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(54) OPTO-ACOUSTIC IMAGING DEVICE

OPTOAKUSTISCHES BILDGEBUNGSGERÄT

DISPOSITIF D'IMAGERIE OPTO-ACOUSTIQUE

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Description

FIELD OF INVENTION

[0001] This invention relates to the field of optical imaging and more specifically to the design of fiber-optic probes for optical coherence tomography (OCT) and other optical imaging technologies, such as ultrasound.

BACKGROUND

[0002] In recent years, the underlying cause of sudden heart attacks (acute myocardial infarctions or AMI) has been the subject of much attention. The older prevailing theory of gradual occlusion of the coronary artery has been superseded by a new theory based on extensive histopathologic evidence that AMI is the result of a rupture in the coronary artery wall, specifically a rupture of a "vulnerable plaque." A vulnerable plaque, also known as Thin-Capped Fibro-Artheroma (TCFA), is characterized by a thin fibrous cap covering a lipid pool located under the artery wall. Conventional x-ray based angiographic techniques can be used to detect narrowing of the artery. However, directly seeing the surface of the artery wall is essential to detect TCFA. Accordingly, a need therefore exists for a probe design that enables detecting and visualizing subsurface biological tissues and lipid pools.

[0003] US 2005/0101859 discloses a catheter provided with a first sensor of an imaging system for optical coherence tomography, and a second sensor of an intravascular ultrasound imaging system. US 6501551 discloses an endoscopic imaging system using optical coherence tomography and ultrasound.

SUMMARY OF THE INVENTION

[0004] The invention relates to an apparatus for imaging biological tissues and other materials using optical and acoustic imaging techniques. A combination of Optical Coherent Tomography (OCT), an interferometric imaging technology, and Intravascular Ultrasound (IVUS), is ideally suited to subsurface visualization of biological tissue, such as the artery wall, via small-diameter probes.

[0005] The disclosed methods are based on a combination of IVUS (Intravascular ultrasound) and OCT (Optical Coherence Tomography) techniques that advantageously overcomes the weakness of each individual technique. In particular, the combination of both IVUS and OCT allows for a robust probe with many advantages.

[0006] IVUS is a medium-resolution (~100 um), medium-penetration (~2 cm) imaging technique. In contrast, OCT is a high-resolution (5-20 um), shallow-penetration (~1 mm) technique. Neither technique individually can detect the state of the arterial wall. For example, the cap thickness in a potentially hazardous TCFA can range from ~25um to ~100 um. This range is within the measurement resolution of OCT, but beyond the measurement resolution of IVUS. Conversely, deep lipid pools beneath a thin cap greatly increases the risk of an AMI. OCT cannot be used to readily penetrate such deep lipid pools, but IVUS can readily be used to visualize such pools.

[0007] It is an object of the present invention to describe devices whereby IVUS and OCT can be performed simultaneously. It is a further object of the invention to describe OCT optical sensors and IVUS ultrasound sensors that can be combined into the same catheter delivery system.

[0008] One advantage of the invention is the aligned nature of the OCT and ultrasound sensors such that co-registration of the cross-sectional images obtained by the two sensors can be obtained with high precision. Previous descriptions of such combined catheters did not provide the co-registration levels needed. Co-registration is important because coronary morphology changes rapidly, often in less than a millimeter of longitudinal distance.

[0009] It is another object of the invention to describe a sensor structure wherein two probe beams are orientated at substantially the same angle with respect to the longitudinal axis of the catheter. Again, this is to facilitate proper co-registration of the images. Differing launch angles of the probe beams implies that the two images diverge each other with depth. Computational correction of this divergence is complex and can lead to errors in image presentation.

[0010] It is a further object of the invention to describe mechanisms and configurations of the probe that will simultaneously reduce unwanted parasitic acoustical and optical back-reflections while still providing an aligned and otherwise functional probe assembly.

[0011] Furthermore, an efficient rotary mechanisms for coupling both electrical and optical energy simultaneously into the catheter is described.

[0012] It is another object of the invention to describe a combined probe utilizing capacitive micro-machined ultrasonic transducers (CMUT) to create a dual element probe such that both the ultrasound and optical beams focus on substantially the same tissue spot simultaneously.

[0013] The invention provides a probe as set out in claim 1.

[0014] In one embodiment, a portion of the first and second beams scan the same region at different points in time. Alternatively, the first beam can be directed to scan a first band of a region that is substantially adjacent to a second band of the region, wherein the second beam scans the second band.

[0015] Embodiments also provide a system for medical examination. The system includes a first image processing device and a second image processing device. The system also includes a probe, in electrical communication with the first and second image processing devices. In turn, the probe includes a first sensor of an imaging system for optical coherence tomography having an optical fiber for directing and emitting light into an area adjacent to a catheter tip introduced into an examination area and for directing reflected light from the illuminated examination area to the first image processing device; and a second sensor of an intravascular ultrasound imaging system for transmitting and receiving acoustic signals to a second image processing device as electrical signals. Further, the system also includes a display device for outputting of images processed by the first and the second image processing devices.

[0016] Embodiments also provide an imaging probe adapted for insertion in a lumen. The probe includes a sheath having a core and an endface, an optical subsystem having an optical focus, the optical subsystem positioned within the core; and an array of ultrasound transducers having an acoustic focus, the array disposed on a portion of the endface.

[0017] Embodiments also provide a probe which includes a sheath, a first ultrasound subsystem, the first ultrasound subsystem positioned within the sheath and adapted to propagate energy along a first vector, and a second ultrasound subsystem, the second ultrasound subsystem positioned within the sheath and adapted to propagate energy along a second vector, wherein the first and second vectors are substantially parallel and opposite in direction.

[0018] Embodiments can be used in a method of imaging a tissue region. The method includes the steps of inserting a combination ultrasound and OCT imaging probe in a lumen, and performing ultrasound imaging, and then performing optical coherence tomography imaging. In one embodiment of this method a flush solution is applied during the optical coherence tomography imaging. In another related method of this aspect, the ultrasound imaging is performed simultaneously with the optical coherence tomography imaging.

[0019] Embodiments can also be used in a method of imaging a tissue region, the method comprising the steps of inserting a combination ultrasound and OCT imaging probe in a lumen, performing ultrasound imaging simultaneously with optical coherence tomography imaging whereby a flush solution is applied during the imaging.

[0020] Additional aspects include methods of fabricating probes that include sensor arrays, wherein each sensor includes an ultrasound transducer and a driver.

[0021] It should be understood that the terms "a," "an," and "the" mean "one or more," unless expressly specified otherwise.

[0022] The foregoing, and other features and advantages of the invention, as well as the invention itself, will be more fully understood from the description, drawings, and claims which follow.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The objects and features of the invention can be better understood with reference to the drawings described below, and the claims. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. The drawings associated with the disclosure are addressed on an individual basis within the disclosure as they are introduced.

Figure 1A depicts a cross-sectional view of a longitudinally aligned IVUS/OCT probe according to an illustrative embodiment of the invention;

Figure 1B depicts a probe utilizing a metal coated fiber with a shield tube according to an illustrative embodiment of the invention;

Figure 1C depicts a probe utilizing the coils of the torque cable assembly as conductors according to an illustrative embodiment of the invention;

Figure 1D depicts a cross-sectional view of the probe embodiment depicted in Figure 1C;

Figure 1E depicts a probe that includes two transducers adapted for operating at different frequencies according to an illustrative embodiment of the invention;

Figures 2 depicts a rotating coupling mechanism for delivering both RF and optical energy to a rotating probe assembly according to an illustrative example of the invention;

Figure 3 depicts a rotating coupling mechanism wherein the stationary coil is part of the probe interface unit according to an illustrative embodiment of the invention;

Figure 4 depicts a probe tip wherein CMUT technology is employed to achieve a dual focused beam according to an illustrative embodiment of the invention;

Figure 5A depicts a fused OCT-IVUS schematic according to an illustrative embodiment of the invention; and

Figure 5B depicts a fused OCT-IVUS image according to an illustrative embodiment of the invention.

[0024] The claimed invention will be more completely understood through the following detailed description, which should be read in conjunction with the attached drawings. In this description, like numbers refer to similar elements within various embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0025] The following description refers to the accompanying drawings that illustrate certain embodiments of the present invention. Other embodiments are possible and modifications may be made to the embodiments without departing from the scope of the invention. Therefore, the following detailed description is not meant to limit the present invention. Rather, the scope of the present invention is defined by the appended claims.

[0026] It should be understood that the order of the steps of the methods of the invention is immaterial so long as the invention remains operable. Moreover, two or more steps may be conducted simultaneously or in a different order than recited herein unless otherwise specified.

