



(11) **EP 2 470 267 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
11.11.2015 Bulletin 2015/46

(51) Int Cl.:
A61N 7/00 (2006.01) A61B 8/00 (2006.01)
A61B 8/13 (2006.01) B25J 7/00 (2006.01)

(21) Application number: **10814299.3**

(86) International application number:
PCT/US2010/046794

(22) Date of filing: **26.08.2010**

(87) International publication number:
WO 2011/028603 (10.03.2011 Gazette 2011/10)

(54) **MICROMANIPULATOR CONTROL ARM FOR THERAPEUTIC AND IMAGING ULTRASOUND TRANSDUCERS**

MIKROMANIPULATOR-STEUERARM FÜR THERAPIE- UND BILDGEBUNGS-ULTRASCHALLWANDLER

BRAS DE COMMANDE DE MICROMANIPULATEUR POUR TRANSDUCTEURS THÉRAPEUTIQUES ET D'IMAGERIE DU TYPE À ULTRASON

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR

(30) Priority: **26.08.2009 US 237017 P**

(43) Date of publication of application:
04.07.2012 Bulletin 2012/27

(73) Proprietors:
• **The Regents of The University of Michigan**
Ann Arbor, MI 48109-2590 (US)
• **Histosonics, Inc.**
Ann Arbor, MI 48103 (US)

(72) Inventors:
• **ROBERTS, William, W.**
Saline
MI 48176 (US)
• **HALL, Timothy, L.**
Ann Arbor
MI 48104 (US)
• **CAIN, Charles, A.**
Ann Arbor
MI 48105 (US)

• **FOWLKES, J., Brian**
Ann Arbor
MI 48103 (US)
• **XU, Zhen**
Ann Arbor
MI 48105 (US)
• **KUSNER, Michael, Thomas, Jr.**
Perrysburg
OH 43551 (US)
• **TEOFILOVIC, Dejan**
Ann Arbor
MI 48108 (US)

(74) Representative: **Price, Nigel John King**
J A Kemp
14 South Square
Gray's Inn
London WC1R 5JJ (GB)

(56) References cited:
WO-A2-2009/094554 DE-A1- 10 236 174
US-A- 4 669 483 US-A- 4 984 575
US-A- 5 624 382 US-A- 5 666 954
US-A1- 2003 149 352 US-A1- 2006 074 303
US-A1- 2008 091 123 US-A1- 2008 312 561
US-A1- 2008 312 561 US-A1- 2009 030 339
US-A1- 2009 198 094

EP 2 470 267 B1

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description**FIELD OF THE INVENTION**

[0001] The present invention generally relates to imaging and treating tissue with ultrasound devices. More specifically, the present invention relates to imaging and ablating tissue with Histotripsy devices.

BACKGROUND OF THE INVENTION

[0002] Histotripsy and Lithotripsy are non-invasive tissue ablation modalities that focus pulsed ultrasound from outside the body to a target tissue inside the body. Histotripsy mechanically damages tissue through cavitation of micro bubbles which homogenizes cellular tissues into an a-cellular liquid that can be expelled or absorbed by the body, and Lithotripsy is typically used to fragment urinary stones with acoustic shockwaves.

[0003] Histotripsy is the mechanical disruption via acoustic cavitation of a target tissue volume or tissue embedded inclusion as part of a surgical or other therapeutic procedure. Histotripsy works best when a whole set of acoustic and transducer scan parameters controlling the spatial extent of periodic cavitation events are within a rather narrow range. Small changes in any of the parameters can result in discontinuation of the ongoing process.

[0004] Histotripsy requires high peak intensity acoustic pulses which in turn require large surface area focused transducers. These transducers are often very similar to the transducers used for Lithotripsy and often operate in the same frequency range. The primary difference is in how the devices are driven electrically.

[0005] Histotripsy pulses consist of a (usually) small number of cycles of a sinusoidal driving voltage whereas Lithotripsy is (most usually) driven by a single high voltage pulse with the transducer responding at its natural frequencies. Even though the Lithotripsy pulse is only one cycle, its negative pressure phase length is equal to or greater than the entire length of the Histotripsy pulse, lasting tens of microseconds. This negative pressure phase allows generation and continual growth of the bubbles, resulting in bubbles of sizes up to 1 mm. The Lithotripsy pulses use the mechanical stress produced by a shockwave and these 1 mm bubbles to cause tissue damage or fractionate stones.

[0006] In comparison, each negative and positive cycle of a Histotripsy pulse grows and collapses the bubbles, and the next cycle repeats the same process. The maximal sizes of bubbles reach approximately tens to hundreds of microns. These micron size bubbles interact with a tissue surface to mechanically damage tissue.

[0007] In addition, Histotripsy delivers hundreds to thousands of pulses per second, i.e., 100-1kHz pulse repetition frequency. Lithotripsy only works well within a narrow range of pulse repetition frequency (usually 0.5-1Hz). Studies show that the efficacy and efficiency

of lithotripsy decreases significantly when the pulse repetition frequency is increased to 10-100Hz. The reduced efficiency is likely due to the increased number of mm size bubbles blocking the shock waves and other energy from reaching the stone.

[0008] Histotripsy typically comprises delivering acoustic pulses that operate at a frequency between approximately 50 KHz and 5MHz, having a pulse intensity with a peak negative pressure of approximately 8-40 MPa, a peak positive pressure of more than 10 MPa, a pulse length shorter than 50 cycles, a duty cycle between approximately 0.1% and 5% and in some embodiments less than 5%, and a pulse repetition frequency of less than 5 KHz.

[0009] Diagnostic ultrasound can be used during Histotripsy procedures to visualize the surgical anatomy and monitor the process in real time. The Histotripsy cavitation bubble cloud can appear very clearly on diagnostic ultrasound as a hyperechoic (light) region and ablated homogenized tissue can appear as a hypoechoic (dark) region. Large and irregular tissue volumes can be ablated using Histotripsy by electronically changing the focus of a therapeutic array or by mechanically moving the focus of the therapeutic transducer within the surgical target area.

[0010] Document WO 2009/094 554 discloses a combined ultrasound histotripsy and imaging system having a computer-controlled positioner.

SUMMARY OF THE INVENTION

[0011] According to the present invention there is provided the imaging and therapy system of claim 1.

[0012] Additional aspects of the present invention are set out in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS**[0013]**

Fig. 1 illustrates one embodiment of an imaging and therapy system including a micro-manipulator system.

Figs. 2A-2B illustrate an imaging system inside a patient.

Figs. 3A-3B and 4A-4B illustrate an imaging system and a therapeutic ultrasound transducer attached to a micro-manipulator system.

