US 20100179434A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2010/0179434 A1

Thornton (43) Pub. Date: Jul. 15, 2010

(54) SYSTEMS AND METHODS FOR MAKING AND USING INTRAVASCULAR ULTRASOUND SYSTEMS WITH PHOTO-ACOUSTIC IMAGING CAPABILITIES

(75) Inventor: **Peter Thornton**, Los Altos, CA (US)

Correspondence Address:
Boston Scientific Corporation
c/o Frommer Lawrence & Haug LLP
745 Fifth Avenue
New York, NY 10151 (US)

(73) Assignee: **Boston Scientific SciMed, Inc.**, Maple Grove, MN (US)

(21) Appl. No.: **12/351,322**

(22) Filed: **Jan. 9, 2009**

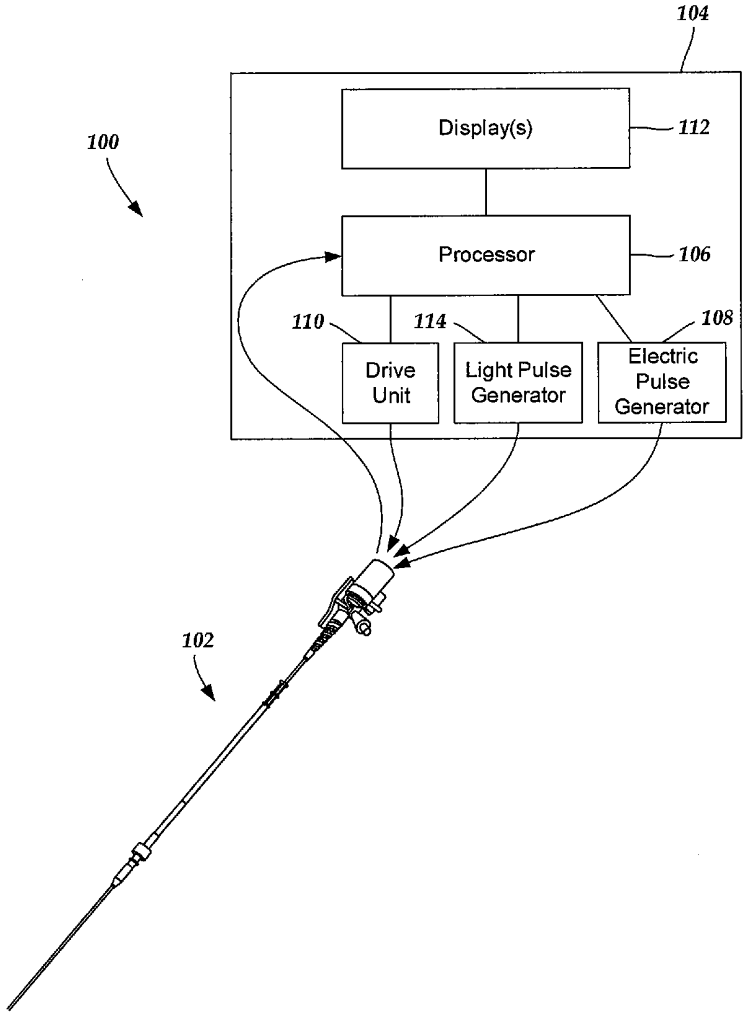
Publication Classification

(51) Int. Cl.
A61B 8/00 (2006.01)
A61B 6/00 (2006.01)

(52) U.S. Cl. **600/467**; 600/476

(57) **ABSTRACT**

A catheter assembly for an intravascular ultrasound system includes a catheter and an imaging core disposed in the catheter. The imaging core includes a rotatable driveshaft, at least one light source, and at least one transducer. The at least one light source is disposed at a distal end of the rotatable driveshaft. The at least one light source is configured and arranged for rotating with the driveshaft and also for transforming applied electrical signals to light for illuminating an object in proximity to the catheter. The at least one transducer is also disposed at the distal end of the rotatable driveshaft. The at least one transducer is configured and arranged for rotating with the driveshaft. The at least one transducer is configured and arranged for receiving acoustic signals generated by the object in response to illumination of the object by the light emitted from the at least one light source.



