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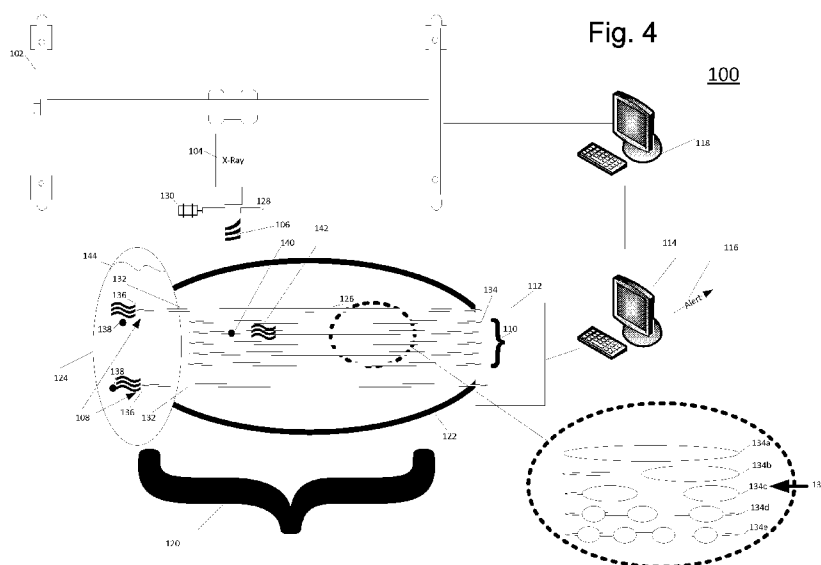
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(54) Title: TREATMENT BALLOON WITH BEAM POSITION DETECTOR



(57) Abstract: Techniques are generally described for an treatment balloon, and methods and systems effective to detect a position of a beam. The system may include an treatment balloon effective to receive the beam. The treatment balloon may include a shaft and a balloon portion with an open end in communication with the shaft. The balloon portion may be effective to be at least partially filled with a fluid. The treatment balloon may be effective to generate a light wave when the treatment beam is incident on the treatment balloon. A waveguide in the treatment balloon may be effective to receive the light wave. A light detector in optical communication with the waveguide may be effective to detect the light wave. A processor in communication with the light detector may be effective to detect the position of the beam.

TREATMENT BALLOON WITH BEAM POSITION DETECTOR

BACKGROUND

[0001] Unless otherwise expressly indicated herein, none of the material presented in this section is prior art to the claims of this application and is not admitted to be prior art by having been included herein.

[0002] During treatment of prostate cancer, a treatment balloon may be used to stabilize a position of the prostate. The treatment balloon may include a shaft and a balloon portion with an open end in communication with the shaft. When the treatment balloon is used, the shaft may be inserted into a patient's rectum and the balloon portion may be inflated. The inflated balloon portion may stabilize a position of the prostate during treatment.

SUMMARY

[0003] In one example, a method for detecting a position of a beam is generally described. The method may include receiving the beam by a treatment balloon. The treatment balloon may include a shaft and a balloon portion with an open end in communication with the shaft. The balloon portion may be effective to be at least partially filled with a fluid. The treatment balloon may be effective to generate a light wave when the treatment beam is incident upon the treatment balloon. The method may further include receiving the light wave by a waveguide in the treatment balloon. The method may further include detecting the light wave by a light detector in optical communication with the waveguide. The method may further include detecting the position of the beam by a processor in communication with the light detector.

[0004] In one example, a treatment balloon is generally described. The treatment balloon may include an opaque shaft. The treatment balloon may include an opaque balloon portion with an opening in communication with the shaft. The balloon portion may be effective to be at least partially filled with a fluid. The treatment balloon may include at least one waveguide in the treatment balloon. The treatment balloon may include a light detector in optical communication with the waveguide. The light detector may be effective to receive and detect light from the waveguide.

[0005] In one example a system effective to detect a position of a beam is generally described. The system may include a treatment balloon effective to receive the beam. The treatment balloon may include a shaft and a balloon portion with an open end in communication with the shaft. The balloon portion may be effective to be at least partially filled with a fluid. The treatment balloon may be effective to generate a light wave when the treatment beam is incident on the treatment balloon. A waveguide may be in the treatment balloon. The waveguide may be effective to receive the light wave. The system may include a light detector in optical communication with the waveguide. The light detector may be effective to detect the light wave. The system may further include a processor in communication with the light detector. The processor may be effective to detect the position of the beam.

[0006] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF THE FIGURES

[0007] The foregoing and other features of this disclosure will become more fully apparent from the following description and appended claims taken in conjunction with the accompanying drawings. Understanding that these drawings depict only some embodiments in accordance with the disclosure and are therefore not to be considered limiting of its scope, the disclosure will be described with additional specificity and detail by reference to the accompanying drawings in which:

Fig. 1 is a system diagram illustrating an example treatment balloon with beam position detector;

Fig. 2 is a system diagram illustrating an example treatment balloon with beam position detector;

Fig. 3 is a system diagram illustrating an example treatment balloon with beam position detector;

Fig. 4 is a system diagram illustrating an example treatment balloon with beam position detector;

Fig. 5 is a system diagram illustrating an example treatment balloon with beam position detector; and

Fig. 6 depicts a flow diagram for example processes for implementing an treatment balloon with beam position detector;

all arranged according to at least some embodiments described herein.

DETAILED DESCRIPTION

[0008] In the following detailed description, reference is made to the accompanying drawings which form a part thereof. In the drawings, similar symbols typically identify similar components unless context indicates otherwise. The illustrative embodiments described in the detailed description, drawings and claims are not meant to be limiting. Other embodiments may be utilized and other changes may be made without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure as generally described herein and as illustrated in the accompanying figures can be arranged, substituted, combined, separated and/or designed in a wide variety of different configurations all of which are explicitly contemplated herein.

[0009] This disclosure is generally drawn, *inter alia*, to devices, apparatus, systems and methods relating to an treatment balloon with beam position detector.

[0010] Briefly stated, technologies are generally described for an treatment balloon, and methods and systems effective to detect a position of a beam. The system may include an treatment balloon effective to receive the beam. The treatment balloon may include a shaft and a balloon portion with an open end in communication with the shaft. The balloon portion may be effective to be at least partially filled with a fluid. The treatment balloon may be effective to generate a light wave when the treatment beam is incident on the treatment balloon. A waveguide in the treatment balloon may be effective to receive the light wave. A light detector in optical communication with the waveguide may be effective to detect the light wave. A processor in communication with the light detector may be effective to detect the position of the beam.

[0011] Fig. 1 is a system diagram illustrating an example treatment balloon with beam position detector according to at least some embodiments described herein. In some

examples, a beam position detector 100 may include a gantry 102, a treatment source 104, an treatment balloon 120, a light detector 112, a processor 114 and/or a processor 118. Treatment balloon 120 may include a shaft 122 and a balloon portion 124. An open end of balloon portion 124 may be in communication with shaft 122. Light detector 112, processor 114, processor 118 and/or gantry 102 may be configured to be in communication such as through a wired or wireless network.