[0027] Figure 1A illustrates a portion of an imaging probe 10a, using a conventional IVUS ultrasonic transducer 12, an optical transducer 14 which includes an angled-tip optical lens assembly 16 attached to a single mode fiber 18, a standard miniature RF cable 20 delivering power to the IVUS ultrasonic transducer, and a torque cable 22 providing a stable revolution rate to the assembly.

[0028] Torque cables are generally preferred in this dual probe catheter as the optical fiber is known to have a very low torsional (rotational) stiffness. For example, a 1 cm length of standard telecomm fiber 125 μm in diameter with approximately 1 millionth of a N-m of applied torque will twist one degree. Therefore, it is unrealistic to expect the fiber to be sufficiently torsionally rigid to drive the complete assembly.

[0029] In Figure 1A, both the optical transducer 14 and the IVUS ultrasonic transducer 12 are angled to minimize unwanted parasitic reflections from reaching the respective transducers, and to create an aligned cross-sectional "cut" through the tissue. As shown, the acoustic beam (ab) emanating from the transducer is parallel to optical beam (ob) emanating from the fiber. The direction of these two parallel beams is rotated by an angle α relative to the longitudinal axis of the probe. As shown in the figure, a small amount of longitudinal displacement is acceptable.

[0030] As a first order approximation, this allowable displacement is the approximate maximum beam width of the combined probe 10a. In most cases, this will be the width of the ultrasound beam, which typically has a width of ~100 to 300 um (the OCT beam width is typically 25 um). Keeping the longitudinal displacement below this longitudinal displacement limit ensures the beams remain overlapped. Furthermore, having the two beams at 180 degrees opposite to each other ensures easier real-time or post-processing alignment of the two images for an overlay display.

[0031] Figure 1B depicts a probe 10b for imaging whereby the overall diameter is reduced. Here, a metal coated fiber 24 is shown inside an insulated tube 26. These two cylindrical surfaces (tube and coating), the dielectric constant of the insulation, and the insulation thickness can be configured to form a simple coaxial transmission line for the RF signals. Such RF signals may vary from 10 to 60 MHz depending on the IVUS ultrasonic transducer design.

[0032] Figure 1C illustrates another probe embodiment 10c with a different conduction mechanism. Specifically, in the probe 10c shown, the inner 28 and outer 30 coils of a torque cable 22 form a coaxial transmission line 32. An insulated spacer 34 is inserted between the inner and outer coils to prevent a short circuit condition. The embodiment shown in Figure 1C allows RF power to be transmitted using an integral torque wire. In one example, the transducer is coated with epoxy. In one example, both the ultrasound transducer and the optical fiber rotate together, being driven by the same torque wire. The distal tip epoxy encases the optical fiber, the ultrasound transducer and its associated supply wires. Hence, the epoxy is selected for suitable optical and acoustic properties, as well as the required electrical insulation. Various epoxies and silicon compounds can be purchased and/or specifically tailored that meet these requirements.

[0033] Figure 1D illustrates a cross-section of the embodiment of Figure 1C. The two wires connected to the transducer shown in Figures 1C and 1D are rigid and rotate with the transducer.

[0034] Figure 1E illustrates another optical probe example wherein two IVUS ultrasonic transducers T_1, T_2 operating at different frequencies are integrated in the device. The lower frequency transducer T_1 allows for ultrasound with s deeper scanning range, but lower resolution. Conversely; the higher frequency T_2 transducer allows for ultrasound with increased resolution but less depth penetration. In one example, one transducer operates at about 5 MHz and the other transducer operates at about 60 MHz. By using transducers with differing frequency ranges, an optical probe gains the advantages of both transducers, and mitigates disadvantages of each transducer, respectively. This dual transducer probe achieves the same overall goals as the combined OCT/IVUS catheter in the case where very high resolution (~10 um, OCT) is not needed in favor of very high penetration (~3-5 cm) offered by a lower frequency ultrasound transducer.

[0035] Figure 2 depicts a probe example 40 that incorporates a mechanism for transmitting both RF energy and optical energy to the rotating assembly. Specifically, a transformer scheme is used wherein a first coil 42 is attached to the rotating assembly 44, and a second coil 46 is integrated with the connector 48 of the optical probe. This configuration has the advantage that both coils move with the assembly during a 'pull-back' (longitudinal) scan operation. Such pullbacks are used in both OCT and IVUS scans. When coupled with a rotation, a spiral scan pattern is created inside the arterial lumen. However, this approach results in an increased cost for a one-time-use catheter.

[0036] Figure 3 illustrates an alternative coupling scheme wherein the fixed coil 42 is part of the drive unit 50 (motorized assembly providing rotational and longitudinal motions). In this embodiment, the fixed coil is permanent, and must be long enough to efficiently couple the RF energy into the rotating catheter coil over the entire pullback length. Although incorporating the fixed coil to the drive unit imposes additional requirements to the drive electronics, the decrease in catheter usage provides an overall cost savings.

[0037] Currently, conventional slip-ring technology is widely used in the field of optical imaging. Alternatively to Figures 2 and 3, slip-ring technology can be used in IVUS probes described herein. However, for a probe with a centered optics configuration, the slip-ring is more difficult to manufacture than in the IVUS-only case.

[0038] Figure 4 illustrates an embodiment that includes capacitive micro-machined ultrasonic transducers (CMUT) 52 integrated in a coronary imaging probe 54. The advantage of the CMUT is the small size of the transducer, which is fabricated via conventional electronic CMOS processes. The small size and photolithographic fabrication allows customized arrays of transducers to be built with the drive electronics on the same substrate. In this example, an array is formed in an annular region around the optical transducer. As a result, a co-focused, aligned and combined beam can be formed, which eliminates the need for software registration and removes a potential source of error. However, this probe tip may be larger than the embodiment shown in Figure 1.

[0039] Figure 5A illustrates a fused OCT-IVUS image 56, wherein the demarcation line 58 is chosen near the OCT penetration limit. As shown, by registering the relative images of the ultrasound 60 and the OCT scans 62, it is possible for a clinician to view a composite image that shows additional physiological data. This approach can be used to image subsurface lipid pools.

[0040] Figure 5B illustrates a fused OCT/IVUS image wherein the OCT portion appears in the image center and the IVUS portion appears in the periphery. The outer boundary indicates approximately the boundary where the two regions intersect.

[0041] Not shown in the embodiments depicted in the figures is a guide catheter. Typically, the guide catheter is a larger bore catheter used to introduce the smaller imaging catheter into the main arterial trunk. From the guide catheter, a flush solution can be expelled to create a clear, blood-free imaging region when OCT imaging is performed. Alternative embodiments may include a flush lumen within the imaging catheter whereby the flush solution is ejected at the imaging tip rather than from the guide catheter.

[0042] The aspects and embodiments of the invention can incorporate various components of varying dimension and materials as is known to one of ordinary skill. Various specific dimensions and materials are described herein, however, these exemplary materials are not meant to be limiting, but only to evidence additional more specific embodiments. For all of the measurements discussed below, the dimension given also includes a range of greater than about 10-20% of the dimension given and less than about 10%-20% of the dimension given. In addition, for all of the measurements discussed below, the dimension given also includes a range of greater than about 20-50% of the dimension given and less than about 20%-50% of the dimension given. Further, in addition, for all of the measurements discussed below, the dimension given also includes a range of greater than about 50-100% of the dimension given and less than about 50%-100% of the dimension given.

[0043] In one probe example, the viewing window used is a transparent epoxy-based window. Further, in another example, the transducers used have a first dimension of about 0.1 mm and a second dimension of about 0.5 mm. The forward viewing angle is about 10 degrees in one example of the probe. The end-cap used in one probe example includes a metal. The probe can include a hollow core that is substantially filled with an epoxy material in some examples. In one example, the width of the shield RF cable is about 0.18 mm.

[0044] It should be appreciated that various aspects of the claimed invention are directed to subsets of the techniques disclosed herein. Further, the terms and expressions employed herein are used as terms of description and not of limitation, but it is recognized that various modifications are possible within the scope of the invention claimed.

Claims

1. A probe comprising:

   a sheath;
   a flexible, bi-directionally rotatable, optical subsystem positioned within the sheath, the optical subsystem comprises a transmission fiber (18), the optical subsystem capable of transmitting and collecting light of a predetermined range of wavelengths along a first beam having a predetermined beam size;
   an ultrasound subsystem, the ultrasound subsystem positioned within the sheath and
   adapted to propagate energy of a predetermined range of frequencies along a second beam having a second predetermined beam size;
   characterized by
   a transformer positioned at a proximal end of the probe, the transformer comprising a non-rotating first coil (42) and a rotatable second coil (46), the second coil slidably disposed within the first coil and wherein the transmission fiber is disposed within the second coil.