Fig. 5 is an ultrasound image of tissue damaged with a Histotripsy procedure.

Figs. 6A-6B are two views of a micro-manipulator system.

DETAILED DESCRIPTION OF THE INVENTION

[0014] Histotripsy may be used to ablate or damage tissue for treatment of a variety of disorders. Particularly, Histotripsy can be used to ablate tissue for the treatment

of benign prostate hyperplasia (BPH) and prostate cancer. In one Histotripsy system, an imaging system and an ultrasound therapy system are held and positioned by an electromechanical micro-manipulator system. The micro-manipulator system can be attached to a procedure table or can be held above the procedure table and secured to the ceiling. In some embodiments, the micro-manipulator system can be joystick controlled or controlled by a computer tracking and positioning program. A trans-rectal (TR) ultrasound imaging system can be inserted in the patient's rectum to confirm accurate targeting and localization of the bubble cloud formed by the therapy system during treatment, and for imaging of target tissue during the Histotripsy procedure. The imaging system can be attached to the micro-manipulator system and repositioned axially and rotated radially during the procedure to image and track therapy.

[0015] The micro-manipulator system can be a small, portable and easy to use system and can include attachment points for both an ultrasound therapy system and an imaging system. The micro-manipulator system can be configured to independently control movement of both the therapy system and the imaging system.

[0016] Referring now to Fig. 1, imaging and therapy system 100 can comprise micro-manipulator system 102, control system 104, ultrasound therapy system 106, and imaging system 108. Micro-manipulator system 102 can be adapted and configured to attach to and move the ultrasound therapy system 106 in up to six degrees of freedom (e.g., forward/back, left/right, up/down, yaw, pitch, and roll in the x, y, and z planes shown in Fig. 1). It should be understood that some systems may not require all six degrees of freedom of movement. The micro-manipulator system can also be configured to attach to and move the imaging system in up to six degrees of freedom, however, typically only the forward/back and roll degrees of freedom are required for the imaging system. In some embodiments, the micro-manipulator system comprises a robotic arm with up to six degrees of freedom. The robotic arm can be configured to hold the weight of both the imaging system and the ultrasound therapy system steady during positioning and treatment. In the embodiment of Fig. 1, micro-manipulator system 102 is attached to a separate mobile stand 116. Alternatively, the micro-manipulator system can be mounted on a procedure table (not shown).

[0017] Control system 104 can include controller 110, input device 112, and display 114. The controller can be a computer having hardware and software configured to control movement of the micro-manipulator system. For example, the controller can comprise a CPU, memory, operating system, and other computing essentials required to load software and control attached hardware. The input device 112 can be a keyboard and mouse or a joystick, for example. Display 114 can be, for example, an electronic display or a graphical user interface (GUI).

[0018] Ultrasound therapy system 106 can comprise an ultrasound therapy transducer or transducers config-

ured to deliver ultrasound energy to a target tissue volume. In some embodiments, the ultrasound therapy transducer can be a Histotripsy ultrasound transducer configured to generate cavitation micro bubbles in tissue. In some embodiments, the Histotripsy ultrasound transducer can be configured to deliver acoustic pulses that operate at a frequency between approximately 50 KHz and 5MHz, having a pulse intensity with a peak negative pressure of approximately 8-40 MPa, a peak positive pressure of more than 10 MPa, a pulse length shorter than 50 cycles, a duty cycle between approximately 0.1% and 5% and in some embodiments less than 5%, and a pulse repetition frequency of less than 5 KHz. In other embodiments, the ultrasound therapy system 106 can comprise a Lithotripsy ultrasound transducer or a HIFU transducer. The ultrasound therapy system 106 can include a coupling mechanism 118 for acoustically coupling the transducer to a patient, such as a bellows. Alternatively, the coupling mechanism can be separate from the ultrasound therapy system and attached to the patient instead. Several embodiments of a suitable coupling mechanism are described in U.S. Pat. App. No. 12/858,242, filed 8/17/2010, titled "Disposable Acoustic Coupling Medium Container".

[0019] In some embodiments, the imaging system 108 is configured to image the target tissue volume and comprises a C-mode diagnostic ultrasound imaging system. In some embodiments, the imaging system can be a trans-rectal imaging probe. The imaging system can be configured to image tissue in 2D or 3D. In some embodiments, a trans-rectal imaging probe can be configured to be inserted into the rectum of a patient to image the prostate and surrounding tissues. In other embodiments, a secondary imaging transducer may be held in the center of the ultrasound therapy system 106.

[0020] Methods of using a imaging and therapy system will now be described. Fig. 2A illustrates an imaging system 208 inserted in the rectum R of a patient. Imaging transducer 220 of imaging system 208 can be positioned adjacent to the prostate P of the patient. Fig. 2B illustrates the imaging system 208 coupled to a micro-manipulator system 202, such as the micro-manipulator system described above. In some embodiments, the imaging system and the micro-manipulator system can be positioned manually at the beginning of the procedure. In some embodiments, the imaging system 208 can be positioned in the rectum, as shown in Fig. 2A, then the micro-manipulator system can be positioned and attached to the imaging system, as shown in Fig. 2B. The imaging system can be advanced in the rectum so that its imaging aperture defined by imaging transducer 220 is adjacent to the prostate and is configured to acquire an image of the prostate in the transverse plane. The imaging system can also be positioned by rotating radially along the longitudinal axis of the probe so as to acquire an image of the prostate in the medial sagittal plane.

[0021] As shown in Figs. 3A-B, ultrasound therapy system 306 can mount on micro-manipulator system 302

such that it is facing the perineal region between the anus and scrotum of the patient. The ultrasound therapy system 306 can be configured to have a focal point of approximately 0.8 cm to 4 cm (such as, e.g., 1 cm) away from the front of the ultrasound therapy system. Thus, referring to Fig. 3B for treatment of the prostate, the ultrasound therapy system can be positioned so as to locate the focal point 322 of the ultrasound therapy system 302 within the field of view of the imaging system 308 and within the prostate to be treated. In Figs. 3A-3B, the micro-manipulator system is adapted and configured to position the imaging system within a rectum of the patient and to position the ultrasound therapy system in acoustic contact with the perineum while the imaging system is in the rectum.

[0022] Movement of the micro-manipulator system, imaging of the target tissue with the imaging system, and treatment of the target tissue with the ultrasound therapy system can be managed, observed, and controlled with a control system, such as control system 104 described above and illustrated in Fig. 1. Referring now to Figs. 4A-B and Fig. 1, the initial positioning of focal point 422 can be established mechanically by the micro-manipulator system 402. As shown in Fig. 4A, ultrasound therapy system 406 can be moved by micro-manipulator system 402 to position focal point 422 on target tissues in the prostate P and within the field of view of the imaging system. The micro-manipulator system is configured to position the focal point 422 on one or both lobes of the prostate, as shown in Figs. 4A-B.

