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(54) **MEDICAL SYSTEM HAVING MULTIPLE ULTRASOUND TRANSDUCERS OR AN ULTRASOUND TRANSDUCER AND AN RF ELECTRODE**

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(52) **U.S. Cl.** **600/439**; 600/437; 600/459; 600/462; 601/2

(58) **Field of Classification Search** 600/439, 600/437, 459, 462; 607/97; 601/2
See application file for complete search history.

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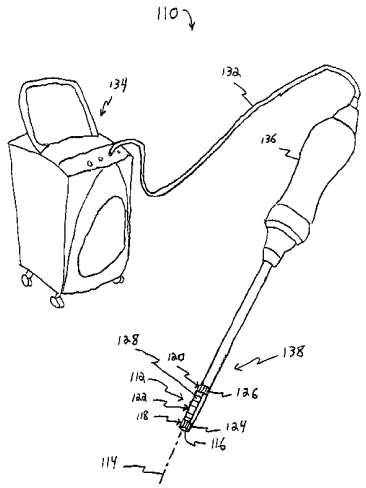
(57) **ABSTRACT**

An ultrasound medical system includes an ultrasound transducer assembly having various combinations of ultrasound transducers having different-shaped ultrasound emitting surfaces and/or different ultrasound transducer types, wherein the types are ultrasound-medical-treatment-only type, ultrasound-medical-treatment-and-imaging type, and ultrasound-medical-imaging-only type ultrasound transducers. Another ultrasound medical system includes a transducer assembly having an RF (radio-frequency) medical-treatment electrode and an ultrasound medical transducer.

22 Claims, 4 Drawing Sheets



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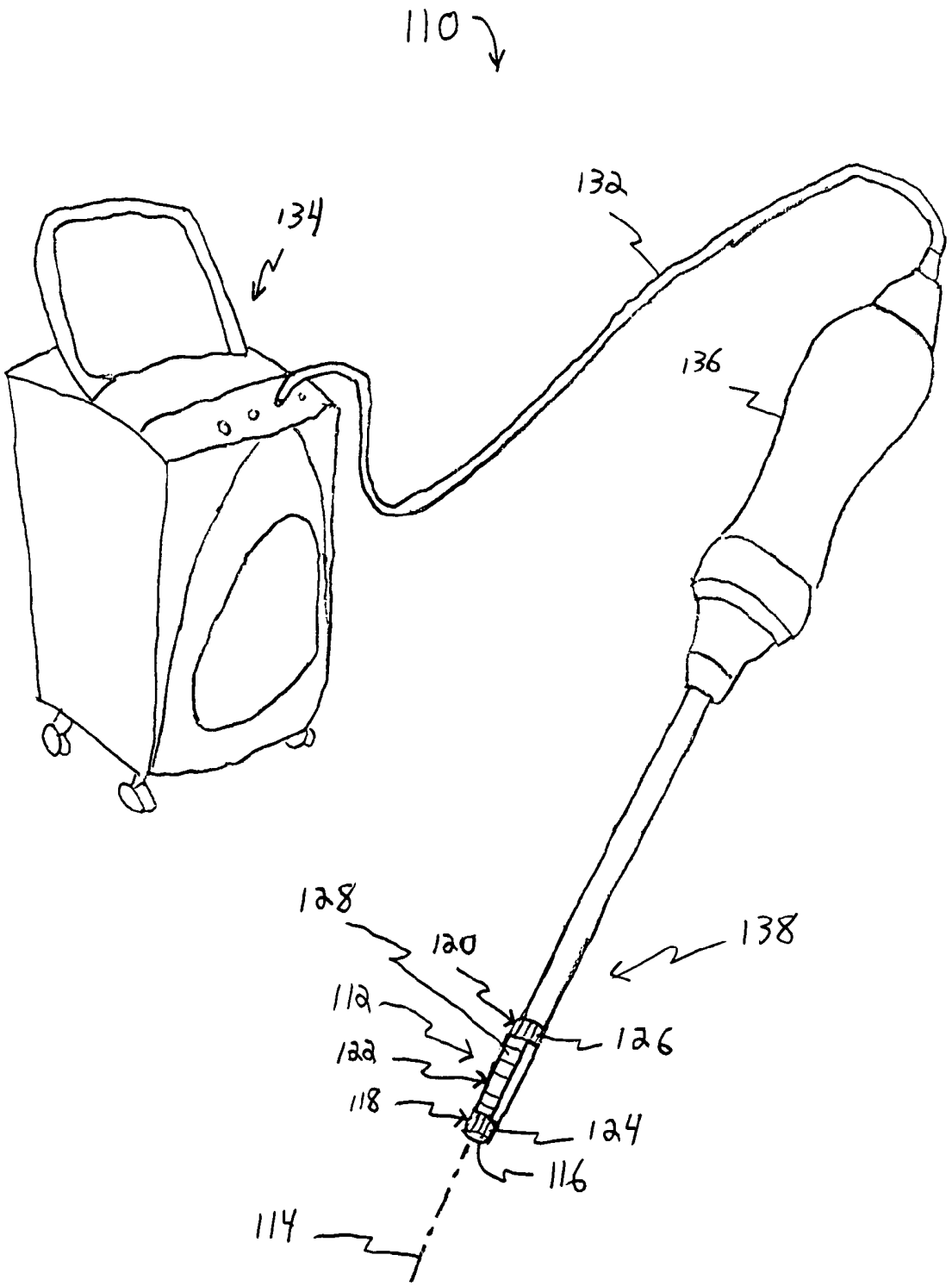