2. The probe of claim 1, wherein the first and second beams are substantially parallel and opposite in direction.

3. The probe of claim 1, wherein the probe further comprises a coupling element, wherein the coupling element is adapted to rotate the transmission fiber and transmit a signal received from the ultrasound subsystem.

4. The probe of claim 1, wherein the longitudinal displacement between the centers of the optical subsystem and the ultrasound subsystem is less than the beam width of the ultrasound subsystem.

5. The probe of claim 1, wherein the longitudinal displacement between the centers of the optical subsystem and the ultrasound subsystem is less than the beam width of the optical subsystem.

6. The probe of claim 1, wherein a relative orientation of the ultrasound subsystem and optical subsystems is chosen to reduce parasitic acoustic and optical reflections arising from the sheath.

7. The probe of claim 1, wherein a rotatable electrical coil and a non-rotating electrical coil are positioned at a proximal end of the probe.

8. The probe of claim 3, wherein the coupling element is selected from the group consisting of a metal coating (24) applied to the transmission fiber, a portion of a torque wire (22), a metal tube, and a metal coil.

9. The probe of claim 1, wherein the first and second beams are substantially parallel, and wherein the probe further comprises an insulated metallic tube having an inner coil and an outer coil, the insulated metallic tube encloses the metal-coated coupling element longitudinally whereby electrical energy is delivered to the ultrasound subsystem via the coupling element.

10. A system for medical examination, the system comprises:

   a first image processing device;
   a second image processing device;
   a probe (10) as set out in any preceding claim, the probe being in electrical communication with the first and second image processing devices, the optical subsystem of the probe comprising a first sensor of an imaging system for optical coherence tomography having an optical fiber for directing and emitting light into an area adjacent to a catheter tip introduced into an examination area and for directing reflected light from the illuminated examination area to the first image processing device,
   the ultrasound subsystem of the probe comprising a second sensor of an intravascular ultrasound imaging system for transmitting and receiving acoustic signals to a second image processing device as electrical signals; and
   a display device for outputting of images processed by the first and the second image processing devices.

11. The system according to claim 10 wherein the display device is adapted to display an image generated by the optical image processing device in a center area on a screen of the display device, and jointly display an image generated by the acoustic image processing device in an outer area on the screen of the display device.

12. The probe of any of claims 1 to 11 implemented as an imaging probe adapted for insertion in a lumen, wherein:

   the sheath has a core and an endface;
   said optical subsystem has an optical focus, the optical subsystem positioned within the core; and
   said ultrasound system comprises an array of ultrasound transducers having an acoustic focus, the array disposed on a portion of the endface.

13. The probe of claim 12, wherein the array of ultrasound transducers is positioned concentrically around the optical subsystem.

14. The probe of claim 12, wherein at least one transducers is a capacitive micro-machined ultrasonic transducer.

15. The apparatus of any of claims 1 to 11 wherein the probe comprises:

   said ultrasound subsystem, the said ultrasound subsystem positioned within the sheath and adapted to propagate energy along a first vector; and
   a second ultrasound subsystem, the second ultrasound subsystem positioned within the sheath and adapted to propagate energy along a second vector, wherein the first and second vectors are substantially parallel and opposite in direction.

Patentansprüche

1. Sonde, umfassend:

   eine Hülle,
   ein flexibles, bidirektional drehbares, optisches Subsystem, das innerhalb der Hülle angeordnet ist, wobei das optische Subsystem eine Über-

tragungsfaser (18) umfasst, wobei das optische Subsystem dazu in der Lage ist, Licht in einem vorbestimmten Wellenlängen-Bereich entlang einem ersten Strahl mit einer vorbestimmten Strahlgröße zu übertragen und zu sammeln,
ein Ultraschall-Subsystem, wobei das Ultraschall-Subsystem innerhalb der Hülle positioniert und dazu angepasst ist, Energie in einem vorbestimmten Frequenzbereich entlang einem zweiten Strahl mit einer zweiten vorbestimmten Strahlgröße auszubreiten,
gekennzeichnet durch
einen Wandler, der an einem proximalen Ende der Sonde positioniert ist, wobei der Wandler eine nicht-drehende erste Spule (42) und eine drehbare zweite Spule (46) umfasst, wobei die zweite Spule verschiebbar innerhalb der ersten Spule angeordnet ist, und wobei die Übertragungsfaser innerhalb der zweiten Spule angeordnet ist.

2. Sonde nach Anspruch 1, wobei der erste und der zweite Strahl im Wesentlichen parallel und einander entgegengesetzt gerichtet sind.

3. Sonde nach Anspruch 1, wobei die Sonde weiter ein Kopplungselement umfasst, wobei das Kopplungselement dazu angepasst ist, die Übertragungsfaser zu drehen und ein Signal zu übertragen, das von dem Ultraschall-Subsystem empfangen wird.

4. Sonde nach Anspruch 1, wobei der longitudinale Abstand zwischen den Mittelpunkten des optischen Subsystems und des Ultraschall-Subsystems kleiner ist als die Strahlbreite von dem Ultraschall-Subsystem.

5. Sonde nach Anspruch 1, wobei der longitudinale Abstand zwischen den Mittelpunkten von dem optischen Subsystem und dem Ultraschall-Subsystem kleiner ist als die Strahlbreite von dem optischen Subsystem.

6. Sonde nach Anspruch 1, wobei eine relative Orientierung von dem Ultraschall-Subsystem und den optischen Subsystemen so ausgewählt ist, dass parasitäre akustische und optische Reflexionen reduziert werden, die von der Hülle ausgehen.

7. Sonde nach Anspruch 1, wobei eine drehbare elektrische Spule und eine nicht-drehende elektrische Spule an einem proximalen Ende der Sonde positioniert sind.

8. Sonde nach Anspruch 3, wobei das Kopplungselement ausgewählt ist aus der Gruppe bestehend aus einer auf die Übertragungsfaser aufgebrachten Metallbeschichtung (24), einem Abschnitt von einem Drehmoment-Draht (22), einem Metallrohr und einer Metallspule.

9. Sonde nach Anspruch 1, wobei der erste und der zweite Strahl im Wesentlichen parallel sind, und wobei die Sonde weiterhin ein isoliertes Metallrohr umfasst, mit einer inneren Spule und einer äußeren Spule, wobei das isolierte Metallrohr das metallbeschichtete Kopplungselement longitudinal umschließt, wodurch dem Ultraschall-Subsystem elektrische Energie über das Kopplungselement zugeführt wird.

10. System zur medizinischen Untersuchung, wobei das System umfasst:

eine erste Bildverarbeitungseinrichtung,
eine zweite Bildverarbeitungseinrichtung,
eine Sonde (10) nach einem vorhergehenden Anspruch, wobei die Sonde sich in elektrischer Kommunikation mit der ersten und der zweiten Bildverarbeitungseinrichtung befindet,
wobei das optische Subsystem der Sonde einen ersten Sensor von einem Bildgebungssystem zur optischen Kohärenztomographie umfasst, mit einer optischen Faser zum Lenken und Emittieren von Licht in einen Bereich benachbart zu einer in einen Untersuchungsbereich eingeführten Katheter-Spitze, und um von dem beleuchteten Untersuchungsbereich reflektiertes Licht zu der ersten Bildverarbeitungseinrichtung zu lenken,
wobei das Ultraschall-Subsystem der Sonde einen zweiten Sensor von einem intravaskulären Ultraschall-Bildgebungssystem zum Übertragen und Empfangen akustischer Signale zu einer zweiten Bildverarbeitungseinrichtung als elektrische Signale umfasst, und
eine Anzeigeeinrichtung zum Ausgeben von Bildern, welche durch die erste und die zweite Bildverarbeitungseinrichtung verarbeitet wurden.

11. System nach Anspruch 10, wobei die Anzeigeeinrichtung dazu angepasst ist, ein durch die optische Bildverarbeitungseinrichtung erzeugtes Bild in einem mittleren Bereich auf einem Bildschirm der Anzeigeeinrichtung anzuzeigen, und gemeinsam damit ein Bild in einem äußeren Bereich auf dem Bildschirm der Anzeigeeinrichtung anzuzeigen, welches durch die akustische Bildverarbeitungseinrichtung erzeugt wurde.

12. Sonde nach einem der Ansprüche 1 bis 11, implementiert als eine Bildgebungssonde, die dazu angepasst ist, in ein Lumen eingesetzt zu werden, wobei:

die Hülle einen Kern und eine Endfläche umfasst, das optische Subsystem einen optischen Brennpunkt hat, wobei das optische Subsystem innerhalb von dem Kern positioniert ist, und

das Ultraschall-System eine Anordnung von Ultraschall-Wandlern umfasst, die einen akustischen Brennpunkt haben, wobei die Anordnung an einem Abschnitt der Endfläche positioniert ist.

