can be analyzed to derive distance information (e.g. by triangulation), and thereby enable the shape of the internal airway passage to be derived.

[0010] For example, an endoscope or catheter may have one or more light generating means capable of producing an outwardly directed ring (or radial plane) of light, such that when inserted into a tube-like airway, cross sectional contours of the airway may be illuminated for inspection by a camera.

[0011] One known means of providing such a light pattern is to direct collimated laser light from an optical fiber toward a deflecting cone whose angle is such as to deflect the incident light radially, for example at 90 degrees, from its surface in all directions around it. The effect is to create a 'ring' pattern of light projecting outwards from the cone, which may then be used to illuminate a circumferential section of an airway. In particular, there are two variations of this concept. In a first, the cone has a reflective outer surface, and is arranged with its tip facing in the direction of the oncoming light, such that light is reflected directly out from its surface. In a second, the cone is arranged with its base facing toward the oncoming light and the pitch arranged such that light incident from the optical fiber on the internal walls of the cone is reflected by total internal reflection in the direction of the opposing wall, through which it is transmitted, deflecting due to refraction as it does so into a path which is at 90 degrees to the initial incident light.

[0012] The reflected light is then captured by a camera. This may be achieved by positioning the camera with the inner wall being examined within the field of view, or else another reflecting cone may be used to redirect the reflected light back to an almost axial direction for capture by an axially aligned camera.

[0013] It is possible to create multiple ring patterns of light, at a series of spaced points along the airway. This can for example be achieved by means of providing multiple illumination units along the catheter, each with its own laser, optical fiber (optionally a GRIN lens) and cone.

[0014] When a catheter is deployed, gravity, the stiffness of the catheter material and the shape of airway will usually cause a catheter to stick closely to the anterior or the posterior airway wall at different depths of the airway.

[0015] This position of the catheter minimizes the distance between the sensor and the closest airway wall but maximizes the distance to the opposite airway wall. This typically leads to problems, in particular problems relating to the light intensity and the sensor range.

[0016] The light intensity that is reflected back towards the sensor decreases with the distance to the airway approximately as an inverse function with distance cubed. This is because the intensity of a ring light pattern is inversely proportional to distance (since it decreases in proportion with the circumference of the ring) while the light scattered back from the airway wall is diffusely scattered into all directions (approximately following Lambert's cosine law) leading to an intensity dependency proportional to the inverse of distance squared. For small distances between the sensor and the airway wall, the light intensity is very high, leading to blooming in the camera blurring the ring position. For large distances, the intensity is very low, making the ring difficult to see among the camera noise. The position of the catheter close to one airway wall thus maximizes the changes in wall distance, and therefore the light intensity differences.

[0017] Figure 3 shows in the left image a catheter 40 in cross section within the airway 42 and located to one side of the airway rather than in the middle. The right image shows a captured image in which there is blooming 44 at one part of the image and the image is dark in other parts of the image 55 so that the airway wall shape cannot be seen. The blooming also obscures the image of the airway wall shape. To capture a high quality image in such a situation, a camera with a high dynamic range (which is expensive) is needed to record the light pattern at all angles.

[0018] In addition the light dose that the airway closest to the sensor receives is unnecessarily high. This might cause unwanted side effects and compromise the safety of the patient by causing tissue damage. It is good practice to always minimize the radiation dose as much as possible.

[0019] With regard to the sensor range, it is difficult to optimize the optics part of a sensor to detect an airway wall both at very large distances and at very close distances. This is because a small camera typically has a very limited number of pixels. It is easy to optimize the sensor optics for short or for long airway wall distances but not for both.

[0020] There is therefore a need for a design which enables the imaging system to be able to tolerate non-central placement within the passageway being imaged, but without requiring highly complex imaging equipment.

SUMMARY OF THE INVENTION

[0021] The invention is defined by the catheter of independent claim 1. Preferred embodiments are defined by the dependent claims. Any example or embodiment which does not fall under the scope of the independent claim is not part of the invention.

[0022] By ensuring that the position of the catheter is known within the passageway, the optical system can then be designed so that the light received by the image sensor has a reduced intensity when blooming would otherwise occur. In this way, a higher quality image may be obtained without needing to increase the complexity of the image sensor. The position of the catheter is preferably known in that at a particular position along the length of the catheter, the position of the catheter cross section within the overall cross section of the passageway is approximately known, and also the angular orientation of the catheter is approximately known at that position. Thus, the catheter preferably has a known orientation relative to the closest passageway wall, i.e. a known orientation relative to the anterior-posterior plane. There is an asymmetric optical design adapted to the expected shape of the passageway and the expected orientation of the sensor with respect to the closest passageway wall.

[0023] The envelope shape of the light output intensity distribution around the catheter is the general shape around the catheter when following a light output intensity with a constant value. For example, for radial directions where the light output intensity is lower or there is more attenuation, the envelope shape will be nearer to the catheter. The general ring shape of illumination around the catheter is thus non-circular. The light output intensity may be a continuous ring or it maybe discontinuous and then formed as a set of discrete points around a ring. In the latter case, it is this general ring shape which defines the envelope shape.

[0024] The light transmission function (to the optical sensor) is the amount of light transmission as a function of radial position. Thus, a non-circular light transmission function means the transmission is non-uniform around the circumference.

[0025] There are various ways to arrange that the catheter position is predetermined and therefore known in advance. It means that there is no need for feedback control of the envelope shape of the light intensity distribution or the transmission function. Instead, the catheter is designed to adopt a particular path (of position and orientation) within the passageway which is known in advance and the optical system (light source and image sensor and all optics between) is designed taking into account that known path.

[0026] In all examples, the catheter has a non-circular outer shape in cross section across the catheter length. This non circular shape means the catheter will have a preference to bending in certain directions. The non-circular shape is thus designed so that the inserted catheter follows a known path within a passageway which is itself of known general shape.

[0027] By way of example, the radius of curvature of the catheter outer shape, in cross section across the catheter length, may be greater at one angular position around the catheter compared to an opposite angular position around the catheter. The radius of curvature is designed to be greater at angular positions around the catheter where the catheter is to be in contact with the passageway wall. This gives rise to a generally squashed shape, i.e. wide and flat, with the flat parts against the passageway wall. A wide flat shape will bend preferentially around an axis parallel to the width direction.