[0023] The micro-manipulator system 402 can be manually positioned by the user, such as a physician, by using input device 112 while under visual guidance from an imaging system 108 and display 114 of Fig. 1. In other embodiments, the micro-manipulator system can also be positioned automatically with a controller, such as controller 110 of Fig. 1. The controller can be programmed with software and/or hardware according to a surgical plan to automatically position and move the micro-manipulator system and the ultrasound therapy system to locate the focal point in the target tissue and ablate the desired tissues within the target tissue volume.

[0024] Referring still to Fig. 1, the imaging system 108 can be integrated with the ultrasound therapy system 106 and control system 104 for surgical planning. Surgical planning can be facilitated by acquiring multiple transverse or sagittal images of the target tissue volume, such as the prostate, with imaging system 108, and storing these images in controller 110 of control system 104. In some embodiments, scanned images can be spaced approximately 1-10 mm apart. These images can be stored in the controller 110 and inputted into surgical planning software within the controller. The images can be retrieved by the surgical planning software, and the treatment area can then be drawn or marked on each image to identify a desired ablation volume, as illustrated by the ablation volume 524 outlined in Fig. 5.

[0025] In other embodiments, scanning the target tis-

sue volume can comprise rotating the imaging system through the sagittal (longitudinal) plane to acquire images through the entire volume in order to reconstruct a three-dimensional (3D) image of the target tissue volume.

5 Transverse or sagittal plane images can then be acquired and examined by the user or the control system for detailed surgical planning. The treatment volume can be drawn or marked on the image, as described above.

[0026] In some embodiments, the surgical planning software or the user can create a surgical plan within the target tissue volume, such as within the prostate, with subsequent treatment volumes separated by 1 mm increments (e.g., total range 0.2 mm-1 cm). Each treatment target can be assigned a different dose of ultrasound therapy. The ultrasound dose can be determined, e.g., by the number of pulses delivered or the treatment duration in each treatment target. In some embodiments, the ultrasound therapy comprises Histotripsy therapy. Histotripsy can be performed within the planned treatment volume. The treatment can be tracked on the control system display, which can also display the images from the imaging system. In some embodiments, the focal point of the ultrasound therapy transducer can be automatically moved by the micro-manipulator system through the surgical treatment volume (e.g., of the prostate) to ablate the treatment volume under real time imaging from the imaging system. In some embodiments, the ultrasound therapy system is configured to ablate or mechanically damage the treatment volume. The ultrasound therapy system can be configured to ablate or mechanically damage tissue of the prostate to treat BPH or prostate cancer, for example.

[0027] In some embodiments, the initial default position of the imaging system is in the middle of the prostate, and the initial default position of the ultrasound therapy system focal point is within the transverse and sagittal field of view of the imaging system. In some embodiments, the default positions of the imaging and therapy systems may be reestablished by pressing a default control element (e.g., a button or a key) on the control system.

[0028] Referring still to Figs. 4A-B and Fig. 1, the imaging system 408 can be advanced and rotated manually during a Histotripsy procedure to keep the cavitation bubble cloud in the imaging field and to facilitate real time monitoring. Alternatively, the control system can automatically position the micro-manipulator system, imaging system, and the ultrasound therapy system to keep the cavitation bubble cloud in the imaging field. For example, the micro-manipulator system can be rotated and/or advanced in the axial direction automatically by the control system to a degree that is calculated based on the movement of the therapy system and the field of view of the imaging system. As another alternative, imaging feedback can be used to guide the rotation of the imaging system. The imaging system can rotate for small steps, until the imaging feedback indicates a hyperechoic zone (i.e., high backscatter amplitude) in the treatment region, which would indicate a Histotripsy cavitation bubble

cloud.

[0029] In some embodiments, the ultrasound therapy system can generate an ultrasonically induced cavitation bubble cloud in a tissue volume using pulsed ultrasound at a frequency of between about 100 kHz and about 5 MHz having high amplitude pressure waves with peak negative pressure above 5 MPa, an ultrasound pulse duration of 1-1000 cycles, a pulse repetition frequency of less than about 5 kHz and a duty cycle less than about 5%.

[0030] In other embodiments, the focused ultrasound therapy transducer generates an ultrasonically induced cavitation bubble cloud in a tissue volume using an ultrasound frequency between about 250 kHz and about 1.5 MHz, high amplitude pressure waves with intensities exceeding 2000 W/cm² and peak positive pressure above 20 MPa (such as, e.g., between 30 MPa and 500 MPa) and peak negative pressure less than 5 MPa (such as, e.g., between 5 MPa and 40 MPa), ultrasound pulse duration of less than 30 cycles (such as, e.g., between 0.2μs and 30μs (1 to 20 cycles)), a pulse repetition frequency of less than about 5 kHz and a duty cycle less than about 5%.

[0031] Figs. 1-4 above described and illustrated the micro-manipulator system as a robotic arm. However, Figs. 6A-B illustrate an alternative embodiment of a micro-manipulator system 602. As described above, ultrasound therapy system 606 and imaging system 608 can be attached to the micro-manipulator system. The micro-manipulator system as shown in Figs. 6A can be configured to move the ultrasound therapy system 606 in up to three degrees of freedom (e.g., forward/back, yaw, and pitch) and can be configured to move the imaging system 608 in one degree of freedom (e.g., roll). The micro-manipulator system 602 of Figs. 6A-B can further be automatically controlled by a control system, such as control system 104 of Fig. 1, to automatically position and control the ultrasound therapy system and the imaging systems described herein.

[0032] To achieve rotation along the yaw axis, defined by arrow 626, stepper motor 628 can be attached to slide-block 630 with screw rod 632. The screw rod and slide-block can include mating external and internal threading, respectively. When stepper motor 628 rotates screw rod 632, the threading of screw rod causes slide-block to move linearly along slot 634. Slide-block 630 can be attached to rotation tray 636 with connecting rod 638. The connecting rod can be attached to rotation tray at a position away from rotation pin 640 of the tray. When slide-block moves linearly along slot 634, connecting rod 638 pushes against rotation tray 636, causing the tray, and thus the ultrasound therapy system 606, to rotate in the yaw axis around rotation pin 640.

[0033] The micro-manipulator system can achieve rotation along the pitch axis, defined by arrow 642, in a similar manner. In Fig. 6A, stepper motor 644 can rotate screw rod 646, causing slide-block 648 to move linearly in slot 650. This can cause connecting rod 652 to push

against ultrasound therapy system 606 to rotate in the pitch axis around rotation pins 654.