13. Verfahren nach Anspruch 12, wobei die Anordnung von UltraschallWandlern konzentrisch um das optische Subsystem herum positioniert ist.

14. Sonde nach Anspruch 12, wobei wenigstens ein Wandler ein kapazitiver, mikrobearbeiteter Ultraschall-Wandler ist.

15. Einrichtung nach einem der Ansprüche 1 bis 11, wobei die Sonde umfasst:

das Ultraschall-Subsystem, wobei das Ultraschall-Subsystem innerhalb der Hülle positioniert und dazu angepasst ist, Energie entlang von einem ersten Vektor auszubreiten, und

ein zweites Ultraschall-Subsystem, wobei das zweite Ultraschall-Subsystem innerhalb der Hülle positioniert und dazu angepasst ist, Energie entlang von einem zweiten Vektor auszubreiten, wobei der erste und

der zweite Vektor im Wesentlichen parallel und einander entgegengesetzt gerichtet sind.

Revendications

1. Sonde comprenant :

une gaine ;

un sous-système optique flexible, apte à tourner de manière bidirectionnelle, positionné dans la gaine, le sous-système optique comprend une fibre de transmission (18), le sous-système optique étant apte à transmettre et à recueillir la lumière d'une plage de longueurs d'onde prédéterminée le long d'un premier faisceau d'une taille de faisceau prédéterminée ;

un sous-système ultrasonore, le sous-système ultrasonore étant positionné dans la gaine et étant apte à propager l'énergie d'une plage de fréquences prédéterminée le long d'un deuxième faisceau ayant une deuxième taille de faisceau prédéterminée ;

caractérisé par

un transformateur positionné à une extrémité proximale de la sonde, le transformateur comprenant une première bobine non tournante (42) et une deuxième bobine tournante (46), la deuxième bobine étant disposée d'une manière coulissante dans la première bobine, et où la fibre de transmission est disposée dans la deuxième bobine.

2. Sonde selon la revendication 1, dans laquelle les premier et deuxième faisceaux sont sensiblement parallèles et opposés en direction.

3. Sonde selon la revendication 1, où la sonde comprend en outre un élément de couplage, où l'élément de couplage est apte à faire tourner la fibre de transmission et transmet un signal reçu du sous-système ultrasonore.

4. Sonde selon la revendication 1, dans laquelle le déplacement longitudinal entre les centres du sous-système optique et du sous-système ultrasonore est plus petit que la largueur de faisceau du sous-système ultrasonore.

5. Sonde selon la revendication 1, dans laquelle le déplacement longitudinal entre les centres du sous-système optique et du sous-système ultrasonore est plus petit que la largueur de faisceau du sous-système optique.

6. Sonde selon la revendication 1, dans laquelle une orientation relative du sous-système ultrasonore et des sous-systèmes optiques est sélectionnée pour réduire les réflexions acoustiques et optiques parasites engendrées par la gaine.

7. Sonde selon la revendication 1, dans laquelle une bobine électrique tournante et une bobine électrique non tournante sont positionnées à une extrémité proximale de la sonde.

8. Sonde selon la revendication 3, dans laquelle l'élément de couplage est sélectionné dans le groupe consistant en un revêtement métallique (24) appliqué à la fibre de transmission, une portion d'un fil de couple (22), un tube métallique et une bobine métallique.

9. Sonde selon la revendication 1, dans laquelle les première et deuxième faisceaux sont sensiblement parallèles, et où la sonde comprend en outre un tube métallique isolé ayant une bobine intérieure et une bobine extérieure, le tube métallique isolé renferme l'élément de couplage revêtu de métal longitudinalement moyennant quoi de l'énergie électrique est délivrée au sous-système ultrasonore via l'élément de couplage.

10. Système pour un examen médical, le système comprend :

un premier dispositif de traitement d'image ;

un deuxième dispositif de traitement d'image ;
une sonde (10) telle qu'exposée dans l'une quelconque des revendications précédentes, la sonde étant en counication électrique avec les premier et deuxième dispositifs de traitement d'image,
le sous-système optique de la sonde comprend un premier capteur d'un système d'imagerie pour une tomographie de cohérence optique ayant une fibre optique pour diriger et émettre de la lumière dans une zone adjacente à une pointe de cathéter introduite dans une zone d'examen et pour diriger la lumière réfléchie de la zone d'examen éclairée au premier dispositif de traitement d'image,
le sous-système ultrasonore de la sonde comprenant un deuxième capteur d'un système d'imagerie ultrasonore intravasculaire pour transmettre et recevoir des signaux acoustiques à un deuxième dispositif de traitement d'image coe signaux s ; et
un dispositif d'affichage pour émettre les images traitées par les premier et deuxième dispositifs de traitement d'image.

11. Système selon la revendication 10, dans lequel le dispositif d'affichage est apte à afficher une image produite par le dispositif de traitement d'image optique dans une zone centrale sur un écran du dispositif d'affichage, et pour afficher conjointement une image produite par le dispositif de traitement d'image acoustique dans une zone extérieure sur l'écran du dispositif d'affichage.

12. Sonde selon l'une quelconque des revendications 1 à 11 mise en oeuvre coe une sonde d'imagerie apte à être insérée dans une lumière, où :

la gaine possède une âme et une face d'extrémité ;
ledit sous-système optique possède un foyer optique, le sous-système optique étant positionné dans l'âme ; et
ledit système ultrasonore comprend un groupement de transducteurs ultrasonores ayant un foyer acoustique, le groupement étant disposé sur une portion de la face d'extrémité.

13. Sonde selon la revendication 12, dans laquelle le groupement de transducteurs ultrasonores est positionné concentriquement autour du sous-système optique.

14. Sonde selon la revendication 12, dans laquelle au moins un des transducteurs est un transducteur ultrasonore capacitif micro-usiné.

15. Appareil selon l'une quelconque des revendications 1 à 11, où la sonde comprend :

ledit sous-système ultrasonore, ledit sous-système ultrasonore étant positionné dans la gaine et étant apte à propager de l'énergie le long d'un premier vecteur ; et
un deuxième sous-système ultrasonore, le deuxième sous-système ultrasonore étant positionné dans la gaine et étant apte à propager l'énergie le long d'un deuxième vecteur, où les premier et deuxième vecteurs sont sensiblement parallèles et opposés en direction.

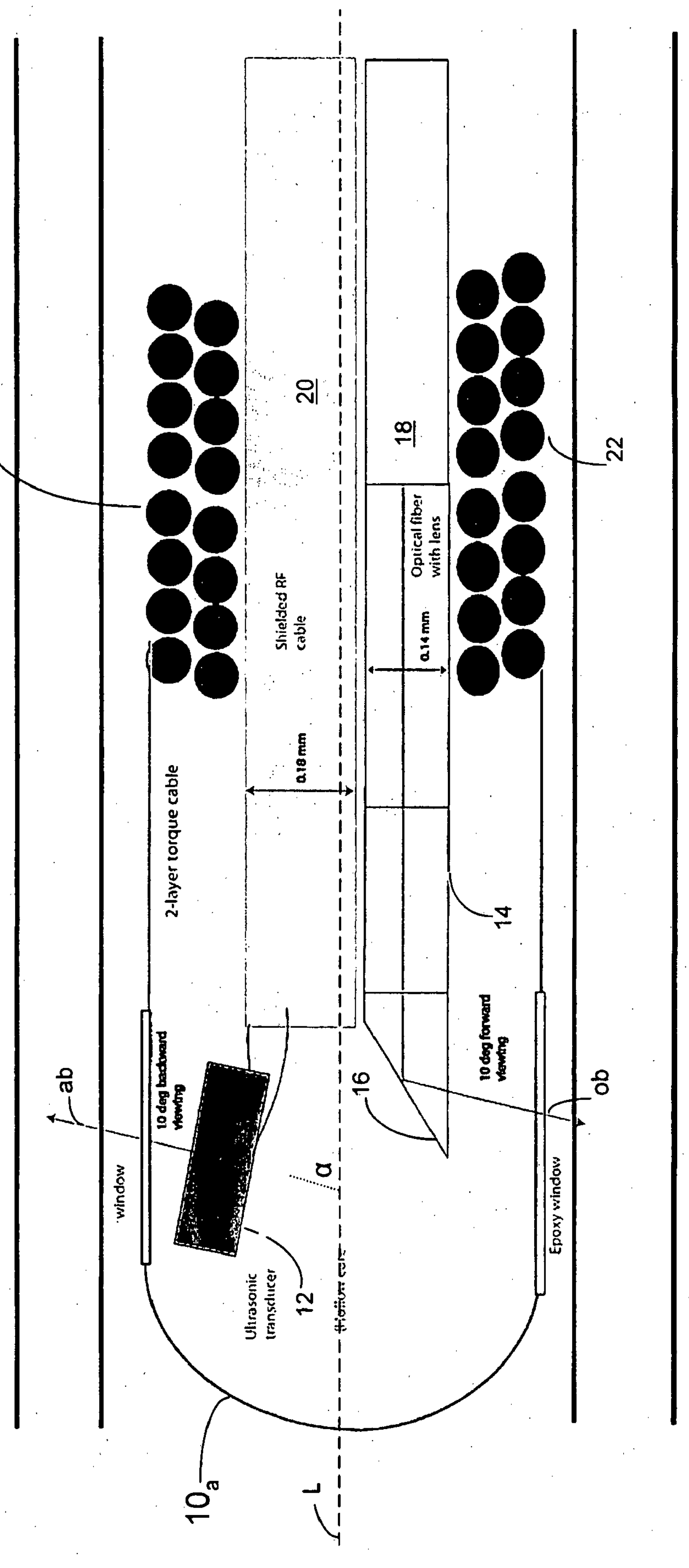
22
20
18
22
Shielded RF cable
Optical fiber with lens
0.14 mm
0.18 mm
2-layer torque cable
14
10 deg backward viewing
10 deg forward viewing
ab
16
ob
window
α
Epoxy window
Ultrasonic transducer
12
10_a
L