[0028] The catheter may have a flat edge in its outer shape, in cross section across the catheter length, where the catheter is to be in contact with the passageway wall. The flat edge will preferentially stick to the airway wall, while the rounder parts are less likely to stick to the airway wall.

[0029] In all cases, the outer shape or angular orientation of the outer shape may vary along the catheter length. This means the catheter may be designed to follow a more complex path rather than simply bending around one curve. At different points along the length of the catheter, the catheter may make contact with a complex passageway at different angular positions. The angular orientation of the catheter shape or else the shape itself is thus varied to enable the flatter regions to be against the passageway wall.

[0030] In a second example, the bending properties of the catheter vary along the length of the catheter. This provides another way to control the way the catheter is steered into a known shape and location within the passageway. The catheter stiffness to bending in particular directions may for example vary along the length of the catheter.

[0031] These two approaches may be combined so that both shape and stiffness parameters are variables which together enable the catheter to adopt a desired shape when guided by the passageway, itself of generally known shape.

[0032] The light output has a different intensity at different radial directions and/or the catheter comprises a light transmission arrangement which gives rise to different transmission of the light output to the image sensor for different radial directions. These provide various options for controlling the light intensity reaching the image sensor from different directions. The intensity may be controlled at the light source (for example if different light source elements are responsible for light in different radial directions), or else the light intensity may be controlled as a function of radial direction before it is directed to the interior wall (for example by using an attenuation arrangement) or else the light intensity may be controlled as a function of radial direction when it is finally directed to the image sensor (for example by directing light to the image sensor differently for different directions from which the light is received from the interior wall). Controlling the light intensity involves changing the light transmission, whether by using attenuation or redirection of light away from the image sensor.

[0033] The light transmission may be controlled by varying an attenuation of an otherwise constant light source intensity.

[0034] The light output intensity may be least where the catheter is to be closest to the passageway wall. In this way, the output intensity is reduced where needed to avoid blooming, and it may be increased where there is a large distance to the passageway wall.

[0035] If a light attenuation arrangement is used, it may comprise electrical cables or optical fibers. In this way, existing components of the overall system may be used to provide a desired light blocking function, by designing their locations. This avoids the need for additional components. However, a dedicated light attenuation arrangement may of course be provided.

[0036] The light attenuation (as a function of radial position) may take place before the pattern is projected to the inner wall of the passageway or it may take place after reflection by the inner wall. The attenuation may involve absorption, or it may involve steering the light towards or away from specific directions. For example attenuation or reduced transmission insofar as the image sensor is concerned may be achieved be directing light away from the image sensor.

[0037] The terms "attenuation" and "transmission" should be understood accordingly.

[0038] The light source arrangement may comprise a light source inside the catheter, and optionally a collimator to collimate the light from the light source. The light source may direct light radially outwardly, or else it may direct light axially and a reflector may then be provided for redirecting the emitted light to form a ring of generally radially directed light around the catheter length.

[0039] Alternatively, the light source arrangement may comprise:

a light source outside the catheter;
an optical fiber which is adapted to transmit the light output from outside the catheter to the inside of the catheter and to emit the light in a direction centered parallel to the catheter elongate axis;
optionally a collimator to collimate light from the optical fiber; and
a reflector for redirecting the emitted light to form a ring of generally radially directed light around the catheter length.

[0040] This provides a compact design in which axially directed light is converted to radial light by a reflector, such as a reflecting cone.

[0041] The light source preferably comprises a laser or an LED.

[0042] The reflector may be non-axisymmetric thereby creating a non-uniform light intensity with respect to radial direction. In this way, a non-uniform radial light pattern is implemented by the reflector without requiring complex optical alterations to the light output.

[0043] The catheter may further comprise a second reflector for redirecting the radial light after reflection by the interior wall toward the image sensor. The second reflector may then be non-axisymmetric thereby creating a non-uniform camera sensitivity with respect to radial direction. Thus, the image sensor reflector is then used to implement the attenuation as a function of radial direction.

[0044] The catheter may be for use in determining the presence and location of obstructions in an upper airway, the catheter comprising a plurality of radial imaging systems along the length of the catheter. In this way, each radial imaging system is optimized for a particular one of the locations at which airway obstructions can be ascertained.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045] Examples of the invention will now be described in detail with reference to the accompanying drawings, in which:

Figure 1 shows a schematic illustration of a length section of an example catheter disposed inside an airway;
Figure 2 shows a schematic illustration of an example catheter inserted into a patient's nasal cavity and upper airway;
Figure 3 shows a problem which arises due to non-central catheter positioning;
Figure 4 shows how the catheter shape can influence the bending performance;
Figure 5 shows a catheter with non-circular outer shape within a passageway;
Figure 6 shows how attenuation may be used to alter a radial light pattern;
Figure 7 shows how different orientations may be appropriate at different positions along the length of the catheter; and
Figure 8 shows a catheter design.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0046] The invention provides a catheter having an image sensing system for imaging the interior wall of a passageway in which the catheter is to be located. The catheter has a radial imaging system comprising a light source arrangement for generating a light output radially around the catheter and an image sensor for receiving the generally radial light after the light has been scattered back by the interior wall. The catheter is positioned within the passageway with a known position and orientation, for example a known angle with respect to the anterior-posterior plane along the length of the catheter, so that it is known where along the catheter length, and at which angular position around the catheter, it will be closest to the passageway wall. The light output has a different intensity at different radial directions and/or the catheter comprises a light attenuation arrangement which gives rise to different attenuation of the light output at different radial directions. These provide alternative measures to reduce the light received by the image sensor, thereby to prevent blooming in the captured image.

[0047] The invention may for example be used for imaging with a conduit. This may have non-medical applications for imaging non-living objects such as pipes, channels and tunnels as well as for medical imaging applications such as for imaging airway passages, intestinal passageway or capillaries or arteries.

[0048] By way of illustration, Figure 1 schematically depicts an example catheter 12 of known basic configuration, arranged within a stretch of an upper airway 14. Along the length of the airway are indicated four anatomical regions or features, labeled 18, 20, 22, and 24, these, by way of non-limiting example, representing the soft palate (velum), the oropharynx, the tongue base and the epiglottis respectively. Disposed within the airway 14 is the catheter 12, which comprises a series of optical sensors S1 to S5. They each comprise a laser light source for generating light generally axially, a first reflector for redirecting the light to include at least a component in the radial direction, a second reflector for redirecting reflected light from the side wall of the duct being investigated towards an image sensor for capturing an image of side wall of the duct being investigated. Figure 1 shows schematically a space and therefore a radial distance between the catheter and the airway 14.