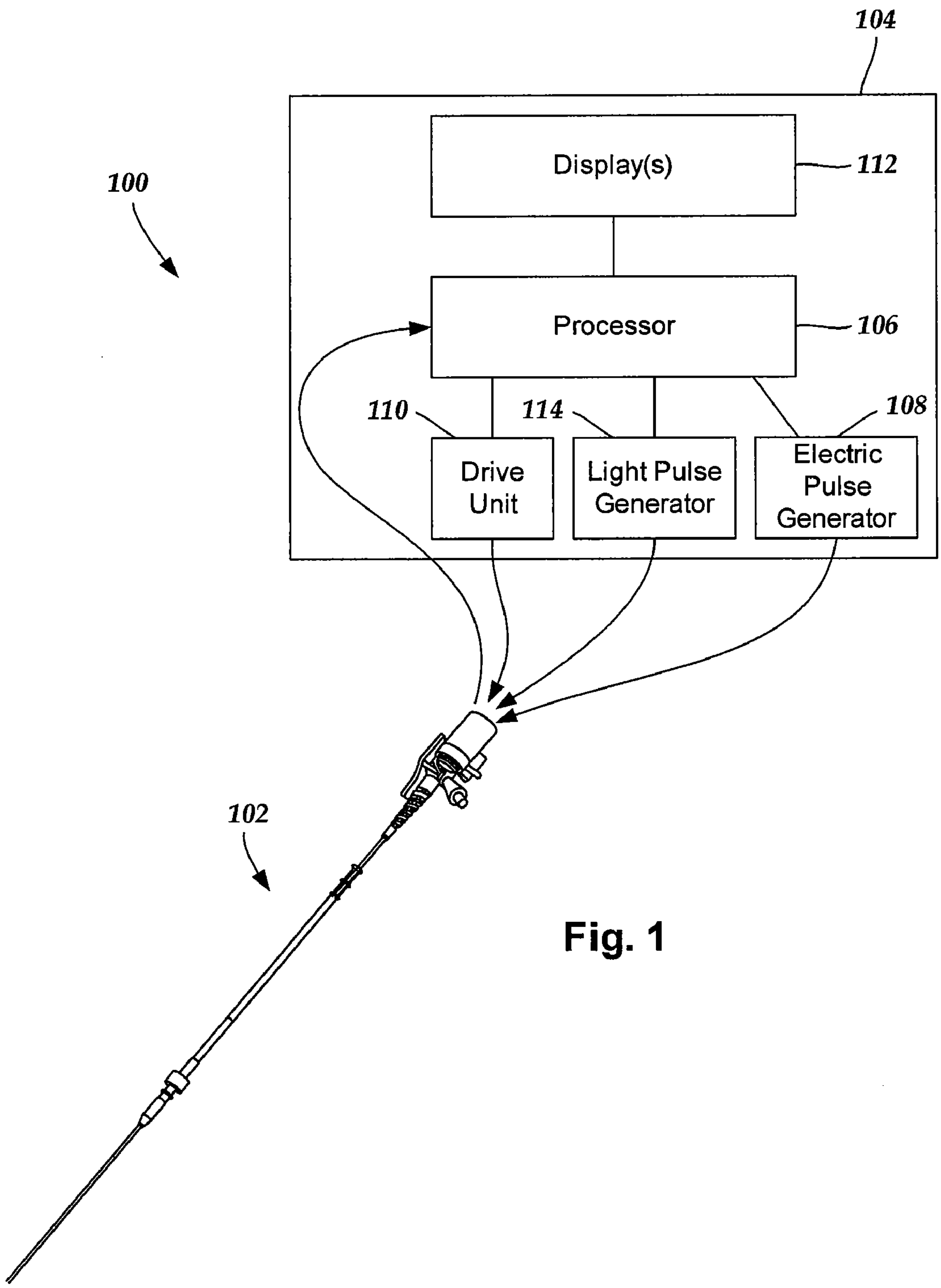

104
Display(s)
112
100
Processor
106
110
114
108
Drive Unit
Light Pulse Generator
Electric Pulse Generator
102

Fig. 1

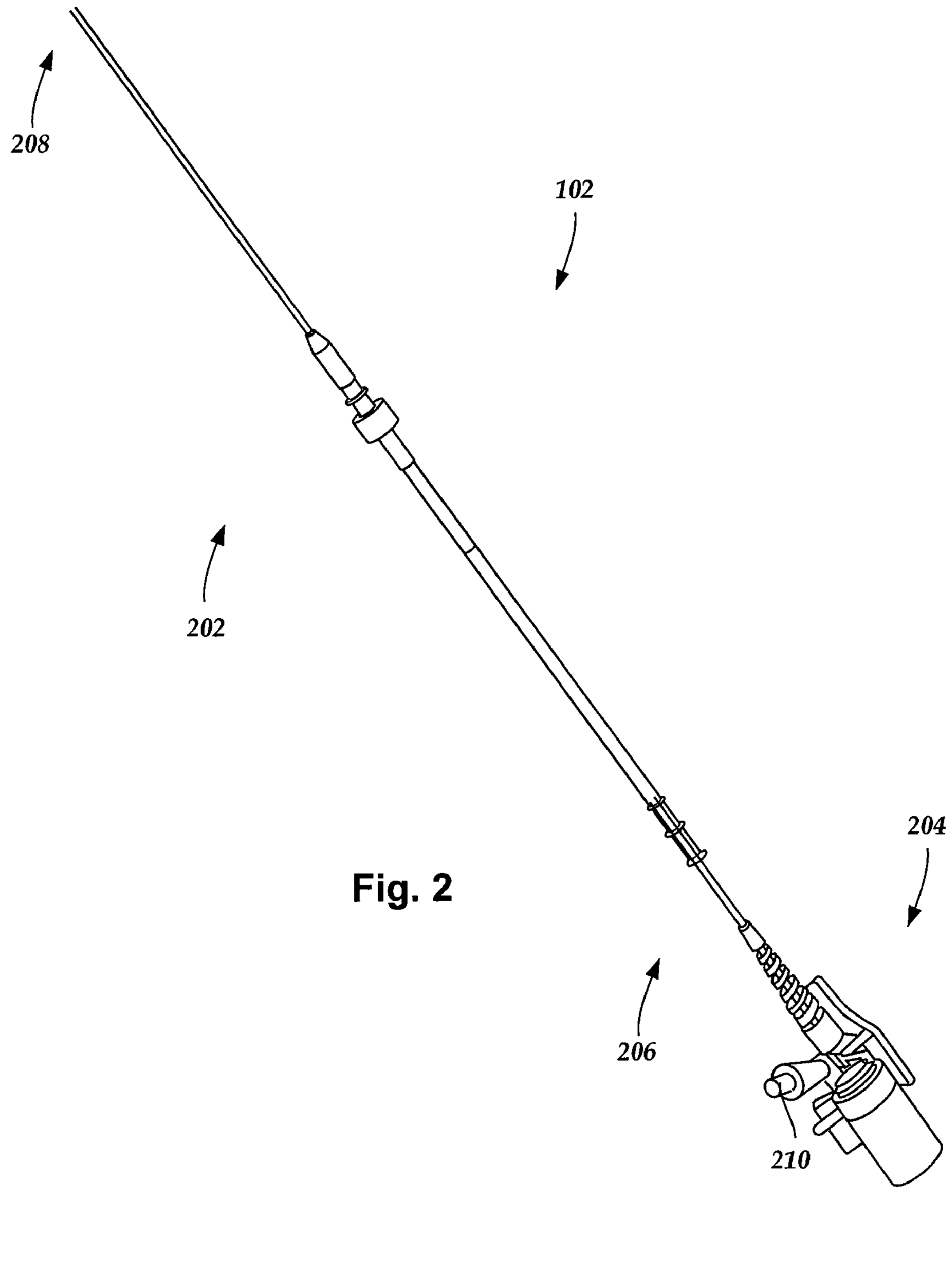


Fig. 2

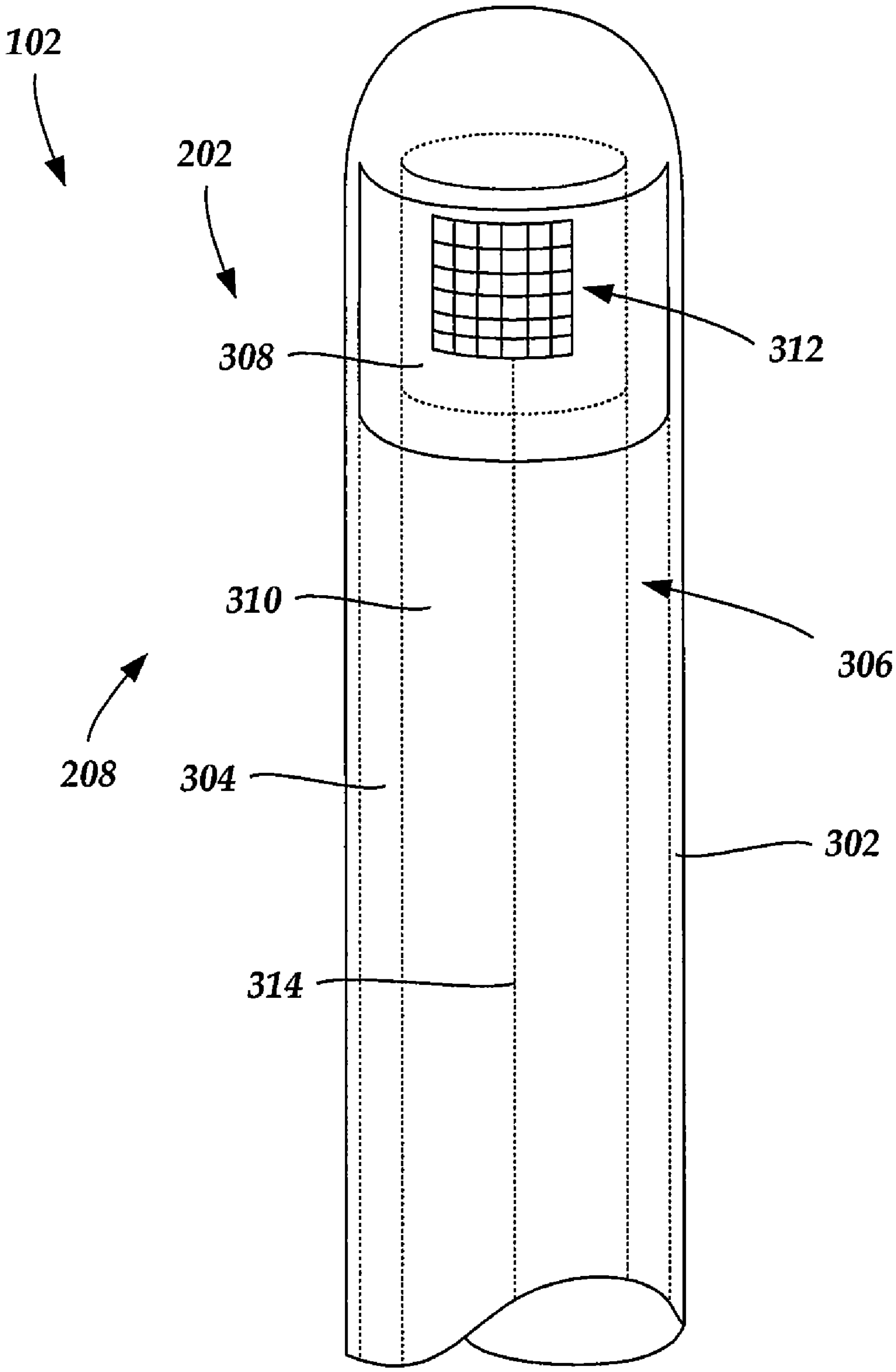


Fig. 3

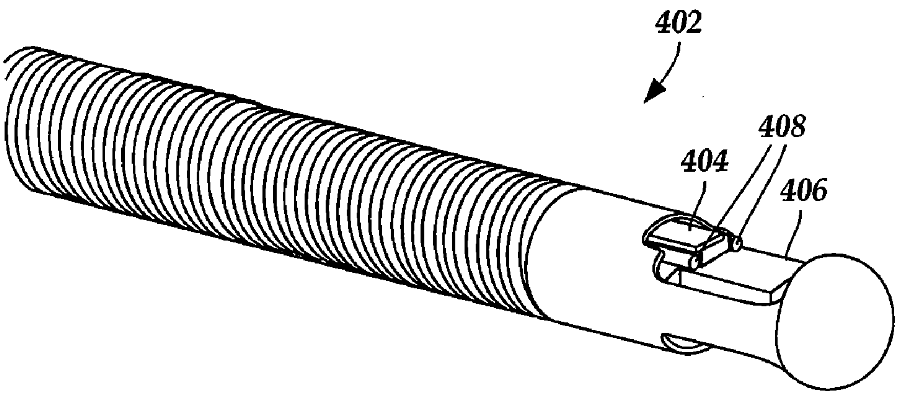


Fig. 4A

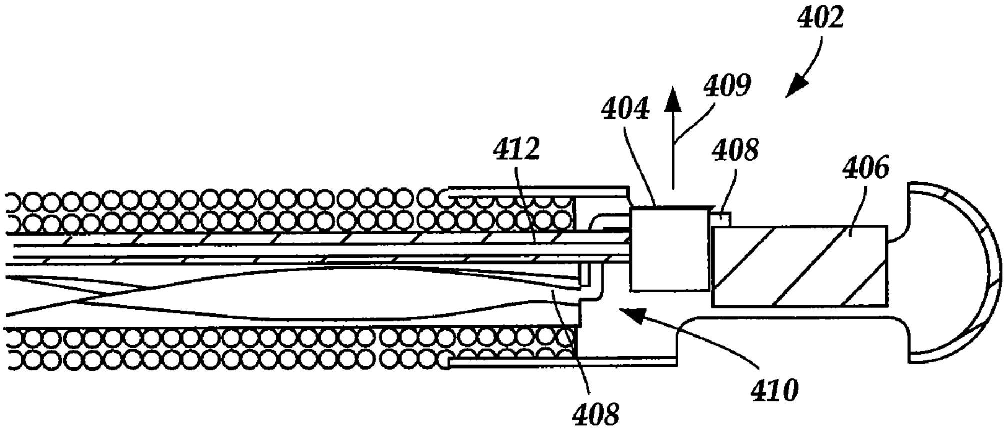


Fig. 4B

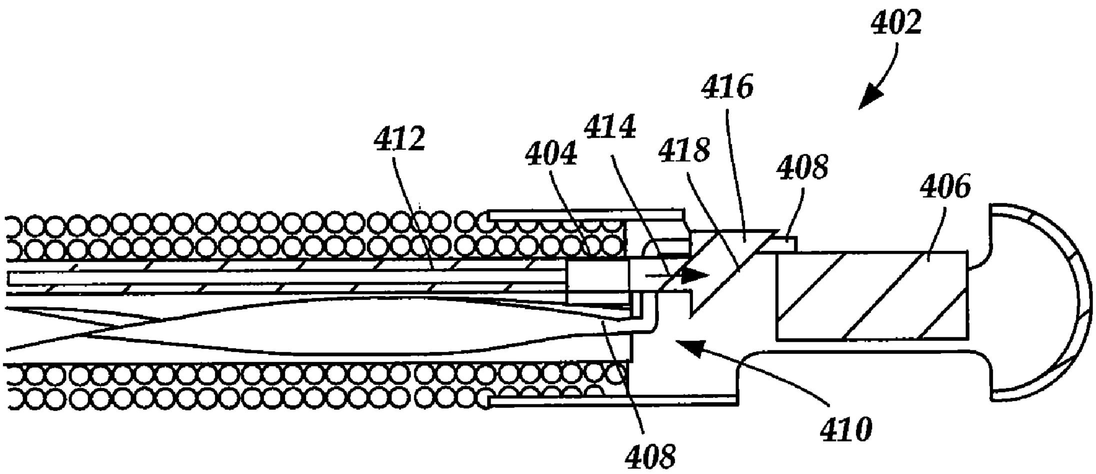


Fig. 4C

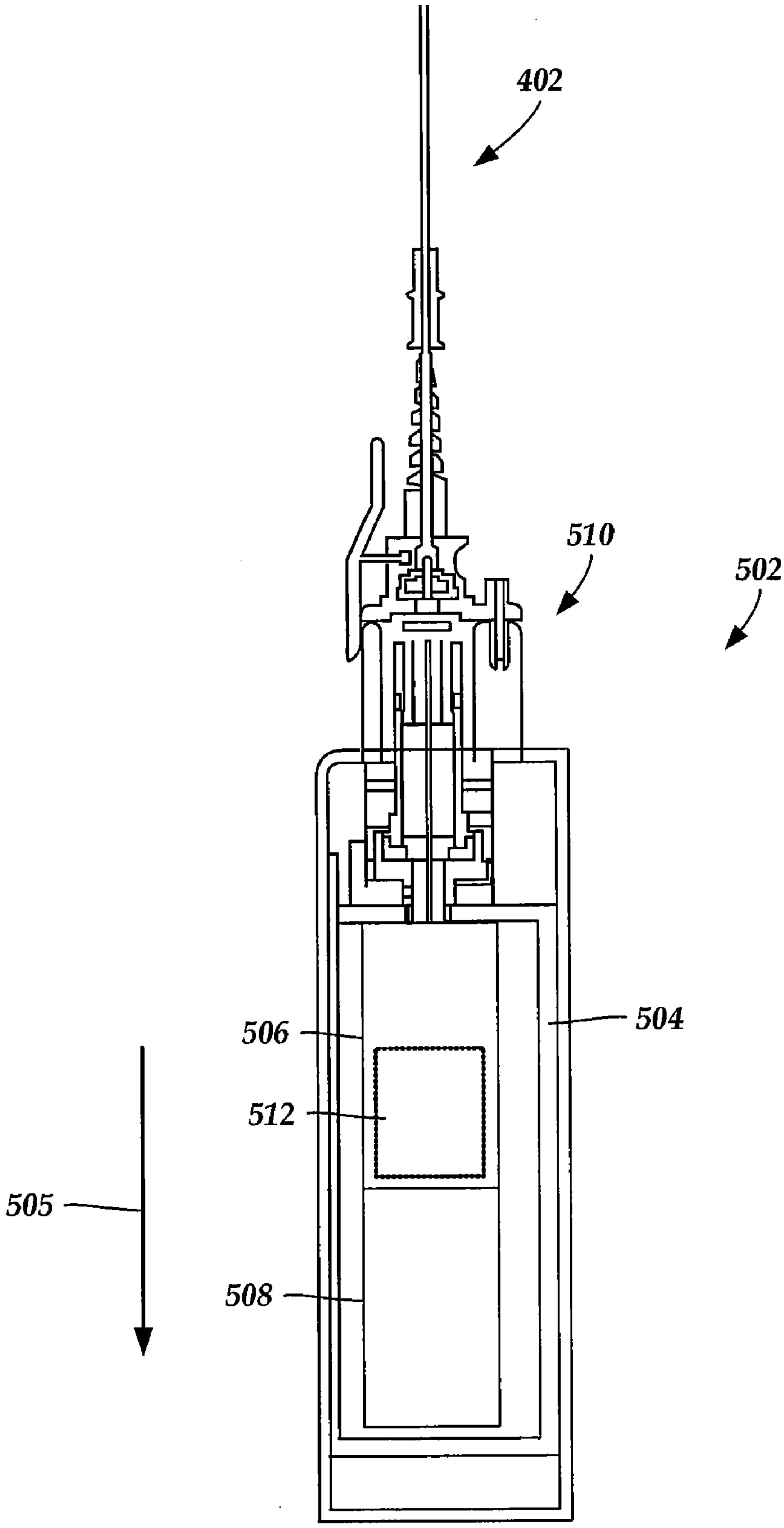


Fig. 5

SYSTEMS AND METHODS FOR MAKING AND USING INTRAVASCULAR ULTRASOUND SYSTEMS WITH PHOTO-ACOUSTIC IMAGING CAPABILITIES

TECHNICAL FIELD

[0001] The present invention is directed to the area of intravascular ultrasound imaging systems and methods of making and using the systems. The present invention is also directed to intravascular ultrasound systems that also include photo-acoustic imaging, as well as methods of making and using the intravascular ultrasound systems.

BACKGROUND

[0002] Intravascular ultrasound ("IVUS") imaging systems have proven diagnostic capabilities for a variety of diseases and disorders. For example, IVUS imaging systems have been used as an imaging modality for diagnosing blocked blood vessels and providing information to aid medical practitioners in selecting and placing stents and other devices to restore or increase blood flow. IVUS imaging systems have been used to diagnose atheromatous plaque build-up at particular locations within blood vessels. IVUS imaging systems can be used to determine the existence of an intravascular obstruction or stenosis, as well as the nature and degree of the obstruction or stenosis. IVUS imaging systems can be used