[0012] In use, treatment balloon 120 may be inserted into a patient's urethra or rectum. Balloon portion 124 may be fully or partially filled with a fluid 144 to limit a movement of the patient's prostate. A migration stopper 126 may be used to limit movement of treatment balloon 120 after insertion. Treatment balloon 120 may be an endorectal balloon. As discussed in more detail below, treatment source 104 may generate a treatment beam 106 that may be used to treat a tumor in the prostate. Balloon portion 124 may include a Cernekov detector 108 and shaft 122 may include a Cernekov detector 110. Cernekov detectors 108, 110 may be effective to detect light generated when beam 106 travels through portions of treatment balloon 120 faster than the speed of light in that material. Light detector 112 may receive light from Cernekov detectors 108, 110 and generate electrical signals in response. The electrical signals may be processed by processor 114 to detect a position of beam 106. In response to the detection, processor 114 may generate an alert 116. Processor 114 may also, or alternatively, communicate with processor 118 to control a movement of gantry 102 to move gantry 102, and beam 106, to a different position or stop beam 106. Processor 114 may detect that beam 106 has been at the correct position for a long enough period of time so that less dosage of beam 106 may be used. Conversely, processor 114 may detect that beam 106 has not been at the correct position for a long enough period of time so that more dosage of beam 106 should be used.

[0013] Cernekov protons and light waves may be generated when a charged particle moves faster than the speed of light in a given medium. A threshold condition for the generation of the lights waves may be given by

[0014] $\beta n > 1$ (Eq. 1)

[0015] where n is the refractive index of the medium and

$$\beta = \left[1 - \left(\frac{1}{\frac{E(\text{keV})}{511} + 1} \right)^2 \right]^{\frac{1}{2}}$$

(Eq. 2)

[0016] In an example, with an average electron energy of 1MeV, β may be 0.94 and a value of n over 1.06 may result in the generation of Cerenkov protons. An optical fiber, which may be used as discussed below, may have an n in the core of 1.52.

[0017] At a given wavelength λ , and assuming that particles maintain a constant velocity as they traverse a fiber, the intensity of the radiation may be given by

$$I_{cap} = N_P \frac{2\pi\rho^3}{\sin\gamma} \frac{e^2}{4\pi^2\epsilon_0\lambda^2c^2} \left(1 - \frac{c^2}{n_{co}^2v^2} \right) \times \cos^{-1} \left(\frac{v(n_{co} - \Delta n) - c \times \cos\gamma}{\sin\gamma \sqrt{v^2n_{co}^2 - c^2}} \right)$$

[0018]

[0019] (Eq. 3)

[0020] and in the relativistic case

$$I_{cap} = N_P \frac{2\pi\rho^3}{\sin\gamma} \frac{e^2}{4\pi^2\epsilon_0\lambda^2c^2} \left(1 - \frac{1}{n_{co}^2} \right) \times \cos^{-1} \left(\frac{n_{co} - \Delta n - \cos\gamma}{\sin\gamma \sqrt{n_{co}^2}} \right)$$

[0021]

[0022] (Eq. 4)

[0023] where N_P is the number of particles, ρ is the fiber core radius, e is the charge on an electron, c is the speed of light in a vacuum, v is the speed of the particle, n_{co} is the refractive index of the fiber core, Δn is the fiber core/cladding refractive index difference, ϵ_0 is the permittivity of a vacuum, and γ is the angle between the possible track and the fiber axis in the direction of the detector.

[0024] Fig. 2 is a system diagram illustrating an example treatment balloon with beam position detector according to at least some embodiments described herein. Those components in Fig. 2 that are labelled identically to components of Fig. 1 will not be described again for the purposes of clarity.

[0025] In Fig. 2, treatment balloon 120 is shown further magnified to focus on additional details. In the example shown in Fig. 2, treatment source 104 may be an X-Ray source and beam 106 may be an X-Ray beam. One or more collimators 128 may be

used to modulate a shape of beam 106. Collimators 128 may be steel plates that may be adjusted to produce a beam of any desired shape such as by control of a motor 130. Collimators 128 may be used to adjust a shape of beam 106 to correspond to the shape of a tumor. Collimators 128 may be implemented using a single plate with a hole bored therethrough.

[0026] Cernekov detector 108 may include one or more fiber optic waveguides 132. As discussed in more detail below, in examples where Cernekov photons are generated in balloon portion 124, such photons may generate a light wave. The light wave may travel down fiber optic waveguides 132 to light detector 112. Light detector 112 may receive and detect the light wave.

[0027] Cernekov detector 110 may include one or more fiber optic waveguides 134. As discussed in more detail below, in examples where Cernekov photons are generated in shaft 122, such photons may generate light waves that travel down fiber optic waveguides 134 to light detector 110. Light detector 110 may be in optical communication with waveguides 134 and may receive and detect the light waves.

[0028] Gantry 102 may be used to move around a patient so that beams 106 may be incident upon a tumor at multiple angles. As mentioned above, treatment balloon 120 may be inserted into a patient. Balloon portion 124 may be at least partially filled with water or another fluid 144 with an index of refraction greater than n as discussed above with reference to equations 1 and 2. The at least partially filled balloon may limit a movement of the patient's prostate. X-Ray beam 106 may be incident upon the patient's prostate, balloon portion 124, and/or shaft 122.

[0029] Light detector 112 may include, for example, photodiodes such as avalanche photodiodes. The photodiodes may be selected to have a relatively high sensitivity in the blue wavelength range - about 450 nm to about 495nm. Light detector 112 may include photomultiplier tubes and/or charged coupled diodes.

[0030] Fig. 3 is a system diagram illustrating an example treatment balloon with beam position detector according to at least some embodiments described herein. Those components in Fig. 3 that are labelled identically to components of Figs. 1 and 2 will not be described again for the purposes of clarity.

[0031] As balloon portion 124 is filed with a fluid 144 with an index of refraction greater than n as discussed above with reference to equations 1 and 2, Cerenkov protons 134 may be generated in examples where beam 106 is incident upon balloon portion 124 and fluid 144. Cerenkov protons 134 in turn, may generate light waves 136. Light waves 136 may travel down fiber optic waveguides 132 and may be detected by light detector 112. For example, light waves 136 may have a blue color and may have wavelengths of about 450 nm to about 495nm.

[0032] Fiber optic waveguides 132 may be disposed at different locations inside balloon portion 124. An intensity of light waves 136 at each waveguide 132 may be detected by light detector 112 and so a relative position of beam 106 with respect to balloon portion 124 may be detected by processor 114 based on the intensities of waves 136. For example, processor 144 may compare a photon count from one waveguide 132 to the other waveguide 132 to estimate a position of beam 106. Waveguides 132 may thus be used, for example, to determine a position of beam 106 with respect to a sagittal plane of a patient depending on a positioning of waveguides 132.

[0033] Balloon portion 124 may be made of an opaque material so that stray visible light may be inhibited from entering balloon portion 124. Light detector 112 may be used to detect waves 136 before beam 106 is incident upon balloon portion 124 so that an ambient light may be calculated by processor 114. The ambient light may be subtracted from future calculations by processor 114 when beam 106 is applied. If ends of waveguides 132 are bent, a prism may be added to refract light waves from balloon portion 124 into waveguides 132.