[0049] The optical arrangement is represented schematically in Figure 1 as a single triangle.

[0050] For illustration, Figure 2 schematically shows the catheter 12 disposed in the upper airway of a patient 34, having been inserted via the nostril 36 of the patient. The distal end of the sensor is anchored in the esophagus. The approximate positions of the four anatomical regions of Figure 1 (velum 18, oropharynx 20, tongue base 22, and epiglottis 24) are indicated along the airway 14 of the patient 34.

[0051] This invention relates in particular to the issue of a non-central position of the catheter within the passageway and the effect this has on the radial light intensity captured by the imaging sensor.

[0052] The light source arrangement generates a radial ring of light emitting radially outwardly from the catheter to illuminate a ring shaped section of the wall of the upper airway 14. The ring may be continuous, but it may instead be formed as a set of discrete points generally following an annular path.

[0053] The radial projection may be entirely radial, i.e. at 90 degrees to the catheter axis, but it may be inclined at an acute angle to this perfectly radial direction. For compactness, for example to fit the optical system within a catheter, the light is routed axially along the catheter, and a reflection arrangement redirects the light to form the radial pattern.

[0054] As explained above, the distance between the catheter and airway wall influences the light intensity of the received light.

[0055] A first aspect of the invention involves ensuring the catheter has a known position within the passageway being imaged. One way to control this is to have control over the path followed by the catheter when it is inserted into the passageway.

[0056] Figure 4 shows how the catheter shape can influence the bending performance, which can then be used to control the shape and position adopted by the catheter. A circular cross section is shown as 50, and a cross section which is fattened is shown as 52. The outer shape 52 is non-circular in cross section across the catheter length. This non circular shape means the catheter will have a preference to bending in certain directions. In particular, it will preferentially bend around an axis 54 parallel to the width direction. In this way, the inserted catheter can be designed to follow a particular path to match the shape of a passageway which is itself of known general shape.

[0057] The radius of curvature of the catheter outer shape at the bottom is greater (i.e. there is a more gentle curve) than at the sides. This flatter bottom is where the catheter is to be in contact with the passageway wall. The outer shape is thus generally squashed. It may be an asymmetrical shape (i.e. with rotational order of symmetry equal to 1) but it may still have some symmetry, for example an ellipse which has a rotational order of symmetry of 2. The flatter bottom may be a completely flat edge

[0058] The catheter thus has a smaller diameter in the height direction than in the width direction.

[0059] The most flattened side (the bottom in the example shown) is also particularly optimized to stick to the passageway wall.

[0060] When the catheter bends or flexes around the axis 54 the flat region will preferably orient itself towards the passageway wall. The catheter is entered into the passageway to support the correct alignment. In this way it is possible to predict the part of the sensor that will be closest to a passageway wall with a high degree of confidence.

[0061] It is also possible to obtain a similar behavior, without changing the geometric cross section of the catheter, but by adapting the mechanical properties for different orientations. This could be done for example by including stiff fibers in the catheter. In this way, the bending properties of the catheter vary along the length of the catheter. This provides another way to control the way the catheter is steered into a known shape and location within the passageway. The catheter stiffness to bending in particular directions may for example vary along the length of the catheter.

[0062] These two approaches may be combined so that both shape and stiffness parameters are variables which together enable the catheter to adopt a desired shape when guided by the passageway.

[0063] The approximate shape of the passageway, for example the upper airway, at a given depth is known. By controlling which side of the catheter is close to the airway, the light intensity can then be shaped according to the expected distance to the airway.

[0064] The light intensity can then be increased in directions where a large distance is expected to the airway wall, and the intensity can be decreased in directions where a small distance is expected.

[0065] Thus, in a second aspect, once the catheter position is known, there is control of the light pattern and/or the sensing optics to provide a non-rotationally symmetric function. In particular, when the light output intensity is controlled, the envelope shape of the light output intensity distribution around the catheter is non-circular. When the light intensity received by the image sensor is controlled by varying the light transmission with angle, the light transmission function is non-circular.The light dose and optical field of view around the sensor can then be optimized taking account of the known positioning.

[0066] Figure 5 shows a catheter 52 with non-circular outer shape within a passageway 42. The intensity of the illumination pattern depends on the expected distance from the catheter. The light intensity is thus controlled to depend on the angular radial position around the catheter. For example, the intensity is highest in general region 60, lower in general region 62 and lowest in general region 64. The light intensity is not uniform in these regions, and they are only shown as three distinct regions for the purposes of explanation. In practice, there will be a function which relates the intensity to the angle around the catheter.

[0067] An asymmetric light pattern can be easily realized for example by adding different concentration of absorbers, or purposely misaligning the deflection cone which generates the radial light pattern from the center of the beam. In this way, the light pattern may be created by manipulating the output of the light source or the way it is reflected.

[0068] An alternative is to provide selective absorption of the light after it has been reflected for redirection radially. A dedicated light attenuation arrangement may be used for this purpose, but it may make use of existing parts of the device.

[0069] Figure 6 shows a non-circular catheter outer shape 52 (in cross section across the catheter length) with a flat edge 70 to be closest to the passageway wall. The catheter contains a camera and optical components 72 generally aligned along its central axis. There are various electrical cables or optical fibers 74 forming part of the device, and these are arranged at the flat side 70 to provide deliberate attenuation of the light from that area of the catheter outer wall. In this way, existing components of the overall system may be used to provide a desired light blocking function, by suitable selection of their locations. This avoids the need for additional components.

[0070] The various measures explained above for creating asymmetry may be oriented differently at different locations along the catheter length.

[0071] Like Figure 2, Figure 7 shows the catheter in use in the upper airway of a patient. In the manner explained above, the catheter is adapted along its length to match the orientation of the catheter to the airway wall.

[0072] For example, in Figure 7 the catheter might prefer to stick close to the posterior walls at the level of the oropharynx until the epiglottis (location 80a) and stick close to the anterior airway wall at the velum level (location 80b). Therefore the catheter has the orientations of the flatter side change accordingly. Of course the other parameters could be adapted along the length of the catheter accordingly, such as the ring intensity, the orientation of cables or the catheter stiffness.