to visualize segments of a vascular system that may be difficult to visualize using other intravascular imaging techniques, such as angiography, due to, for example, movement (e.g., a beating heart) or obstruction by one or more structures (e.g., one or more blood vessels not desired to be imaged). IVUS imaging systems can be used to monitor or assess ongoing intravascular treatments, such as angiography and stent placement in real (or almost real) time. Moreover, IVUS imaging systems can be used to monitor one or more heart chambers.

[0003] IVUS imaging systems have been developed to provide a diagnostic tool for visualizing a variety is diseases or disorders. An IVUS imaging system can include a control module (with an electric pulse generator, an image processor, and a monitor), a catheter, and one or more transducers disposed in the catheter. The transducer-containing catheter can be positioned in a lumen or cavity within, or in proximity to, a region to be imaged, such as a blood vessel wall or patient tissue in proximity to a blood vessel wall. The electric pulse generator in the control module generates electrical pulses that are delivered to the one or more transducers and transformed to acoustic pulses that are transmitted through patient tissue. Reflected pulses of the transmitted acoustic pulses are absorbed by the one or more transducers and transformed to electric pulses. The transformed electric pulses are delivered to the image processor and converted to an image displayable on the monitor.

[0004] Photo-acoustic imaging utilizes light and acoustic signals to form displayable images. In one exemplary photo-acoustic imaging technique, patient tissue is pulsed with light from a light source, such as a laser diode. Some of the emitted light is absorbed by the tissue and converted to heat. The heat causes a transient ultrasonic expansion of the illuminated tissue and a corresponding ultrasonic emission, which may be received by one or more transducers and processed into a displayable image.

BRIEF SUMMARY

[0005] In one embodiment, a catheter assembly for an intravascular ultrasound system includes a catheter and an imaging core. The catheter has a distal end, a proximal end, and a longitudinal length, and defines a lumen extending along the longitudinal length of the catheter from the proximal end to the distal end. The imaging core is configured and arranged for inserting into the lumen. The imaging core includes a rotatable driveshaft, at least one light source, and at least one transducer. The rotatable driveshaft has a distal end, a proximal end, and a longitudinal length. The at least one light source is disposed at the distal end of the rotatable driveshaft. The at least one light source is configured and arranged for rotating with the driveshaft and also for transforming applied electrical signals to light for illuminating an object in proximity to the catheter. The at least one transducer is disposed at the distal end of the rotatable driveshaft. The at least one transducer is configured and arranged for rotating with the driveshaft. The at least one transducer is configured and arranged for receiving acoustic signals generated by the object in response to illumination of the object by the light emitted from the at least one light source.