Figure 1A

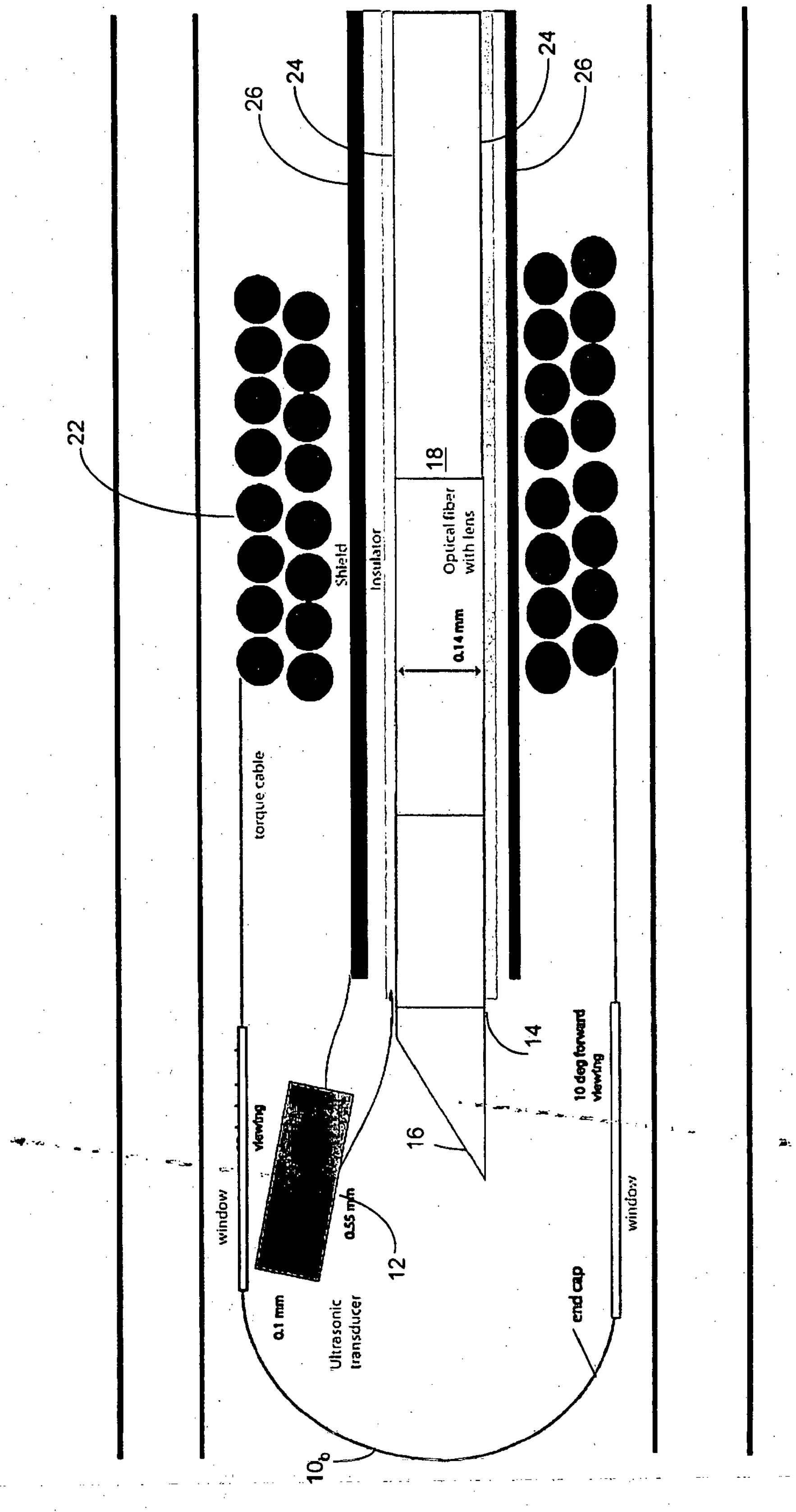
22
26
24
Shield
Insulator
Optical fiber with lens
18
0.14 mm
torque cable
14
10 deg forward viewing
16
window
viewing
0.55 mm
12
0.1 mm
Ultrasonic transducer
end cap
10b

Figure 1B

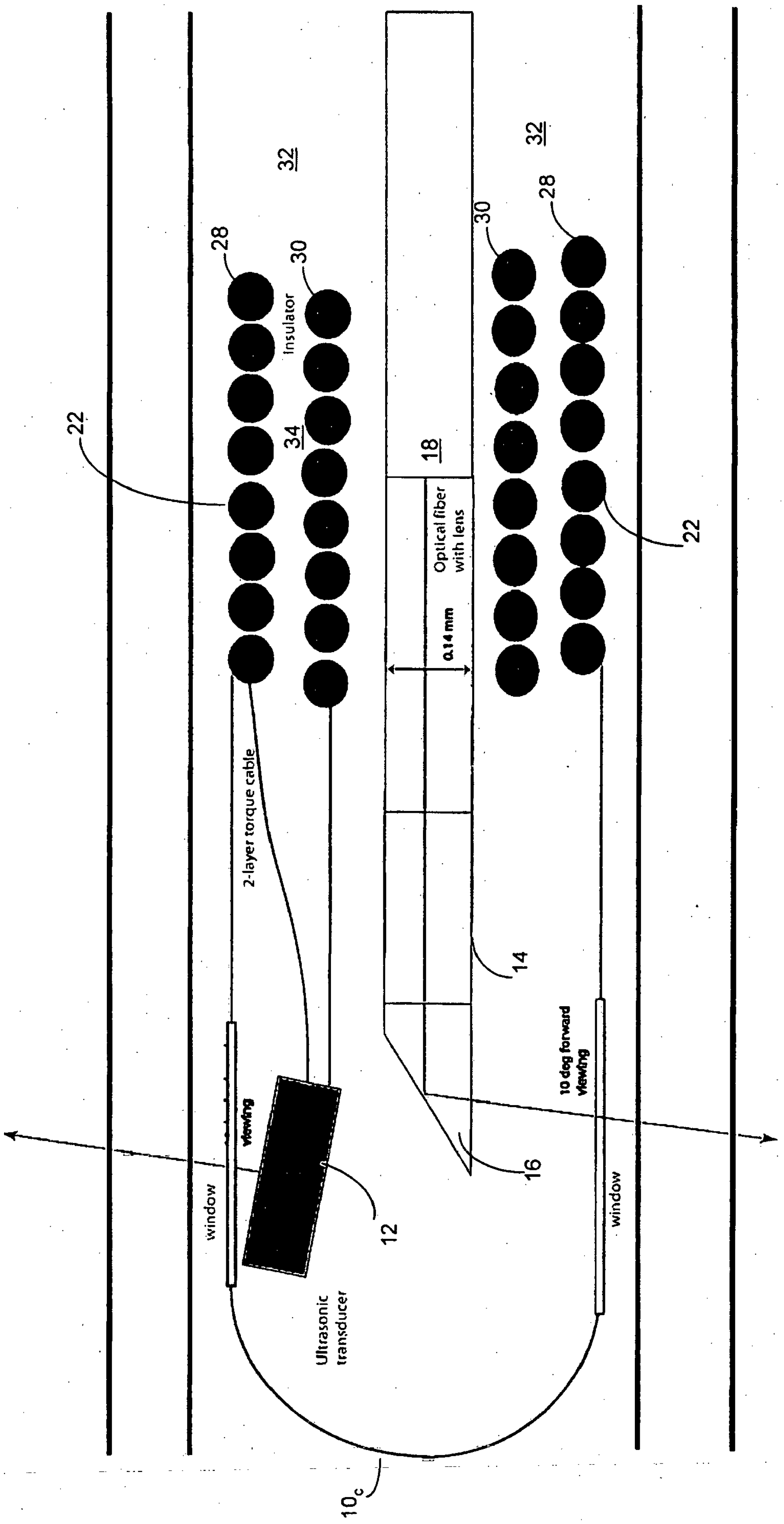
32
32
28
30
28
30
Insulator
22
34
18
Optical fiber with lens
22
0.14 mm
2-layer torque cable
14
10 deg forward viewing
viewing
16
window
12
window
Ultrasonic transducer
10c