[0034] Fig. 4 is a system diagram illustrating an example treatment balloon with beam position detector according to at least some embodiments described herein. Those components in Fig. 4 that are labelled identically to components of Figs. 1, 2 and 3 will not be described again for the purposes of clarity.

[0035] As mentioned above, Cerenkov detector 110 may include one or more waveguides 134. In examples where beam 106 is incident upon waveguides 134, Cerenkov protons 140 may be generated as an index of refraction of waveguides 134 may be greater than n as discussed above with reference to equations 1 and 2. Cerenkov protons 140 may, in turn, generate light waves 142. Light waves 142 may travel down

waveguides 134 and be detected by light detector 112. Waveguides 134 may have a reflective cap at an end distal from light detector 112 so that waves which travel away from light detector 112 may be reflected back toward light detector 112.

[0036] As shown in the magnified view in Fig. 4, waveguides 134 may include waveguides 134a, 134b, 134c, 134d, and/or 134e. A number of photons per second in light wave 142 generated by Cernekov photon 140 may be proportional to a width of waveguide 134. Waveguides 134 may be modulated to have varying thick and thin sections, as shown for waveguides 134a, 134b, 134c, 134d, and 134e. By using waveguides with varying thicknesses, light detector 112 may be able to detect a position of beam 106 with respect to waveguides 134. Waveguides 134 may help detect a position in a patient's transverse plane and/or detect a more fine granularity of a position of beam 106. For example, each waveguide 134a, 134b, 134c, 134d, 134e may generate a different number of photons in light wave 142 in response to generation of Cernekov photon 140. Processor 114 may detect a position of beam 106 and how beam 106 is moving with respect to waveguides 134. For example, light detector 112 may be able to detect that beam 106 is incident upon a particular waveguide of waveguides 134 based on whether light is detected from the particular waveguide. Further, light detector 112 may be able to detect a position along the particular waveguide where beam 106 is incident based upon the number of photons per second output from the waveguide. A higher number of photons per second may indicate that the beam is incident on a relatively thicker section of the particular waveguide. A lower number of photons per second may indicate that the beam is incident on a relatively thinner section of the particular waveguide - or perhaps on both a thicker section and a thinner section. In the example, 5 waveguides 134a, 134b, 134c, 134d and 134e are shown and so a binary pattern with $2^5 = 32$ positions may be realized. Shaft 122 may be opaque to inhibit stray visible light from entering waveguides 134.

[0037] In an example, as beam 106 moves in position from waveguide 134e to waveguide 134d, less light photons per second may be generated in waveguide 134e and more light photons per second may be generated by waveguide 134d. Consequently, processor 114 may determine that beam 106 has moved from a position corresponding to waveguide 134e to a position corresponding to waveguide 134d.

[0038] Processor 114 may also determine a change in distance between shaft 122 and gantry 102. For example, processor 114 may determine a position of endpoints of waveguides 136, determine an angle between the endpoints and gantry 102, and then perform a trigonometric function to determine the distance between shaft 122 and gantry 102.

[0039] Waveguides 134 may be made of a dielectric such as glass or plastic. A relatively higher index of refraction may increase an efficiency of Cernekov proton generation. For a 6MV treatment beam, a silica fiber could be used. Plastic or glass could be used. An index of refraction for cladding for waveguides 134 may be lower than a refractive index of the core and may be relatively low such as 1.62.

[0040] In some examples, waveguides 134 may be designed to be insertable into and removable from shaft 122. For example, shaft 122 and balloon portion 124 may be designed to be disposable. Waveguides 134 may be removed after use of treatment balloon 120 and sterilized for use in another shaft 122. Waveguides 134 may be reused for the same patient.

[0041] Waveguides 134 may be used in an endorectal balloon as mentioned above. Waveguides 134 may further be used in connection with treatment of cervical, bladder or endometrial cancer. Shaft 122 may be used in an endoscope such as for treatments relating to the lungs, stomach, colon, esophagus, small intestine, etc. Shaft 122 may be inserted into a patient through the digestive system and/or the trachea.

[0042] Fig. 5 is a system diagram illustrating an example treatment balloon with beam position detector according to at least some embodiments described herein. Those components in Fig. 5 that are labelled identically to components of Figs. 1, 2, 3, and 4 will not be described again for the purposes of clarity.

[0043] In an example, treatment source 104 may include a proton source and beam 106 may be a proton beam. Proton beam 106 may be designed to have a power to pass into and stop inside a tumor. In this example, waveguides 134, 136 may be used to detect whether beam 106 have overshoot and gone past the tumor indicating that too much power is being used. A depth of dosage of proton treatment source 104 may then be adjusted. In this example, ends of waveguides 134 may be placed toward a top of balloon portion 124. For example, ends of waveguides 134 may be placed on the inside and top of balloon

portion 124 so that an overshoot of beam 106 may be relatively quickly detected by processor 114. An undershoot of beam 106 may be detected by processor 114 based on a low photon count relative to an expected photon count. A zero photon count may indicate that beam 106 is too shallow, or in the wrong position.

[0044] In this example, fluid 144 in balloon portion 124 may be air. Alternatively, balloon portion 124 may be filled on a bottom with water (as shown in Fig. 5) and a top may be filled with air. In this example, having air on a top of balloon portion 124 may avoid attenuation of beam 106 before being detected by waveguides 134. Having water on the bottom of balloon portion 124 may attenuate beam 106 after waveguides 134 to protect the patient's rectum. Waveguides 134 may be made of plastic or other flexible material so that waveguides 134 may bend and change in shape as balloon portion 124 inflates and deflates.

[0045] Beam detector system 100 may be initial aligned with a patient by turning on beam 106, scanning beam 106 across a patient and detecting light waves 136, 142. A position of beam 106 may be detected based on where beam 106 falls with respect to waveguides 132 and waveguides 134. After alignment, a patient may be treated. An alignment position may be used as a reference point when gantry 102 is moved during treatment.

[0046] In an example, waveguides 134, 136 may be made of silicon carbide, silicon carbide with an epoxy, solid crystal silicon carbide, rutile (TiO₂) etc. For a 2mm wide waveguide, an accuracy of position may be detected within 2mm. Curve fitting processing may be performed by processor 114 to obtain greater accuracy.

[0047] In an example model GEANT4 software was used to model an input beam of 6MeV photons (Gamma rays/ X-Rays) pass through a cube of water (n=1.330), 2mm per side, suspended in a vacuum. The result was 1.072141 optical photons per X-Ray photon - that is 1,072,141 optical photons for 1,000,000 X-Ray photons. In an example, waveguides may be made with LASF35, from SCHOTT GLASS with a refractive index of about 2.02. In another example, waveguides may be made of a heavy glint glass such as SF 6 1.8051 25.43 5.18 90; or SF 11 1.7847 25.76 4.74 69; LaF and LaSF Glasses such as LaF 9 1.795 28.38 4.96 81; LaSF 8 1.80741 31.61 4.87 70; LaSF N 3 1.8080

40.75 4.68 72; LaSF 11 1.80166 44.26 4.62 70; or LaSF 30 1.80200 46.47 4.90 71. The cladding may be MY-130 Series by ELECTRO OPTICAL COMPONENTS.