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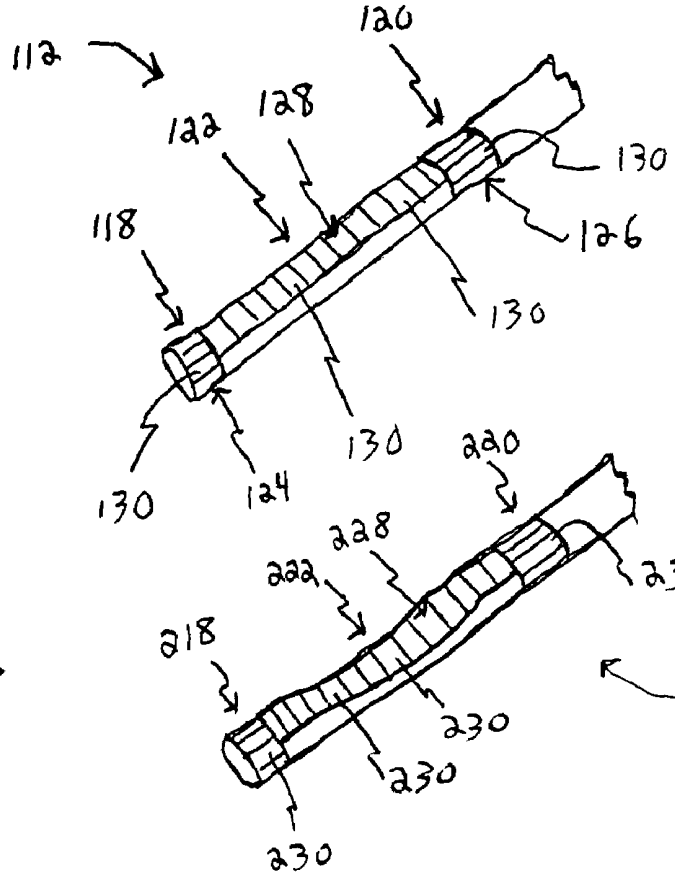
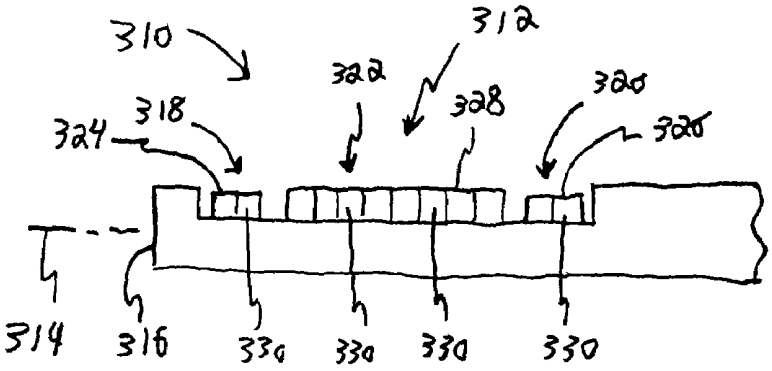


Fig. 2

Fig 3



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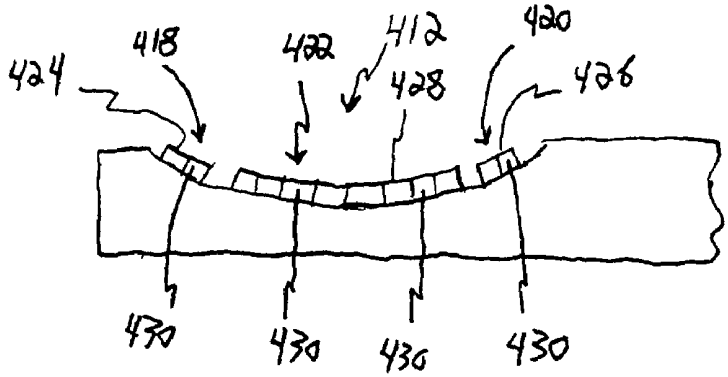

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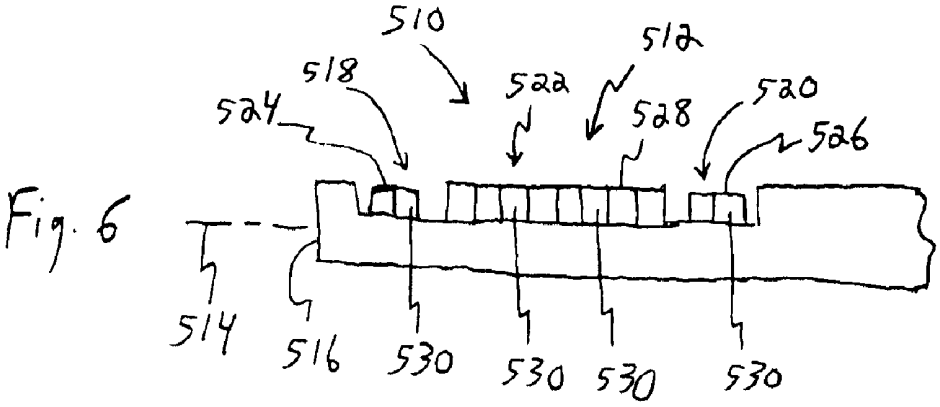
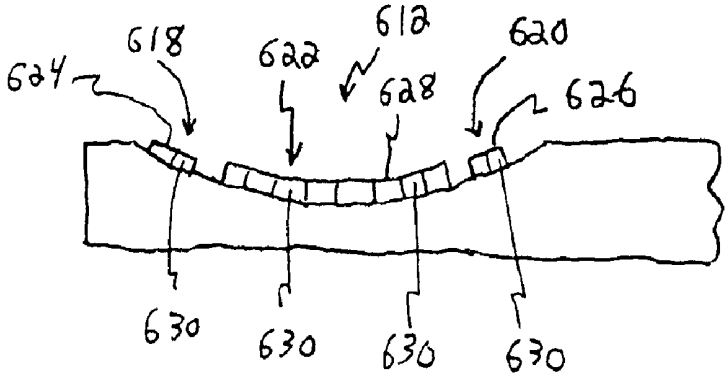


Fig. 6



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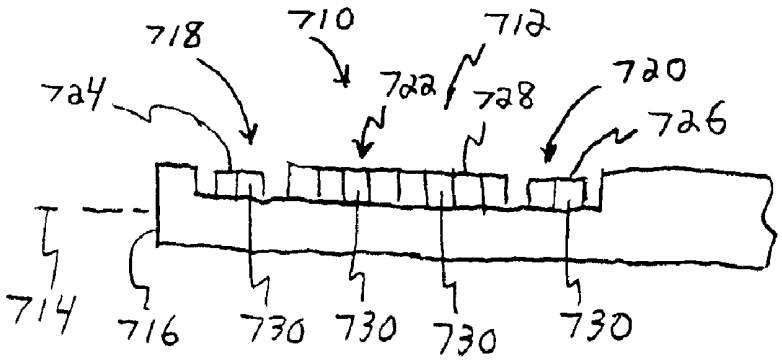