Figure 1C

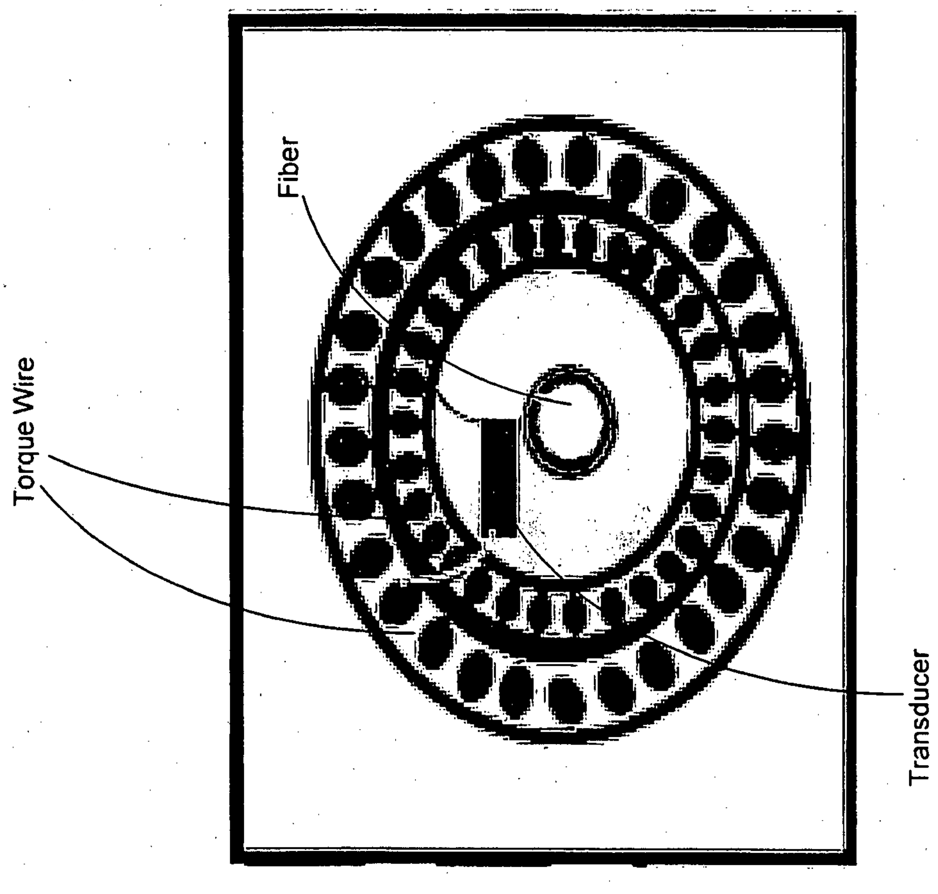

Figure 1D

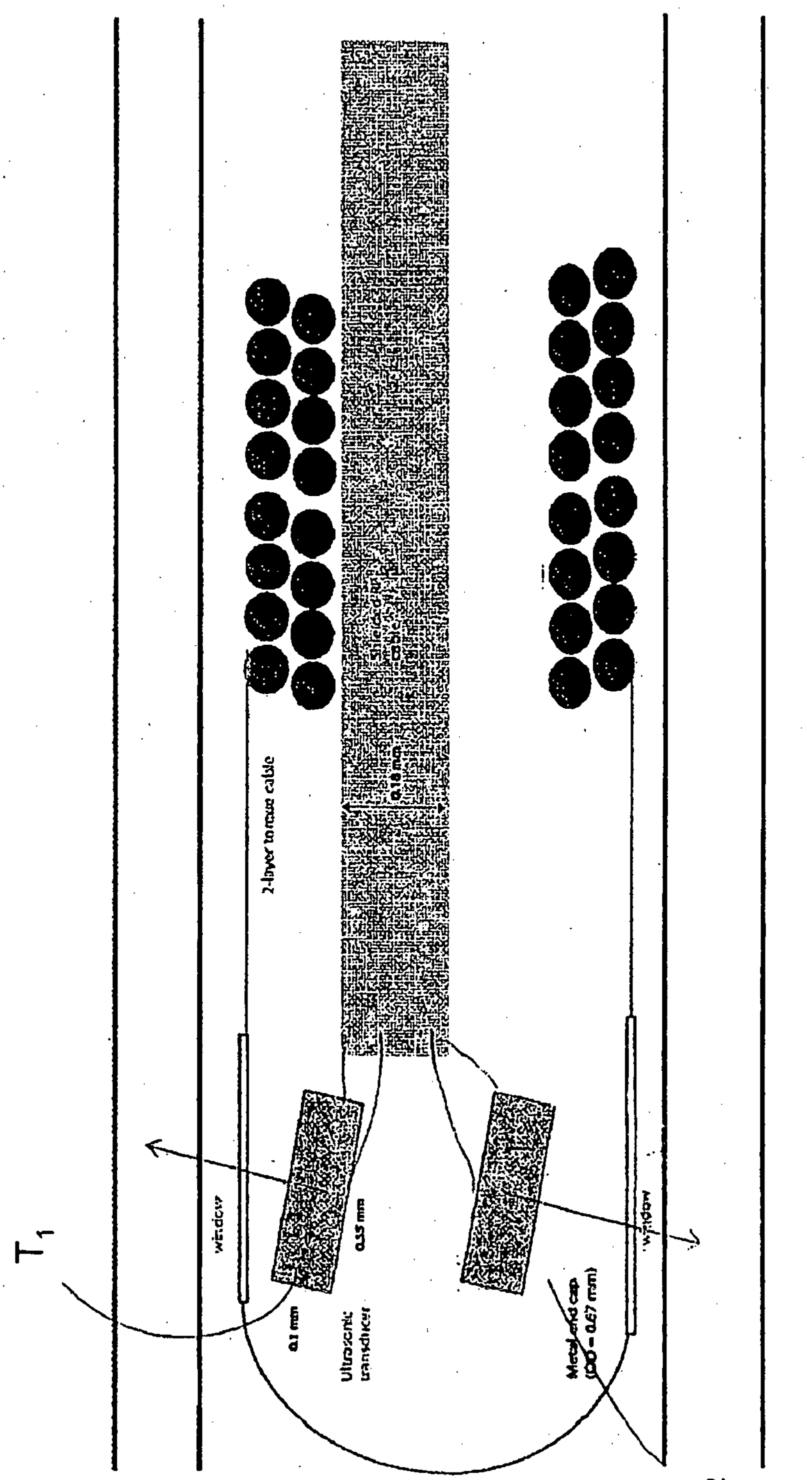
T1
T2
window
window
2-layer torque cable
Ultrasonic transducer