[0006] In another embodiment, an intravascular ultrasound imaging system includes a catheter, an imaging core, and a drive unit. The catheter has a distal end, a proximal end, and a longitudinal length, and defines a lumen extending along the longitudinal length of the catheter from the proximal end to the distal end. The imaging core is configured and arranged for inserting into the lumen. The imaging core includes a rotatable driveshaft, at least one light source, and at least one transducer. The rotatable driveshaft has a distal end, a proximal end, and a longitudinal length. The at least one light source is disposed at the distal end of the rotatable driveshaft. The at least one light source is configured and arranged for rotating with the driveshaft and also for transforming applied electrical signals to light for illuminating an object in proximity to the catheter. The at least one transducer is disposed at the distal end of the rotatable driveshaft. The at least one transducer is configured and arranged for rotating with the driveshaft. The at least one transducer is configured and arranged for receiving acoustic signals generated by the object in response to illumination of the object by the light emitted from the at least one light source. The drive unit is coupled to the proximal end of the catheter. The drive unit includes at least one rotatable transformer and a motor. The at least one rotatable transformer includes a rotor and a stator. The rotor is coupled to the proximal end of the driveshaft. The motor is for driving rotation of the driveshaft.

[0007] In yet another embodiment, a method for photo-acoustic imaging of a patient using an intravascular ultrasound imaging system includes inserting a catheter into patient vasculature. The catheter includes at least one rotatable light source coupled to a control module, and at least one rotatable transducer electrically coupled to a control module. The at least one light source rotates with the at least one transducer and maintains a constant position and direction relative to the at least one transducer. Patient tissue is illuminated with light emitted from the light source. At least one emitted acoustic signal is received from the illuminated patient tissue. At least one acoustic signal is transmitted to patient tissue from at least one transducer. At least one reflected acoustic signal is received from the patient tissue.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Non-limiting and non-exhaustive embodiments of the present invention are described with reference to the following drawings. In the drawings, like reference numerals refer to like parts throughout the various figures unless otherwise specified.

[0009] For a better understanding of the present invention, reference will be made to the following Detailed Description, which is to be read in association with the accompanying drawings, wherein:

[0010] FIG. **1** is a schematic view of one embodiment of an intravascular ultrasound imaging system, according to the invention;

[0011] FIG. **2** is a schematic side view of one embodiment of a catheter of an intravascular ultrasound imaging system, according to the invention;

[0012] FIG. **3** is a schematic perspective view of one embodiment of a distal end of the catheter shown in FIG. **2** with an imaging core disposed in a lumen defined in the catheter, according to the invention;

[0013] FIG. **4**A is a schematic perspective view of one embodiment of a distal end of a catheter for an IVUS imaging system, the catheter including a light source and at least one transducer, according to the invention;

[0014] FIG. **4**B is a schematic longitudinal cross-sectional view of the distal end of the catheter shown in FIG. **4**A, the catheter including a light source and at least one transducer, according to the invention;

[0015] FIG. **4**C is a schematic longitudinal cross-sectional view of the distal end of the catheter shown in FIG. **4**A, the catheter including a light source and at least one transducer, the catheter also including a light director for directing light emitted from the light source, according to the invention; and

[0016] FIG. **5** is a schematic cross-sectional view of one embodiment of a proximal end of the catheter shown in FIG. **4**A coupled to a drive unit, according to the invention;

DETAILED DESCRIPTION

[0017] The present invention is directed to the area of intravascular ultrasound imaging systems and methods of making and using the systems. The present invention is also directed to intravascular ultrasound systems that also include photoacoustic imaging, as well as methods of making and using the intravascular ultrasound systems.

[0018] Suitable intravascular ultrasound ("IVUS") imaging systems include, but are not limited to, one or more transducers disposed on a distal end of a catheter configured and arranged for percutaneous insertion into a patient. Examples of IVUS imaging systems with catheters are found in, for example, U.S. Pat. Nos. 7,306,561; and 6,945,938; as well as U.S. Patent Application Publication Nos. 20060253028; 20070016054; 20070038111; 20060173350; and 20060100522, all of which are incorporated by reference.

[0019] FIG. **1** illustrates schematically one embodiment of an IVUS imaging system **100**. The IVUS imaging system **100** includes a catheter **102** that is coupleable to a control module **104**. The control module **104** may include, for example, a processor **106**, an electric pulse generator **108**, a drive unit **110**, and one or more displays **112**. In at least some embodiments, the electric pulse generator **108** forms electric pulses that may be input to one or more transducers (**312** in FIG. **3**) disposed in the catheter **102**. In at least some embodiments, mechanical energy from a motor disposed within the drive unit **110** may be used to drive an imaging core (**306** in FIG. **3**) disposed in the catheter **102**. In at least some embodiments, the drive unit **110** additionally includes a transformer.

[0020] In at least some embodiments, electric pulses transmitted from the one or more transducers (**312** in FIG. **3**) may be input to the processor **106** for processing. In at least some embodiments, the processed electric pulses from the one or more transducers (**312** in FIG. **3**) may be displayed as one or more images on the one or more displays **112**. In at least some embodiments, the processor **106** may also be used to control the functioning of one or more of the other components of the control module **104**. For example, the processor **106** may be used to control at least one of the frequency or duration of the electrical pulses transmitted from the electric pulse generator **108**, the rotation rate of the imaging core (**306** in FIG. **3**) by the drive unit **110**, the velocity or length of the pullback of the imaging core (**306** in FIG. **3**) by the drive unit **110**, or one or more properties of one or more images formed on the one or more displays **112**. A light pulse generator **114** is provided to generate electric signals that direct a light source at a distal end of the catheter **102** to generate light to illuminate patient tissue in proximity to the catheter **102**, as discussed in more detail below.

[0021] FIG. **2** is a schematic side view of one embodiment of the catheter **102** of the IVUS imaging system (**100** in FIG. **1**). The catheter **102** includes an elongated member **202** and a hub **204**. The elongated member **202** includes a proximal end **206** and a distal end **208**. In FIG. **2**, the proximal end **206** of the elongated member **202** is coupled to the catheter hub **204** and the distal end **208** of the elongated member is configured and arranged for percutaneous insertion into a patient. In at least some embodiments, the catheter **102** defines at least one flush port, such as flush port **210**. In at least some embodiments, the flush port **210** is defined in the hub **204**. In at least some embodiments, the hub **204** is configured and arranged to couple to the control module (**104** in FIG. **1**). In some embodiments, the elongated member **202** and the hub **204** are formed as a unitary body. In other embodiments, the elongated member **202** and the catheter hub **204** are formed separately and subsequently assembled together.

[0022] FIG. **3** is a schematic perspective view of one embodiment of the distal end **208** of the elongated member **202** of the catheter **102**. The elongated member **202** includes a sheath **302** and a lumen **304**. An imaging core **306** is disposed in the lumen **304**. The imaging core **306** includes an imaging device **308** coupled to a distal end of a rotatable driveshaft **310**.