Fig. 8

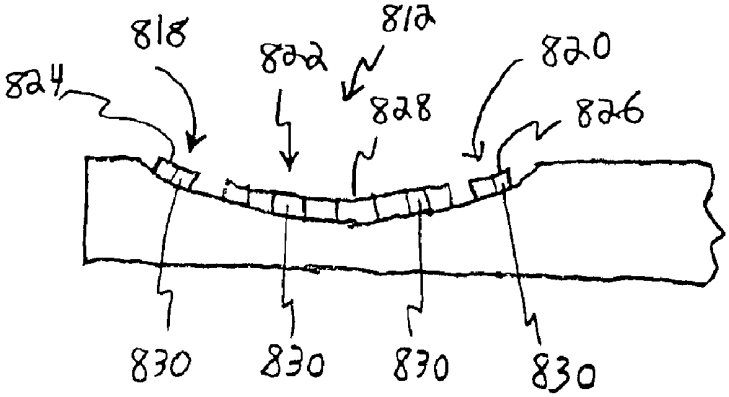

Fig. 9

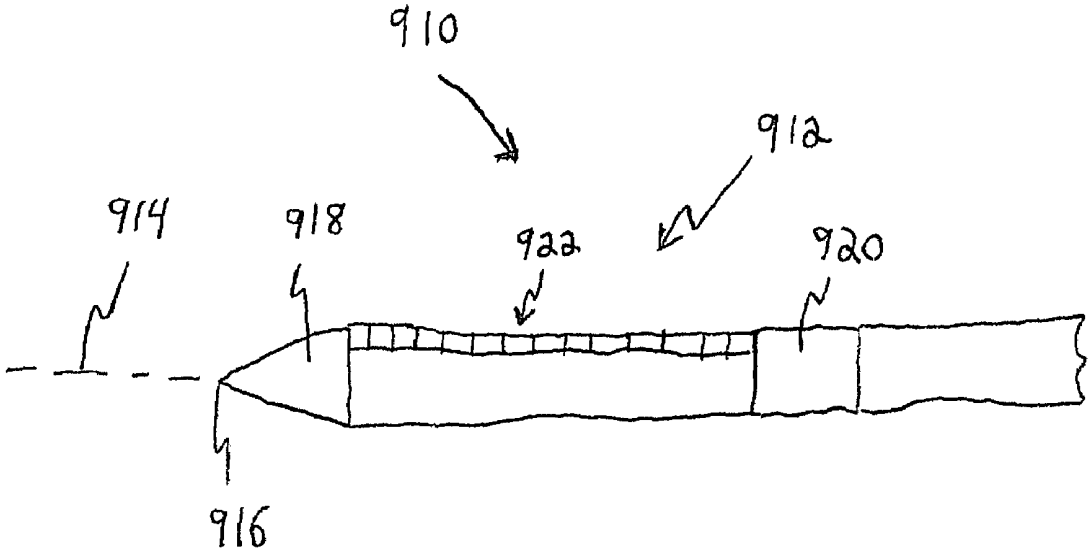

Fig. 10

MEDICAL SYSTEM HAVING MULTIPLE ULTRASOUND TRANSDUCERS OR AN ULTRASOUND TRANSDUCER AND AN RF ELECTRODE

FIELD OF THE INVENTION

The present invention relates generally to ultrasound, and more particularly to an ultrasound medical system having a transducer assembly including multiple ultrasound transducers or an ultrasound transducer and an RF (radio-frequency) electrode.

BACKGROUND OF THE INVENTION

Known ultrasound medical systems include medical systems which use ultrasound imaging of patients to identify patient tissue for medical treatment and which use ultrasound to ablate identified patient tissue (i.e., medically destroy patient tissue by heating the tissue to form a lesion). In one known design, an ultrasound-medical-imaging-only ultrasound transducer is attached on one side of a rotatable shaft and an ultrasound-medical-treatment-only ultrasound transducer is attached on the opposite side of the shaft. In another known design, the ultrasound transducer is an ultrasound-medical-treatment-and-imaging ultrasound transducer wherein medical imaging is done at a lower power and medical treatment is done at a higher power.

In one known example, a transducer assembly includes a single ultrasound transducer having a single transducer element, or an array of transducer elements acting together, to ultrasonically image the patient and/or to ultrasonically ablate identified patient tissue. A known transducer element includes a transducer element having a concave shape to focus ultrasound energy. A known array of transducer elements includes a planar, concave, or convex array of transducer elements. A known array of transducer elements includes an array whose transducer elements are electronically or mechanically controlled together to steer and focus the ultrasound emitted by the array to a focal zone (which may be large or which may be as small as, for example, a grain of rice) to provide three-dimensional medical ultrasound treatment of patient tissue.

Known ultrasound medical systems include medical systems which: deploy an end effector having an ultrasound transducer outside the body to break up kidney stones inside the body; endoscopically insert an end effector having an ultrasound transducer in the rectum to medically destroy prostate cancer; laparoscopically insert an end effector having an ultrasound transducer in the abdominal cavity to medically destroy a cancerous liver tumor; intravenously insert a catheter end effector having an ultrasound transducer into a vein in the arm and moves the catheter to the heart to medically destroy diseased heart tissue; and interstitially insert a needle end effector having an ultrasound transducer needle into the tongue to medically destroy tissue to reduce tongue volume to reduce snoring.

Still, scientists and engineers continue to seek improved ultrasound medical systems.

SUMMARY OF THE INVENTION

A first embodiment of the invention is an ultrasound medical system including an ultrasound transducer assembly which has a longitudinal axis and a distal end. The ultrasound transducer assembly includes first, second and third ultrasound transducers. The first ultrasound transducer is located proximate the distal end and has a substantially-fully-cylindrical ultrasound-emitting surface which is substantially coaxially aligned with, and outwardly-facing from, the longitudinal axis. The second ultrasound transducer has a substantially-fully-cylindrical ultrasound-emitting surface which is substantially coaxially aligned with, and outwardly-facing from, the longitudinal axis. The third ultrasound transducer is positioned longitudinally between the first and second ultrasound transducers and has an ultrasound-emitting surface which is substantially-entirely planar or includes at least a concave surface portion.