Figure 1E

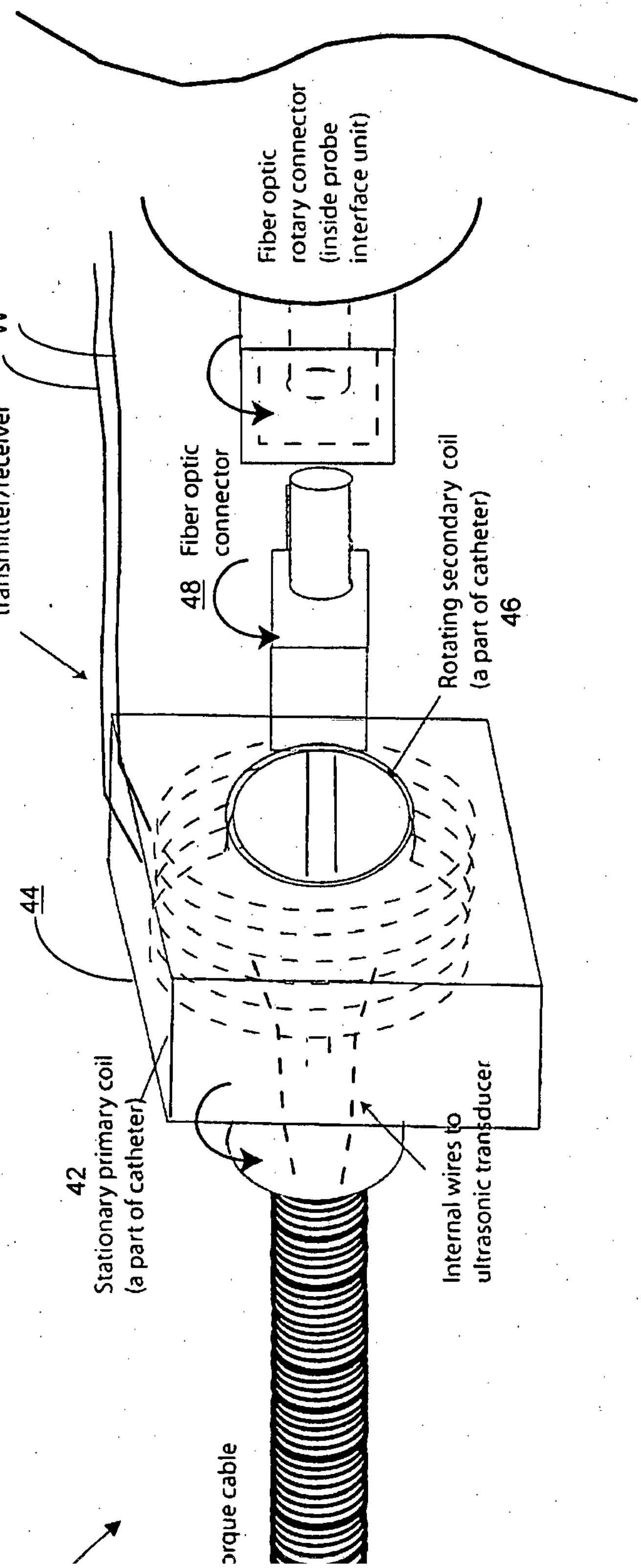
Fiber optic
rotary connector
(inside probe
interface unit)
W
Wires to ultrasonic
transmitter/receiver
48 Fiber optic
connector
Rotating secondary coil
(a part of catheter)
46
44
42
Stationary primary coil
(a part of catheter)
Internal wires to
ultrasonic transducer
orque cable

Figure 2

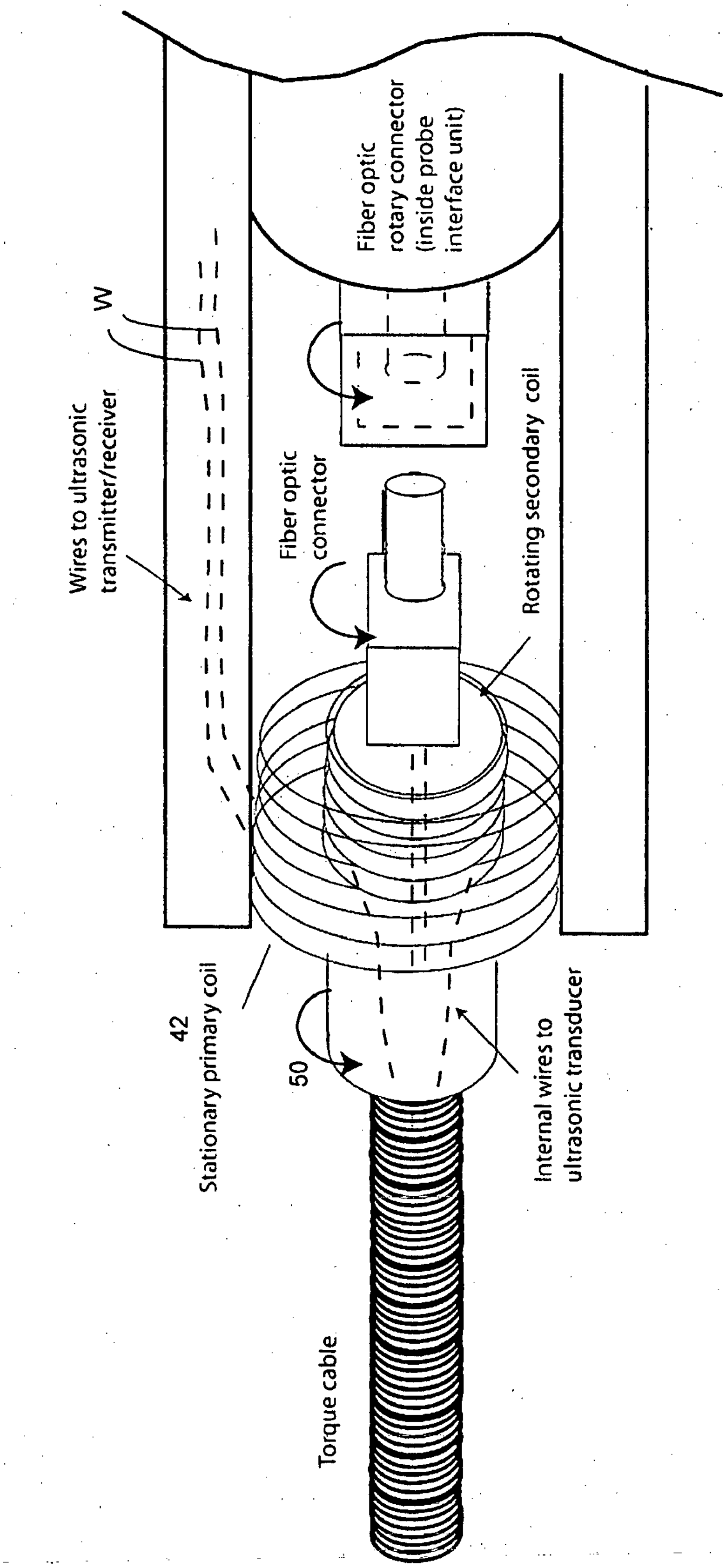
Wires to ultrasonic transmitter/receiver
W
Fiber optic rotary connector (inside probe interface unit)
Fiber optic connector
Rotating secondary coil
42
Stationary primary coil
50
Internal wires to ultrasonic transducer
Torque cable