[0023] The sheath **302** may be formed from any flexible, biocompatible material suitable for insertion into a patient. Examples of suitable materials include, for example, polyethylene, polyurethane, plastic, spiral-cut stainless steel, nitinol hypotube, and the like or combinations thereof.

[0024] One or more transducers **312** may be mounted to the imaging device **308** and employed to transmit and receive acoustic pulses. In a preferred embodiment (as shown in FIG. **3**), an array of transducers **312** are mounted to the imaging device **308**. In other embodiments, a single transducer may be employed. In yet other embodiments, multiple transducers in an irregular-array may be employed. Any number of transducers **312** can be used. For example, there can be two, three, four, five, six, seven, eight, nine, ten, twelve, fifteen, sixteen, twenty, twenty-five, fifty, one hundred, five hundred, one thousand, or more transducers. As will be recognized, other numbers of transducers may also be used.

[0025] The one or more transducers **312** may be formed from one or more known materials or devices capable of transforming applied electrical pulses to pressure distortions on the surface of the one or more transducers **312**, and vice versa. Examples of suitable materials or devices include piezoelectric ceramic materials, piezocomposite materials, piezoelectric plastics, barium titanates, lead zirconate titanates, lead metaniobates, polyvinylidenefluorides, capacitive micromachined ultrasonic transducers, and the like.

[0026] The pressure distortions on the surface of the one or more transducers **312** form acoustic pulses of a frequency based on the resonant frequencies of the one or more transducers **312**. The resonant frequencies of the one or more transducers **312** may be affected by the size, shape, and material used to form the one or more transducers **312**. The one or more transducers **312** may be formed in any shape suitable for positioning within the catheter **102** and for propagating acoustic pulses of a desired frequency in one or more selected directions. For example, transducers may be disc-shaped, block-shaped, rectangular-shaped, oval-shaped, and the like. The one or more transducers may be formed in the desired shape by any process including, for example, dicing, dice and fill, machining, microfabrication, and the like.

[0027] As an example, each of the one or more transducers **312** may include a layer of piezoelectric material sandwiched between a conductive acoustic lens and a conductive backing material formed from an acoustically absorbent material (e.g., an epoxy substrate with tungsten particles). During operation, the piezoelectric layer may be electrically excited by both the backing material and the acoustic lens to cause the emission of acoustic pulses.

[0028] In at least some embodiments, the one or more transducers **312** can be used to form a radial cross-sectional image of a surrounding space. Thus, for example, when the one or more transducers **312** are disposed in the catheter **102** and inserted into a blood vessel of a patient, the one more transducers **312** may be used to form an image of the walls of the blood vessel and tissue surrounding the blood vessel.

[0029] The imaging core **306** is rotated about a longitudinal axis of the catheter **102**. As the imaging core **306** rotates, the one or more transducers **312** emit acoustic pulses in different radial directions. When an emitted acoustic pulse with sufficient energy encounters one or more medium boundaries, such as one or more tissue boundaries, a portion of the emitted acoustic pulse is reflected back to the emitting transducer as an echo pulse. Each echo pulse that reaches a transducer with sufficient energy to be detected is transformed to an electrical signal in the receiving transducer. The one or more transformed electrical signals are transmitted to the control module (**104** in FIG. **1**) where the processor **106** processes the electrical-signal characteristics to form a displayable image of the imaged region based, at least in part, on a collection of information from each of the acoustic pulses transmitted and the echo pulses received.

[0030] As the one or more transducers **312** rotate about the longitudinal axis of the catheter **102** emitting acoustic pulses, a plurality of images are formed that collectively form a radial cross-sectional image of a portion of the region surrounding the one or more transducers **312**, such as the walls of a blood vessel of interest and the tissue surrounding the blood vessel. In at least some embodiments, the radial cross-sectional image can be displayed on one or more displays **112**.

[0031] In at least some embodiments, the imaging core **306** may move longitudinally within the lumen of the catheter **102** while the catheter **102** remains stationary. For example, the imaging core **306** may be advanced (moved towards the distal end of the catheter **102**) or retracted/pulled back (moved towards the proximal end of the catheter **102**) within the lumen **304** of the catheter **102** while the catheter **102** remains in a fixed location within patient vasculature (e.g., blood vessels, the heart, and the like). During longitudinal movement (e.g., pullback) of the imaging core **306**, an imaging procedure may be performed, wherein a plurality of cross-sectional images are formed along a longitudinal length of patient vasculature.

[0032] In at least some embodiments, the catheter **102** includes at least one retractable section that can be retracted during an imaging procedure. In at least some embodiments, a motor disposed in the drive unit (**110** in FIG. **1**) drives the pullback of the imaging core **306** within the catheter **102**. In at least some embodiments, the pullback distance of the imaging core is at least 5 cm. In at least some embodiments, the pullback distance of the imaging core is at least 10 cm. In at least some embodiments, the pullback distance of the imaging core is at least 15 cm. In at least some embodiments, the pullback distance of the imaging core is at least 20 cm. In at least some embodiments, the pullback distance of the imaging core is at least 25 cm.

[0033] The quality of an image produced at different depths from the one or more transducers **312** may be affected by one or more factors including, for example, bandwidth, transducer focus, beam pattern, as well as the frequency of the acoustic pulse. The frequency of the acoustic pulse output from the one or more transducers **312** may also affect the penetration depth of the acoustic pulse output from the one or more transducers **312**. In general, as the frequency of an acoustic pulse is lowered, the depth of the penetration of the acoustic pulse within patient tissue increases. In at least some embodiments, the IVUS imaging system **100** operates within a frequency range of 5 MHz to 60 MHz.

[0034] In at least some embodiments, one or more conductors **314** electrically couple the transducers **312** to the control module (**104** in FIG. **1**). In at least some embodiments, the one or more conductors **314** extend along a longitudinal length of the imaging core **306**. In at least some embodiments, the one or more conductors **314** may extend along at least a portion of the longitudinal length of the catheter **102** as shielded electrical cables, such as a coaxial cable, or a twisted pair cable, or the like.

[0035] In at least some embodiments, the catheter **102** with one or more transducers **312** mounted to the distal end **208** of the imaging core **306** may be inserted percutaneously into a patient via an accessible blood vessel, such as the femoral artery, at a site remote from the selected portion of the selected region, such as a blood vessel, to be imaged. The catheter **102** may then be advanced through the blood vessels of the patient to the selected imaging site, such as a portion of a selected blood vessel.

[0036] Differentiating between two or more different tissue types displayed on an IVUS image is desirable, but can be difficult using the IVUS image. For example, it may be difficult to determine where a border between two or more tissue types is located, or even if a border exists.

[0037] One technique for tissue differentiation is photo-acoustic imaging, wherein patient tissue is pulsed with light from a light source, such as a laser diode. When patient tissue is pulsed with light, some of the emitted light is absorbed by the tissue and converted to heat. The heat causes a transient ultrasonic expansion of the illuminated tissue and a corresponding ultrasonic emission, which may be received by one or more transducers and processed into a displayable image.