[0034] The micro-manipulator system can achieve movement along the forward/back axis, defined by arrow 656, in a similar manner. In Figs. 6A-6B, stepper motor 658 can rotate screw rod 660, causing slide-block 662 to move linearly in slot 664. Slide-block 662 can be attached to frame 666, which is attached to ultrasound therapy system 606. Thus, linear movement of the slide block can cause the frame to move linearly along wheels 668, thereby advancing ultrasound therapy system 606 in the forward/back direction 656.

[0035] The micro-manipulator system can achieve movement of the imaging system 608 in the roll axis, defined by arrow 676 in a similar manner. Stepper motor 670 can be attached directly to imaging system 608 with screw rod 672. Stepper motor 670 can rotate screw rod 672, causing rotation of imaging system 606. The stepper motor 670 may further include knob 674 to allow for manual rotation of imaging system 608.

[0036] As for additional details pertinent to the present invention, materials and manufacturing techniques may be employed as within the level of those with skill in the relevant art. The same may hold true with respect to method-based aspects of the invention in terms of additional acts commonly or logically employed. Also, it is contemplated that any optional feature of the inventive variations described may be set forth and claimed independently, or in combination with any one or more of the features described herein. Likewise, reference to a singular item, includes the possibility that there are plural of the same items present. More specifically, as used herein and in the appended claims, the singular forms "a," "and," "said," and "the" include plural referents unless the context clearly dictates otherwise. It is further noted that the claims may be drafted to exclude any optional element. As such, this statement is intended to serve as antecedent basis for use of such exclusive terminology as "solely," "only" and the like in connection with the recitation of claim elements, or use of a "negative" limitation. Unless defined otherwise herein, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. The breadth of the present invention is not to be limited by the subject specification, but rather only by the plain meaning of the claim terms employed.

Claims

1. An imaging and therapy system (100), comprising:
 - a micro-manipulator system (102, 202, 302, 402, 602);
 - an ultrasound therapy system (106, 306, 406, 606) supported by the micro-manipulator system and configured to generate a cavitation bubble cloud in a target tissue volume;

- an imaging system (108, 208, 308, 408, 608) supported by the micro-manipulator system apart from the ultrasound therapy system and configured to monitor the cavitation bubble cloud in real time;
 wherein the micro-manipulator system comprises a control system (104) configured to automatically position and move the micro-manipulator system and the ultrasound therapy system to locate the focal point to ablate desired tissue within the target tissue volume; and
 wherein the control system is configured to independently control relative movement of the ultrasound therapy system and the imaging system so as to automatically maintain the cavitation bubble cloud generated by the ultrasound therapy system within a field of view of the imaging system.
2. The imaging and therapy system of claim 1, wherein the micro-manipulator is adapted and configured to position the imaging system within a rectum of a human male patient and to position the ultrasound therapy system in acoustic contact with a perineum of the patient while the imaging system is in the rectum.
 3. The imaging and therapy system of claim 2, wherein the focal point of the ultrasound therapy system is positionable in the range from 0.8 cm to 4 cm from the imaging system.
 4. The imaging and therapy system of claim 1, wherein the ultrasound therapy system comprises a histotripsy system.
 5. The imaging and therapy system of claim 1, wherein the ultrasound therapy system comprises an ultrasound therapy transducer configured to deliver acoustic pulses that operate at a frequency between 50 KHz and 5 MHz, having a pulse intensity with a peak negative pressure between 8-40 MPa, a peak positive pressure of more than 10 MPa, a pulse duration shorter than 50 cycles, a duty cycle of less than 5%, and a pulse repetition frequency of less than 5 KHz.
 6. The imaging and therapy system of claim 1, wherein the imaging system comprises a trans-rectal probe.
 7. The imaging and therapy system of claim 1, wherein the micro-manipulator system comprises a robotic arm.
 8. The imaging and therapy system of claim 1, wherein the micro-manipulator system comprises at least four stepper motors configured to move the micro-manipulator system in up to four degrees of freedom.
9. The imaging and therapy system of claim 8, wherein one of the at least four stepper motors is configured to rotate the imaging system about a roll axis.
 10. The imaging and therapy system of claim 8, wherein one of the at least four stepper motors is configured to advance the ultrasound therapy system along a longitudinal axis.
- Patentansprüche**
1. Bildgebungs- und Therapie-System (100), umfassend:
 - ein Mikro-Manipulator-System (102, 202, 302, 402, 602);
 - ein Ultraschall-Therapie-System (106, 306, 406, 606), welches durch das Mikro-Manipulator-System gehalten ist und konfiguriert ist, um eine Kavitationsblasenwolke in einem Zielgewebevolumen zu erzeugen;
 - ein Bildgebungssystem (108, 208, 308, 408, 608), welches durch das Mikro-Manipulator-System entfernt von dem Ultraschall-Therapie-System gehalten ist und konfiguriert ist, um die Kavitationsblasenwolke in Echtzeit zu überwachen;
 - wobei das Mikro-Manipulator-System ein Steuersystem (104) umfasst, welches konfiguriert ist, um das Mikro-Manipulator-System und das Ultraschall-Therapie-System automatisch zu positionieren und zu bewegen, um den Brennpunkt zu lokalisieren, um erwünschtes Gewebe innerhalb des Zielgewebevolumens abzutragen; und
 - wobei das Steuersystem konfiguriert ist, um eine Relativbewegung des Ultraschall-Therapie-Systems und des Bildgebungssystems unabhängig zu steuern, um so die Kavitationsblasenwolke, welche durch das Ultraschall-Therapie-System erzeugt wird, innerhalb eines Sichtfelds des Bildgebungssystems zu halten.
 2. Bildgebungs- und Therapie-System nach Anspruch 1, wobei der Mikro-Manipulator eingerichtet und konfiguriert ist, um das Bildgebungssystem in einem Rektum eines menschlichen männlichen Patienten zu positionieren und um das Ultraschall-Therapie-System in einem akustischen Kontakt mit einem Perineum des Patienten zu positionieren, während sich das Bildgebungssystem in dem Rektum befindet.
 3. Bildgebungs- und Therapie-System nach Anspruch 2, wobei der Brennpunkt des Ultraschall-Therapie-Systems in dem Bereich von 0,8 cm bis 4 cm von dem Bildgebungssystem entfernt positionierbar ist.