[0073] To provide an image sensor sensitivity which is dependent on radial direction, it is not only possible to adapt the intensity of the ring pattern according to the expected distance to the airway wall (as explained above), but it is also possible to adapt the distance range of the sensor. This can for example be implemented by using a non-rotational symmetric light collection cone in front of the camera, or by purposely misaligning the camera and the cone.

[0074] The resolution of such a sensor is typically limited by the number of pixels available in a small camera and by the field-of-view of the camera together with the light reflection cone. By using non-symmetric optics in front of the camera, the field of view of the camera changes depending on the radial direction. That means also that the pixels of the camera chip will be mapped differently depending on the radial direction. The asymmetry may be before the radial illumination pattern is formed (e.g. by design of the first reflector) or after it is formed but before it reaches the image sensor (e.g. by design of the second reflector) or both.

[0075] The invention may be applied to the catheter shown in Figure 1.

[0076] The light source arrangement may comprise a light source such as a laser, an optical fiber which transmits the light output and emits the light in a direction centered parallel to the catheter elongate axis, and a first reflector for redirecting the emitted light to form a ring of generally radially directed light around the catheter length. It might also comprise a collimating element, which collimates the light from the fiber. This collimating element may be combined with the first reflector. This reflector may be designed to provide the asymmetric ring by its alignment or shape. For example, the reflector may be non-axisymmetric thereby creating a non-uniform light intensity with respect to radial direction. In this way, a non-uniform radial light pattern is implemented by the reflector without requiring complex optical alterations to the light output.

[0077] As mentioned above, an alternative is to implement the asymmetry using a second reflector which is for directing the light received from the passageway wall to the image sensor.

[0078] To illustrate the components mentioned above more clearly, Figure 8 shows an illustrative example of a catheter 91 incorporating a radial illumination system as described above. The catheter 91 is encapsulated within a transparent capillary, and received a light output from a laser 92 which is outside the catheter, arranged to propagate generated laser light in an axial direction along an optical fiber 94. The laser is mounted at the end of the optical fiber. The optical fiber has a collimator and conical reflector 96 at its end 97.

[0079] The reflector 96 may in some examples be designed to provide the required non-uniform light output intensity with respect to the radial direction as explained above.

[0080] The cross sectional shape of the catheter cannot be seen in Figure 8. It may be non-circular as explained above.

[0081] The radial illumination system generates the radial light output, and after reflection by the channel in which the catheter is mounted (for example a patient airway 98), it is reflected by a cone reflector 100 towards an image sensor 102.

[0082] The catheter may comprise multiple imaging systems in series, whereas Figure 8 shows only one such imaging system.

[0083] Figure 8 also shows an external light source, whereas the light source may be inside the catheter. It may also for example comprise a ring of lighting elements which face outwardly (rather than axially), so that the reflector 96 is not needed. In this case, different lighting elements may have different intensity in order to vary the intensity with angular position around the catheter.

[0084] The catheter may be for use in determining the presence and location of obstructions in an upper airway, the catheter comprising a plurality of radial imaging systems along the length of the catheter. In this way, each radial imaging system is for a particular one of the locations at which airway obstructions can be ascertained.

[0085] As mentioned above, one application of particular interest is to improve the performance of an optical catheter sensor for measuring the upper airway patency in OSA patients during natural (or sedated) sleep; in this application a laser plane is created in the sensor module that is approximately perpendicular to the image sensor and cone axis and in the associated cross section in the upper airway a contour lights up. The sensor elements are contained in a capillary.

[0086] Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

Claims

1. A catheter having an image sensing system for imaging the interior wall of a passageway (42) in which the catheter is to be located, comprising:

a radial imaging system comprising a light source arrangement (91,94,96) for generating a light output radially around the catheter and an image sensor (102) for receiving the radial light output after reflection by the interior wall,
wherein the catheter is adapted to be positioned within the passageway with predetermined position and orientation within the passageway along its length, and
the catheter has a non-circular outer shape (52) in cross section across the catheter length, the non-circular shape being such that the catheter adopts a particular known path of position and orientation within the passageway, and
wherein the light output has a different intensity at different radial directions and/or the catheter comprises a light transmission arrangement which gives rise to different transmission of the light output to the image sensor for different radial directions, such that an envelope shape of the light output intensity distribution around the catheter or a light transmission function of the light transmission arrangement around the catheter is non-circular and designed taking account of the known positioning and orientation the catheter adopts.

2. A catheter as claimed in claim 1, wherein the radius of curvature of the catheter outer shape (52), in cross section across the catheter length, is greater at one angular position around the catheter compared to an opposite angular position around the catheter.

3. A catheter as claimed in claim 2, wherein the catheter has a flat edge in its outer shape, in cross section across the catheter length, where the catheter is to be in contact or in close proximity with the passageway wall.

4. A catheter as claimed in any preceding claim, wherein the outer shape or angular orientation of the outer shape varies along the catheter length.

5. A catheter as claimed in any preceding claim, wherein the bending properties of the catheter vary along the length of the catheter.

6. A catheter as claimed in claim 5, wherein the catheter stiffness to bending in particular directions varies along the length of the catheter.

7. A catheter as claimed in any preceding claim, wherein the light output intensity is least where the catheter is to be closest to the passageway wall.

8. A catheter as claimed in any preceding claim, wherein the light transmission arrangement comprises electrical cables or optical fibers (74) which provide attenuation.

9. A catheter as claimed in any preceding claim, wherein the light source arrangement comprises:
a light source inside the catheter and optionally a collimator for collimating the light source output.

10. A catheter as claimed in any one of claims 1 to 8, wherein the light source arrangement comprises:

a light source outside the catheter;
an optical fiber which is adapted to transmit the light output from the light source from outside the catheter to inside the catheter and to emit the light in a direction centered parallel to the catheter elongate axis;
optionally a collimator for collimating the light from the optical fiber; and
a reflector for redirecting the emitted light to form a ring of generally radially directed light around the catheter length.

11. A catheter as claimed in claim 10, wherein the reflector is non-axisymmetric thereby creating a non-uniform light intensity with respect to radial direction.

12. A catheter as claimed in claim 9, 10 or 11, further comprising a second reflector for redirecting the radial light after reflection by the interior wall toward the image sensor.