A broadened expression of the first embodiment is for an ultrasound medical system including an ultrasound transducer assembly having a longitudinal axis, having a distal end, and having two ultrasound transducers. One of the ultrasound transducers has a substantially-fully-cylindrical ultrasound-emitting surface which is substantially coaxially aligned with, and outwardly-facing from, the longitudinal axis. An other of the ultrasound transducers is positioned longitudinally proximal or distal to the one ultrasound transducer and has an ultrasound-emitting surface which is substantially-entirely planar or includes at least a concave surface portion.

A second embodiment of the invention is an ultrasound medical system including an ultrasound transducer assembly having a longitudinal axis. The ultrasound transducer assembly includes first, second and third ultrasound transducers each having an ultrasound-emitting surface which is substantially-entirely planar or includes at least a concave surface portion. The first and second ultrasound transducers are ultrasound-medical-treatment-only ultrasound transducers. The third ultrasound transducer is an ultrasound-medical-treatment-and-imaging ultrasound transducer positioned longitudinally between the first and second ultrasound transducers.

A third embodiment of the invention is an ultrasound medical system including an ultrasound transducer assembly having a longitudinal axis. The ultrasound transducer assembly includes first, second and third ultrasound transducers each having an ultrasound-emitting surface which is substantially-entirely planar or includes at least a concave surface portion. The first and second ultrasound transducers are ultrasound-medical-treatment-only ultrasound transducers. The third ultrasound transducer is an ultrasound-medical-imaging-only ultrasound transducer positioned longitudinally between the first and second ultrasound transducers.

A fourth embodiment of the invention is an ultrasound medical system including an ultrasound transducer assembly having a longitudinal axis. The ultrasound transducer assembly includes first, second and third ultrasound transducers each having an ultrasound-emitting surface which is substantially-entirely planar or includes at least a concave surface portion. The first and second ultrasound transducers are ultrasound-medical-treatment-and-imaging ultrasound transducers. The third ultrasound transducer is an ultrasound-medical-treatment-only ultrasound transducer positioned longitudinally between the first and second ultrasound transducers.

A broadened expression of the second through fourth embodiments is for an ultrasound medical system including an ultrasound transducer assembly having a longitudinal axis, and having two ultrasound transducers each having an ultrasound-emitting surface which is substantially-entirely planar or includes at least a concave surface portion. One of the ultrasound transducers is positioned longitudinally proximal or distal to an other of the ultrasound transducers. The one and the other ultrasound transducers are different types of medi-

cal-treatment-only type, medical-treatment-and-imaging type, and medical-imaging-only type transducers.

A fifth embodiment of the invention is an ultrasound medical system including a transducer assembly having a longitudinal axis, having a distal end, having a first RF (radio-frequency) medical-treatment electrode, and having an ultrasound medical transducer positioned longitudinally proximal or distal to the first RF medical-treatment electrode.

Several benefits and advantages are obtained from one or more of the embodiments of the ultrasound medical system of the invention. In one example of the first embodiment, the first and second ultrasound transducers are ultrasound-medical-treatment-only ultrasound transducers and the third ultrasound transducer is an ultrasound-medical-treatment-and imaging ultrasound transducer which provides 360-degree treatment of patient tissue from the first and second transducers while also providing imaging (and treatment) from the third transducer. The second, third and fourth embodiments provide, in one example, treatment (from treat-only or treat-and-image first and second transducers) at the longitudinal ends of the transducer assembly which enhances the axial (longitudinal) ablation dimension while also providing imaging (from an image-only or a treat-and image third transducer or from treat-and-image first and second transducers). In one example of the fifth embodiment, the first RF medical-treatment electrode is less expensive, and easier to taper to a tissue-penetrating edge, than using an ultrasound medical-treatment transducer in its place.

The present invention has, without limitation, application in conventional endoscopic, laparoscopic, and open surgical instrumentation as well as application in robotic-assisted surgery.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** is a schematic view of a first embodiment of an ultrasound medical treatment system of the invention;

FIG. **2** is an enlarged view of the ultrasound transducer assembly of FIG. **1**, wherein the ultrasound-emitting surface of the third ultrasound transducer is substantially-entirely planar;

FIG. **3** is a view, as in FIG. **2**, but of an alternate embodiment of the ultrasound transducer assembly having a third ultrasound transducer whose ultrasound-emitting surface has a concave surface portion;

FIGS. **4-9** are side-elevational views of an ultrasound transducer assembly portion of additional embodiments of an ultrasound medical system of the invention, wherein the transducer assembly has three transducers whose ultrasound-emitting surfaces each are substantially-entirely planar or include at least a concave surface portion, and wherein the three transducers are various combinations of two types of treat-only, image-only and treat-and-image type ultrasound transducers; and

FIG. **10** is a side-elevational view of a transducer assembly portion of another embodiment of the ultrasound medical system of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Before explaining the present invention in detail, it should be noted that the invention is not limited in its application or use to the details of construction and arrangement of parts illustrated in the accompanying drawings and description. The illustrative embodiments of the invention may be implemented or incorporated in other embodiments, variations and modifications, and may be practiced or carried out in various ways. Furthermore, unless otherwise indicated, the terms and expressions employed herein have been chosen for the purpose of describing the illustrative embodiments of the present invention for the convenience of the reader and are not for the purpose of limiting the invention. It is understood that the embodiments of FIGS. **1-9** can include one or more additional ultrasound transducers than those shown, and that the embodiment of FIG. **10** can include one or more additional ultrasound transducers and/or one or more additional RF electrodes than those shown.

It is understood that any one or more of the following-described embodiments, examples, etc. can be combined with any one or more of the other following-described embodiments, examples, etc.

Referring now to the drawings, FIGS. **1-2** illustrate an embodiment of the present invention which is an ultrasound medical system **110** including an ultrasound transducer assembly **112**. The ultrasound transducer assembly **112** has a longitudinal axis **114** and a distal end **116**. The ultrasound transducer assembly **112** includes first, second and third ultrasound transducers **118**, **120** and **122**. It is noted that the phrase "ultrasound transducer" means ultrasound medical transducer. The first ultrasound transducer **118** is disposed proximate the distal end **116** and has a substantially-fully-cylindrical ultrasound-emitting surface **124** which is substantially coaxially aligned with, and outwardly-facing from, the longitudinal axis **114**. The second ultrasound transducer **120** has a substantially-fully-cylindrical ultrasound-emitting surface **126** which is substantially coaxially aligned with, and outwardly-facing from, the longitudinal axis **114**. The third ultrasound transducer **122** is disposed longitudinally between the first and second ultrasound transducers **118** and **120** and has an ultrasound-emitting surface **128** which is substantially-entirely planar or includes at least a concave surface portion.