[0048] Among other possible benefits, positioning of a treatment beam may be detected. Undesirable affects of treatment such as impotence, incontinence, rectal bleeding, etc. may be reduced. Using an treatment balloon, an appropriate dose for treatment may be determined and more accurate dosing may be administered. Feedback may be provided to an operator or gantry with respect to positioning. Accuracy of external beam therapy may be improved even when the treated area is in motion such as when the target moves from an original position during treatment. Extra radiation need not necessarily be applied to determine a location of a treated area. A lower dosage of treatment may be used because a position of the treatment beam may be more reliably detected.

[0049] Fig. 6 depicts a flow diagram for example processes for implementing an treatment balloon with beam position detector arranged according to at least some embodiments described herein. The process in Fig. 6 could be implemented using, for example, system 100 discussed above and may be used to detect a position of beam. An example process may include one or more operations, actions, or functions as illustrated by one or more of blocks S2, S4, S6 and/or S8. Although illustrated as discrete blocks, various blocks may be divided into additional blocks, combined into fewer blocks, or eliminated, depending on the desired implementation.

[0050] Processing may begin at block S2, "Receive the beam by an treatment balloon, where the treatment balloon includes a shaft and a balloon portion with an open end in communication with the shaft, the balloon portion effective to be at least partially filled with a fluid, the treatment balloon effective to generate a light wave when the treatment beam is incident upon the treatment balloon." A block S2, the beam may be received by an treatment balloon. A first waveguide may be in the balloon portion and protons may be generated in the fluid. A second waveguide may be in the shaft and protons may be generated with the beam is incident on the second waveguide. The second waveguide may include two or more waveguides with different thicknesses. The second waveguide may insertable into and removable from the shaft. The balloon portion and the

shaft may be opaque. The second waveguide may be on a top and inside of the balloon portion.

[0051] Processing may continue from block S2 to block S4, "Receive the light wave by a waveguide in the treatment balloon." The light may be received by the first and/or the second waveguide.

[0052] Processing may continue from block S4 to block S6, "Detect the light wave by a light detector in optical communication with the waveguide." The light may be detected from the first and/or the second waveguide.

[0053] Processing may continue from block S6 to block S8, "Detect the position of the beam by a processor in communication with the light detector." The position may be detected by analyzing intensities of light in the first and second waveguides. In response to detecting the position, a processor may control the position of the beam to be moved or may stop the beam.

[0054] The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, reagents, compounds compositions or biological systems, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

[0055] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[0056] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (*e.g.*, bodies of the appended claims) are generally intended as “open” terms (*e.g.*, the term “including” should be interpreted as “including but not limited to,” the term “having” should be interpreted as “having at least,” the term “includes” should be interpreted as “includes but is not limited to,” etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases “at least one” and “one or more” to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles “a” or “an” limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases “one or more” or “at least one” and indefinite articles such as “a” or “an” (*e.g.*, “a” and/or “an” should be interpreted to mean “at least one” or “one or more”); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (*e.g.*, the bare recitation of “two recitations,” without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to “at least one of A, B, and C, etc.” is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (*e.g.*, “a system having at least one of A, B, and C” would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to “at least one of A, B, or C, etc.” is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (*e.g.*, “a system having at least one of A, B, or C” would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further

understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase “A or B” will be understood to include the possibilities of “A” or “B” or “A and B.”

[0057] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[0058] As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, etc. As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, etc. As will also be understood by one skilled in the art all language such as “up to,” “at least,” “greater than,” “less than,” and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

[0059] While various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

CLAIMS

What is claimed is:

1. A method for detecting a position of a beam, the method comprising:
receiving the beam by an treatment balloon, where the treatment balloon includes a shaft and a balloon portion with an open end in communication with the shaft, the balloon portion effective to be at least partially filled with a fluid, the treatment balloon effective to generate a light wave when the treatment beam is incident upon the treatment balloon;

receiving the light wave by a waveguide in the treatment balloon;
detecting the light wave by a light detector in optical communication with the waveguide; and

detecting the position of the beam by a processor in communication with the light detector.

2. The method of claim 1, wherein:
the waveguide is in the balloon portion; and
the light wave is generated in the fluid.

3. The method of claim 1, wherein
the waveguide is in the shaft; and
the light wave is generated in the waveguide when the beam is incident on the waveguide.

4. The method of claim 1, wherein:
the waveguide is a first waveguide;
the beam is incident on the balloon portion;
the first waveguide is in the balloon portion;
a first light wave is generated in the fluid;

a second waveguide is in the shaft and in optical communication with the light detector;

a second light wave is generated in the second waveguide when the beam is incident on the second waveguide; and

the method further comprises detecting the position of the beam based on light detected from the first waveguide and the second waveguide.

5. The method of claim 4, wherein the second waveguide includes two or more waveguides with different thicknesses.

6. The method of claim 4, wherein the first waveguide includes a third waveguide and a fourth waveguide at different positions in the balloon portion; and detecting the position of the beam includes detecting an intensity of the light in the third waveguide and detecting an intensity of the light in the fourth waveguide.

7. The method of claim 4, wherein the second waveguide is insertable into and removable from the shaft.

8. The method of claim 1, wherein the balloon portion and the shaft are opaque.

9. The method of claim 1, wherein:
the waveguide is a first waveguide;
the beam is incident on the balloon portion;
the first waveguide is in the balloon portion;
a first light wave is generated in the fluid;
a second waveguide is on a top and inside of the balloon portion, the second waveguide is in the shaft and in optical communication with the light detector;
a second light wave is generated in the second waveguide when the beam is incident on the second waveguide; and

the method further comprises detecting the position of the beam based on light detected from the first waveguide and the second waveguide.

10. The method of claim 9, wherein the second waveguide includes two or more waveguides with different thicknesses.

11. The method of claim 1, wherein the light detector is one of a photodiode, a photomultiplier tube, or a charged coupled diode.

12. The method of claim 1, further comprising partially filling the balloon portion with water and partially filling the balloon portion with air.

13. The method of claim 1, further comprising moving a position of the beam in response to detecting the position of the beam.

14. The method of claim 1, further comprising stopping the beam in response to detecting the position of the beam.

15. An treatment balloon comprising:
an opaque shaft;
an opaque balloon portion with an opening in communication with the shaft, the balloon portion effective to be at least partially filled with a fluid;
at least one waveguide in the treatment balloon; and
a light detector in optical communication with the waveguide, the light detector effective to receive and detect light from the waveguide.

16. The treatment balloon of claim 15, wherein:
the waveguide is a first waveguide in the balloon portion; and
a second waveguide is in the shaft and in optical communication with the light detector.

17. The treatment balloon of claim 16, wherein the second waveguide includes two or more waveguides with different thicknesses.
18. The treatment balloon of claim 16, wherein the first waveguide includes a third waveguide and a fourth waveguide at different positions in the balloon portion.
19. The treatment balloon of claim 16, wherein the second waveguide is insertable into and removable from the shaft.
20. The treatment balloon of claim 15, wherein:
the waveguide is a first waveguide and is in the balloon portion; and
a second waveguide is on a top and inside of the balloon portion, the second waveguide is in the shaft and in optical communication with the light detector.
21. A system effective to detect a position of a beam, the system comprising:
an treatment balloon effective to receive the beam, where the treatment balloon includes a shaft and a balloon portion with an open end in communication with the shaft, the balloon portion effective to be at least partially filled with a fluid, the treatment balloon effective to generate a light wave when the treatment beam is incident on the treatment balloon;
a waveguide in the treatment balloon, the waveguide effective to receive the light wave;
a light detector in optical communication with the waveguide, the light detector effective to detect the light wave; and
a processor in communication with the light detector, the processor effective to detect the position of the beam.
22. The system of claim 21, wherein the waveguide is in the balloon portion.
23. The system of claim 21, wherein the waveguide is in the shaft.