[0038] Photo-acoustic imaging capabilities may be incorporated into an IVUS imaging system. Such an arrangement includes one or more transducers disposed at a distal end of catheter and a light source also disposed at the distal end of the catheter in proximity to the one or more transducers. Light emitted from the light source is directed to patient tissue such that the subsequently-emitted acoustic pulses from the illuminated tissue may be received by the one or more transducers. It is desirable to have the light source and the one or more transducers both be disposed on the imaging core within the catheter so that the light source rotates with the one or more transducers, thereby maintaining a constant relative position with respect to the one or more transducers.

[0039] Previous systems have embedded optical fibers in a sheath of a catheter. However, embedding optical fibers in the sheath can make sheath manufacturing difficult. Moreover, the embedded optical fibers do not rotate with transducers. Additionally, embedding optical fibers in the sheath may hinder, or even eliminate, the pullback function of the imaging core during an imaging procedure.

[0040] In at least some embodiments, an IVUS imaging system incorporates photo-acoustic imaging capabilities into the IVUS imaging system. One or more light sources (e.g., laser diodes, or the like) are disposed in an imaging core of the IVUS imaging system. In at least some embodiments, the one or more light sources disposed in the imaging core couple to the distal end(s) of one or more conductors extending along a longitudinal length of the imaging core. In at least some embodiments, the proximal end(s) of the one or more conductors are coupled to a transformer disposed in a drive unit of the IVUS imaging system.

[0041] FIG. 4A is a schematic perspective view of one embodiment of a distal end of a catheter **402** for an IVUS imaging system (**100** in FIG. **1**). The catheter **402** includes a light source **404** (e.g., a laser diode, or the like) and one or more transducers **406**. The one or more transducers **406** are coupled to the processor (**106** in FIG. **1**) via one or more electrical conductors **408** disposed in an imaging core (**410** in FIG. 4B). In at least some embodiments, the one or more electrical conductors **408** provide power to the one or more transducers **406**. In at least some embodiments, the one or more electrical conductors **408** provide signals to and from the transducers **406**.

[0042] In at least some embodiments, the light source **404** is configured and arranged such that light emitted from the light source **404** is directed outward from the catheter **402**, as shown by directional arrow **409**. In at least some embodiments, the light source **404** is configured and arranged such that light emitted from the light source **404** is directed outward from the catheter **402** in a direction that is approximately perpendicular to a longitudinal axis of the distal end of the catheter **402**. In at least some embodiments, a diffuser (see e.g., **416** in FIG. 4C) is positioned over the light source **404** to diffuse light emitted from the light source **404**.

[0043] FIG. 4B is a schematic longitudinal cross-sectional view of one embodiment of a distal end of the catheter **402**. The catheter **402** includes a lumen into which an imaging core **410** is disposed. In at least some embodiments, the imaging core **410** includes the one or more electrical conductors **408** extending along at least a portion of the imaging core **410**. The light source **404** is coupled to the processor (**106** in FIG. **1**) via one or more electrical conductors **412** disposed in an imaging core (**410** in FIG. 4B). In at least some embodiments, the one or more electrical conductors **412** provide power to the light source **404**. In at least some embodiments, the one or more electrical conductors **412** provide electrical signals to and from the light source **404**.

[0044] In at least some embodiments, the one or more electrical conductors **408** may extend along at least a portion of the longitudinal length of the catheter **402** as shielded electrical cables, such as a coaxial cable, or a twisted pair cable, or the like. In at least some embodiments, the one or more electrical conductors **412** may extend along at least a portion of the longitudinal length of the catheter **402** as shielded electrical cables, such as a coaxial cable, or a twisted pair cable, or the like. In at least some embodiments, the one or more electrical conductors **412** wrap at least one time around the one or more electrical conductors **408**. In at least some embodiments, the light source **404** and the one or more transducers **406** both use the same one or more conductors.

[0045] In at least some embodiments, the light source **404** and the one or more transducers **406** have the same rotational velocity. In at least some embodiments, the light source **404** maintains a constant relative position with respect to the one or more transducers **406**. In at least some embodiments, the light source **404** is fixed to the one or more transducers **406**. In some embodiments, the light source **404** is proximal to the one or more transducers **406**. In other embodiments, the light source **404** is distal to the one or more transducers **406**.

[0046] Light provided from a light source **404** may be used to illuminate selected patient tissue for photo-acoustic imaging. In at least some embodiments, the light may be emitted in one or more timed patterns, such as pulses.

[0047] In at least some embodiments, the IVUS imaging system may be used to perform photo-acoustic imaging without performing ultrasound imaging. In at least some embodiments, the IVUS imaging system is configured to perform both photo-acoustic imaging and ultrasound imaging, either sequentially or independently. In at least some embodiment, the data from a photo-acoustic image and an ultrasound image may be combined to form a composite image.

[0048] FIG. 4C is a schematic longitudinal cross-sectional view of another embodiment of a distal end of the catheter **402**. The light source **404** is configured and arranged such that light emitted from the light source **404** is directed along the longitudinal length of the distal end of the catheter **402**, as indicated by directional arrow **414**, and redirected by a light director **416**. In at least some embodiments, the light director **416** includes a mirror **418** to redirect the light from the light source **404** to a desired tissue. In at least some embodiments, the light director **416** includes a diffuser to diffuse light from a narrow point source (e.g., a laser diode, or the like). In at least some embodiments, the light director **416** includes a mirror **418** and a diffuser. In at least some embodiments, the mirror **418** and the diffuser are separate from one another. In at least some embodiments, the mirror **418** has a light-diffusing reflective surface. The light director **416** may be fabricated from any material suitable for reflecting or orienting light including, for example, glass, plastic, and the like or combinations thereof.

[0049] In at least some embodiments, a proximal end of the catheter **402** couples with at least one transformer disposed in a drive unit. FIG. **5** is a schematic cross-sectional view of one embodiment of a proximal end of the catheter **402** coupled to a drive unit **502**. The drive unit **502** includes a drive sled **504** configured and arranged to slide along a length of the drive unit **502** during pullback of the imaging core (**410** in FIG. **4**B) in the direction shown by directional arrow **505**, thereby retracting the proximal end of the catheter **402**. The drive unit **502** also includes a transformer **506** and a motor **508**. In FIG. **5**, the transformer **506** and the motor **508** are shown coupled to the drive sled **504**.

[0050] In at least some embodiments, the motor **508** drives the rotation of the imaging core (**410** in FIG. **4**B) and a rotating portion of the transformer **506**. The transformer **506** is coupled to the one or more electrical conductors **408** and also to the control module (**104** in FIG. **1**) and allows signals to pass between the stationary control module (**104** in FIG. **1**) and the rotating imaging core (**410** in FIG. **4**B). In at least some embodiments, the transformer **506** is also coupled to the one or more electrical conductors **412**. In at least some other embodiments, the one or more electrical conductors **412** are coupled to another transformer **512**. In at least some embodiments, when the one or more electrical conductors **412** are coupled to the transformer **512**, the transformer **512** is disposed inside the transformer **506**.