In one arrangement of the embodiment of FIGS. **1-2**, the first ultrasound transducer **118** is disposed at the distal end **116**, and the third ultrasound transducer **122** is disposed proximate the first and second ultrasound transducers **118** and **120**. In one variation, the third ultrasound transducer **122** abuts the first and second ultrasound transducers **118** and **120**.

In one example of the embodiment of FIGS. **1-2**, the ultrasound-emitting surface **128** of the third ultrasound transducer **122** is substantially-entirely planar. In an alternate embodiment of the ultrasound transducer assembly **212**, shown in FIG. **3**, the ultrasound-emitting surface **228** of the third ultrasound transducer **222** includes at least a concave surface portion. In one variation, the ultrasound-emitting surface of the third ultrasound transducer in its entirety has a substantially-cylindrically-focused shape (e.g., the ultrasound is focused substantially along a focal line, having a line thickness, such as a focal line which is parallel to, or perpendicular to, the longitudinal axis of the ultrasound transducer assembly). In another variation, the ultrasound-emitting surface of the third ultrasound transducer in its entirety has a substantially-spherically-focused shape (e.g., the ultrasound is focused substantially at a focal zone such as a dot having a dot size).

In one enablement of the embodiment of FIGS. **1-2**, and/or the alternate embodiment of FIG. **3**, the first and second ultrasound transducers **118** and **120** & **218** and **220** are ultrasound-medical-treatment-only ultrasound transducers. In the same or a different enablement, the third ultrasound transducer **122** and **222** is an ultrasound-medical-treatment-and-imaging ultrasound transducer. In one implementation of the embodiment of FIGS. **1-2**, and/or the alternate embodiment of FIG. **3**, at least one (and in one variation all) of the first, second and third ultrasound transducers **118-122** & **218-222**

has a plurality of ultrasound transducer elements **130** & **230**. In one variation, the transducer elements of an array of a plurality of transducer elements of an ultrasound transducer are electronically controlled together to steer and focus the ultrasound emitted by the array. It is noted that planar ultrasound transducer elements, when tilted inward, can be arranged to form an ultrasound transducer whose ultrasound-emitting surface has at least a concave portion. Similarly, planar ultrasound transducer elements, when not tilted, can be arranged to form an ultrasound transducer whose ultrasound-emitting surface is substantially-entirely planar. Likewise, planar ultrasound transducer elements, when tilted outward, can be arranged to form an ultrasound transducer having a substantially-fully-cylindrical ultrasound-emitting surface. In a different implementation, at least one (and in one variation all) of the first, second and third ultrasound transducers has only one ultrasound transducer element.

In one construction of the embodiment of FIGS. **1-2**, a cable **132** operatively connects a controller **134** to the ultrasound transducer assembly **112**. In one variation, the cable **132** connects the controller **134** to a handpiece **136** which is operatively connected to an end effector **138** which supports the ultrasound transducer assembly **112**. In one modification, the end effector **138** is an articulated end effector **138**, which is also rotatable about the longitudinal axis **114**, allowing the user and/or the controller **134** to rotate and/or translate the ultrasound transducer assembly **112** as desired. In one procedure, the first and second ultrasound transducers **118** and **120** are used to ablate (which is one form of ultrasound medical treatment) patient tissue in contact with the end effector **138**, along the end effector insertion track, which sterilizes such patient tissue and is useful, for example, when the end effector **138** passes through cancerous tissue which is to be medically treated with ultrasound from the ultrasound transducer assembly **112**.

A broadened expression of the embodiments of FIGS. **1-3** is for an ultrasound medical system **110** comprising an ultrasound transducer assembly **112** and **212** having a longitudinal axis **114**, having a distal end **116**, and having two ultrasound transducers (**122/222** and either **118/218** or **120/220**). One of the ultrasound transducers (either **118/218** or **120/220**) has a substantially-fully-cylindrical ultrasound-emitting surface (**124** or **126**) which is substantially coaxially aligned with, and outwardly-facing from, the longitudinal axis **114**. An other of the ultrasound transducers **122/222** is disposed longitudinally proximal or distal to the one ultrasound transducer (either **118/218** or **120/220**) and has an ultrasound-emitting surface **128** which is substantially-entirely planar or includes at least a concave surface portion.

In one example of the broadened expression of the embodiment of FIGS. **1-3**, the one ultrasound transducer **118/218** is disposed proximate the distal end **116**, and the other ultrasound transducer **122/222** is disposed proximate, and proximal to, the one ultrasound transducer **118/218**.

Another embodiment of the invention is an ultrasound medical system **310** (only an ultrasound-transducer-assembly portion of which is shown in FIG. **4**). The ultrasound medical system **310** includes an ultrasound transducer assembly **312** having a longitudinal axis **314**. The ultrasound transducer assembly **312** includes first, second and third ultrasound transducers **318**, **320** and **322** each having an ultrasound-emitting surface **324**, **326** and **328** which is substantially-entirely planar or includes at least a concave surface portion. The first and second ultrasound transducers **318** and **320** are ultrasound-medical-treatment-only ultrasound transducers. The third ultrasound transducer **322** is an ultrasound-medical-treatment-and-imaging ultrasound transducer disposed longitudinally between the first and second ultrasound transducers **318** and **320**.

In one arrangement of the embodiment of FIG. **4**, the ultrasound transducer assembly **312** has a distal end **316**. The first ultrasound transducer **318** is disposed proximate the distal end **316**, and the third ultrasound transducer **322** is disposed proximate the first and second ultrasound transducers **318** and **320**. In one variation, not shown, the third ultrasound transducer **322** abuts the first and second ultrasound transducers **318** and **320**.