24. The system of claim 21, wherein:
the waveguide is a first waveguide and is in the balloon portion;
a second waveguide is in the shaft and in optical communication with the light detector; and
the processor is effective to detect the position of the beam based on light detected from the first waveguide and the second waveguide.

25. The system of claim 24, wherein the second waveguide includes two or more waveguides with different thicknesses.

26. The system of claim 24, wherein the first waveguide includes a third waveguide and a fourth waveguide at different positions in the balloon portion; and
the processor is effective to detect the position of the beam by detection of an intensity of the light in the third waveguide and detection of an intensity of the light in the fourth waveguide.

27. The system of claim 24, wherein the second waveguide is insertable into and removable from the shaft.

28. The system of claim 21, wherein the balloon portion and the shaft are opaque.

29. The system of claim 21, wherein:
the waveguide is a first waveguide and is in the balloon portion;
a second waveguide is on a top and inside of the balloon portion, the second waveguide is in the shaft and in optical communication with the light detector; and
the processor is further effective to detect the position of the beam based on light detected from the first waveguide and the second waveguide.

30. The system of claim 29, wherein the second waveguide includes two or more waveguides with different thicknesses.

31. The system of claim 29, wherein the light detector is one of a photodiode, a photomultiplier tube, or a charged coupled diode.

32. The system of claim 29, wherein the balloon portion is partially filled with water and partially filled with air.

33. The system of claim 21, wherein the processor is further effective to cause movement of a position of the beam in response to a detection of the position of the beam.

34. The system of claim 21, wherein the processor is further effective to stop the beam in response to a detection of the position of the beam.