4. Bildgebungs- und Therapie-System nach Anspruch 1, wobei das Ultraschall-Therapie-System ein Histotripsy-System umfasst.
5. Bildgebungs- und Therapie-System nach Anspruch 1, wobei das Ultraschall-Therapie-System einen Ultraschall-Therapie-Messumformer umfasst, welcher konfiguriert ist, um akustische Pulse abzugeben, welche bei einer Frequenz zwischen 50 kHz und 5 MHz arbeiten, welche eine Pulsintensität mit einem negativen Spitzendruck zwischen 8-40 MPa, einen positiven Spitzendruck von mehr als 10 MPa, eine Pulsdauer kürzer als 50 Zyklen, einen Tastgrad von weniger als 5 % und eine Pulswiederholungsfrequenz von weniger als 5 kHz aufweisen.
6. Bildgebungs- und Therapie-System nach Anspruch 1, wobei das Bildgebungssystem einen transrektalen Fühler umfasst.
7. Bildgebungs- und Therapie-System nach Anspruch 1, wobei das Mikro-Manipulator-System einen Roboterarm umfasst.
8. Bildgebungs- und Therapie-System nach Anspruch 1, wobei das Mikro-Manipulator-System mindestens vier Schrittmotoren umfasst, welche konfiguriert sind, um das Mikro-Manipulator-System in bis zu vier Freiheitsgraden zu bewegen.
9. Bildgebungs- und Therapie-System nach Anspruch 8, wobei einer der mindestens vier Schrittmotoren konfiguriert ist, um das Bildgebungssystem um eine Rollachse zu drehen.
10. Bildgebungs- und Therapie-System nach Anspruch 8, wobei einer der mindestens vier Schrittmotoren konfiguriert ist, um das Ultraschall-Therapie-System entlang einer Längsachse vorwärts zu bewegen.

Revendications

1. Système d'imagerie et de thérapie (100), comportant :
- un système de micromanipulateur (102, 202, 302, 402, 602);
 - un système d'ultrasonothérapie (106, 306, 406, 606) supporté par le système de micromanipulateur et conçu pour créer un nuage de bulles de cavitation dans un volume de tissus ciblé;
 - un système d'imagerie (108, 208, 308, 408, 608) supporté séparément du système d'ultrasonothérapie par le système de micromanipulateur et conçu pour contrôler en temps réel le nuage de bulles de cavitation;
 - le système de micromanipulateur comprenant

un système de commande (104) conçu pour positionner et déplacer automatiquement le système de micro manipulateur et le système d'ultrasonothérapie afin de localiser le foyer pour une ablation de tissus voulus dans le volume de tissus ciblé ; et

le système de commande étant conçu pour commander d'une manière indépendante les déplacements du système de micromanipulateur et du système d'ultrasonothérapie l'un par rapport à l'autre afin de maintenir automatiquement dans un champ de vision du système d'imagerie le nuage de bulles de cavitation créé par le système d'ultrasonothérapie.

2. Système d'imagerie et de thérapie selon la revendication 1, dans lequel le micromanipulateur est conçu et configuré pour placer le système d'imagerie dans un rectum de patient humain mâle et mettre le système d'ultrasonothérapie acoustiquement au contact d'un périnée du patient pendant que le système d'imagerie est dans le rectum.
3. Système d'imagerie et de thérapie selon la revendication 2, dans lequel le foyer du système d'ultrasonothérapie peut être placé à une distance de 0,8 cm à 4 cm du système d'imagerie.
4. Système d'imagerie et de thérapie selon la revendication 1, dans lequel le système d'ultrasonothérapie comprend un système d'histotripsy.
5. Système d'imagerie et de thérapie selon la revendication 1, dans lequel le système d'ultrasonothérapie comprend un transducteur pour ultrasonothérapie conçu pour délivrer des impulsions acoustiques opérant à une fréquence de 50 KHz à 5 MHz, ayant une intensité d'impulsions avec un pic de pression négative de 8 à 40 MPa, un pic de pression positive supérieur à 10 MPa, une durée d'impulsions inférieure à 50 cycles, un rapport cyclique inférieur à 5 % et une fréquence de répétition d'impulsions inférieure à 5 KHz.
6. Système d'imagerie et de thérapie selon la revendication 1, dans lequel le système d'imagerie comprend une sonde transrectale.
7. Système d'imagerie et de thérapie selon la revendication 1, dans lequel le système de micromanipulateur comprend un bras robotisé.
8. Système d'imagerie et de thérapie selon la revendication 1, dans lequel le système de micro manipulateur comprend au moins quatre moteurs pas-à-pas conçus pour animer le système de micromanipulateur avec un maximum de quatre degrés de liberté.

9. Système d'imagerie et de thérapie selon la revendication 8, dans lequel un des au moins quatre moteurs pas-à-pas est conçu pour faire tourner le système d'imagerie autour d'un axe de roulis.

5

10. Système d'imagerie et de thérapie selon la revendication 8, dans lequel un des au moins quatre moteurs pas-à-pas est conçu pour faire avancer le système d'ultrasonothérapie sur un axe longitudinal.