In one example of the embodiment of FIG. **4**, the ultrasound-emitting surfaces **324**, **326** and **328** of the first, second and third ultrasound transducers **318**, **320** and **322** together are substantially-entirely planar. In an alternate embodiment of the ultrasound transducer assembly **412**, shown in FIG. **5**, at least one of the ultrasound-emitting surfaces **424**, **426** and **428** of the first, second and third ultrasound transducers **418**, **420** and **422** includes at least a concave surface portion. In one variation, the ultrasound-emitting surfaces of the first, second and third ultrasound transducers together in their entirety have a substantially-cylindrically-focused shape. In a different variation, the ultrasound-emitting surfaces of the first, second and third ultrasound transducers together in their entirety have a substantially-spherically-focused shape.

In one implementation of the embodiment of FIG. **4**, and/or the alternate embodiment of FIG. **5**, at least one (and in one variation all) of the first, second and third ultrasound transducers **318-322** & **418-422** has a plurality of ultrasound transducer elements **330** & **430**. In a different implementation, at least one (and in one variation all) of the first, second and third ultrasound transducers has only one ultrasound transducer element.

An additional embodiment of the invention is an ultrasound medical system **510** (only an ultrasound-transducer-assembly portion of which is shown in FIG. **6**). The ultrasound medical system **510** includes an ultrasound transducer assembly **512** having a longitudinal axis **514**. The ultrasound transducer assembly **512** includes first, second and third ultrasound transducers **518**, **520** and **522** each having an ultrasound-emitting surface **524**, **526** and **528** which is substantially-entirely planar or includes at least a concave surface portion. The first and second ultrasound transducers **518** and **520** are ultrasound-medical-treatment-only ultrasound transducers. The third ultrasound transducer **522** is an ultrasound-medical-imaging-only ultrasound transducer disposed longitudinally between the first and second ultrasound transducers **518** and **520**.

In one arrangement of the embodiment of FIG. **6**, the ultrasound transducer assembly **512** has a distal end **516**. The first ultrasound transducer **518** is disposed proximate the distal end **516**, and the third ultrasound transducer **522** is disposed proximate the first and second ultrasound transducers **518** and **520**. In one variation, not shown, the third ultrasound transducer **522** abuts the first and second ultrasound transducers **518** and **520**.

In one example of the embodiment of FIG. **6**, the ultrasound-emitting surfaces **524**, **526** and **528** of the first, second and third ultrasound transducers **518**, **520** and **522** together are substantially-entirely planar. In an alternate embodiment, shown in FIG. **7**, at least one of the ultrasound-emitting surfaces **624**, **626** and **628** of the first, second and third ultrasound transducers **618**, **620** and **622** includes at least a concave surface portion. In one variation, the ultrasound-emitting surfaces of the first, second and third ultrasound transducers together in their entirety have a substantially-cylindrically-focused shape. In a different variation, the ultra-

sound-emitting surfaces of the first, second and third ultrasound transducers together in their entirety have a substantially-spherically-focused shape.

In one implementation of the embodiment of FIG. **6**, and/or the alternate embodiment of FIG. **7**, at least one (and in one variation all) of the first, second and third ultrasound transducers **518-522** & **618-622** has a plurality of ultrasound transducer elements **530** & **630**. In a different implementation, at least one (and in one variation all) of the first, second and third ultrasound transducers has only one ultrasound transducer element.

A further embodiment of the invention is an ultrasound medical system **710** (only an ultrasound-transducer-assembly portion of which is shown in FIG. **8**). The ultrasound medical system **710** includes an ultrasound transducer assembly **712** having a longitudinal axis **714**. The ultrasound transducer assembly **712** includes first, second and third ultrasound transducers **718**, **720** and **722** each having an ultrasound-emitting surface **724**, **726** and **728** which is substantially-entirely planar or includes at least a concave surface portion. The first and second ultrasound transducers **718** and **720** are ultrasound-medical-treatment-and-imaging ultrasound transducers. The third ultrasound transducer **722** is an ultrasound-medical-treatment-only ultrasound transducer disposed longitudinally between the first and second ultrasound transducers **718** and **720**.

In one arrangement of the embodiment of FIG. **8**, the ultrasound transducer assembly **712** has a distal end **716**. The first ultrasound transducer **718** is proximate the distal end **716**, and the third ultrasound transducer **722** is disposed proximate the first and second ultrasound transducers **718** and **720**. In one variation, not shown, the third ultrasound transducer **722** abuts the first and second ultrasound transducers **718** and **720**.

In one example of the embodiment of FIG. **8**, the ultrasound-emitting surfaces **724**, **726** and **728** of the first, second and third ultrasound transducers **718**, **720** and **722** together are substantially-entirely planar. In an alternate embodiment, shown in FIG. **9**, at least one of the ultrasound-emitting surfaces **824**, **826** and **828** of the first, second and third ultrasound transducers **818**, **820** and **822** includes at least a concave surface portion. In one variation, the ultrasound-emitting surfaces of the first, second and third ultrasound transducers together in their entirety have a substantially-cylindrically-focused shape. In a different variation, the ultrasound-emitting surfaces of the first, second and third ultrasound transducers together in their entirety have a substantially-spherically-focused shape.

In one implementation of the embodiment of FIG. **8**, and/or the alternate embodiment of FIG. **9**, at least one (and in one variation all) of the first, second and third ultrasound transducers **718-722** & **818-822** has a plurality of ultrasound transducer elements **730** & **830**. In a different implementation, at least one (and in one variation all) of the first, second and third ultrasound transducers has only one ultrasound transducer element.

A broadened expression of the embodiments of FIGS. **4-9** (with only part numbers from FIG. **4** being hereinafter listed for clarity) is for an ultrasound medical system **310** comprising an ultrasound transducer assembly **312** having a longitudinal axis **314**, and having two ultrasound transducers (**322** and either **318** or **320**) each having an ultrasound-emitting surface (**328** and either **324** or **326**) which is substantially-entirely planar or includes at least a concave surface portion. One of the ultrasound transducers is disposed longitudinally proximal or distal to an other of the ultrasound transducers. The one and the other ultrasound transducers are different types of medical-treatment-only type, medical-treatment-and-imaging type, and medical-imaging-only type transducers. In one example, the one ultrasound transducer is a medical-treatment-only type ultrasound transducer and the other ultrasound transducer is a medical-treatment-and-imaging type ultrasound transducer. Other examples are left to the artisan. In one extension, the system **310** includes additional ultrasound transducers.