[0051] The above specification, examples and data provide a description of the manufacture and use of the composition of the invention. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention also resides in the claims hereinafter appended.

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A catheter assembly for an intravascular ultrasound system, the catheter assembly comprising:

a catheter having a distal end, a proximal end, and a longitudinal length, the catheter defining a lumen extending along the longitudinal length of the catheter from the proximal end to the distal end; and

an imaging core configured and arranged for inserting into the lumen, the imaging core comprising

a rotatable driveshaft having a distal end, a proximal end, and a longitudinal length,

at least one light source disposed at the distal end of the rotatable driveshaft, the at least one light source configured and arranged for rotating with the driveshaft and also for transforming applied electrical signals to light for illuminating an object in proximity to the catheter, and

at least one transducer disposed at the distal end of the rotatable driveshaft, the at least one transducer configured and arranged for rotating with the driveshaft, wherein the at least one transducer is configured and arranged for receiving acoustic signals generated by the object in response to illumination of the object by the light emitted from the at least one light source.

2. The catheter assembly of claim **1**, wherein the imaging core further comprises at least one light director configured and arranged for directing light emitted from the at least one light source towards a desired tissue region.

3. The catheter assembly of claim **2**, wherein the at least one light director comprises a mirror.

4. The catheter assembly of claim **2**, wherein the at least one light director comprises a diffuser.

5. The catheter assembly of claim **1**, wherein the at least one light source is a laser diode.

6. The catheter assembly of claim **1**, wherein the at least one transducer is configured and arranged for transforming applied electrical signals to acoustic signals, and also for transforming received acoustic signals to electrical signals.

7. The catheter assembly of claim **1**, wherein the at least one light source is disposed on the imaging core proximal to the at least one transformer.

8. The catheter assembly of claim **6**, wherein the at least one light source is disposed on the imaging core distal to the at least one transformer.

9. The catheter assembly of claim **1**, wherein the at least one light source is configured and arranged to generate pulses of light at one or more selected frequencies.

10. An intravascular ultrasound imaging system comprising:

a catheter having a distal end, a proximal end, and a longitudinal length, the catheter defining a lumen extending along the longitudinal length of the catheter from the proximal end to the distal end;

an imaging core configured and arranged for inserting into the lumen, the imaging core comprising

a rotatable driveshaft having a distal end, a proximal end, and a longitudinal length,

at least one light source disposed at the distal end of the rotatable driveshaft, the at least one light source configured and arranged for rotating with the driveshaft and also for transforming applied electrical signals to light for illuminating an object in proximity to the catheter, and

at least one transducer disposed at the distal end of the rotatable driveshaft, the at least one transducer configured and arranged for rotating with the driveshaft, wherein the at least one transducer is configured and arranged to receive acoustic signals generated by the object in response to illumination of the object by the light emitted from the light source; and

a drive unit coupled to the proximal end of the catheter, the drive unit comprising

at least one rotatable transformer comprising a rotor and a stator, wherein the rotor is coupled to the proximal end of the driveshaft, and

a motor for driving rotation of the driveshaft.

11. The system of claim **10**, further comprising a control module coupled to the imaging core, the control module comprising

an electric pulse generator configured and arranged for providing electric signals to the at least one transducer, the electric pulse generator electrically coupled to the at least one transducer via the one or more electrical conductors and at least one of the rotatable transformers;

a light source controller configured and arranged for providing electric signals to the at least one light source, the light source controller electrically coupled to the at least one light source via the one or more electrical conductors and at least one of the rotatable transformers; and

a processor configured and arranged for processing received electrical signals from the at least one transducer to form at least one image, the processor electrically coupled to the at least one transducer via the one or more electrical conductors and at least one of the rotatable transformers.

12. The system of claim **11**, wherein the at least one transducer and the at least one light source are each coupled to a different one of the at least one rotatable transformers.

13. The system of claim **11**, wherein the at least one transducer and the at least one light source are each coupled to the same one of the at least one rotatable transformers.

14. The system of claim **11**, wherein the control module further comprises at least one display electrically coupled to the processor, the at least one display configured and arranged for displaying the at least one image formed by the processor.

15. The system of claim **11**, wherein the at least one light source is configured and arranged to generate pulses of light.

16. The system of claim **11**, wherein the at least one light source is a laser diode.

17. A method for photo-acoustic imaging of a patient using an intravascular ultrasound imaging system, the method comprising:

inserting a catheter into patient vasculature, the catheter comprising at least one rotatable light source coupled to a control module and at least one rotatable transducer electrically coupled to a control module, wherein the at least one light source rotates with the at least one transducer and maintains a constant position and direction relative to the at least one transducer;

illuminating patient tissue with light emitted from the light source;

receiving at least one emitted acoustic signal from the illuminated patient tissue;

transmitting at least one acoustic signal to patient tissue from the at least one transducer; and

receiving at least one reflected acoustic signal from the patient tissue.

18. The method of claim **17**, wherein the received at least one emitted acoustic signal and the received at least one reflected acoustic signal are transmitted to a processor for processing.

19. The method of claim **18**, further comprising displaying an image based on the received and processed at least one emitted acoustic signal and the received and processed at least one reflected acoustic signal.

20. The method of claim **17**, wherein illuminating patient tissue with light emitted from the light source comprises passing the emitted light from the light source through a light director.

* * * * *

专利名称(译)	用于制造和使用具有光声成像能力的血管内超声系统的系统和方法		
公开(公告)号	US20100179434A1	公开(公告)日	2010-07-15
申请号	US12/351322	申请日	2009-01-09
[标]申请(专利权)人(译)	波士顿科学西美德公司		
申请(专利权)人(译)	BOSTON SCIENTIFIC SCIMED , INC.		
当前申请(专利权)人(译)	BOSTON SCIENTIFIC SCIMED , INC.		
[标]发明人	THORNTON PETER		
发明人	THORNTON, PETER		
IPC分类号	A61B8/00 A61B6/00		
CPC分类号	A61B5/0084 A61B5/0095 A61B8/445 A61B8/12 A61B5/02007		
外部链接	Espacenet USPTO		

摘要(译)

用于血管内超声系统的导管组件包括导管和设置在导管中的成像核心。成像芯包括可旋转的驱动轴，至少一个光源和至少一个换能器。至少一个光源设置在可旋转驱动轴的远端。至少一个光源被配置和布置成与驱动轴一起旋转，并且还用于将所施加的电信号转换成光，以照射导管附近的物体。至少一个换能器也设置在可旋转驱动轴的远端。至少一个换能器配置和布置成与驱动轴一起旋转。所述至少一个换能器被配置和布置用于响应于从所述至少一个光源发射的光对所述物体的照射而接收由所述物体产生的声信号。