



- (51) **International Patent Classification:**
G02B 6/02 (2006.01) *A61B 6/00* (2006.01)
G02B 6/04 (2006.01) *A61B 8/00* (2006.01)
- (21) **International Application Number:** PCT/IB2012/051971
- (22) **International Filing Date:** 19 April 2012 (19.04.2012)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:** 61/477,192 20 April 2011 (20.04.2011) US
- (71) **Applicant** (for all designated States except US): **KONINKLIJKE PHILIPS ELECTRONICS N.V.** [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).
- (72) **Inventors; and**
- (75) **Inventors/Applicants** (for US only): **MANZKE, Robert** [DE/US]; c/o High Tech Campus, Building 44, NL-5656 AE Eindhoven (NL). **CHAN, Raymond** [US/CA]; c/o High Tech Campus, Building 44, NL-5656 AE Eindhoven (NL).
- (74) **Agents:** **VAN VELZEN, Maaïke, M.** et al.; High Tech Campus, Building 44, NL-5656 AE Eindhoven (NL).
- (81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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(54) **Title:** VISIBLE OPTICAL FIBER FOR MEDICAL IMAGING APPLICATIONS

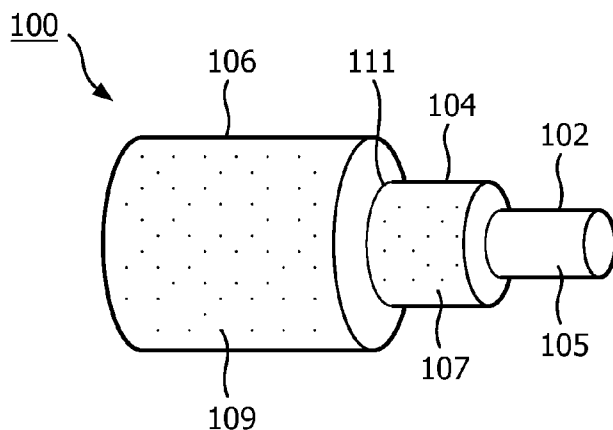


FIG. 1

(57) **Abstract:** An optical fiber or fiber assemblies include a core(102), cladding(104)surrounding the core and a coating (106) over the cladding. The core, the cladding and/or the coating includes an opaque material(105, 107, 109)to render the fiber visible in internal medical images.

**Declarations under Rule 4.17:**

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

- *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

VISIBLE OPTICAL FIBER FOR MEDICAL IMAGING APPLICATIONS

This disclosure relates to medical imaging and more particularly to an optical fiber configured to be opaque to provide visibility in medical images.

Optical biomedical sensing systems, such as optical shape interrogation systems, provide excellent tracking accuracy over a significant device length. Using such systems, different medical devices may be developed for in-vivo use during which information carried by optical fibers inserted into the human body are employed for medical monitoring.

Silicate-based (multi-core) optical fibers are invisible to X-rays, which limits their use with mainstay X-ray guidance techniques. For cases where these fibers are embedded within devices that are typically visible under fluoroscopy, the location of the fibers and attachment points within the instrument cannot be determined unambiguously, especially in cases where fiber shape sensing or localization and imaging are used together.

In accordance with the present principles, an optical fiber and fiber assemblies include a core, cladding surrounding the core and a coating over the cladding. The core, the cladding or the coating includes an opaque material to render the fiber visible in internal medical images.

An optical fiber assembly includes a plurality of optical fibers, each includes a core, cladding surrounding the core and a coating applied over the cladding. A glue material is configured to combine the plurality of fibers in a bundle wherein the glue includes an opaque material to render the bundle visible in internal medical images.

An optical fiber assembly includes one or more optical fibers including a core, cladding surrounding the core and a coating applied over the cladding. A wire or string includes an opaque material to render the wire or string visible in internal medical images. A connective

material is configured to connect the one or more fibers to the wire or string.

A medical device includes a device wall having one or more optical fibers mounted on the device wall, the one more fibers including a core, cladding surrounding the core and a coating applied over the cladding. An opaque material is applied on the device wall and configured to be adjacent to the optical fibers and to follow a path of the optical fibers within the medical device such that the opaque material renders a position of the fibers visible in internal medical images.

Another medical device includes a device wall having one or more optical fibers mounted on the device wall, the one more fibers including a core, cladding surrounding the core and a coating applied over the cladding. At least one of the core, the cladding and the coating includes an opaque material to render the one or more optical fibers visible in internal medical images.

A method for rendering an optical fiber visible in internal medical images includes providing an optical fiber having a component including a radiopaque material to render the optical fiber visible in internal medical images; introducing the optical fiber into a subject; and imaging the subject with an imaging modality to render the optical fiber visible in an image.

These and other objects, features and advantages of the present disclosure will become apparent from the following detailed description of illustrative embodiments thereof, which is to be read in connection with the accompanying drawings.

This disclosure will present in detail the following description of preferred embodiments with reference to the following figures wherein:

FIG. 1 is a section of an optical fiber having opaque materials formed into a core, a cladding and/or a coating in accordance with one embodiment;

FIG. 2 is a section of an optical fiber having an additional jacket or coating including

opaque materials in accordance with another embodiment;

FIG. 3 is a section of an optical fiber assembly having an opaque glue connecting the fibers to form a bundle in accordance with one embodiment;

FIG. 4 is a section of an optical fiber assembly having an opaque wire or string and being connected to one or more fibers to form a bundle in accordance with another embodiment;

FIG. 5 is a partial cross section of a shape-sensing enabled medical device having optical fibers formed on or adjacent to opaque features in accordance with one embodiment;

FIG. 6 is a partial cross section of a shape-sensing enabled medical device having optical fibers with opaque features including identifying features in accordance with another embodiment;

FIG. 7 is a section of an optical fiber which is opaque for multiple imaging modalities includes microbubbles formed into a coating and a wire attached thereto in accordance with another embodiment;

FIG. 8 is a block/flow diagram showing a system/method for employing optical fibers visible in medical images in accordance with the present principles; and

FIG. 9 is a flow diagram showing a method for imaging optical fibers rendered visible in medical images in accordance with the present principles.