13. A catheter as claimed in claim 12, wherein the second reflector is non-axisymmetric thereby creating a non-axisymmetric field-of view of the sensor with respect to radial direction.

14. A catheter as claimed in any preceding claim for use in determining the presence and location of obstructions in an upper airway, the catheter comprising a plurality of radial imaging systems along the length of the catheter.

Patentansprüche

1. Katheter mit einem Bilderfassungssystem zum Abbilden der Innenwand eines Durchgangs (42), in den der Katheter positioniert werden soll, umfassend:

ein Radialbildgebungssystem, umfassend eine Lichtquellenanordnung (91,94,96) zum Erzeugen einer Lichtausgabe radial um den Katheter herum, und einen Bildsensor (102) zum Empfangen der radialen Lichtausgabe nach Reflexion von der Innenwand,
wobei der Katheter angepasst ist, um mit vorher festgelegter Position und Orientierung innerhalb des Durchgangs entlang seiner Länge innerhalb des Durchgangs positioniert zu werden, und der Katheter im Querschnitt durch die Katheterlänge eine nicht-kreisförmige äußere Form (52) aufweist, die nicht-kreisförmige Form derart ist, dass der Katheter einen bestimmten bekannten Weg der Position und Orientierung innerhalb des Durchgangs annimmt, und
wobei die Lichtausgabe in unterschiedlichen radialen Richtungen eine unterschiedliche Intensität aufweist und/oder der Katheter eine Lichttransmissionsanordnung umfasst, die für unterschiedliche radiale Richtungen unterschiedliche Transmission der Lichtausgabe zu dem Bildsensor verursacht, sodass eine Hüllenform der Lichtausgabenintensitätsverteilung um den Katheter herum oder eine Lichttransmissionsfunktion der Lichttransmissionsanordnung um den Katheter herum nicht kreisförmig und unter Berücksichtigen der bekannten Positionierung und Orientierung entworfen ist, die der Katheter annimmt.

2. Katheter nach Anspruch 1, wobei der Krümmungsradius der äußeren Form (52) des Katheters im Querschnitt durch die Katheterlänge an einer Winkelposition um den Katheter herum verglichen mit einer gegenüberliegenden Winkelposition um den Katheter herum größer ist.

3. Katheter nach Anspruch 2, wobei der Katheter einen flachen Rand in seiner äußeren Form, im Querschnitt durch die Katheterlänge, aufweist, wo der Katheter mit der Durchgangswand in Kontakt oder in nächster Nähe sein soll.

4. Katheter nach einem vorstehenden Anspruch, wobei die äußere Form oder Winkelorientierung der äußeren Form entlang der Katheterlänge variiert.

5. Katheter nach einem vorstehenden Anspruch, wobei die Biegeeigenschaften des Katheters entlang der Länge des Katheters variieren.

6. Katheter nach Anspruch 5, wobei die Kathetersteifigkeit gegenüber Biegen in bestimmten Richtungen entlang der Länge des Katheters variiert.

7. Katheter nach einem vorstehenden Anspruch, wobei die Lichtausgabenintensität am geringsten ist, wo der Katheter am nächsten zu der Durchgangswand sein soll.

8. Katheter nach einem vorstehenden Anspruch, wobei die Lichttransmissionsanordnung elektrische Kabel oder optische Fasern (74) umfasst, die Dämpfung bereitstellen.

9. Katheter nach einem vorstehenden Anspruch, wobei die Lichtquellenanordnung umfasst:
eine Lichtquelle im Inneren des Katheters und wahlweise einen Kollimator zum Kollimieren der Lichtquellenausgabe.

10. Katheter nach einem der Ansprüche 1 bis 8, wobei die Lichtquellenanordnung umfasst:

eine Lichtquelle außerhalb des Katheters;
eine optische Faser, die angepasst ist, um die

Lichtausgabe von der Lichtquelle von außerhalb des Katheters ins Innere des Katheters zu übertragen und das Licht in eine Richtung zu emittieren, die parallel zu der verlängerten Achse des Katheters zentriert ist;
wahlweise einen Kollimator zum Kollimieren des Lichts von der optischen Faser; und
einen Reflektor zum Umleiten des emittierten Lichts, um einen Ring von allgemein radial gerichtetem Licht um die Katheterlänge herum zu bilden.

11. Katheter nach Anspruch 10, wobei der Reflektor nicht achsensymmetrisch ist, dadurch eine nicht einheitliche Lichtintensität bezüglich der Radialrichtung erzeugt.

12. Katheter nach Anspruch 9, 10 oder 11, weiter umfassend einen zweiten Reflektor zum Umleiten des radialen Lichts nach Reflexion durch die Innenwand in Richtung des Bildsensors.

13. Katheter nach Anspruch 12, wobei der zweite Reflektor nicht achsensymmetrisch ist, dadurch ein nicht achsensymmetrisches Sichtfeld des Sensors bezüglich der Radialrichtung erzeugt.

14. Katheter nach einem vorstehenden Anspruch zur Verwendung beim Bestimmen der Anwesenheit und der Stelle von Obstruktionen in einem oberen Luftweg, wobei der Katheter eine Vielzahl von Radialbildgebungssystemen entlang der Länge des Katheters umfasst.

Revendications

1. Cathéter présentant un système de détection d'image pour imager la paroi intérieure d'un passage (42) dans lequel le cathéter doit se trouver, comprenant :

un système d'imagerie radiale comprenant un agencement de source de lumière (91, 94, 96) destiné à générer une sortie lumineuse radialement autour du cathéter et un capteur d'image (102) destiné à recevoir la sortie lumineuse radiale après réflexion par la paroi intérieure,
dans lequel le cathéter est adapté pour être positionné à l'intérieur du passage avec une position et une orientation prédéterminées à l'intérieur du passage sur sa longueur, et le cathéter présente une forme extérieure (52) non circulaire en coupe transversale sur la longueur du cathéter, la forme non circulaire étant telle que le cathéter adopte un chemin de position et d'orientation connu particulier à l'intérieur du passage, et
dans lequel la sortie lumineuse présente une intensité différente pour différentes directions radiales et/ou le cathéter comprend un agencement de transmission de lumière qui donne lieu à une transmission différente de la sortie lumineuse au capteur d'image pour différentes directions radiales, telle qu'une forme de type enveloppe de la distribution d'intensité de la sortie lumineuse autour du cathéter ou une fonction de transmission de lumière de l'agencement de transmission de lumière autour du cathéter est non circulaire et est conçue pour prendre en compte le positionnement et l'orientation connus que le cathéter adopte.