10

15

20

25

30

35

40

45

50

55

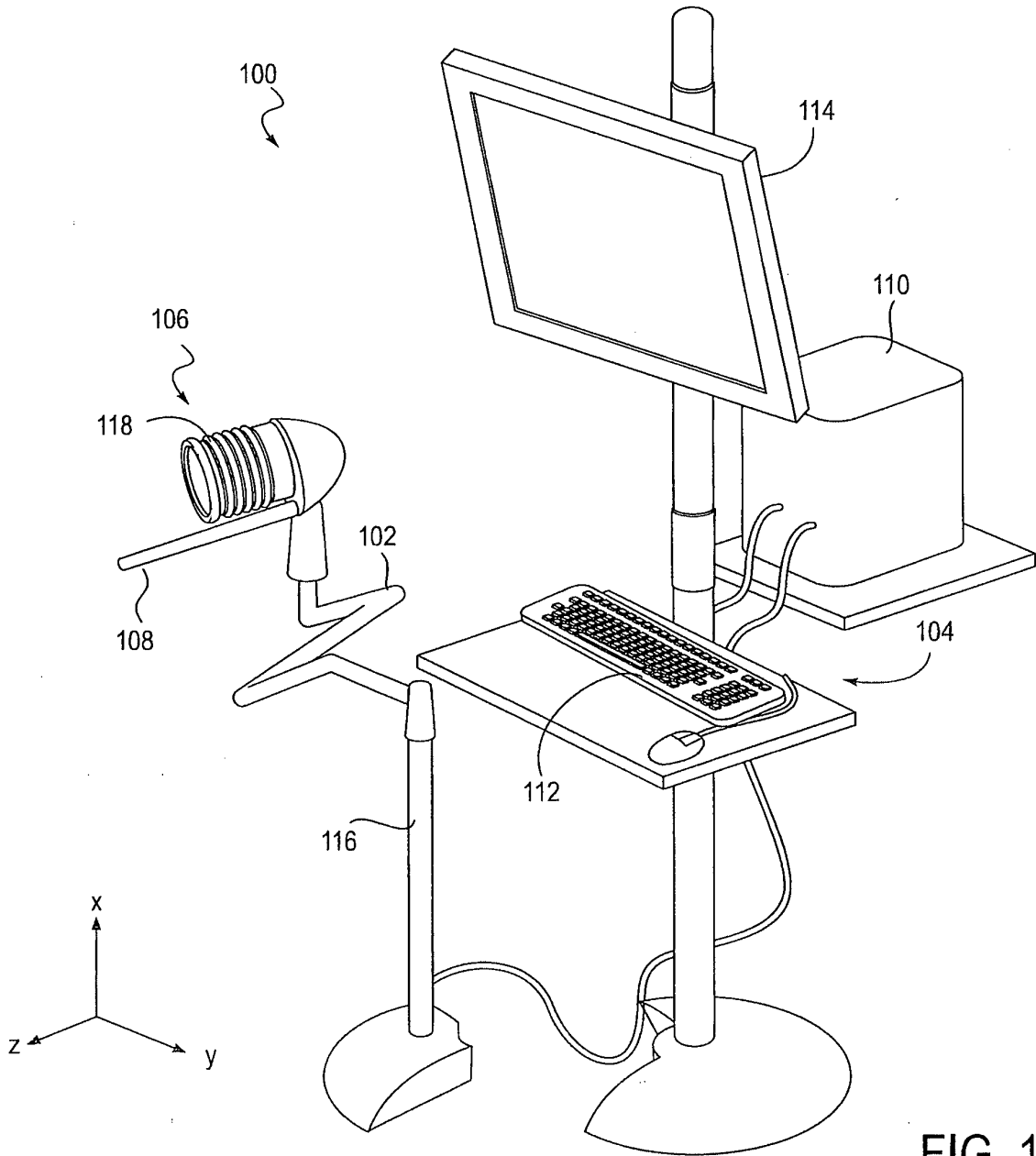


FIG. 1

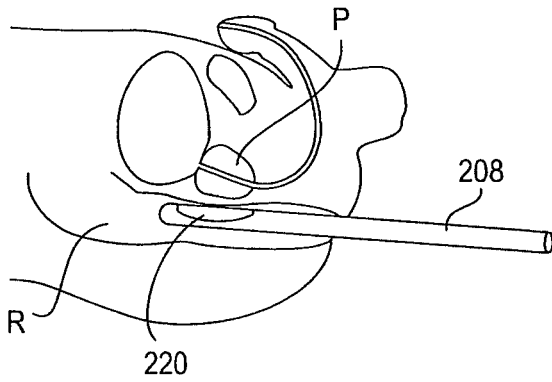


FIG. 2A

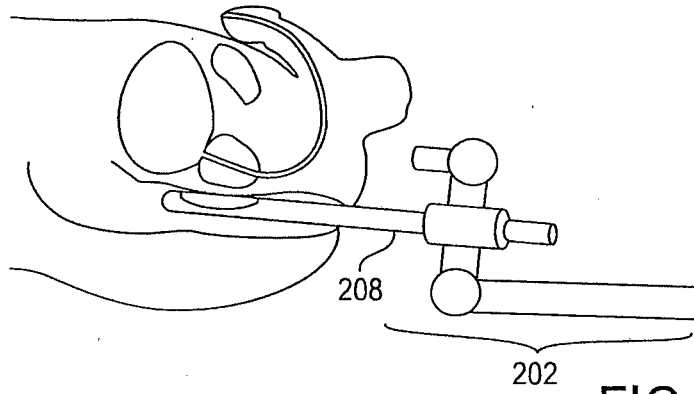


FIG. 2B

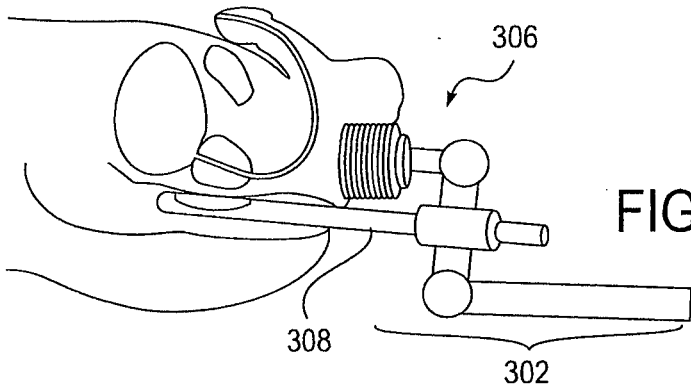


FIG. 3A

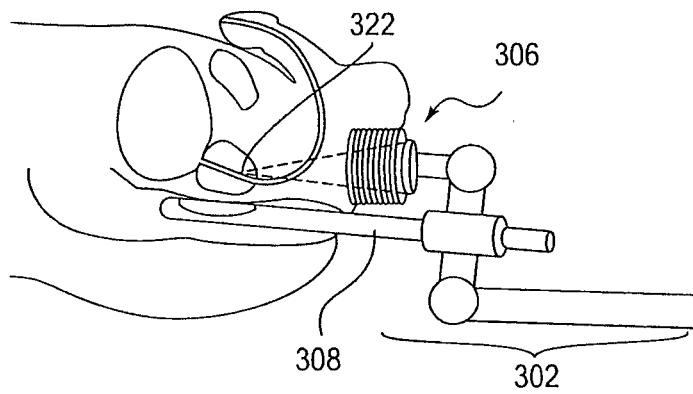


FIG. 3B

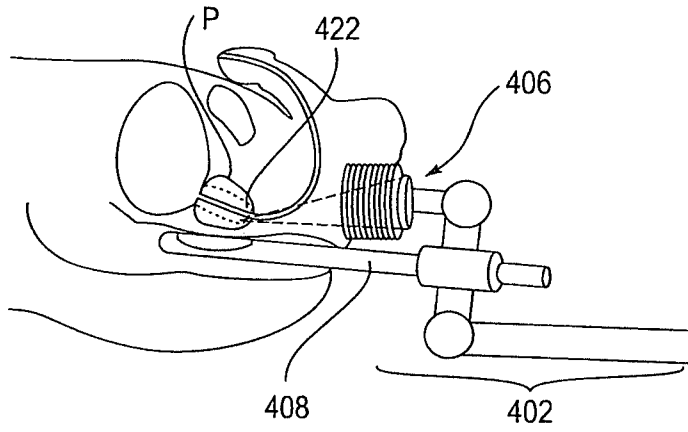


FIG. 4A

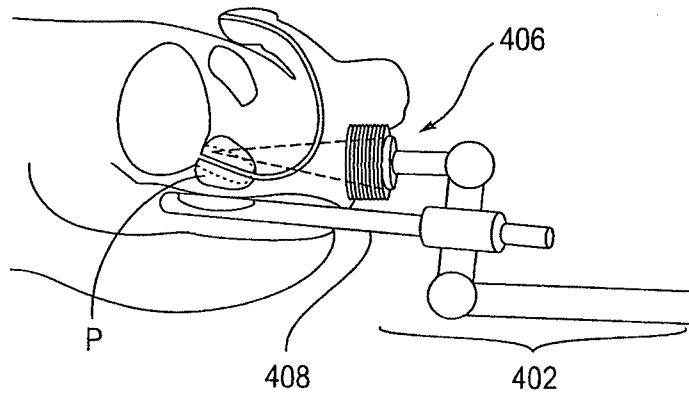


FIG. 4B

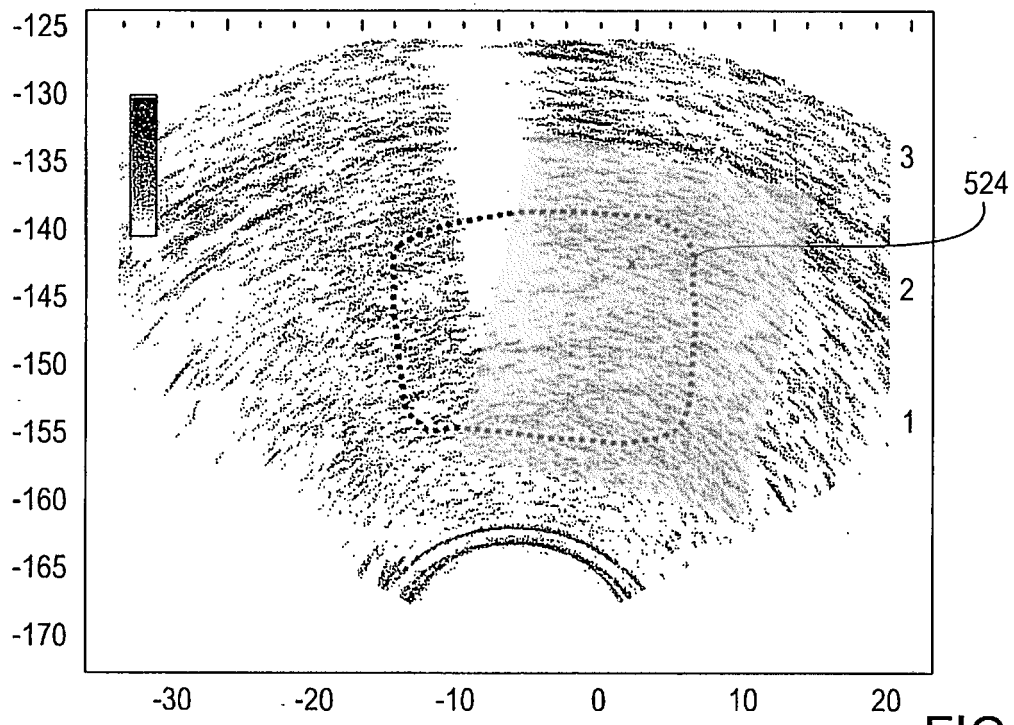


FIG. 5

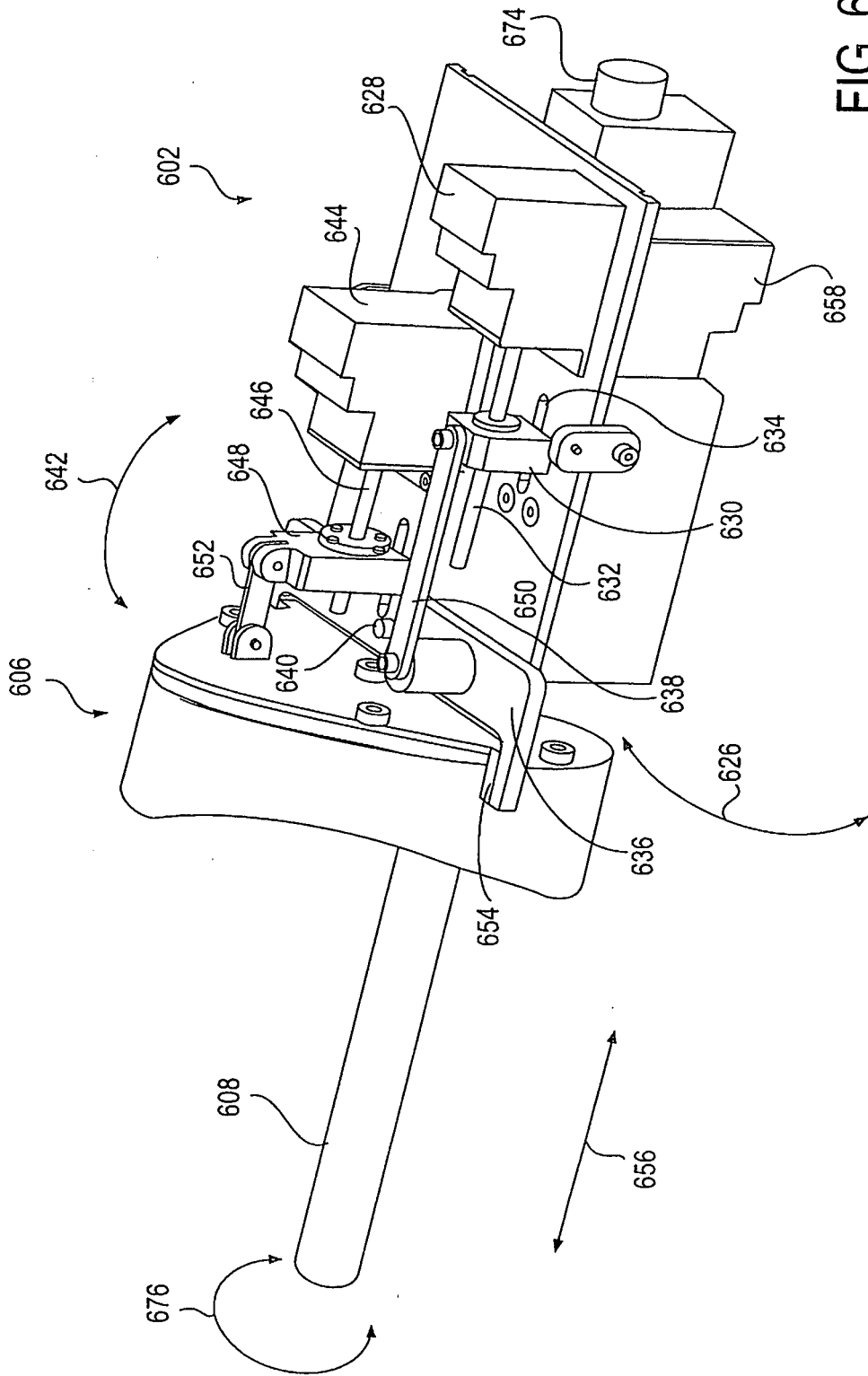


FIG. 6A