In accordance with the present principles, optical fibers are configured to be opaque in fluoroscopic imaging. In accordance with the present embodiments, high X-ray absorbing (or reflective) materials are employed for manufacturing optical fibers or assemblies thereof for medical use. In this way, interventional devices such as guidewires which are based on fiber-glass technology will be visible for physicians during interventions.

In one embodiment, the opaque fibers include materials in a core, cladding, coating

and/or glue for optical fibers to produce opacity. In useful embodiments, opaque fibers may be deployed by themselves and tracked to keep the instrument footprint small. In other embodiments, the opaque fibers may be employed with other devices and may be employed with, e.g., balloons, stents, grafts, guidewires, catheters or other sensing systems incorporating one or several such optical fibers.

Whether employed alone or with other devices, the opaque fibers may be visually tracked under X-ray guidance. The fiber location and/or attachment configuration within another instrument can be visually determined such that the fiber movement and behavior are observable within X-ray images. In this way, individual fibers may be inserted into the human body and tracked under X-ray guidance (or other imaging modality). The fibers may be deployed by themselves, or may be employed with other devices, such as balloons, stents, grafts, guidewires, catheters or other sensing systems incorporating one or several such optical fibers. For cases where these fibers are embedded within devices that are visible under fluoroscopy, the location of the fibers and attachment points within the instrument can be determined unambiguously. This is especially useful in cases where fiber shape sensing or localization and imaging are employed together to improve the results from both systems. (Shape sensing as used herein refers to both shape sensing and localization.)

The present principles may be employed in a plurality of areas some of which may include minimally invasive devices, X-ray or other modality imaging, interventional guidance, optical shape sensing or localization, cross modality systems, etc.

It should be understood that the present invention will be described in terms of medical instruments; however, the teachings of the present invention are much broader and are applicable to any instruments employed in tracking or analyzing complex biological or mechanical systems. In particular, the present principles are applicable to internal tracking

procedures of biological systems, procedures in all areas of the body such as the lungs, gastrointestinal tract, excretory organs, blood vessels, etc. The elements depicted in the FIGS. may be implemented in various combinations of hardware and software and provide functions which may be combined in a single element or multiple elements.

The functions of the various elements shown in the FIGS. (e.g., FIG. 8) can be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor, the functions can be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which can be shared. Moreover, explicit use of the term “processor” or “controller” should not be construed to refer exclusively to hardware capable of executing software, and can implicitly include, without limitation, digital signal processor (“DSP”) hardware, read-only memory (“ROM”) for storing software, random access memory (“RAM”), non-volatile storage, etc.

Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents as well as equivalents developed in the future (i.e., any elements developed that perform the same function, regardless of structure). Thus, for example, it will be appreciated by those skilled in the art that the block diagrams presented herein represent conceptual views of illustrative system components and/or circuitry embodying the principles of the invention. Similarly, it will be appreciated that any flow charts, flow diagrams and the like represent various processes which may be substantially represented in computer readable storage media and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

Furthermore, embodiments of the present invention can take the form of a computer program product accessible from a computer-usable or computer-readable storage medium providing program code for use by or in connection with a computer or any instruction execution system. For the purposes of this description, a computer-usable or computer readable storage medium can be any apparatus that may include, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device. The medium can be an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system (or apparatus or device) or a propagation medium. Examples of a computer-readable medium include a semiconductor or solid state memory, magnetic tape, a removable computer diskette, a random access memory (RAM), a read-only memory (ROM), a rigid magnetic disk and an optical disk. Current examples of optical disks include compact disk – read only memory (CD-ROM), compact disk – read/write (CD-R/W) and DVD.

Referring now to the drawings in which like numerals represent the same or similar elements and initially to FIG. 1, a section of an optical fiber 100 is depicted in accordance with one illustrative embodiment. The optical fiber 100 includes a core 102, cladding 104 and a coating 106. The fibers described herein may include any material or type, e.g., glass, plastic, etc. and single mode, multimode, etc. In accordance with one embodiment, the optical fibers or assemblies thereof may be built with an X-ray opaque core, 102, cladding 104 and/or coating(s) 106. The optical core 102 may include opaque material in addition to or instead of the cladding 104 and/or the coating 106. However, if the opaque material is employed in the core 102, the opaque material should be selected such that it does not interfere with the light propagation characteristics of the core 102 needed for proper operation.

Optical fiber cores 102 may be made from silica preforms which are drawn into fibers

at reasonably high temperatures. Light is guided into the core 102 by applying the optical cladding 104 with a lower refractive index that traps light in the core 102 by total internal reflection. Such cladding material is often based on acrylate composites.

In one embodiment, the core 102, the cladding 104 or coating 106 may be doped with high atomic number elements or other high X-ray absorbing or reflecting components 105, 107, 109. Such elements may include metals, such as, Tungsten, Platinum, Gold, Silver, Lead, Tantalum, Iron, Nickel, Bismuth, etc. It may be preferable to select inexpensive, inert and biocompatible elements. The dopants provide significant X-ray absorption. The metals may be introduced during the manufacture of the fiber or applied (e.g., to the coating) after manufacture. Note that each of materials 105, 107, 109 may include a different type of material (e.g., dopant versus dye), a different form of material (coating/paint versus integrated into the base material), etc. Further, note that embodiments need only one of materials 105, 107, 109 but may include more than one of materials 105, 107, 109.

The core 102, cladding 104 or coating 106 may include X-ray opaque contrast dyes (107, 109). Such dyes may include radiopaque materials such as Barium or Iodine. Types of X-ray contrast agents approved for human use include barium sulfate suspensions, which are used for gastrointestinal (GI) tract imaging, and water-soluble aromatic iodinated contrast agents. Inexpensive BaSO_4 formulations may also be employed. Water-soluble iodinated agents may be employed, such as those that use a 1,3,5-triiodobenzene platform, diatrizoic acid or diatrizoate. Ionic triiodobenzene monomers (such as diatrizoate) as well as nonionic, water-soluble iodinated contrast media may be employed over cladding 104 or over coating materials 106 to provide X-ray contrast.