2. Cathéter selon la revendication 1, dans lequel le rayon de courbure de la forme extérieure (52) du cathéter, en coupe transversale sur la longueur du cathéter, est supérieur à une position angulaire autour du cathéter comparativement à une position angulaire opposée autour du cathéter.

3. Cathéter selon la revendication 2, dans lequel le cathéter présente un bord plat dans sa forme extérieure, en coupe transversale sur la longueur du cathéter, où le cathéter doit être en contact ou à proximité immédiate de la paroi du passage.

4. Cathéter selon l'une quelconque des revendications précédentes, dans lequel la forme extérieure ou l'orientation angulaire de la forme extérieure varie sur la longueur du cathéter.

5. Cathéter selon l'une quelconque des revendications précédentes, dans lequel les propriétés de flexion du cathéter varient sur la longueur du cathéter.

6. Cathéter selon la revendication 5, dans lequel la rigidité du cathéter à la flexion dans des directions particulières varie sur la longueur du cathéter.

7. Cathéter selon l'une quelconque des revendications précédentes, dans lequel l'intensité de la sortie lumineuse est la plus faible lorsque le cathéter doit être le plus proche de la paroi du passage.

8. Cathéter selon l'une quelconque des revendications précédentes, dans lequel l'agencement de transmission de lumière comprend des câbles électriques ou des fibres optiques (74) qui fournissent une atténuation.

9. Cathéter selon l'une quelconque des revendications précédentes, dans lequel l'agencement de source de lumière comprend :
une source de lumière à l'intérieur du cathéter et éventuellement un collimateur pour collimater la sortie de la source de lumière.

10. Cathéter selon l'une quelconque des revendications 1 à 8, dans lequel l'agencement de source de lumière comprend :

une source de lumière à l'extérieur du cathéter ;
une fibre optique qui est adaptée pour transmettre la sortie lumineuse de la source de lumière de l'extérieur du cathéter vers l'intérieur du cathéter et pour émettre la lumière dans une direction centrée parallèle à l'axe allongé du cathéter ;
éventuellement un collimateur pour collimater la lumière de la fibre optique ; et
un réflecteur pour rediriger la lumière émise afin de former un anneau de lumière généralement dirigée radialement autour de la longueur du cathéter.

11. Cathéter selon la revendication 10, dans lequel le réflecteur est non axisymétrique, créant ainsi une intensité de lumière non uniforme par rapport à la direction radiale.

12. Cathéter selon la revendication 9, 10 ou 11, comprenant en outre un second réflecteur pour rediriger la lumière radiale après réflexion par la paroi intérieure vers le capteur d'image.

13. Cathéter selon la revendication 12, dans lequel le second réflecteur est non axisymétrique, créant ainsi un champ de vision non axisymétrique du capteur par rapport à la direction radiale.

14. Cathéter selon l'une quelconque des revendications précédentes destiné à être utilisé pour déterminer la présence et de l'emplacement d'obstructions dans une voie aérienne supérieure, le cathéter comprenant une pluralité de systèmes d'imagerie radiaux sur la longueur du cathéter.