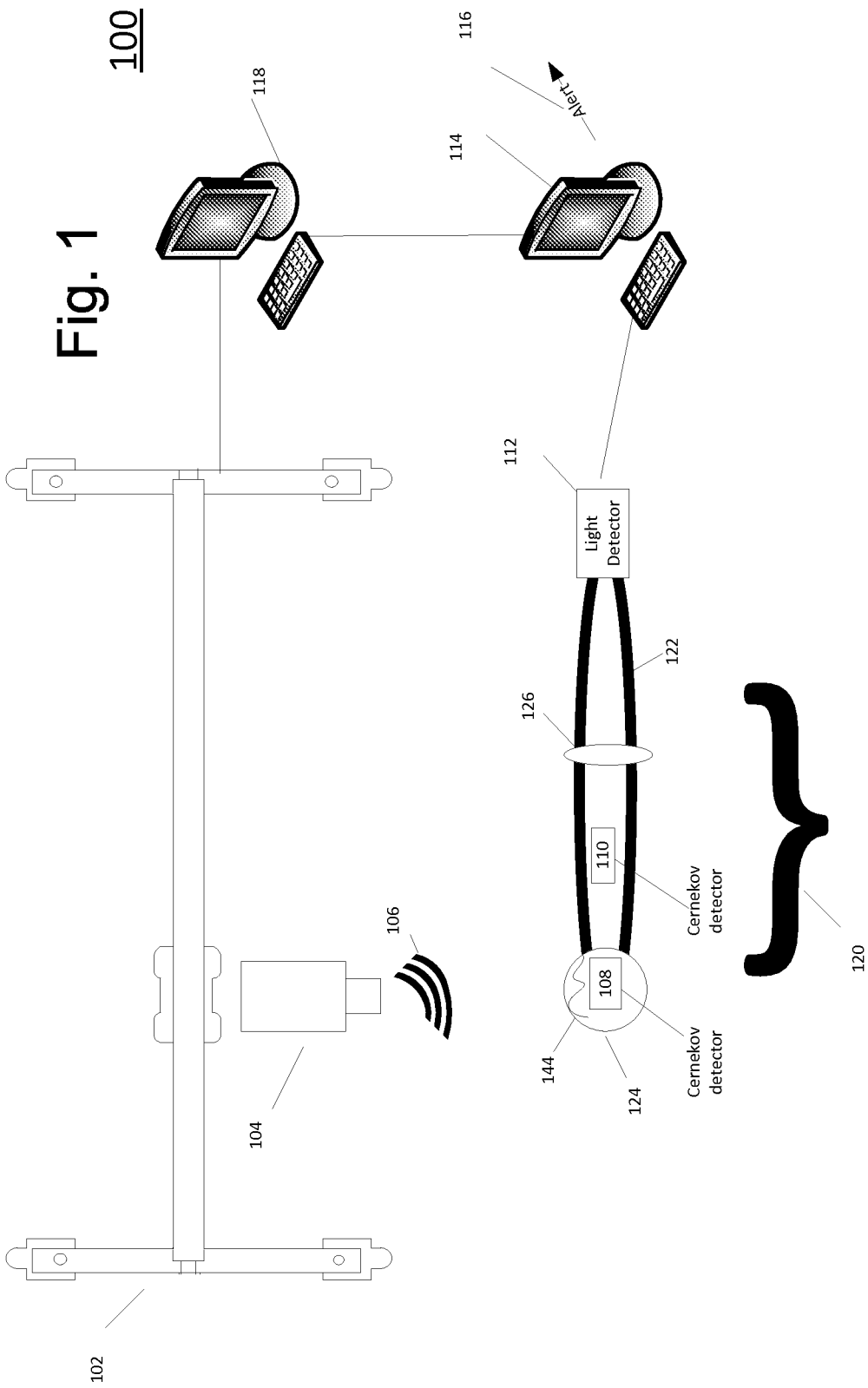


Fig. 2

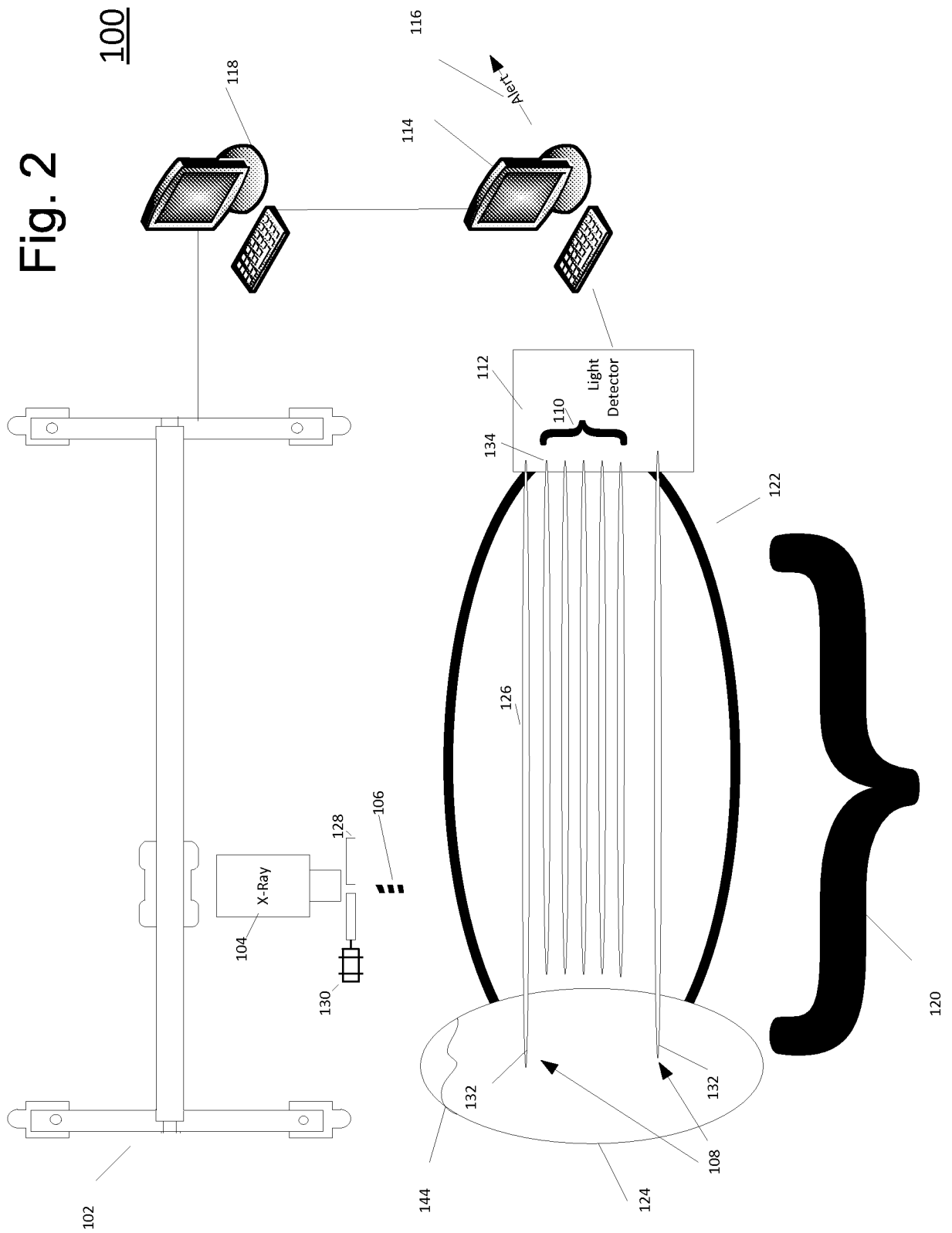
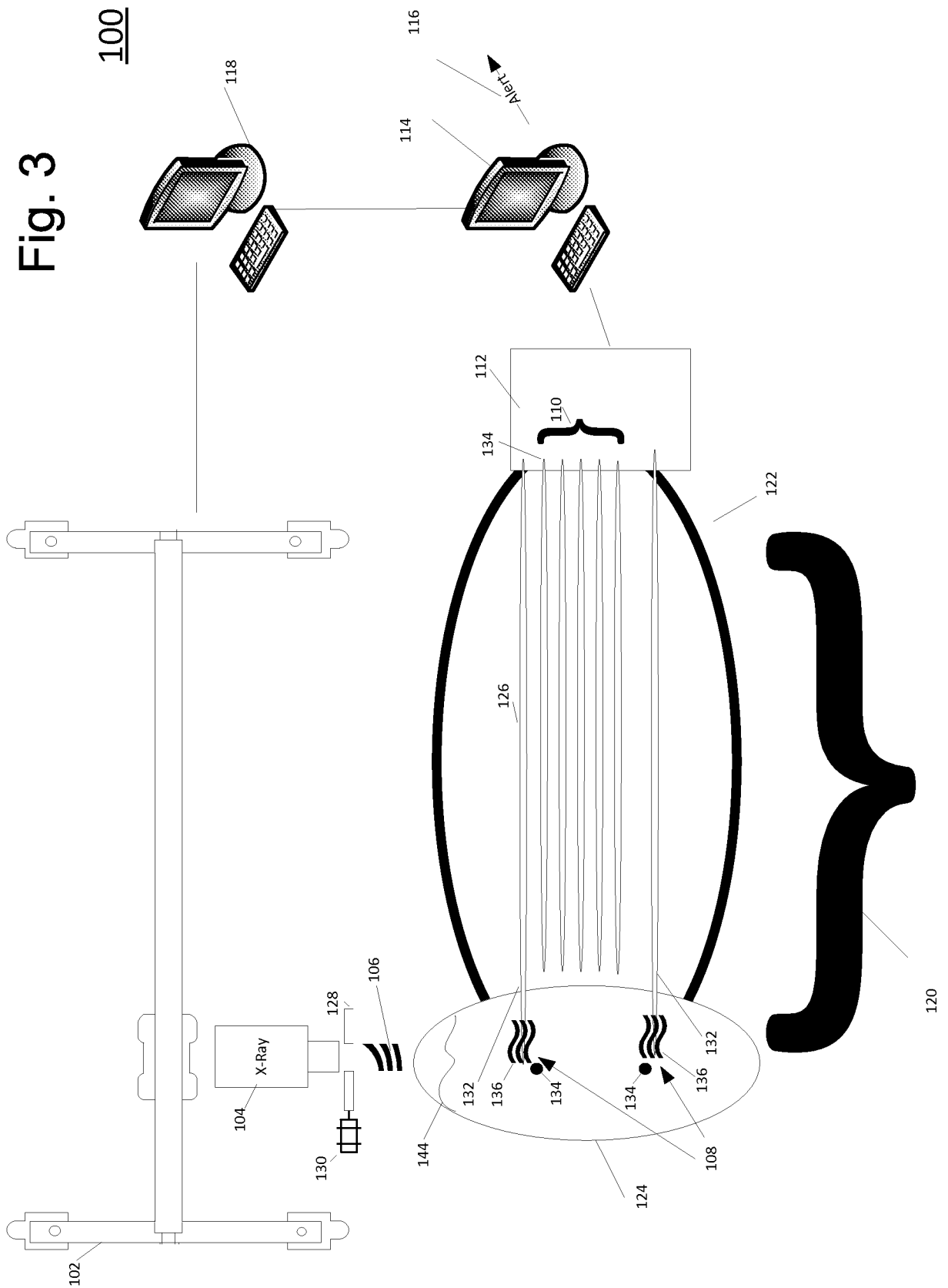