In another embodiment, X-ray opaque polymers (107) may be employed in the cladding 104 or coating 106. For example, halogenated aromatic methacrylate monomers

may be employed, where crystalline synthesis products of these monomers can be homopolymerized in a melt used to produce clear, intensely X-ray opaque glasses possessing high refractive indices, useful for the cladding material 104. The monomers may be soluble in methacrylate monomers with which they could be copolymerized to produce clear radiopaque materials. The stability of the homopolymers in an aqueous environment is excellent as is thermal stability, exhibiting little decomposition below 300 degrees Celsius. Other radiopaque materials may also be employed.

The cladding materials provide total internal reflection for the core 102 while being X-ray opaque. Coating materials 106 may be doped with X-ray absorbing substances (109), such as metals and other opaque materials. In other embodiments, radiopaque polymers may be employed as the coating 106. Dyes or other materials 111 may be interposed between the cladding 104 and coating 106.

It should be understood that the dyes, dopants, polymers etc. may be formulated, prepared and employed with raw materials employed to fabricate the optical fibers. Alternately, such materials may be introduced during the manufacturing process by such methods as spraying, doping, etc. In some instances, the opaque materials may be introduced after the manufacture of the optical fibers, e.g., applying an additional coating, etc.

Referring to FIG. 2, another embodiment employs an additional coating layer 108 formed over the coating 106. The coating layer 108 may include a glue material, a polymer or other adhesive or material. The coating layer 108 may also include the dopants or other materials as described. The material may include glass, silicate or other material that can be drawn during fiber fabrication.

Standard manufacturing methods may be employed until a final coating layer 108 is to be applied. The coating layer 108 may include radiopaque dopants, such as metals,

radiopaque polymers or other radiopaque materials as described herein.

Referring to FIG. 3, in yet another embodiment, glue materials or adhesives 202 may include X-ray absorbing substances or may be formed from material, which is itself radiopaque. The glue 202 may be employed to bond or connect multiple optical fibers 204 together to form a fiber bundle 208. The fiber bundle 208 may be employed for optically interrogated shape sensing or localization systems or other applications. The glue 202 may include contrast dyes, metals, polymers or other materials to make the bundle 208 visible in internal medical images. In one embodiment, the glue 202 includes a glass, a silicate or other material.

Referring to FIG. 4, an optical fiber 302 is attached to an X-ray absorbing (or reflecting) structure(s) 304 to form an assembly 300. The structures 304 may include thin X-ray opaque wires, strings or other materials. The wire 304 may include a metal or other material as described herein. The structure 304 and fiber(s) 302 may be attached using glues or other adhesives 306, which may or may not be radiopaque. It should be understood that a greater number of fibers 302 or structures 304 may be employed and that such assemblies 300 may include different configurations such as, e.g., alternating fibers 302 and structures 304, structures of in the first and last positions, etc.

Referring to FIG. 5, in another embodiment, a medical device 402 is illustratively shown having different fibers which can be differentiated in fluoroscopic images. The device 402 may include any medical device (e.g., catheter, endoscope, etc.) and preferably includes a shape-sense enabled device having one or more optical fibers 408. In one embodiment, device 402 includes radiopaque materials 410 embossed into or otherwise formed or printed on a wall 404 of the device 402. Optical fibers 408 may be mounted or affixed on (or adjacent to) radiopaque materials 410 which can designate a location and identity of each optical fiber in

the device 402. The fibers 408 may be affixed to the outside or the inside of wall 404.

Material 410 may be formed into specific X-ray visible patterns that are embossed when building the medical device 402. For example, X-ray opaque lines or symbols 412 each having a different designation (individually designated) can be implemented by using different opaque materials, embossed symbols, etc. to permit identification of a specific tracking locus or fiber path as well as fiber attachment points or segment/length identifiers within X-ray-based images.

Referring to FIG. 6, another embodiment includes an assembly 500 which employs optical fibers 502 with different opaque cladding materials, coatings, glues, etc. over the length of a fiber assembly. In one embodiment, one fiber may include a doped cladding, another may include a doped coating, another may include a doped core and another may include opaque glue added over the coating. Other embodiments may include metal or other opaque materials (e.g., wires or strings) glued to the fibers 502. The fibers 502 may include an intermittently doped coating (or differently doped cladding materials, coatings, glues, etc. over the length of the fiber assembly) to provide a dashed or segmented effect 510 and 512 in an X-ray. The dashes 510, 512 may be provided with different frequency so that each fiber may be individually identified by its dashed pattern. Other geometrically distinguishing features (e.g., dots, stripes, etc.) may also be provided and are contemplated in accordance with the present principles.

X-ray opaque line segments or dashes 510, 512 of different length can be implemented to identify a specific tracking locus/fiber path as well as fiber attachment points or segment/length identifiers within X-ray-based images.

It should be understood that while fluoroscopic opacity is illustratively described for making optical fibers visible in images, the present principles apply equally to other imaging

modalities. For example, the optical fibers may be doped using magnetic materials to make the fibers visible in magnetic resonance images. Furthermore, in another embodiment, the optical fiber or assembly can incorporate contrast material visible under other modalities, such as, e.g., employing microbubbles within a coating of polystyrene outside the cladding layer, to permit visibility in ultrasound imaging, or other modalities of interest. The patterning of contrast markers can be designed to permit identification of contact/attachment points along the fiber. In addition, the fibers may be invisible in some imaging modalities while visible in others. In other embodiments, the optical fiber may be configured to provide opacity for a plurality of different imaging modalities, such as, fluoroscopy (X-ray and computed tomography (CT)), ultrasound, MRI, etc.