Yet another embodiment of the invention is an ultrasound medical system **910** (only a transducer-assembly portion of which is shown in FIG. **10**). The ultrasound medical system **910** includes a transducer assembly **912** having a longitudinal axis **914**, having a distal end **916**, having a first RF (radio-frequency) medical-treatment electrode **918**, and having an ultrasound medical transducer **922** disposed longitudinally proximal or distal to the first RF medical-treatment electrode **918**.

In one example of the embodiment of FIG. **10**, the first RF medical-treatment electrode **918** is disposed proximate the distal end **916**, and the ultrasound medical transducer **922** is disposed proximate, and longitudinally proximal to, the first RF medical-treatment electrode **918**. In the same or a different example, the ultrasound medical system **910** also includes a second RF (radio-frequency) medical-treatment electrode **920**, wherein the ultrasound medical transducer **922** is disposed longitudinally between the first and second RF medical-treatment electrodes **918** and **920**. In the same or a different example, the first RF medical-treatment electrode **918** is disposed at the distal end **916** and tapers to a tissue-penetrating edge.

In one enablement of the embodiment of FIG. **10**, the first and second RF medical-treatment electrodes **918** and **920** are bipoles of an RF system. In another enablement, the first and, when present, the second RF medical-treatment electrodes are monopoles of an RF system which also includes a dispersive electrode, not shown, as can be appreciated by those skilled in the art. In one variation, the RF system is phased between monopolar and bipolar. In one construction, the first and, when present, the second RF electrodes each are metallic rings (such as stainless steel or a copper alloy with gold plating), or are gold-plated plastic parts or gold-plated ceramic parts, or employ gold-plated flex circuit technology.

In one implementation of the embodiment of FIG. **10**, the ultrasound medical transducer **922** is an ultrasound-medical-imaging-only ultrasound transducer. In a different implementation, the ultrasound medical transducer **922** is an ultrasound-medical-treatment-and-imaging ultrasound transducer. In another implementation, the ultrasound medical transducer **922** is an ultrasound-medical-treatment-only ultrasound transducer.

Several benefits and advantages are obtained from one or more of the embodiments of the ultrasound medical system of the invention. In one example of the embodiments of FIGS. **1-3**, the first and second ultrasound transducers are ultrasound-medical-treatment-only ultrasound transducers and the third ultrasound transducer is an ultrasound-medical-treatment-and imaging ultrasound transducer which provides 360-degree treatment of patient tissue from the first and second transducers while also providing imaging (and treatment) from the third transducer. The embodiments of FIGS. **4-9**) provide, in one example, treatment (from treat-only or treat-and-image first and second transducers) at the longitudinal ends of the transducer assembly which enhances the axial (longitudinal) ablation dimension while also providing imaging (from an image-only or a treat-and image third transducer or from treat-and-image first and second transducers). In one example of the embodiment of FIG. **10**, the first RF medical-

treatment electrode is less expensive, and easier to taper to a tissue-penetrating edge, than using an ultrasound medical-treatment transducer in its place.

Also, as can be appreciated by those skilled in the art, examples of one or more of the embodiments of the ultrasound medical system of the invention provide: better end-effector performance by optimally dividing the drive power over, for example, transducer piezo-electric material; means to more effectively increase the length of the transducer face to achieve tissue effects under high power (e.g., 10-120 watts per square centimeter) source conditions; means to achieve an adequate amount of tissue effect (ablation) at the ends of the transducer assembly (where the power output characteristically tends to be lower); means to achieve circumferential tissue ablation at the ends of the equatorial line of the created lesion (to minimize bleeding due to intervention, etc.); means to provide better mechanical strength to the end effector design (such as larger element size at the ends of the transducer assembly, cylindrical transducer end caps, etc.); and means to provide simpler device designs (such as a smaller number of elements, simpler packaging issues, fewer connecting cables, lower cost, etc.), yet maintain the treatment and imaging capability of the end effector.

While the present invention has been illustrated by a description of several embodiments, it is not the intention of the applicants to restrict or limit the spirit and scope of the appended claims to such detail. Numerous other variations, changes, and substitutions will occur to those skilled in the art without departing from the scope of the invention. For instance, the ultrasound medical system of the invention has application in robotic assisted surgery taking into account the obvious modifications of such systems and components to be compatible with such a robotic system. It will be understood that the foregoing description is provided by way of example, and that other modifications may occur to those skilled in the art without departing from the scope and spirit of the appended claims.

What is claimed is:

1. An ultrasound medical system comprising an ultrasound transducer assembly having a longitudinal axis, having a distal end, and having:

a) a first ultrasound transducer disposed proximate the distal end and having a substantially-fully-cylindrical ultrasound-emitting outer exposed surface which is substantially coaxially aligned with, and outwardly-facing from, the longitudinal axis, wherein the first ultrasound transducer is an ultrasound-medical-treatment-only ultrasound transducer;

b) a second ultrasound transducer having a substantially-fully-cylindrical ultrasound-emitting outer exposed surface which is substantially coaxially aligned with, and outwardly-facing from, the longitudinal axis, wherein the second ultrasound transducer is an ultrasound-medical-treatment-only ultrasound transducer; and

c) a third ultrasound transducer disposed longitudinally between the first and second ultrasound transducers and having a plurality of planar transducer elements arranged to provide the third ultrasound transducer with an ultrasound-emitting outer exposed surface which is substantially-entirely planar or includes at least a concave surface portion.

2. The ultrasound medical system of claim **1**, wherein the first ultrasound transducer is disposed at the distal end, and wherein the third ultrasound transducer is disposed proximate the first and second ultrasound transducers.

3. The ultrasound medical system of claim **1**, wherein the ultrasound-emitting outer exposed surface of the third ultrasound transducer is substantially-entirely planar.

4. The ultrasound medical system of claim **1**, wherein the ultrasound-emitting outer exposed surface of the third ultrasound transducer in its entirety has a substantially-cylindrically-focused shape.

5. The ultrasound medical system of claim **1**, wherein the ultrasound-emitting outer exposed surface of the third ultrasound transducer in its entirety has a substantially-spherically-focused shape.