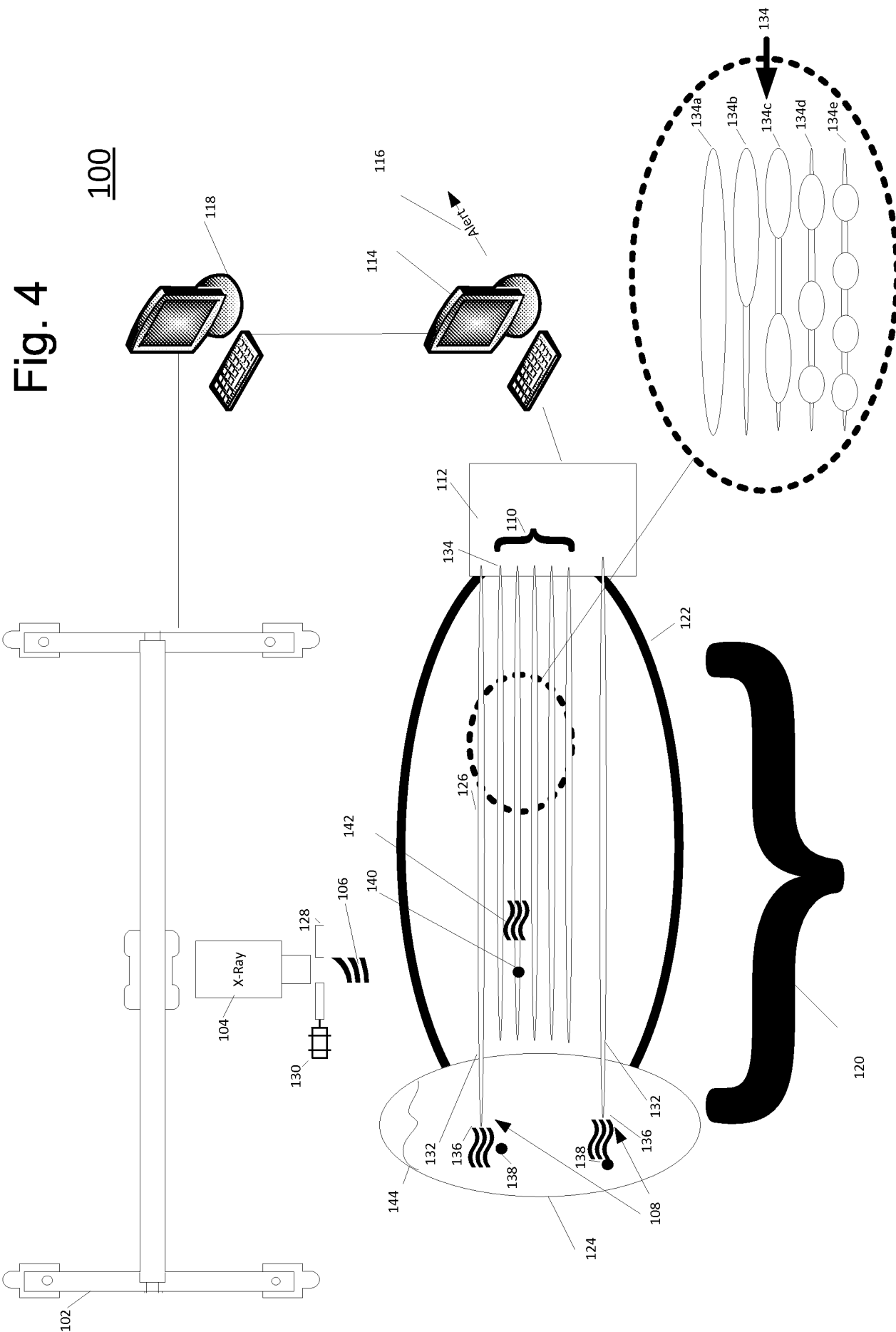
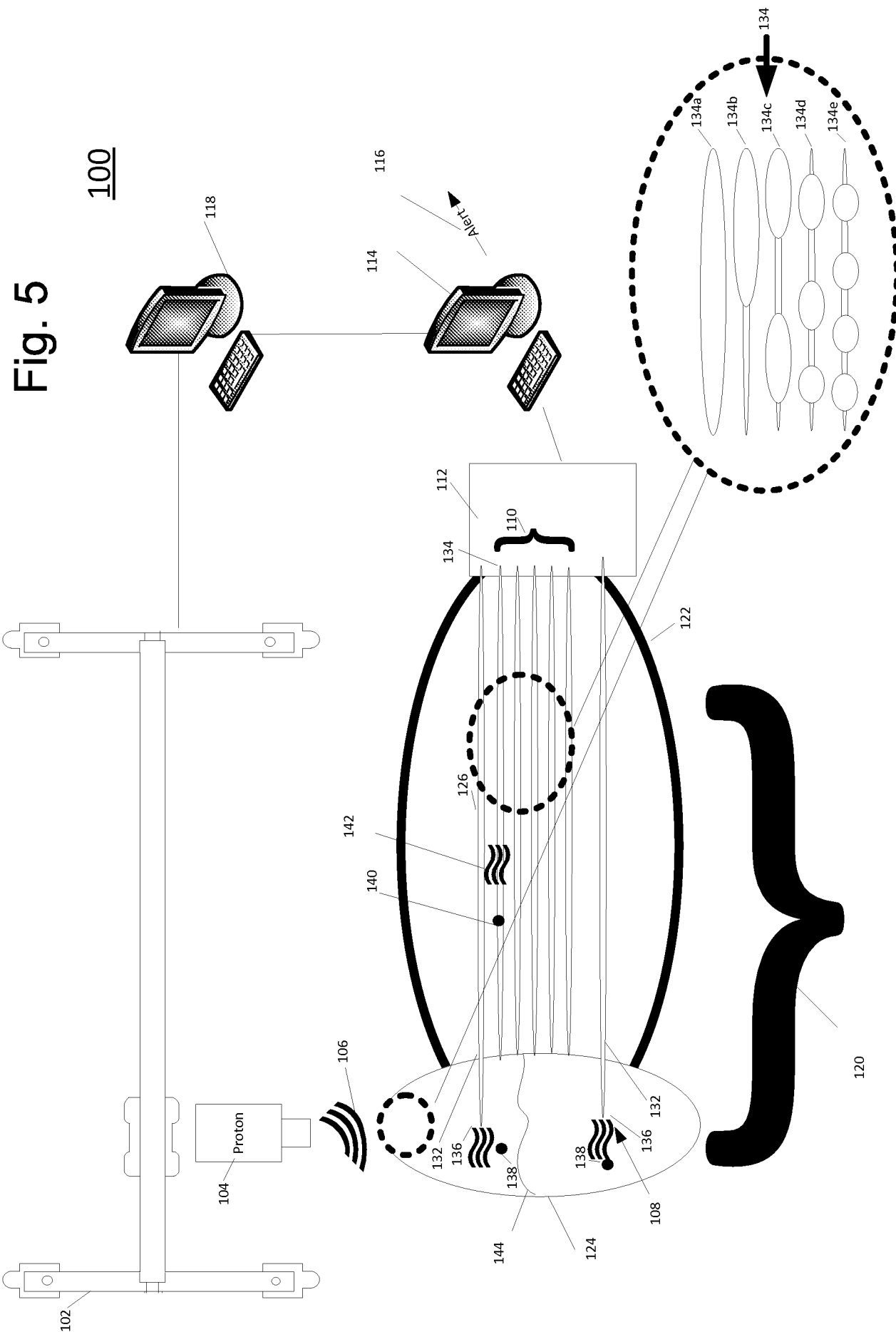
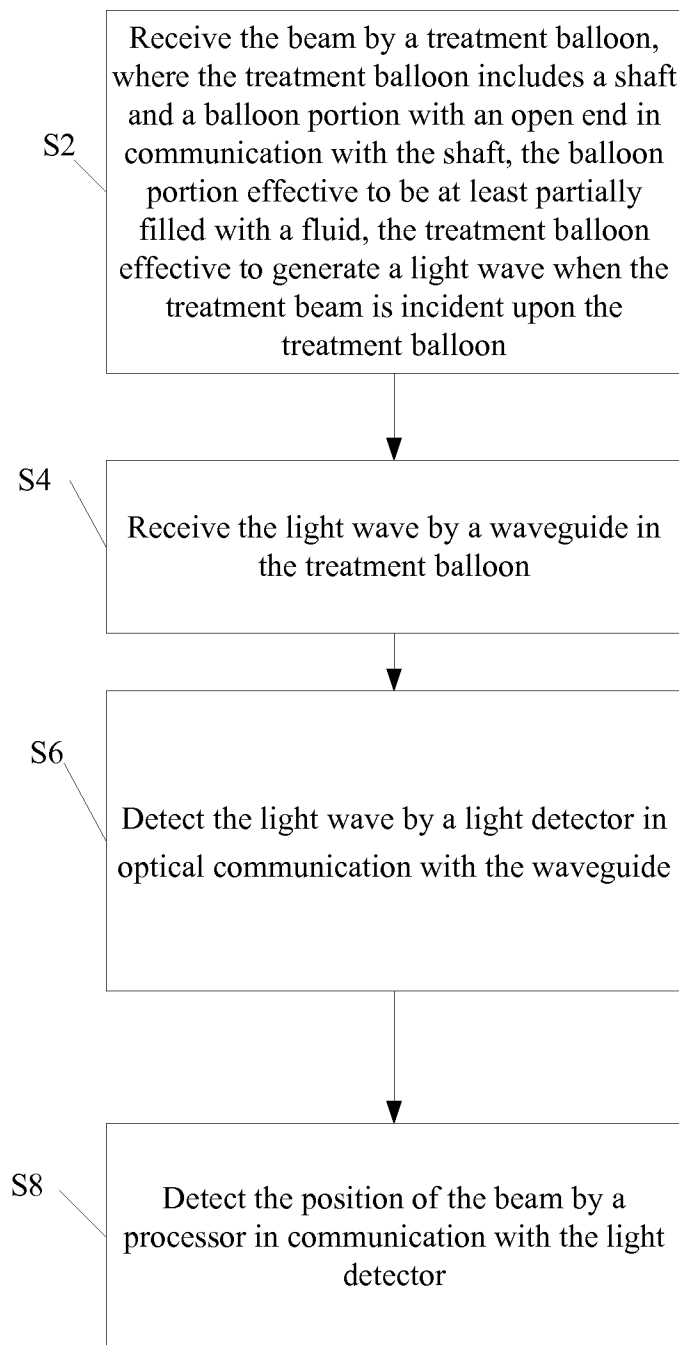