Referring to FIG. 7, an illustrative optical fiber 602 is opaque in ultrasound and fluoroscopic imaging modalities. Fiber 602 includes a coating 610 having microbubbles 604 formed therein to provide visibility in ultrasound imaging. Fiber also includes a wire or string 606 attached to the fiber by glue or other connective material 608 to provide X-ray imaging visibility. In one example, the fiber 602 may be embedded within a device which incorporates X-ray visible channels or marker patterns which permits identification of the fiber path and fiber attachment/tether points within assembly 620. The same fiber 602 may also be employed in another device or the same device where ultrasonic images are employed. In one useful embodiment, the optical fiber 602 may be employed to assist in registration of images between two modalities of imaging.

It should be understood that the present embodiments may be combined in any manner. For example, fibers with cladding or cores opaquely doped may also include coatings made from opaque materials. Further, devices with opaque materials on the walls may also be employed with fibers including opaque materials. In addition, radiopaque coatings may also

include microbubbles or other materials to be opaque to multiple imaging modalities to name a few illustrative permutations.

Referring to FIG. 8, a system 700 for employing a visible optical fiber 726 in images generated by a medical imaging system 710 is illustratively depicted. System 700 may include a workstation or console 712 from which a procedure is supervised and/or managed.

Workstation 712 preferably includes one or more processors 714 and memory 716 for storing programs and applications. Memory 716 may store an optical sensing module 715 configured to interpret optical feedback signals from a fiber or fibers 726, e.g., in a shape sensing or localization device or system 704. Fibers 726 may be employed in other applications as well. Optical sensing module 715 is configured to use the optical signal feedback (and any other feedback, e.g., electromagnetic (EM) tracking) to reconstruct deformations, deflections and other changes associated with a medical device or instrument 702 and/or its surrounding region. The medical device 702 may include a catheter, a guidewire, a probe, an endoscope, a robot, an electrode, a filter device, a balloon device, or other medical component, etc. In one embodiment, a radiopaque optical fiber may be employed alone without a device.

The shape sensing system 704 on device 702 includes one or more optical fibers 726 which are coupled to the device 702 in a set pattern or patterns. The optical fibers 726 connect to the workstation 712 through cabling 727. The cabling 727 may include fiber optics, electrical connections, other instrumentation, etc., as needed. The optical fibers 726 may include radiopaque materials or may be employed adjacent to radiopaque materials as previously described.

Workstation 712 includes a display 718 for viewing internal images of a subject (patient) if an imaging system 710 is employed. Imaging system 710 may include a fluoroscopy system, a computed tomography (CT) system, an ultrasonic system, etc. Display

718 may also permit a user to interact with the workstation 712 and its components and functions, or any other element within the system 700. This is further facilitated by an interface 720 which may include a keyboard, mouse, a joystick, a haptic device, or any other peripheral or control to permit user feedback from and interaction with the workstation 712.

Workstation 712 includes an optical source 706 to provide optical fibers with light. An optical interrogation unit or module 708 is employed to detect light returning from all fibers. This permits the determination of strains or other parameters, which will be used to interpret the shape, orientation, or other characteristics, sensed by the interventional device 702. The light signals will be employed as feedback to make adjustments to assess errors and to calibrate the device 702 or system 700.

Shape sensing device 704 may include one or more fibers 726. Shape sensing is based on fiber optic Bragg grating sensors. A fiber optic Bragg grating (FBG) is a short segment of optical fiber that reflects particular wavelengths of light and transmits all others. This is achieved by adding a periodic variation of the refractive index in the fiber core, which generates a wavelength-specific dielectric mirror. A fiber Bragg grating can therefore be used as an inline optical filter to block certain wavelengths, or as a wavelength-specific reflector. A principle behind the operation of a fiber Bragg grating is Fresnel reflection at each of the interfaces where the refractive index is changing. For some wavelengths the reflected light of the various periods is in phase with one another so that constructive interference exists for reflection and consequently, destructive interference for transmission. The Bragg wavelength is sensitive to strain as well as to temperature. This means that Bragg gratings can be used as sensing elements in fiber optical sensors. In an FBG sensor, the measurand (e.g. strain) causes a shift in the Bragg wavelength. One of the main advantages of the technique is that various sensor elements can be distributed over the length of a fiber. Incorporating three or more

cores with various sensors (gauges) along the length of a fiber that is embedded in a structure allows for the 3 dimensional form of such a structure to be precisely determined. Along the length of the fiber, at various positions, a multitude of FBG sensors are located (e.g. 3 or more fiber sensing cores). From the strain measurement of each FBG the curvature of the structure can be inferred at that position. From the multitude of measured positions, the total 3 dimensional form is determined.

As an alternative to fiber optic Bragg gratings, the inherent backscatter in optical fibers can be exploited. One such approach is to use Rayleigh scatter in standard single-mode communications fiber. Rayleigh scatter occurs as a result of random fluctuations of the index of refraction in the fiber core. These random fluctuations can be modeled as a Bragg grating with a random variation of amplitude and phase along the grating length. By using this effect in 3 or more cores running within a single length of multicore fiber, the 3D shape and dynamics of the surface of interest would be trackable.

Further alternatives to fiber optic Bragg gratings include back scattering technology, optical fiber force sensing, fiber localization sensors, electromagnetic tracking sensors as well as, generally, technology based on detection or measurement of deformation of two or more regions in a fiber.

In accordance with the present principles, the optical fibers performing the shape sensing are also visible images collected during the medical procedures. Advantageously, the radiopaque fibers 726 can be visualized in the medical images. In this way, their exact position and identity can be realized and employed to provide better, more accurate feedback for physicians and technicians.

Referring to FIG. 9, a method for rendering an optical fiber visible in internal medical images includes providing an optical fiber having an opaque material or an assembly with

opaque material (in accordance with any of the embodiments described herein) to render the optical fiber visible in internal medical images in block 802. In block 804, the optical fiber or assembly is introduced into a subject, such as a patient during an interventional or other medical procedure. In block 806, the subject is imaged with an imaging modality to render the optical fiber visible in an image. In block 808, the optical fiber may be rendered visible in a plurality of modalities by employing materials opaque to each of the plurality of modalities.