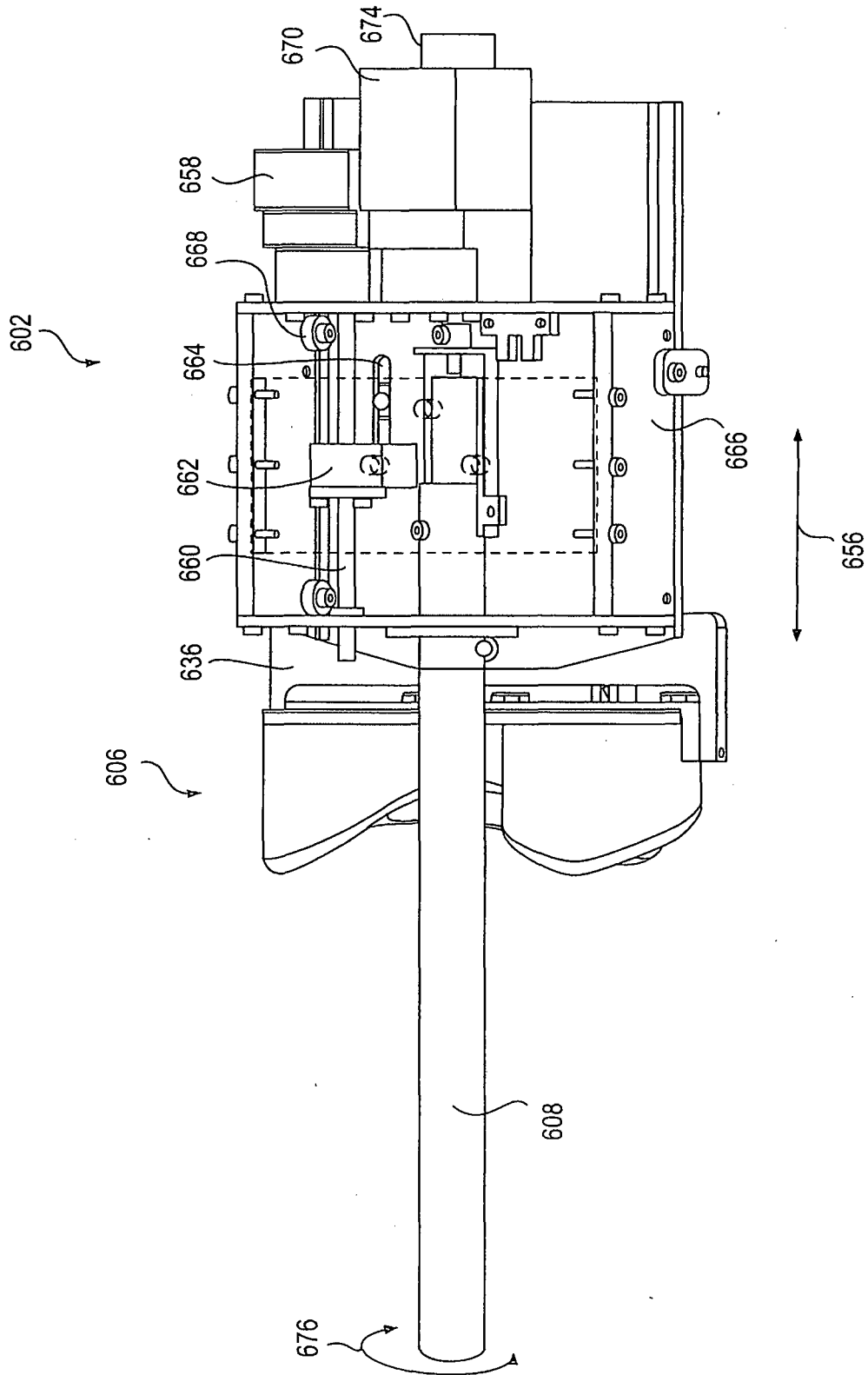


FIG. 6B

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 2009094554 A [0010]
- US 85824210 A [0018]

专利名称(译)	用于治疗 and 成像超声换能器的微操纵器控制臂		
公开(公告)号	EP2470267A4	公开(公告)日	2013-09-18
申请号	EP2010814299	申请日	2010-08-26
[标]申请(专利权)人(译)	密歇根大学 HISTOSONICS		
申请(专利权)人(译)	密歇根大学董事会 HISTOSONICS INC.		
当前申请(专利权)人(译)	密歇根大学董事会 HISTOSONICS INC.		
[标]发明人	ROBERTS WILLIAM W HALL TIMOTHY L CAIN CHARLES A FOWLKES J BRIAN XU ZHEN KUSNER MICHAEL THOMAS JR TEOFILOVIC DEJAN		
发明人	ROBERTS, WILLIAM, W. HALL, TIMOTHY, L. CAIN, CHARLES, A. FOWLKES, J., BRIAN XU, ZHEN KUSNER, MICHAEL, THOMAS, JR. TEOFILOVIC, DEJAN		
IPC分类号	A61N7/00 A61B8/00 A61B8/13 B25J7/00		
CPC分类号	A61N7/02 A61B8/12 A61B8/4218 A61B34/72 A61B90/50 A61B2017/22008 A61B2090/378		
优先权	61/237017 2009-08-26 US		
其他公开文献	EP2470267A2 EP2470267B1		
外部链接	Espacenet		

摘要(译)

提供了一种医学成像和治疗设备，其可以包括许多特征中的任何一个。该装置的一个特征是它可以成像目标组织体积并将超声能量施加到目标组织体积。在一些实施例中，医学成像和治疗设备被配置为通过维持由成像系统产生的前列腺图像内的超声治疗系统产生的空化气泡云来可控地将超声能量施加到前列腺中。医学成像和治疗装置可用于治疗应用，例如Histotripsy，Lithotripsy和HIFU。还涉及与使用医学成像和治疗装置相关的方法。