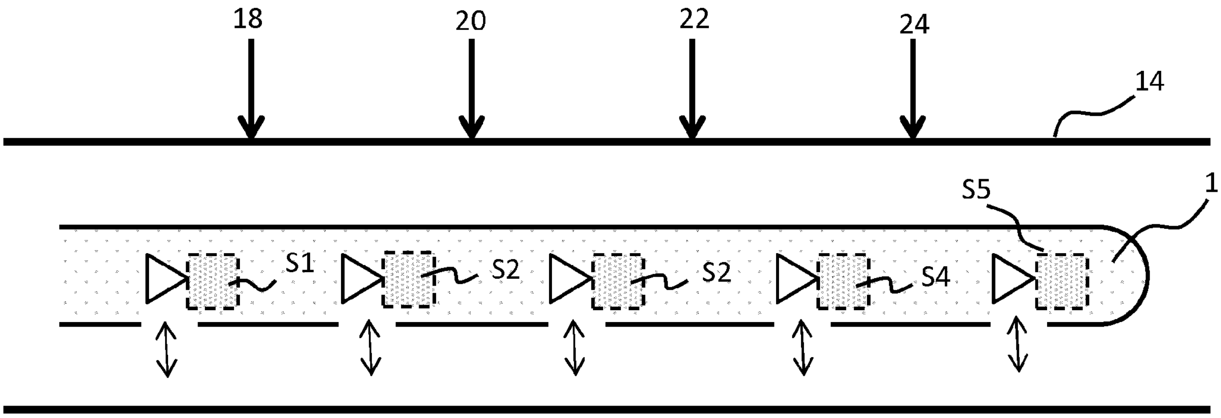

FIG. 1

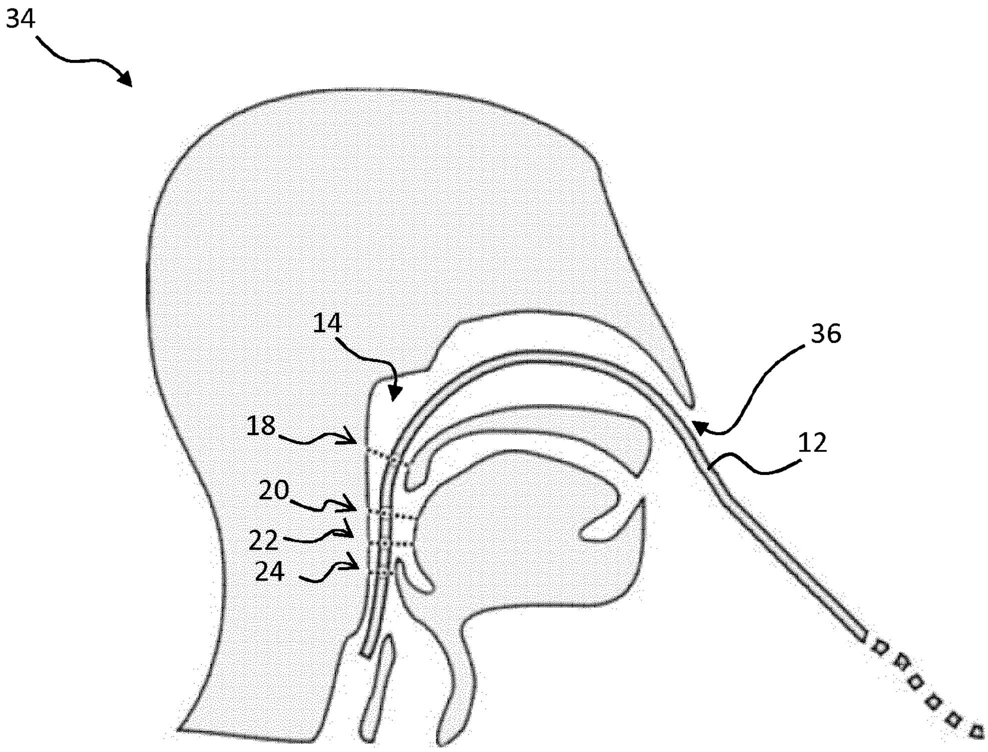

FIG. 2

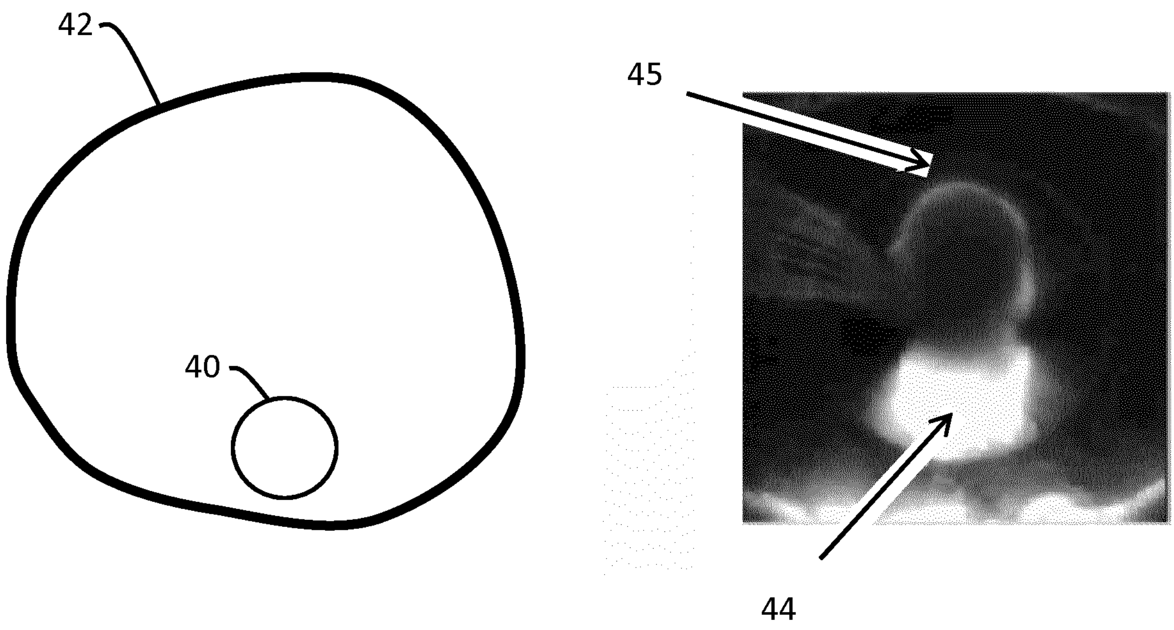

FIG. 3

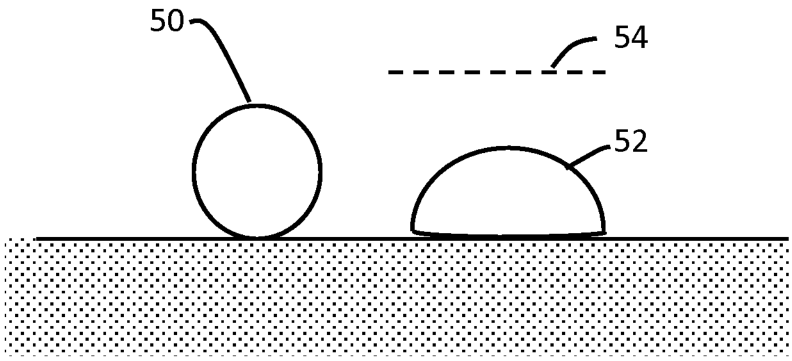

FIG. 4

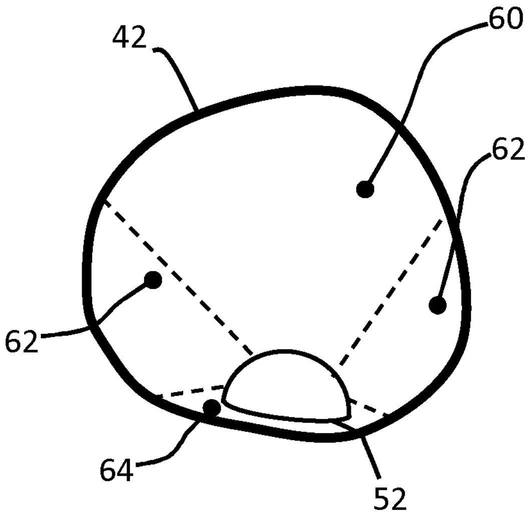

FIG. 5

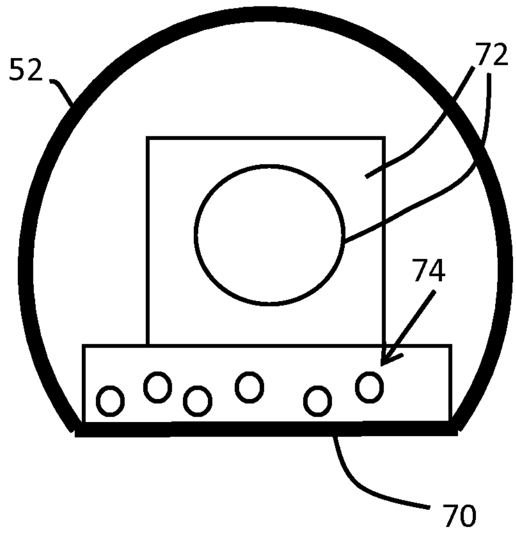

FIG. 6

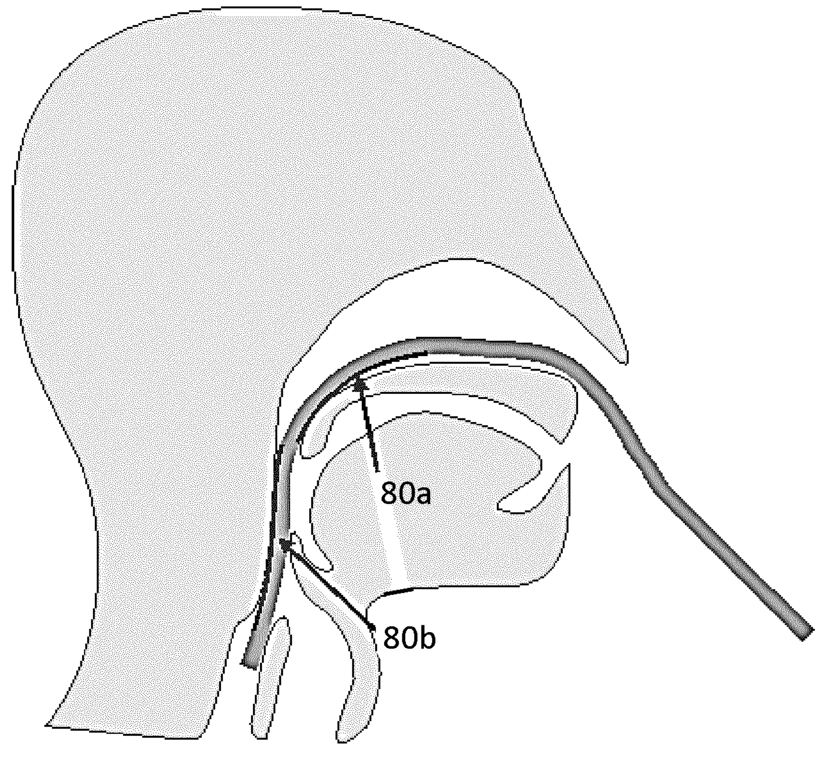

FIG. 7

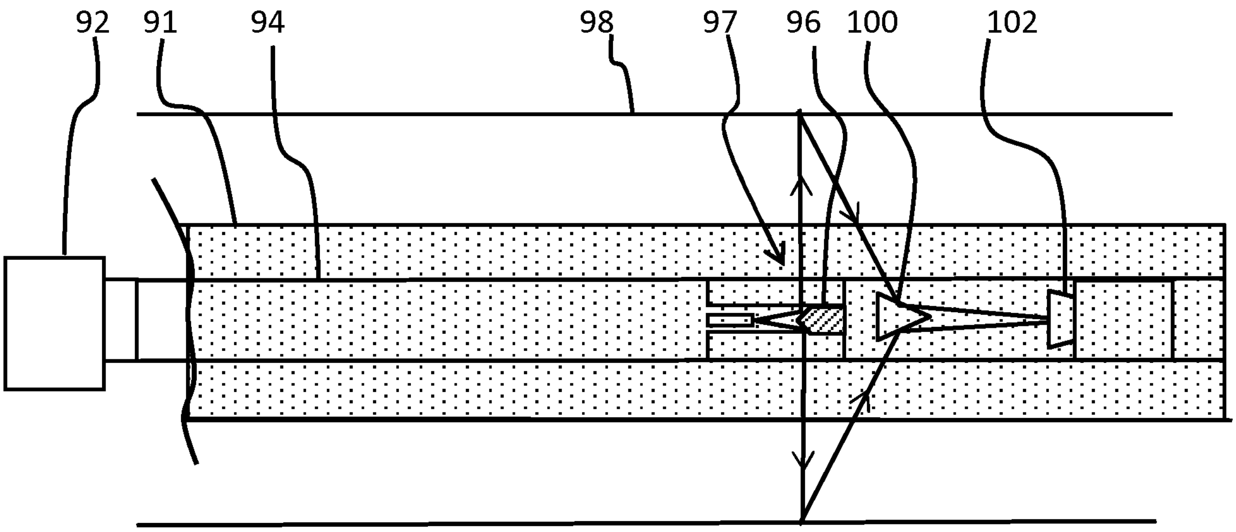

FIG. 8

REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- **HOFFSTEIN, V. ; J. J. FREDBERG.** The acoustic reflection technique for non-invasive assessment of upper airway area. *European Respiratory Journal,* 1991, vol. 4.5, 602-611 **[0005]**