In interpreting the appended claims, it should be understood that:

- a) the word "comprising" does not exclude the presence of other elements or acts than those listed in a given claim;
- b) the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements;
- c) any reference signs in the claims do not limit their scope;
- d) several "means" may be represented by the same item or hardware or software implemented structure or function; and
- e) no specific sequence of acts is intended to be required unless specifically indicated.

Having described preferred embodiments for visible optical fiber for medical imaging applications (which are intended to be illustrative and not limiting), it is noted that modifications and variations can be made by persons skilled in the art in light of the above teachings. It is therefore to be understood that changes may be made in the particular embodiments of the disclosure disclosed which are within the scope of the embodiments disclosed herein as outlined by the appended claims. Having thus described the details and particularity required by the patent laws, what is claimed and desired protected by Letters Patent is set forth in the appended claims.

CLAIMS:

1. An optical fiber, comprising:
a core (102);
cladding (104) surrounding the core; and
a coating (106) applied over the cladding wherein at least one of the core, the cladding and the coating includes an opaque material (105, 107, 109) to render the optical fiber visible in internal medical images.
2. The fiber as recited in claim 1, wherein the medical images include fluoroscopy images and the opaque material includes metal dopants.
3. The fiber as recited in claim 1, wherein the medical images include fluoroscopy images and the opaque material includes X-ray opaque contrast dyes.
4. The fiber as recited in claim 1, wherein the medical images include fluoroscopy images and the opaque material in the cladding includes X-ray opaque polymers.
5. The fiber as recited in claim 4, wherein the X-ray opaque polymers include halogenated aromatic methacrylate monomers.
6. The fiber as recited in claim 1, further comprising an additional coating layer (108) formed over the coating, which includes the opaque material.

7. The fiber as recited in claim 1, wherein the medical images include ultrasonic images and the coating includes microbubbles (604) to make the coating ultrasonically opaque.

8. The fiber as recited in claim 1, wherein the opaque material (105, 107, 109) is distributed to uniquely identify the fiber and/or its disposition in the medical images.

9. An optical fiber assembly, comprising:
a plurality of optical fibers (204), each includes a core, cladding surrounding the core and a coating applied over the cladding;
a glue material (202) configured to combine the plurality of fibers in a bundle (208) wherein the glue includes an opaque material to render the bundle visible in internal medical images.

10. The assembly as recited in claim 9, wherein the medical images include fluoroscopy images and for at least one optical fiber, at least one of the core, the cladding and the coating includes a radiopaque material.

11. The assembly as recited in claim 9, wherein the radiopaque material includes one or more of metal dopants, X-ray opaque contrast dyes and X-ray opaque polymers.

12. The assembly as recited in claim 9, wherein the bundle includes a wire (304) which is opaque in the medical images.

13. The assembly as recited in claim 9, wherein the assembly is included in a shape sensing enabled medical device (402, 500).

14. An optical fiber assembly, comprising:

one or more optical fibers (302) including a core, cladding surrounding the core and a coating applied over the cladding;

a wire or string (304) including an opaque material to render the wire or string visible in internal medical images; and

a connective material (306) configured to connect the one or more fibers to the wire or string.

15. The assembly as recited in claim 14, wherein the medical images include fluoroscopy images and the wire or string includes a radiopaque material.

16. The assembly as recited in claim 15, wherein the wire or string (304) includes a metal wire or an X-ray opaque polymer.

17. The assembly as recited in claim 14, wherein the assembly is included in a shape sensing enabled medical device (402, 500).

18. A medical device, comprising:

a device wall (404) having one or more optical fibers (408) mounted on the device wall, the one more fibers including a core, cladding surrounding the core and a coating applied over the cladding; and

an opaque material (410, 412) applied on the device wall and configured to be adjacent to the optical fibers and to follow a path of the optical fibers within the medical device such that the opaque material renders a position of the fibers visible in internal medical images.

19. The device as recited in claim 18, wherein the medical images include fluoroscopy images and the opaque material includes a radiopaque material.

20. The device as recited in claim 19, wherein the radiopaque material includes one or more of metal, X-ray opaque contrast dyes and X-ray opaque polymers.

21. The device as recited in claim 18, wherein the opaque material includes a wire (304) which is opaque in the medical images.

22. A medical device, comprising:

a device wall (404) having one or more optical fibers (502) mounted on the device wall, the one more fibers including a core, cladding surrounding the core and a coating applied over the cladding; and

at least one of the core, the cladding and the coating including an opaque material (510, 512) to render the one or more optical fibers visible in internal medical images.

23. The device as recited in claim 22, wherein the medical images include fluoroscopy images and at least one of the core, the cladding and the coating includes metal dopants and X-ray opaque contrast dyes.

24. The device as recited in claim 22, wherein the medical images include fluoroscopy images and the cladding includes X-ray opaque polymers.

25. The device as recited in claim 22, further comprising an additional coating layer (108) formed over the coating, which includes the opaque material.

26. The device as recited in claim 22, wherein the medical images include ultrasonic images and the coating includes microbubbles (604) to make the coating ultrasonically opaque.

27. The device as recited in claim 22, wherein the opaque material (510, 512) is distributed in at least one of the core, the cladding and the coating to uniquely identify each fiber and/or its disposition in the medical images.

28. A method for rendering an optical fiber visible in internal medical images, comprising:

providing (802) an optical fiber having a component including a radiopaque material (105, 107, 109) to render the optical fiber visible in internal medical images;

introducing (804) the optical fiber into a subject; and

imaging (806) the subject with an imaging modality to render the optical fiber visible in an image.

29. The method as recited in claim 28, further comprising rendering (808) the

optical fiber visible in a plurality of modalities by employing materials opaque to each of the plurality of modalities.