6. The ultrasound medical system of claim **1**, wherein the third ultrasound transducer is an ultrasound-medical-treatment-and-imaging ultrasound transducer.

7. The ultrasound medical system of claim **1**, wherein at least one of the first and second ultrasound transducers has only one ultrasound transducer element.

8. The ultrasound medical system of claim **1**, wherein at least one of the first and second ultrasound transducers has a plurality of ultrasound transducer elements.

9. An ultrasound medical system comprising an ultrasound transducer assembly having a longitudinal axis, and having first, second and third ultrasound transducers each having a plurality of planar transducer elements arranged to provide each of the first, second, and third ultrasound transducers with an ultrasound-emitting outer exposed surface which includes at least a concave surface portion, wherein the first and second ultrasound transducers are ultrasound-medical-treatment-only ultrasound transducers, and wherein the third ultrasound transducer is an ultrasound-medical-treatment-and-imaging ultrasound transducer disposed longitudinally between the first and second ultrasound transducers.

10. The ultrasound medical system of claim **9**, wherein the ultrasound transducer assembly has a distal end, wherein the first ultrasound transducer is disposed proximate the distal end, and wherein the third ultrasound transducer is disposed proximate the first and second ultrasound transducers.

11. The ultrasound medical system of claim **9**, wherein the ultrasound-emitting outer exposed surfaces of the first, second and third ultrasound transducers together in their entirety have a substantially-cylindrically-focused shape.

12. The ultrasound medical system of claim **9**, wherein the ultrasound-emitting outer exposed surfaces of the first, second and third ultrasound transducers together in their entirety have a substantially-spherically-focused shape.

13. An ultrasound medical system comprising an ultrasound transducer assembly having a longitudinal axis, and having first, second and third ultrasound transducers each having a plurality of planar transducer elements arranged to provide each of the first, second and third ultrasound transducers with an ultrasound-emitting outer exposed surface which includes at least a concave surface portion, wherein the first and second ultrasound transducers are ultrasound-medical-treatment-only ultrasound transducers, and wherein the third ultrasound transducer is an ultrasound-medical-imaging-only ultrasound transducer disposed longitudinally between the first and second ultrasound transducers.

14. The ultrasound medical system of claim **13**, wherein the ultrasound transducer assembly has a distal end, wherein the first ultrasound transducer is disposed proximate the distal end, and wherein the third ultrasound transducer is disposed proximate the first and second ultrasound transducers.

15. The ultrasound medical system of claim **13**, wherein the ultrasound-emitting outer exposed surfaces of the first, second and third ultrasound transducers together in their entirety have a substantially-cylindrically-focused shape.

16. The ultrasound medical system of claim 13, wherein the ultrasound-emitting outer exposed surfaces of the first, second and third ultrasound transducers together in their entirety have a substantially-spherically-focused shape.

17. An ultrasound medical system comprising an ultrasound transducer assembly having a longitudinal axis, and having first, second and third ultrasound transducers each having a plurality of planar transducer elements arranged to provide each of the first, second and third ultrasound transducers with an ultrasound-emitting outer exposed surface which includes at least a concave surface portion, wherein the first and second ultrasound transducers are ultrasound-medical-treatment-and-imaging ultrasound transducers, and wherein the third ultrasound transducer is an ultrasound-medical-treatment-only ultrasound transducer disposed longitudinally between the first and second ultrasound transducers.

18. The ultrasound medical system of claim 17, wherein the ultrasound transducer assembly has a distal end, wherein the first ultrasound transducer is disposed proximate the distal end, and wherein the third ultrasound transducer is disposed proximate the first and second ultrasound transducers.

19. The ultrasound medical system of claim 17, wherein the ultrasound-emitting outer exposed surfaces of the first, second and third ultrasound transducers together in their entirety have a substantially-cylindrically-focused shape.

20. The ultrasound medical system of claim 17, wherein the ultrasound-emitting outer exposed surfaces of the first, second and third ultrasound transducers together in their entirety have a substantially-spherically-focused shape.

21. An ultrasound medical system comprising an ultrasound transducer assembly having a longitudinal axis, having a distal end, and having two ultrasound transducers, wherein one of the ultrasound transducers has a substantially-fully-cylindrical ultrasound-emitting outer exposed surface which is substantially coaxially aligned with, and outwardly-facing from, the longitudinal axis, wherein an other of the ultrasound transducers is disposed longitudinally proximal or distal to the one ultrasound transducer and has a plurality of planar transducer elements arranged to provide the other ultrasound transducer with an ultrasound-emitting outer exposed surface which is substantially-entirely planar or includes at least a concave surface portion, and wherein the one ultrasound transducer is an ultrasound-medical-treatment-only ultrasound transducer.

22. The ultrasound medical system of claim 21, wherein the one ultrasound transducer is disposed proximate the distal end, and wherein the other ultrasound transducer is disposed proximate, and proximal to, the one ultrasound transducer.

* * * * *

专利名称(译)	具有多个超声换能器或超声换能器和RF电极的医疗系统		
公开(公告)号	US7494467	公开(公告)日	2009-02-24
申请号	US10/825952	申请日	2004-04-16
[标]申请(专利权)人(译)	MAKIN因德尔RAJ小号 MAST T d设定 斯雷顿MICHAEL ^ h BARTHE PETER摹 梅瑟利JEFFREYÐ FAIDI克瓦 RUNK MEGAN中号		
申请(专利权)人(译)	MAKIN因德尔RAJ小号 MAST T d设定 斯雷顿MICHAEL ^ h BARTHE PETER摹 梅瑟利JEFFREYÐ FAIDI克瓦 RUNK MEGAN中号		
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CPC分类号	A61B8/12 A61B8/445 A61N7/02 A61B18/148 A61B2019/5276 A61H23/0245 A61N2007/0078 A61B2090/378		
其他公开文献	US20050240125A1		
外部链接	Espacenet USPTO		

摘要(译)

超声医疗系统包括超声换能器组件，其具有各种组合的超声换能器，所述超声换能器具有不同形状的超声发射表面和/或不同的超声换能器类型，其中所述类型是超声医学治疗类型，超声医学治疗 - 和 - 成像型和超声医学成像型超声换能器。另一种超声医疗系统包括具有RF（射频）医疗处理电极和超声医疗换能器的换能器组件。