Figure 3

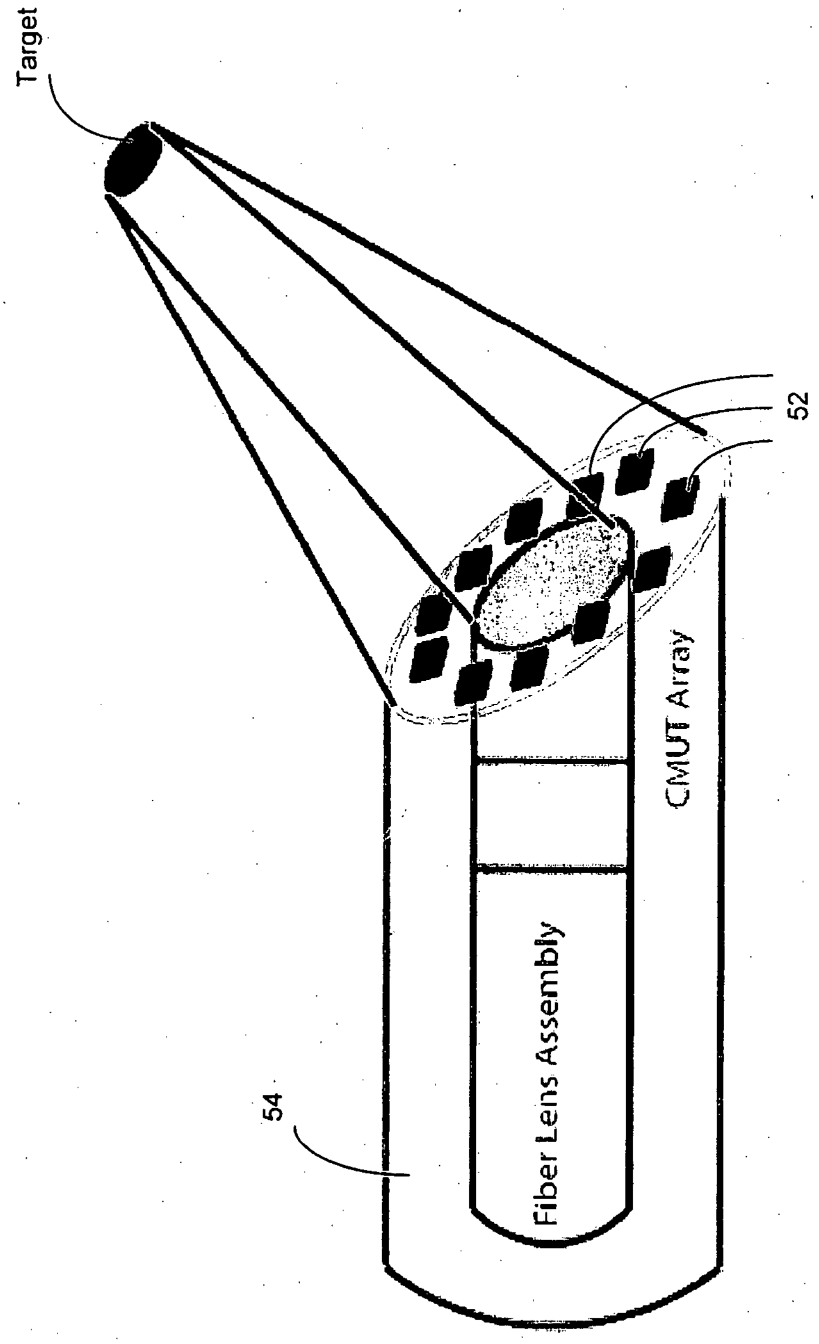

Figure 4

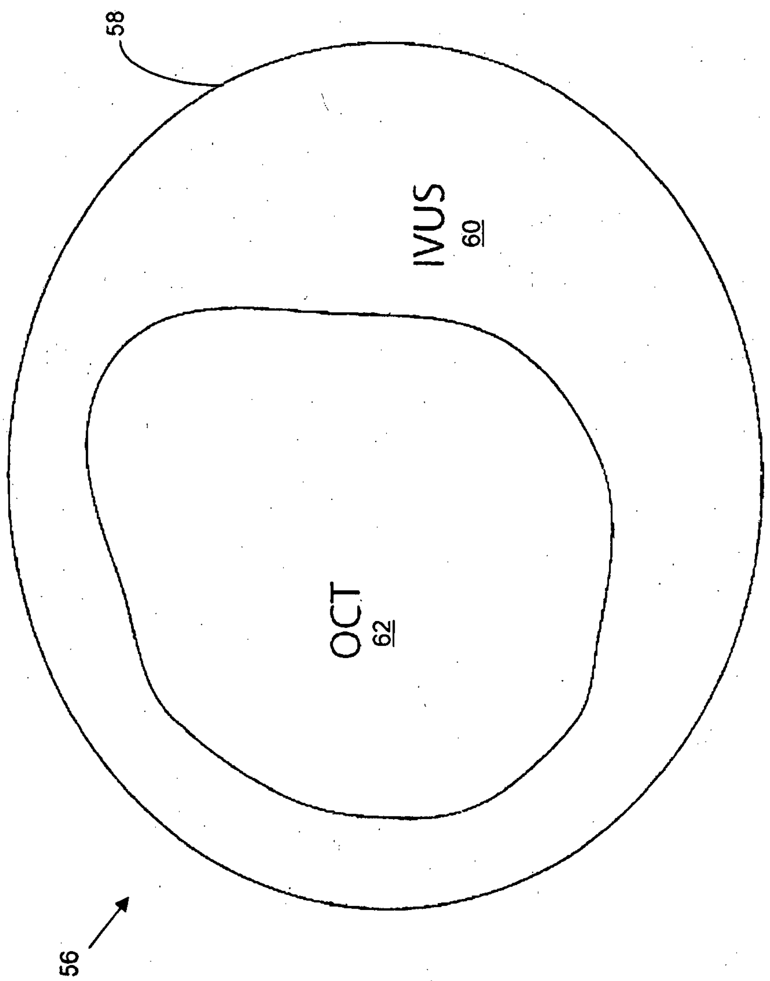

Figure 5A

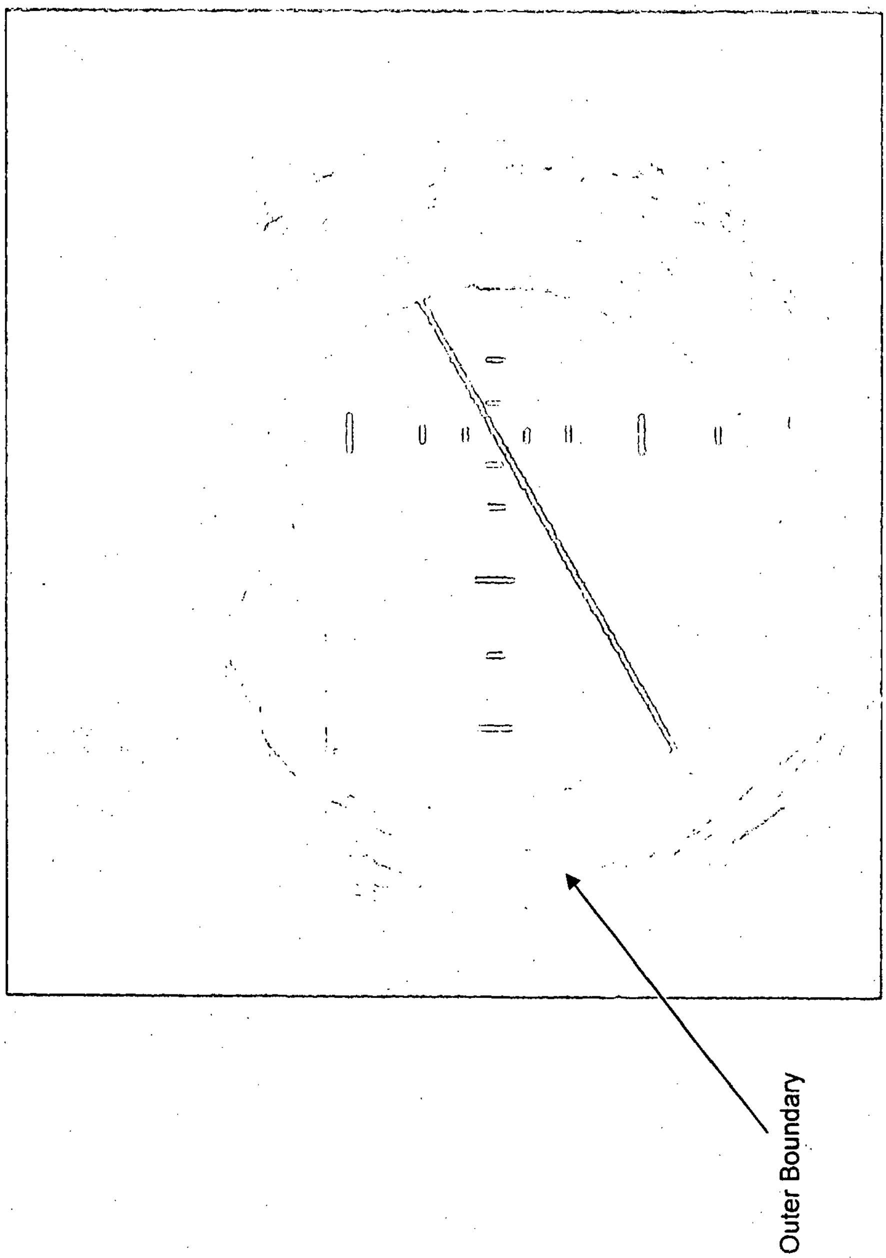

Figure 5B

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 20050101859 A **[0003]**
- US 6501551 B **[0003]**

专利名称(译)	光声成像装置		
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摘要(译)

一方面，本发明涉及探针。探针包括护套，位于护套内的柔性双向可旋转光学子系统，光学子系统包括传输光纤，光学子系统能够沿具有第一光束的第一光束传输和收集预定波长范围的光。预定的光束尺寸。该探头还包括超声子系统，超声子系统位于护套内并适于沿具有第二预定光束尺寸的第二光束传播预定频率范围的能量，其中第一和第二光束的一部分在期间重叠区域。扫描。

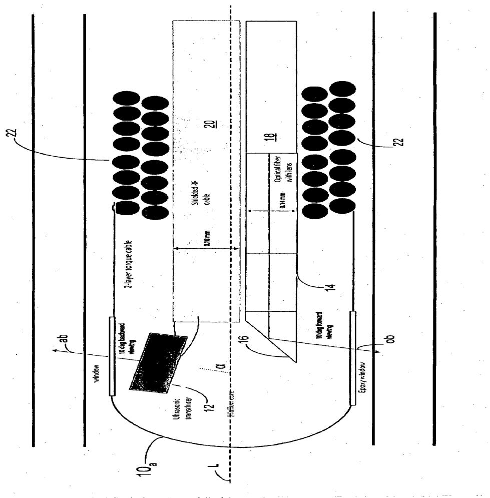

Figure 1A