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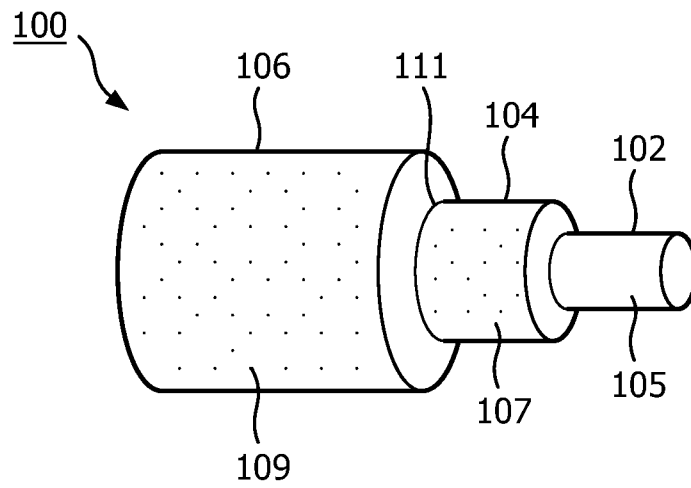


FIG. 1

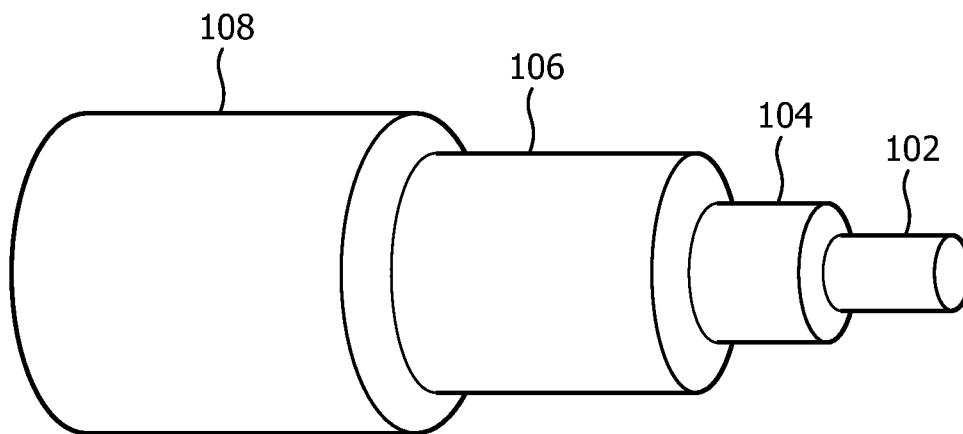


FIG. 2

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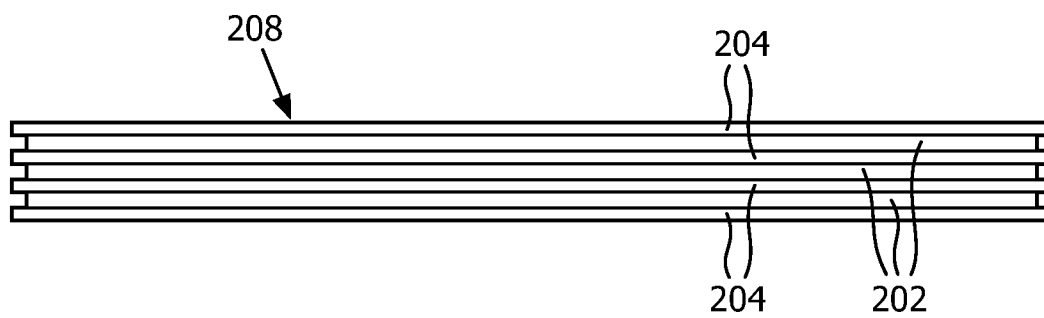