Fig. 3







**Fig. 6**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/57535

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61B 1/00 (2013.01)

USPC - 600/478

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)

IPC(8) - A61B 1/00 (2013.01)

USPC - 600/478

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

600/115, 116, 600/*, 607/*

(Search term limited; see below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PubWest (PGPB, USPT, EPAB, JPAB); Google; PatBase (All);

Search Terms: Balloon catheter, light guide, wave guide, fiber, fiber optic, inflatable member, device, bladder, detect\$, determin\$, sens\$, location, position, localiz\$, beam, photon, \$luminesc\$, \$fluoresc\$, phosphoresc\$, light, cherenkov, cerenkov

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/0288934 A1 (KEPPEL et al.) 18 November 2010 (18.11.2010) Entire document, especially Abstract, para[0012]- para[0015], para[0046], para[0059]- para[0061], para[0089]- para[0092] and FIG. 6a.	1, 3, 11, 13, 14
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Y		12
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A		2, 4-7, 9, 10
X	US 2010/0019170 A1 (HART et al.) 28 January 2010 (28.01.2010) Entire document, especially para[0079]- para[0084], para[0132]- para[0139] and FIGS. 5, 10.	1, 8
Y	US 2006/0025799 A1 (BASU) 02 February 2006 (02.02.2006) Abstract, para[0038].	12
A	US 6,993,376 B2 (TESTARDI) 31 January 2006 (31.01.2006) Entire document, especially Abstract, col 2, ln 35-45	1-14
A	US 8,007,444 B2 (KOKATE et al.) 30 August 2011 (30.08.2011) Entire document, especially Abstract, col 3, ln 4-40	1-14
A	US 2008/0027416 A1 (HAMEL et al.) 31 January 2008 (31.01.2008) Entire document, especially Abstract, para[0008]	1-14
A	US 2002/0188204 A1 (MCNAMARA et al.) 12 December 2002 (12.12.2002) Entire document.	1-14



Further documents are listed in the continuation of Box C.



* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

26 March 2013 (26.03.2013)

Date of mailing of the international search report

11 APR 2013

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents

P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer:

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PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 12/57535

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
-- see extra sheet --

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-14

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/US 12/57535

----- Continuation of Box III: Observations where unity of invention is lacking (Continuation of item 3 of first sheet) -----

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-14, drawn to a method of using a balloon system with a waveguide and light processor

Group II: Claim 15-20 drawn to a balloon with a waveguide

Group III: Claims 21-34 drawn to an apparatus of a balloon system with a waveguide and light processor

The inventions listed as Groups I-III do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Groups I and III are related as an apparatus (Group III) and a method of using the apparatus (Group I), and share the technical features of the apparatus of claim 21. However, these shared technical features fail to provide a contribution over the prior art of US 2002/0188204 A1 (MCNAMARA et al.) which discloses a system effective to detect a position of a beam, the system comprising: an treatment balloon (20, FIG. 1; para[0016]-[0018]) effective to receive the beam (para[0022]: backscatter), where the treatment balloon includes a shaft (30, FIG. 1) and a balloon portion (100 FIG. 1) with an open end in communication with the shaft (para[0020]), the balloon portion effective to be at least partially filled with a fluid (para[0020]), the treatment balloon effective to generate a light wave when the treatment beam is incident on the treatment balloon (para[0021]-[0022]; para[0002]-[0003]); a waveguide (50, FIG. 1) in the treatment balloon, the waveguide effective to receive the light wave (para[0021]-[0022]); a light detector in optical communication with the waveguide, the light detector effective to detect the light wave (para[0017]); and a processor in communication with the light detector, the processor effective to detect the position of the beam (para[0017], para[0002]-[0003]: OCT image).

Finally, Group II and III share common features that are known in the art to McNamara. Namely a treatment balloon comprising: an shaft (30, FIG. 1; para[0018]);

an balloon portion (100, FIG. 1; para[0018]) with an opening in communication with the shaft, the balloon portion effective to be at least partially filled with a fluid (para[0020]);

at least one waveguide (50, FIG. 1) in the treatment balloon (para[0021]-[0022]); and

a light detector in optical communication with the waveguide, the light detector effective to receive and detect light from the waveguide (para[0017], para[0002]-[0003]: OCT image). Leaving Group II as an opaque balloon and Group III as a balloon system with a light processor.

Consequently, the inventions of Groups I-II lack unity of invention under PCT Rule 13 because they do not share a same or corresponding special technical feature providing a contribution over the prior art.