patsnap

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发明人	MUELLER, MANFRED		
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优先权	2015180996 2015-08-13 EP		
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摘要(译)

导管（12）具有用于对要在其中放置导管的通道的内壁成像的图像感测系统（S1-S5）。导管具有径向成像系统，该径向成像系统包括：光源装置，用于在导管周围径向地产生光输出；以及图像传感器，用于在光被内壁散射回之后接收大体上径向的光。导管以已知的位置和定向，例如沿着导管的长度相对于前后平面的已知角度定位在通道内，从而已知沿着导管的长度在什么位置以及在哪个角度位置在导管周围，它靠近通道壁。光输出在不同的径向方向上具有不同的强度和/或导管包括光传输装置，该光传输装置引起光输出在不同的径向方向上的不同传输。这些提供了替代措施以减少图像传感器接收的光，从而防止在捕获的图像中出现光晕。

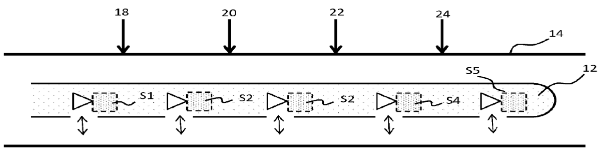

FIG. 1

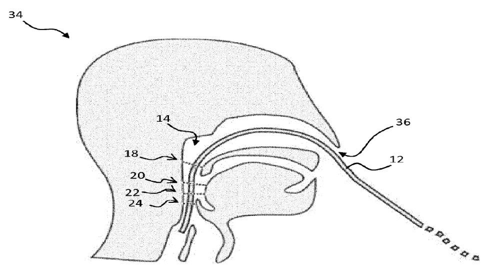

FIG. 2