FIG. 3

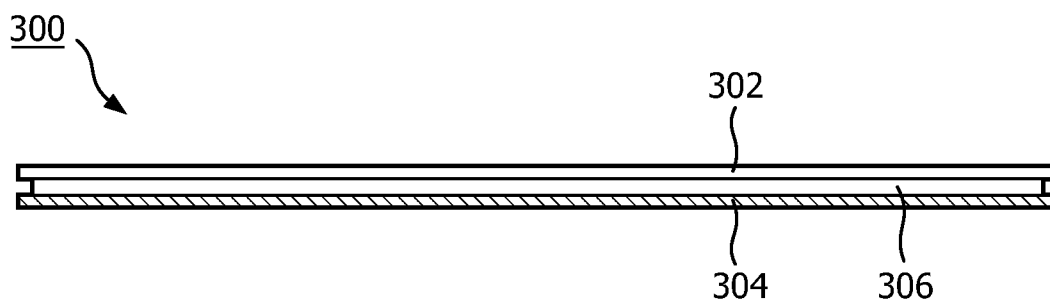


FIG. 4

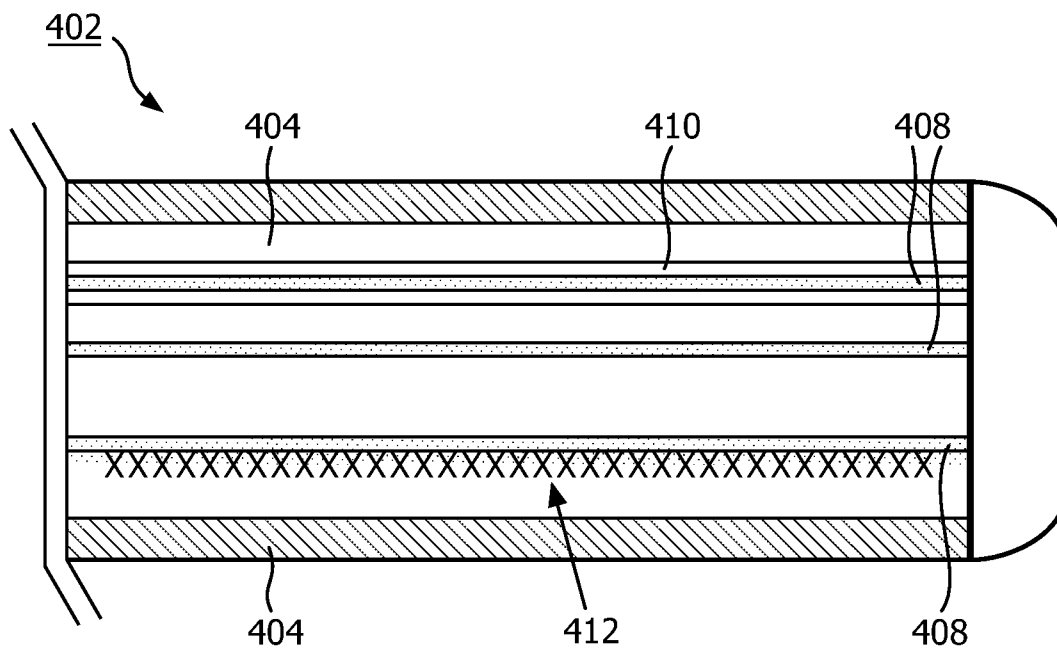


FIG. 5

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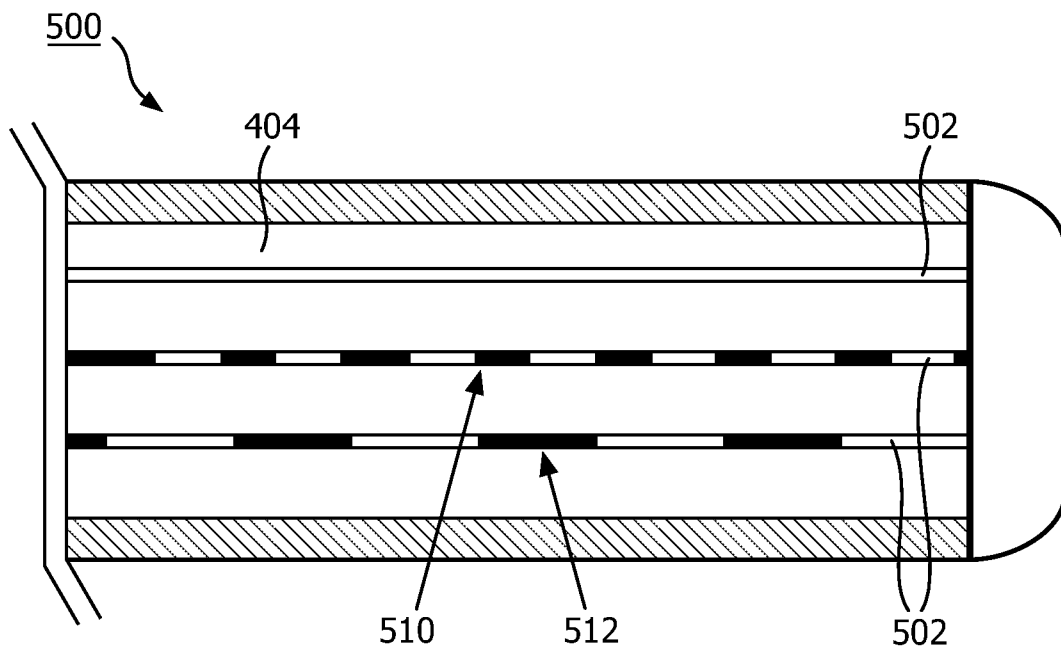


FIG. 6

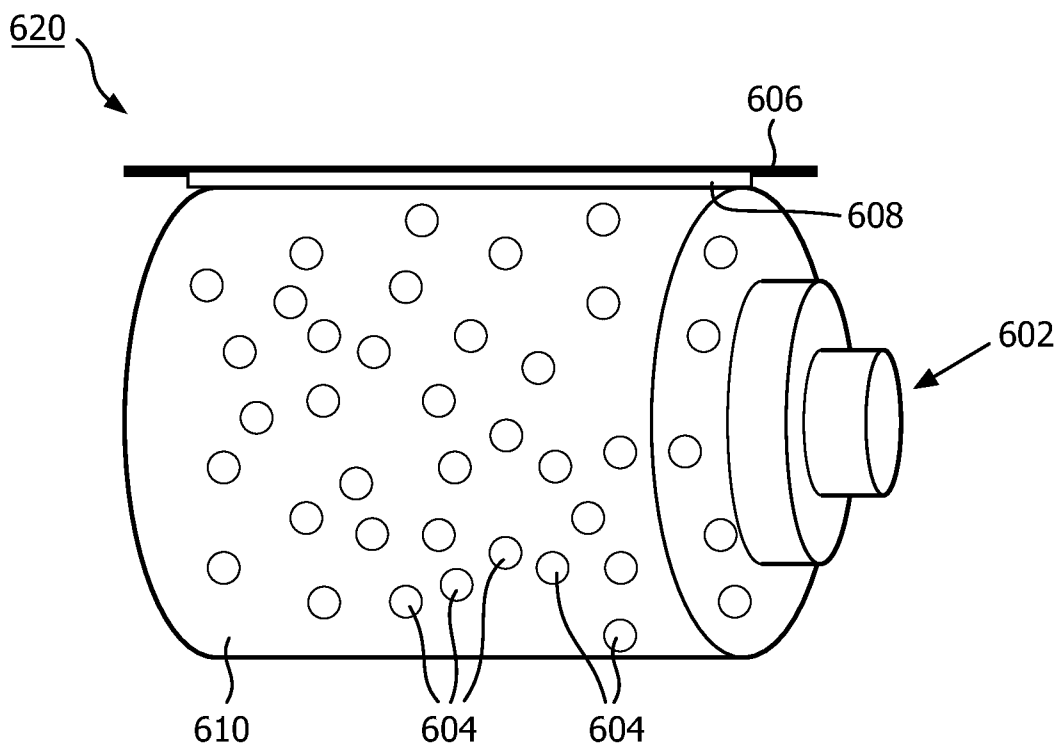


FIG. 7

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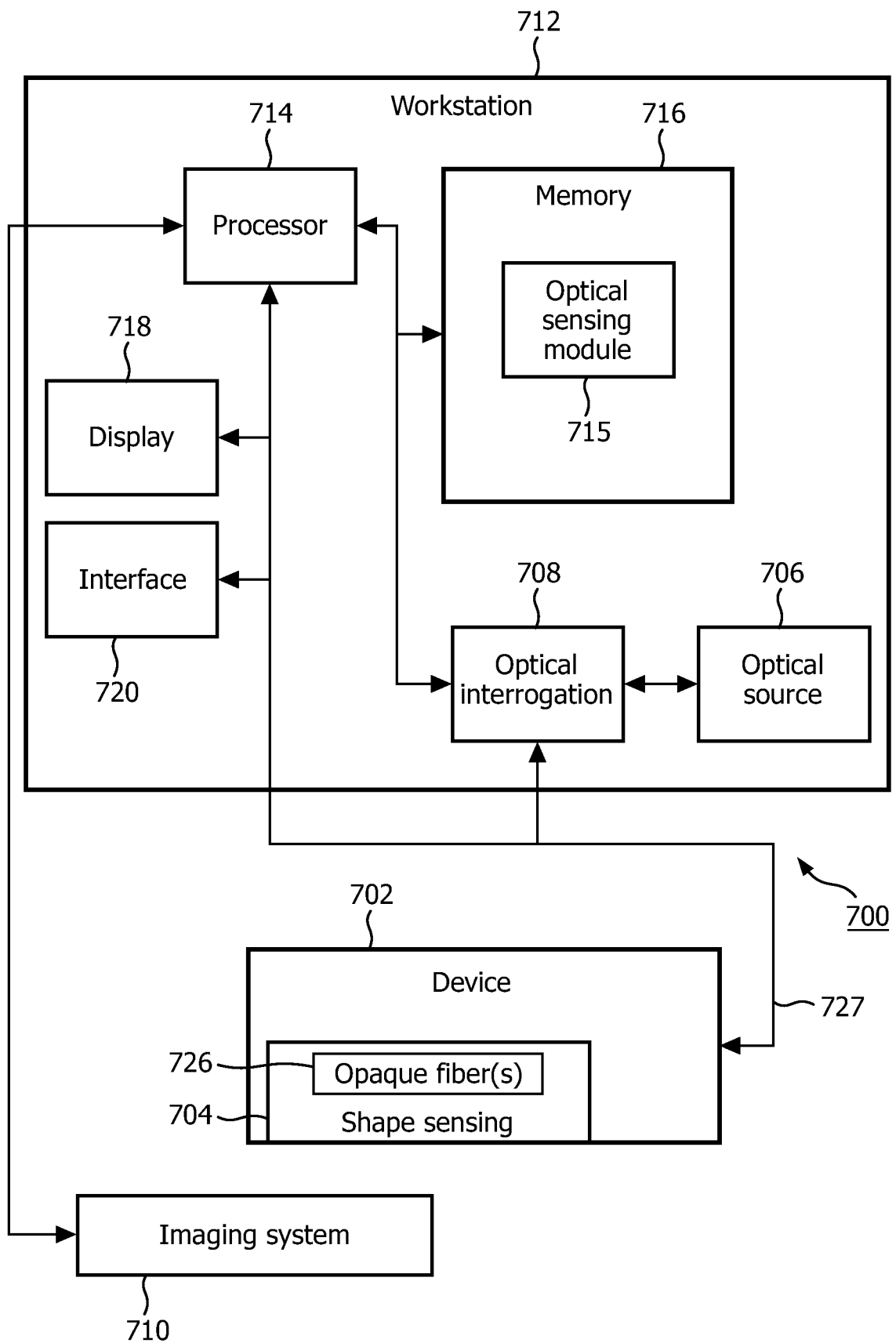


FIG. 8

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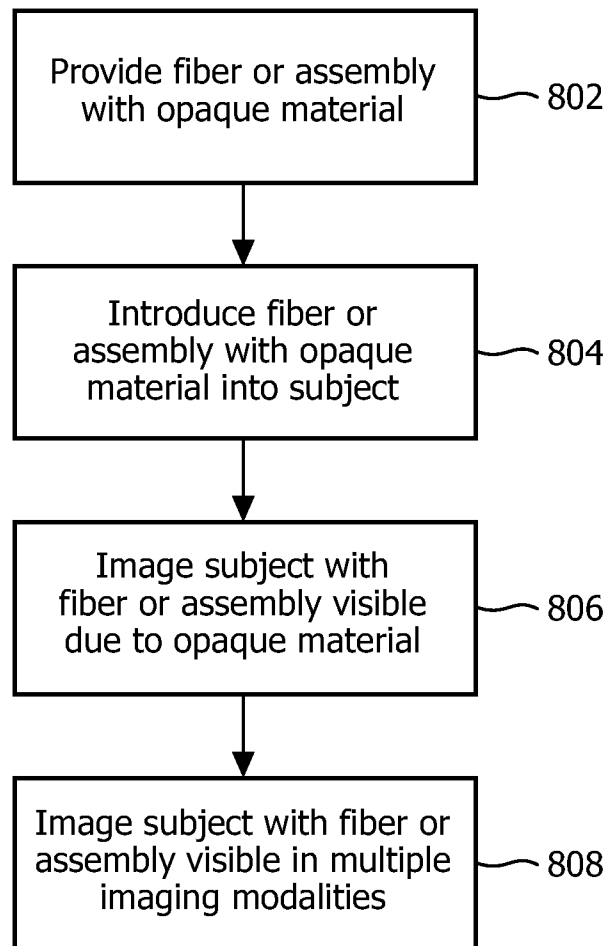


FIG. 9